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Revision 10

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Volume 2 of 2

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NAC INTERNATIONAL

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5.0 SHIELDING EVALUATION

This chapter provides the shielding evaluation of the NAC-MPC storage system. The system is provided in three configurations. The Yankee Class NAC-MPC is designed to store up to 36 Yankee Class spent fuel assemblies or Yankee Class reconfigured fuel assemblies and is referred to as the Yankee-MPC. The Connecticut Yankee-MPC, referred to as the CY-MPC, is designed to store up to 26 Connecticut Yankee spent fuel assemblies, CY-MPC reconfigured fuel assemblies or CY-MPC damaged fuel cans. The analysis of the Yankee Class spent fuel is performed using the SAS4 code series. The analysis of the Connecticut Yankee spent fuel is performed using the MCBEND code. Separate models are used for each of the fuel types.

The Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) MPC, referred to as MPC-LACBWR, is designed to store up to 68 LACBWR spent fuel assemblies, including up to 32 LACBWR damaged fuel cans. The shielding evaluation of the MPC-LACBWR system is presented in Appendix 5.A of this chapter.

The regulation governing spent fuel storage, 10 CFR 72, does not establish specific cask dose rate limits. However, 10 CFR 72.104 and 10 CFR 72.106 specify that for an array of casks in an Independent Spent Fuel Storage Installation (ISFSI), the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other organ during normal operations. In the case of a design basis accident, the dose to an individual outside the area boundary must not exceed 5 rem to the whole body or any organ. The ISFSI must be at least 100 meters from the owner controlled area boundary. In addition, the occupational dose limits and radiation dose limits for individual members of the public in 10 CFR Part 20 (Subparts C and D) must be met. Chapter 10, Section 10.3, demonstrates NAC-MPC compliance with the requirements of 10 CFR 72 with regard to annual and occupational doses at the owner controlled area boundary. This chapter presents the shielding evaluations of the NAC-MPC storage system. Dose rate profiles are calculated as a function of distance from the side, top and bottom of the NAC-MPC storage and transfer casks. Shielded source terms from the NAC-MPC storage cask are calculated to establish owner controlled area boundary dose estimates due to the presence of the ISFSI.

5.1 Discussion and Results

This section provides a summary of the results of the shielding evaluation of the NAC-MPC system when the system holds Yankee Class or Connecticut Yankee spent fuel assemblies and non-fuel hardware. Results are provided for the transfer cask and vertical concrete cask components.

A description of the Yankee Class fuel and a summary of the results of the Yankee Class fuel shielding evaluation are presented in Section 5.1.1. The description of the Connecticut Yankee fuel and a summary of the Connecticut Yankee shielding evaluation results are presented in Section 5.1.2.

The NAC-MPC storage system is comprised of a transportable storage canister, a transfer cask, and a vertical concrete storage cask. License drawings for these items are provided in Section 1.7. The transfer cask containing the canister and the basket is loaded under water in the spent fuel pool. Once filled with fuel, the shield lid is placed on top of the canister and transfer cask is removed from the pool. After draining approximately 50 gallons of water from the Yankee-MPC canister or approximately 65 gallons of water from the CY-MPC canister, the shield lid is welded in place, and the canister is drained and dried. Finally, the structural lid is welded in place. The transfer cask is then used to transfer the canister to the storage cask where it is stored dry until transport. Shielding evaluations are performed for the transfer cask with both a wet and dry canister cavity as would occur during the welding of the shield lid and during the welding of the structural lid, respectively. Shielding evaluations are performed for the storage cask with the cavity dry.

5.1.1 Yankee-MPC System Shielding Discussion and Results

The transfer cask has a multiwall radial shield comprised of 0.75 inches of carbon steel, 3.5 inches of lead, 2 inches of solid borated polymer (NS-4-FR), and 1.25 inches of carbon steel. An additional 0.625 inch of stainless steel shielding is provided, radially, by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.50 inches of carbon steel. The top shielding is provided by the stainless steel canister shield and structural lids, which are 5 inches and 3 inches thick, respectively. In addition, 5 inches of carbon steel is used as temporary shielding during welding, draining, drying and helium backfill operations. This temporary shielding is removed prior to storage.

The storage cask radial shield design is comprised of a 3.5-inch thick carbon steel inner liner surrounded by 21 inches of concrete. Gamma shielding is provided by both the carbon steel and concrete, and neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.625 inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 8 inches of stainless steel from the canister lids, a shield plug containing a 1 inch thickness of NS-4-FR and 4.125 inches of carbon steel, and a 1.5 inch thick carbon steel lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of 1 inch of stainless steel from the canister bottom plate, 2 inches of carbon steel (pedestal plate) and 1 inch of carbon steel cask base plate. The base plate and pedestal base are structural components that position the canister above the air inlets. The cask base plate supports the storage cask during lifting, and forms the cooling air inlet channels at the cask bottom. An optional carbons steel supplemental shielding fixture, shown in Drawing 455-913, may be installed to reduce the radiation does rates at the air inlets.

The Yankee-MPC storage system accommodates up to 36 CE Yankee Class fuel assemblies with a maximum of 36,000 MWD/MTU burnup and with a minimum 8-year cool time. While 8.1 years cooling is required to meet cask total heat load requirements, 8.0 years is conservatively used as the shielding design basis. CE fuel with this burnup and cool time is defined as the design basis fuel. CE, UN and Westinghouse Yankee Class fuel assemblies with a maximum burnup of 32,000 MWD/MTU at minimum cool times of 8, 13 and 24 years, respectively, may also be loaded in the NAC-MPC. Exxon fuel at 36,000 MWD/MTU requires a minimum cool time of 10 years and 16 years for assemblies containing Zircaloy and stainless steel fuel region

hardware, respectively. For shielding evaluation purposes the Exxon assembly type is identical to the CE fuel. The physical parameters of Yankee Class fuel assemblies are presented in Table 5.2.1-1.

A canister may contain one or more reconfigured fuel assemblies. The reconfigured fuel assembly is designed to confine Yankee Class spent fuel rods, or portions thereof, which have been classified as failed. Each assembly can accommodate up to a total of 64 fuel rods, which is significantly less than other Yankee Class fuel assemblies. A depiction of the assembly is provided in Figure 1.3-1. Because the source term (neutron and gamma) is directly proportional to fuel mass, for a given burnup and enrichment, the reconfigured assembly source term is bounded by that of a design basis fuel assembly. Consequently, a separate shielding analysis is not required for the reconfigured fuel assembly.

A canister may also contain damaged fuel cans in the four corner basket locations. To accommodate the damaged fuel can, oversized openings are present in the top and bottom basket weldments. Furthermore, four 9.3-inch square machined areas in the shield lid are necessary to accommodate the top and bottom structure of the damaged fuel cans. The machined area depth is 1.41 inches. The storage cask shielding evaluation of damaged fuel considers the dispersion of 20 fuel rods in the fuel assembly bottom end fitting. Radial dose rates are calculated, with particular emphasis on the dose rates at the air inlets. The transfer cask shielding evaluation of damaged fuel considers the effect on top dose rates due to the amount of material being removed from the shield lid and the proximity of the machined areas to the vent and drain ports. The analysis also considers the additional dose rate on the side and bottom of the transfer cask resulting from the displaced material in the lower end fitting.

Shielding evaluations of the Yankee-MPC transfer and storage casks are performed with SCALE 4.3 for the PC (ORNL) and MCBEND (Serco Assurance). In particular, the SCALE shielding analysis sequence SAS2H (Herman) is used to generate source terms for the design basis fuel, using the 27-group ENDF/B-IV (Jordan) library, 27GROUPNDF4. SAS1 (Knight) is used to perform one-dimensional radial and axial shielding analysis. MCBEND is used to perform the three-dimensional shielding analysis of the storage cask, and a modified version of SAS4 (Tang) is used to perform the three-dimensional shielding analysis of the transfer cask. The SCALE 4.3 SAS4 code sequence has been modified to allow multiple surface detectors; the new code sequence is entitled SAS4A. The use of the surface subdetectors enables the user to obtain surface profiles of the detector response and the surface tallies on the cask surfaces other than the

cask shield. Dose tally routines were modified to accept user-defined surface detectors instead of the fixed surfaces, 1m, 2m, and 4m detectors in SCALE 4.3 SAS4. Each surface can be defined by specifying the cylindrical or disk surface tally location and extent. Each surface may be broken into multiple subdetectors. Code modifications were tested against the SCALE 4.3 manual and NAC test cases. Reliability of the subdetectors was verified by comparison to point detector results. The 27-group neutron, 18 group gamma, coupled cross section library (27N-18COUPLE) based on ENDF/B-IV is used in all SCALE shielding evaluations. Source terms include: fuel neutron, fuel gamma, and activated hardware gamma. Dose rate evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

Dose rate profiles are shown for the storage and transfer casks in Section 5.4.1.4. Maximum dose rates for the storage cask under normal and accident conditions are shown in Table 5.1.1-1 for design basis fuel. These dose rates are based on three-dimensional Monte Carlo and one-dimensional discrete ordinates calculations. Monte Carlo error (1σ) is indicated in parenthesis. In normal conditions with design basis intact fuel, the storage cask maximum side dose rate is 44.1 (1.2%) mrem/hr at the fuel midplane and 75.5 (0.6%) mrem/hr on the top lid surface above the air outlets. The average dose rates on the side and top of the cask are 35.7 (1.1%) and 34.9 (<1%) mrem/hr, respectively. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. The maximum surface dose rate at the lower air inlet openings is 191 (1.2%) mrem/hr with supplemental shielding and 803 (<1%) mrem/hr without supplemental shielding. The maximum surface dose rate at the air outlet openings is 116 (1.1%) mrem/hr. Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 314 mrem/hr at the impact location with design basis fuel. There are no design basis accidents that result in a tip-over of the Yankee-MPC storage cask.

For the damaged fuel can evaluation, the additive radial dose rate due to the presence of debris from 20 fuel rods in the bottom end fitting is 2.7 (0.2%) mrem/hr. This additional dose, however, does not affect the calculated maximum dose rate on the side of the cask and the average dose rate increases by less than 0.5%. The maximum air inlet dose rate due to the combination of intact and damaged fuel is 219 (1.0%) mrem/hr with supplemental shielding in the inlets.

Maximum dose rates for the transfer cask with design basis intact and damaged fuel and with a wet and dry canister cavity are shown in Tables 5.1.1-2 and 5.1.1-3, respectively. The maximum

dose rates with design basis fuel and the canister cavity wet during shield lid welding operations are 210.2 (0.8%), 188.7 (1.1%) and 77.2 (0.7%) mrem/hr on the side, top, and bottom, respectively. The maximum dose rates with design basis fuel and the canister cavity dry during structural lid welding operations are 413.4 (1.5%), 358.9 (2.6%) and 398.0 (3.9%) mrem/hr on the side, top, and bottom, respectively. These values include the addition of 5 inches of carbon steel operational shielding installed on the shield lid during its closure and on the structural lid during its handling and closure. In normal operations during welding of the canister lids, the bottom of the transfer cask is generally inaccessible.

For the damaged fuel can evaluation, additional shielding at the ports is modeled to maintain dose rates ALARA for the shield lid with weld shield models. In the wet canister model, the port cover zone is modeled with half-density stainless steel to simulate the quick disconnect fittings at the ports. For both the dry and wet canister models, an inch of lead is modeled above the ports to simulate additional temporary shielding employed during the welding operations. The maximum dose rate with design basis fuel and the canister cavity wet during shield lid welding operations is 214.1 (0.1%) mrem/hr. An azimuthal peak of 4.0 rem/hr is calculated at the port radius. The maximum dose rate with design basis fuel and the canister cavity dry during structural lid welding operations is 387.9 (0.6%) mrem/hr. Maximum dose rates for the transfer cask with design basis damaged fuel are shown in Table 5.1.1-3.

The damaged fuel case is modeled assuming the fuel content of 20 fuel rods from each of four damaged assemblies is displaced to the lower end fitting region, where the added material is homogeneously represented. No credit is taken for shielding capability of the damaged fuel can; however it is assumed that the can will physically contain the fuel debris. In addition, no credit is taken for the ability of the displaced material to shield the hardware and remaining intact fuel assemblies. Also, no reduction in the intact fuel source term is made to compensate for the displaced material. Results show that the maximum additional contribution to the cask surface dose rate is less than 40 mrem/hr under both wet and dry canister conditions. Specifically, under dry conditions, the maximum radial and bottom axial transfer cask surface dose rates are 444.8 (1.6%) mrem/hr and 435.7 (0.9%) mrem/hr, respectively. Under wet conditions, the maximum bottom axial transfer cask surface dose rate is 96.3 (0.6%) mrem/hr. The wet condition maximum radial surface dose rate is unchanged due to the presence of damaged fuel in the lower end fitting, since the location of the peak remains near the top of the cask due to the assumed draining of water from the cask to facilitate lid welding operations.

Table 5.1.1-1 Summary of Yankee-MPC Storage Cask Maximum Dose Rates with Yankee Class Design Basis Fuel

Condition	Source	Cask Surface (mrem/hr)				1 Meter From Surface (mrem/hr)			
		Side	Top	Inlet[1]	Outlet	Side	Top	Inlet[1]	Outlet
NORMAL	neutron	1.0	1.6	14.0	1.5	0.4	6.4	1.3	0.1
	gamma	43.1	73.9	177.0	114.8	20.8	6.8	36.1	13.3
	Total	44.1 (1.2%)	75.5 (0.6%)	191.0 (1.2%)	116.3 (1.1%)	21.2 (0.7%)	13.2 (0.7%)	37.4 (1.4%)	13.4 (1.9%)
POSTULATED ACCIDENT[2]	neutron	4.0	na	na	na	1.5	na	na	na
	gamma	310.0	na	na	na	137.5	na	na	na
	Total	314.0	na	na	na	139.0	na	na	na

1. Listed values are for the intact fuel basket configuration with supplemental air inlet shielding included. Failure of 20 rods in the damaged fuel canister increases inlet dose rates to 219 (1%) mrem/hr at the cask surface and 41.6 (1.2%) mrem/hr at 1 meter from the cask surface.
2. Projectile impact, 6 inches loss of concrete.

Table 5.1.1-2 Summary of the Yankee-MPC Transfer Cask Maximum Dose Rates with Yankee Class Design Basis Intact Fuel

Condition	Source	Transfer Cask Surface (mrem/hr)			1 Meter From Surface (mrem/hr)		
		Side	Top	Bottom	Side	Top	Bottom
NORMAL WET[1]	neutron	0.0	1.2	0.1	0.7	0.3	0.0
	gamma	210.2	187.5	77.1	39.8	388.8	19.0
	Total	210.2 (0.8%)	188.7 (1.1%)	77.2 (0.7%)	40.5 (0.7%)	389.1 (5.1%)	19.0 (2.1%)
NORMAL DRY[2]	neutron	77.5	116.6	276.2	44.8	13.5	33.4
	gamma	335.9	242.3	122.2	58.6	26.1	33.3
	Total	413.4 (1.5%)	358.9 (2.6%)	398.4 (1.0%)	103.4 (0.6%)	39.6 (4.5%)	66.7 (1.2%)

1. Five inches of carbon steel temporary shielding, shield lid in position.
2. Five inches of carbon steel temporary shielding, shield lid and structural lid in position.
Note: Total may differ from sum of components due to roundoff.

Table 5.1.1-3 Summary of the Yankee-MPC Transfer Cask Maximum Dose Rates with Design Basis Damaged Fuel

Condition	Source	Transfer Cask Surface (mrem/hr)			1 Meter From Surface (mrem/hr)		
		Side	Top	Bottom	Side	Top	Bottom
NORMAL WET[1]	neutron	0.0	1.1	6.4	0.5	0.3	1.5
	gamma	210.2	213.0	89.9	39.8	387.1	22.2
	Total	210.2 (0.8%)	214.1 (0.1%)	96.3 (0.6%)	40.3 (0.7%)	387.4 (0.7%)	23.7(1.7%)
NORMAL DRY[2]	neutron	85.1	78.8	298.4	44.6	19.7	40.0
	gamma	359.8	309.1	137.3	59.2	71.2	37.1
	Total	444.8 (1.6%)	387.9 (0.6%)	435.7 (0.9%)	103.9 (0.5%)	90.9 (2.7%)	77.0 (1.0 %)

1. Five inches of carbon steel temporary shielding, shield lid in position.
2. Five inches of carbon steel temporary shielding, shield lid and structural lid in position.
Note: Total may differ from sum of components due to roundoff.

5.1.2 CY-MPC System Shielding Discussion and Results

The CY-MPC transfer cask has a multi-wall radial shield comprised of 0.75 inches of low alloy steel, 4.0 inches of lead, 2.75 inches of solid borated polymer (NS-4-FR), and 1.25 inches of low alloy steel. An additional 0.625 inch of stainless steel shielding is provided, radially, by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.50 inches of low alloy steel. The top shielding is provided by the stainless steel canister shield and structural lids, which are 5 inches and 3 inches thick, respectively. In addition, 5 inches of carbon steel is used as temporary shielding during welding, draining, drying and helium backfill operations. This temporary shielding is removed prior to storage.

The storage cask radial shield design is comprised of a 3.5-inch thick carbon steel inner liner surrounded by a 21-inch thickness of concrete. Gamma shielding is provided by both the carbon steel and the concrete. Neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.625 inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 8 inches of stainless steel from the canister lids, a 3.75-inch thick carbon steel shield plug, a 2.0-inch thick layer of either NS-4-FR or NS-3, a 0.375-inch thick carbon steel cover and a 1.50-inch thick carbon steel lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of the 1.75-inch thick stainless steel canister bottom plate, the 4.0-inch thick carbon steel weldment base plate, and the 1.0-inch thick carbon steel cask bottom plate. The base plate and bottom plate are structural components that position the canister above the air inlets. The cask bottom plate supports the storage cask during lifting and forms the cooling air inlet channels at the cask bottom.

The CY-MPC accommodates up to 26 Connecticut Yankee fuel assemblies. Both stainless steel clad and Zircaloy clad assemblies are acceptable for storage. The stainless steel clad assemblies have a maximum burnup of 38,000 MWD/MTU and a minimum of a 5-year cool time. The Zircaloy-clad fuel assemblies have a maximum burnup of 43,000 MWd/MTU and a minimum 5-year cool time. The physical parameters of the Connecticut Yankee fuel assemblies are presented in Table 5.2.2-1.

A canister may contain up to four CY-MPC reconfigured fuel assemblies and/or damaged fuel cans positioned in the oversized corner locations in the basket. The CY-MPC reconfigured fuel

assembly is designed to confine individual spent fuel rods, or portions thereof, within individual stainless steel tubes. Each CY-MPC reconfigured fuel assembly can accommodate up to 100 fuel rods in a 10 by 10 lattice, which is significantly less than the number of fuel rods in an intact assembly. Because the source term (neutron and gamma) is directly proportional to fuel mass, for a given burnup and enrichment, the source term produced by the fuel rods within the CY-MPC reconfigured assembly is bounded by that of a design basis fuel assembly. Consequently, a separate shielding analysis is not required for the reconfigured fuel assembly.

The CY-MPC damaged fuel can may hold a complete Connecticut Yankee fuel assembly, a lattice or a failed rod storage canister. Since the shielding evaluation conservatively assumes that the damaged fuel cans are not present in the canister, the additional shielding provided by the wall of the can would serve to reduce external dose rates. Consequently, there is no increase in dose rate due to the presence of a Connecticut Yankee fuel assembly or lattice having up to 204 fuel rods or the failed rod storage canister having up to 60 fuel rods.

Shielding evaluations of the CY-MPC transfer cask and storage cask are performed using the MCBEND Monte Carlo transport code. Fuel source terms are developed using the SCALE isotopics sequence SAS2H (Herman). Source terms include: fuel neutron, fuel gamma, fuel n-gamma, and activated hardware gamma. Dose rate evaluations include the effect of axial fuel burnup peaking on fuel neutron and gamma source terms.

The resulting dose rate profiles, along with the maximum and average radial and axial dose rates are presented for the storage cask and transfer cask analyses in Section 5.4.2. The results are presented for the design basis stainless stee- clad and Zircaloy-clad fuel assemblies.

The maximum dose rates for the storage cask under normal conditions are summarized in Tables 5.1.2–1 and 5.1.2–2 for stainless steel and Zircaloy-clad design basis fuel assemblies, respectively. The dose rate calculation for the top of the storage cask with stainless steel clad fuel is based on a 1-inch thick layer of NS-4-FR. The results at the top of the storage cask with the Zircaloy clad fuel are shown for a 1-inch thickness of NS-4-FR and for a 1.5-inch thickness of NS-3. Since the Zircaloy-clad fuel dose rates are higher, these results bound those for the stainless steel clad design basis fuel. The thickness of neutron shield material (either NS-4-FR or NS-3) used in the analysis is conservatively less than the 2.0-inch thickness specified (Drawing 414-864). The standard deviation resulting from the Monte Carlo evaluation used by MCBEND (1σ) is indicated in the tables. The storage cask maximum side dose rate occurs for stainless

steel clad assemblies (due to the elevated fuel assembly hardware source term) and is 167 (1.7%) mrem/hr at the fuel midplane elevation. The maximum storage cask top axial surface dose rate occurs for the Zircaloy-clad fuel (due to the higher neutron source rate at the higher burnup for this fuel) and is 36 (0.7%) mrem/hr on the top lid surface just above the annulus between the canister and the storage cask liner. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. Therefore, no bottom axial dose rates are presented. The average dose rates at the inlets and outlets are 85 (3.2%) mrem/hr and 66 (1.5%) mrem/hr, respectively. The maximum dose rates for the transfer cask for the wet and dry canister cavity configurations encountered during canister closure operations are presented in Table 5.1.2-3 and Table 5.1.2-4 for the stainless steel and Zircaloy clad fuel types, respectively.

During shield lid welding operations, including a wet canister cavity, the maximum dose rates with stainless steel clad fuel are 226 (1.2%) and 3830 (5.5%) mrem/hr on the radial surface and top axial surface, respectively. The bottom surface of the cask has a maximum dose rate of 95 (2.2%) mrem/hr with the stainless steel fuel. For Zircaloy-clad fuel, the maximum radial, top axial and bottom axial surface dose rates are 241 (2.2%), 4050 (1.9%), and 84 (2.0%) mrem/hr, respectively. With eight flow mixer components inserted in the centermost basket positions, the additional dose rate in the top axial position is 46 (3.5%) mrem/hr.

During structural lid welding operations, including a dry canister cavity, the maximum dose rates with stainless steel clad design basis fuel are 405 (3.3%) mrem/hr and 2179 (6.5%) mrem/hr on the radial and top axial surfaces, respectively. The bottom surface of the cask has a maximum dose rate of 307 (1.0%) mrem/hr with the stainless steel fuel. For Zircaloy-clad design basis fuel, the maximum side, top, and bottom dose rates are 394 (2.0%), 2117 (3.5%), and 407 (0.8%) mrem/hr, respectively.

The calculated values for the transfer cask shield lid and structural lid configurations include the addition of 5 inches of carbon steel operational shielding installed on top of the shield lid during its closure and on the structural lid during its handling and closure. As shown in the dose rate profiles presented in Section 5.4.2, the maximum top axial surface dose rates are highly localized to the annular region between the operational shield and the inner shell of the transfer cask. This region will not normally be occupied during welding operations.

Table 5.1.2–1 Summary of CY-MPC Storage Cask Maximum Dose Rates with Design Basis Stainless Steel Clad Fuel

	Cask Surface (mrem/hr with relative uncertainty)				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
Source	**Side**		**Top**		**Side**		**Top**	
Neutron	2	2.4%	2	3.2%	1	1.4%	6	0.5%
Gamma	165	1.7%	30	1.0%	81	0.8%	6	1.9%
Total	167	1.7%	32	1.0%	82	0.8%	12	1.0%

Note: Dose rates rounded up to next whole mrem/hr.

Table 5.1.2–2 Summary of CY-MPC Storage Cask Maximum Dose Rates with Design Basis Zircaloy Clad Fuel

	Cask Surface (mrem/hr with relative uncertainty)						**1 Meter From Surface (mrem/hr with relative uncertainty)**					
Source	**Side**		**Top NS-4-FR**		**Top NS-3**		**Side**		**Top NS-4-FR**		**Top NS-3**	
Neutron	2	1.7%	3	3.1%	3	3.9%	1	1.4%	8	0.5%	7	0.6%
Gamma	138	1.1%	33	0.8%	33	1.3%	68	0.9%	6	0.7%	7	1.1%
Total	140	1.0%	36	0.7%	36	1.2%	69	0.9%	14	0.4%	14	0.6%

Dose rates rounded up to next whole mrem/hr.
Dose rates for Zircaloy clad fuel bound those of stainless steel clad fuel at the top of the storage cask (Table 5.1.2-1).

Table 5.1.2-3 Summary of CY-MPC Transfer Cask Maximum Dose Rates with Design Basis Stainless Steel Clad Fuel

		Transfer Cask Surface (mrem/hr)			1 Meter From Surface (mrem/hr)		
		Side	**Top**	**Bottom**	**Side**	**Top**	**Bottom**
NORMAL WET[1]	Neutron	73 (1.0%)	1 (6.1%)	20 (2.6%)	24 (1.0%)	<1 (7.7%)	5 (1.4%)
	Gamma	153 (1.7%)	3829 (5.5%)	76 (2.7%)	67 (1.7%)	565 (10.6%)	32 (1.1%)
	Total	226 (1.2%)	3830 (5.5%)	95 (2.2%)	91 (1.3%)	565 (10.6%)	36 (1.0%)
NORMAL DRY[2]	Neutron	96 (1.9%)	54 (0.6%)	208 (1.0%)	32 (1.1%)	14 (0.7%)	53 (0.6%)
	Gamma	309 (4.3%)	2125 (6.7%)	100 (2.3%)	132 (1.8%)	288 (9.3%)	42 (1.0%)
	Total	405 (3.3%)	2179 (6.5%)	307 (1.0%)	164 (1.5%)	301 (8.8%)	94 (0.6%)

Shield lid in position with 5 inches of temporary carbon steel shielding, port covers off.
Shield lid and structural lid in position with 5 inches of temporary carbon steel shielding, port covers on.
Note: Total may differ from sum of components due to roundoff.

Table 5.1.2-4 Summary of CY-MPC Transfer Cask Maximum Dose Rates with Design Basis Zircaloy Clad Fuel

		Transfer Cask Surface (mrem/hr)			1 Meter From Surface (mrem/hr)		
		Side	**Top**	**Bottom**	**Side**	**Top**	**Bottom**
NORMAL WET[1]	Neutron	111 (1.7%)	1 (14.6%)	29 (2.6%)	37 (1.0%)	<1 (16.6%)	7 (1.3%)
	Gamma	130 (3.8%)	4049 (1.9%)	54 (2.7%)	56 (1.9%)	532 (3.6%)	22 (1.2%)
	Total	241 (2.2%)	4050 (1.9%)	84 (2.0%)	93 (1.2%)	532 (3.6%)	29 (0.9%)
NORMAL DRY[2]	Neutron	149 (1.8%)	79 (0.6%)	326 (0.9%)	49 (1.0%)	20 (0.8%)	83 (0.6%)
	Gamma	245 (3.1%)	2038 (3.6%)	81 (2.2%)	107 (1.5%)	299 (5.9%)	33 (1.0%)
	Total	394 (2.0%)	2117 (3.5%)	407 (0.8%)	156 (1.0%)	319 (5.6%)	116 (0.5%)

1. Shield lid in position with 5 inches of temporary carbon steel shielding, port covers off.
2. Shield lid and structural lid in position with 5 inches of temporary carbon steel shielding, port covers on.

Note: Total may differ from sum of components due to roundoff.

5.2 Source Term Specification

The method used to identify the design basis fuel assembly for the shielding evaluation is described in this section. For Yankee Class fuel, the shielding design basis fuel assembly is the Combustion Engineering 16 x 16 Type A fuel assembly (Table 5.2.1-2) with a minimum fuel enrichment of 3.7 wt % ^{235}U at 36,000 MWD/MTU burnup and 8-year cool time.

For the Connecticut Yankee fuel, two design basis fuel types are considered. Due to the potential for activation of fuel cladding with stainless-steel clad fuel assemblies, the design basis fuel description is based on limiting characterizations of both stainless steel clad and Zircaloy- clad fuel.

The SAS2H code sequence (Herman) is used to generate source terms for both the Yankee Class and Connecticut Yankee fuel assemblies.

Non-fuel hardware is assumed to be Type 304 stainless steel with 1.2 g/kg of ^{59}Co impurity. For the stainless steel clad Connecticut Yankee fuel, the cladding has a reduced cobalt concentration of 0.5 g/kg ^{59}Co based on utility records. The effects of axial flux spectrum and magnitude variation on hardware activation are estimated by flux ratios based on empirical data (Luksic).

5.2.1 Yankee Class Fuel Source Term Specification

The Yankee-MPC storage system can safely transfer and store Yankee Class fuel from four vendors in two fuel rod configurations. These are: Combustion Engineering (CE) 16 x 16 Type A and Type B, Exxon 16 x 16 Type A and Type B, United Nuclear (UN) 16 x 16 Type A and Type B, and Westinghouse (WE) 18 x 18 stainless steel clad Type A and Type B. The geometry of the Type A and Type B fuel assemblies allows a cruciform control rod to be inserted between assemblies during reactor operation. The cross-section of a typical Yankee Class fuel assembly is shown in Figure 5.2.1-1.

The Yankee-MPC accommodates up to 36 CE Yankee Class fuel assemblies with a maximum of 36,000 MWD/MTU burnup and with a minimum of 8 years cool time. While 8.1 years cooling is required to meet cask total heat load requirements, 8.0 years is conservatively used as the shielding design basis. CE fuel with this burnup and cool time is defined as the design basis fuel. Minimum cool times for the remaining Yankee Class fuel assemblies are determined using on e–dimensional SAS1 results as discussed in Section 5.4.1.4.1. CE, UN and Westinghouse Yankee Class fuel assemblies with a maximum burnup of 32,000 MWD/MTU at minimum cool times of 8, 13, and 24 years, respectively, may also be loaded in the Yankee-MPC. Exxon fuel at 36,000 MWd/MTU requires a minimum cool time of 10 years and 16 years for assemblies containing Zircaloy and stainless steel fuel region hardware, respectively. The 10-year cool time for Exxon fuel assemblies with Zircaloy fuel region hardware includes the activation of four hollow Zircaloy replacement rods with stainless steel slugs. For shielding evaluation purposes, the Exxon assembly type is identical to the CE fuel. The physical parameters of the Yankee Class fuel assemblies are presented in Table 5.2.1-1. Note that multiple inert/dummy rod configurations were employed in CE and Exxon fuel assemblies, while only the stainless steel slugs are considered in the shielding evaluation based on their contribution to the activated hardware source term. Also of note, the cool time of 24 years for Westinghouse fuel assemblies is based in 120 kg of activated fuel region hardware.

The SAS2H code sequence (Herman) is used to generate source terms. This code sequence is part of the SCALE 4.3 code package for the PC (ORNL). SAS2H includes an XSDRNPM (Greene) neutronics model of the fuel assembly and ORIGEN-S (Herman) fuel depletion/source terms calculations. Source terms are generated for both UO_2 fuel and fuel assembly hardware. The hardware activation is calculated by light element transmutation using the incore neutron flux spectrum produced by the SAS2H neutronics model. The hardware is assumed to be Type

304 stainless steel with 1.2 g/kg of ^{59}Co impurity. The effects of axial flux spectrum and magnitude variation on hardware activation are estimated by flux ratios based on empirical data (Luskic).

An evaluation of the Yankee Class fuel types established the Combustion Engineering (CE) 16 x 16 Type A fuel assembly (Table 5.2.1-2) at 36,000 MWD/MTU burnup and a 8-year cool time as the Yankee Class design basis fuel assembly for the shielding evaluations. A minimum fuel enrichment of 3.7 wt % ^{235}U is assumed to maximize the fuel neutron source. Reactor operating conditions assumed for the analysis are shown in Table 5.2.1-3.

The Yankee Class fuel design basis fuel source terms are shown Table 5.2.1-4. Source strengths are defined for five source regions: active fuel, upper end fitting, upper plenum, lower end fitting and lower plenum. The fuel assembly length, active fuel region length and fuel assembly hardware elevations are shown for the design basis fuel assembly in Figure 5.2.1-2.

Additional assembly detail is employed in the MCBEND assembly models. Three-dimensional parameters for the MCBEND fuel assembly model are shown in Table 5.2.1-7. The MCBEND design basis source spectra energy boundaries are shown in Table 5.2.1-10.

5.2.1.1 Yankee Class Fuel Gamma Source

The design basis fuel and hardware gamma source spectra are shown in Table 5.2.1-5. The fuel gamma source contains contributions from both fission products and actinides. The hardware gamma spectra contains contributions primarily from ^{60}Co due to the activation of Type 304 stainless steel with 1.2 g/kg ^{59}Co impurity and with some minor contributions from ^{59}Ni and ^{58}Fe. The magnitude of this spectra is based on the irradiation of 1 kg of stainless steel in the incore flux spectrum produced by the SAS2H neutronics calculation.

The activated fuel assembly hardware source terms are found by multiplying the source strength from 1 kilogram by the number of kilograms of steel or inconel material in the plenum, upper end fitting and lower end fitting regions, and by multiplying by a regional flux ratio. The regional flux ratio accounts for the effects of both magnitude and spectrum variation on hardware activation. These ratios are based on empirical data (Luskic). A flux ratio of 0.2 is applied to hardware regions directly adjacent to the active core region, i.e., upper and lower plenum. A

flux ratio of 0.1 is applied to hardware regions once removed from the active core region, i.e., upper and lower end fitting region.

In evaluations using the SCALE package, spectra are presented in the 18-group structure consistent with the SCALE 4.3 27N-18COUPLE cross-section library. MCBEND evaluations employ the same spectra rebinned onto the 22-group structure inherent to the code, shown in Table 5.2.1-9. The rebin is performed using ORIGEN-S.

5.2.1.2 Yankee Class Fuel Neutron Source

The design basis fuel neutron spectrum is shown in Table 5.2.1-6. The neutron source results from actinide spontaneous fission and from (α,n) reactions with the oxygen in UO_2. The isotopes ^{242}Cm and ^{244}Cm characteristically produce all, but a few percent of the spontaneous fission neutrons and (α,n) source in light water reactor fuel. The next largest contribution is from (α,n) reactions from ^{238}Pu. The neutron spectra from spontaneous fission are based on fission spectrum measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions is based on Po-α-O source measurements. These spectra are included in the ORIGEN-S nuclear data libraries of the SCALE 4.3 code package

In evaluations using the SCALE package, the spectra are collapsed from the energy group structure of the data library into that of the SCALE 27-group neutron cross-section library. MCBEND evaluations employ the same spectra rebinned onto the 28-group structure inherent to the code, shown in Table 5.2.1-8. The rebin is performed using ORIGEN-S.

Neutron shielding evaluations for fissile material must account for subcritical multiplication (neutron production) inside the system being evaluated. This subcritical multiplication may be taken into account either by directly calculating the additional neutron source during the Monte Carlo simulation, as done in MORSE, or by adjusting the input neutron source term or output dose result by a scale factor. The code module in MCBEND responsible for accelerating result convergence by importance biasing does not efficiently account for subcritical multiplication. Code biasing is set to optimize the speed at which cask surface dose rates are obtained. Thermal energy neutrons within the fuel region are not likely to escape the shielded storage system and tend to be biased out of the evaluation. However, the thermal neutrons account for a significant portion of the subcritical multiplication. Removing the thermal neutrons from the system by biasing for cask surface dose, therefore, undersamples the subcritical multiplication. To account

for undersampling, neutron source rates are scaled by a subcritical multiplication factor based on the system multiplication factor, k_{eff}:

$$\text{Scale Factor} = \frac{1}{1 - k_{eff}}$$

For dry cask conditions, the system k_{eff} is taken as 0.4, with a resulting scale factor of 1.67. The scale factor is applied in MCBEND input as a component to the source.

5.2.1.3 Yankee Class Fuel Source Axial Profile

An enveloping burnup shape for three-dimensional shielding and thermal evaluations is created based on core depletion calculations for the Yankee Class fuel. The normalized burnup profile, averaged over the range from 30,000 to 36,000 MWD/MTU, and the corresponding enveloping shape, is shown in Figure 5.2.1-3. A burnup peak of 1.15 is found to envelope the design basis fuel axial burnup distribution. The corresponding gamma and neutron source distribution is shown in Figure 5.2.1-4. The gamma source distribution follows the burnup shape directly and has a 1.15 peaking factor. However, the neutron source distribution peaks to a higher level. Based on SAS2H calculations of the neutron source magnitude as a function of burnup, a 4.2 power dependence of the neutron source on burnup, i.e., neutron source $\sim B^{4.2}$, is exhibited. This yields a 1.80 peaking factor for neutrons.

Figure 5.2.1-1 Yankee Class Combustion Engineering Design Basis Fuel Assembly Array

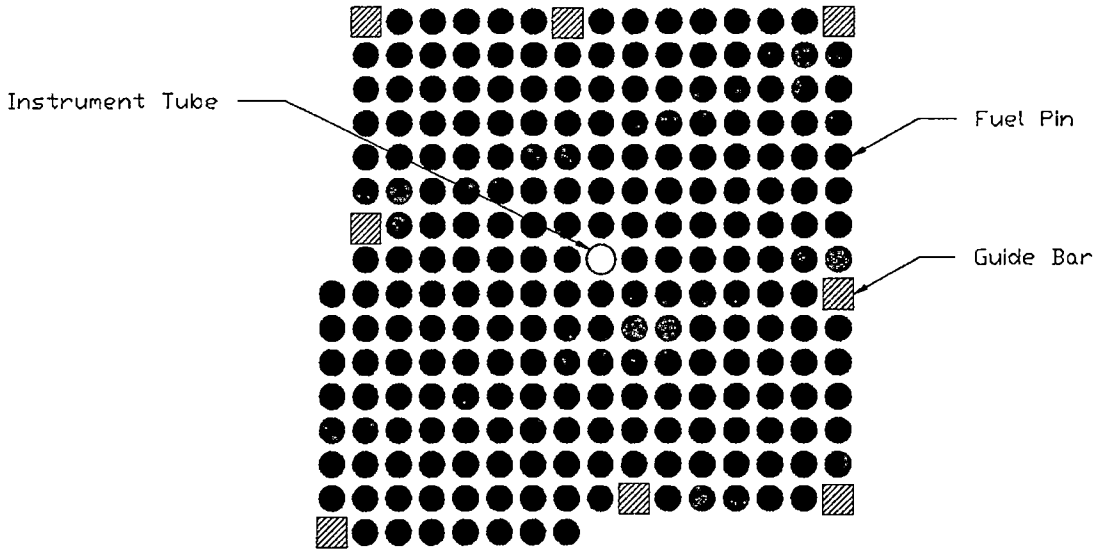
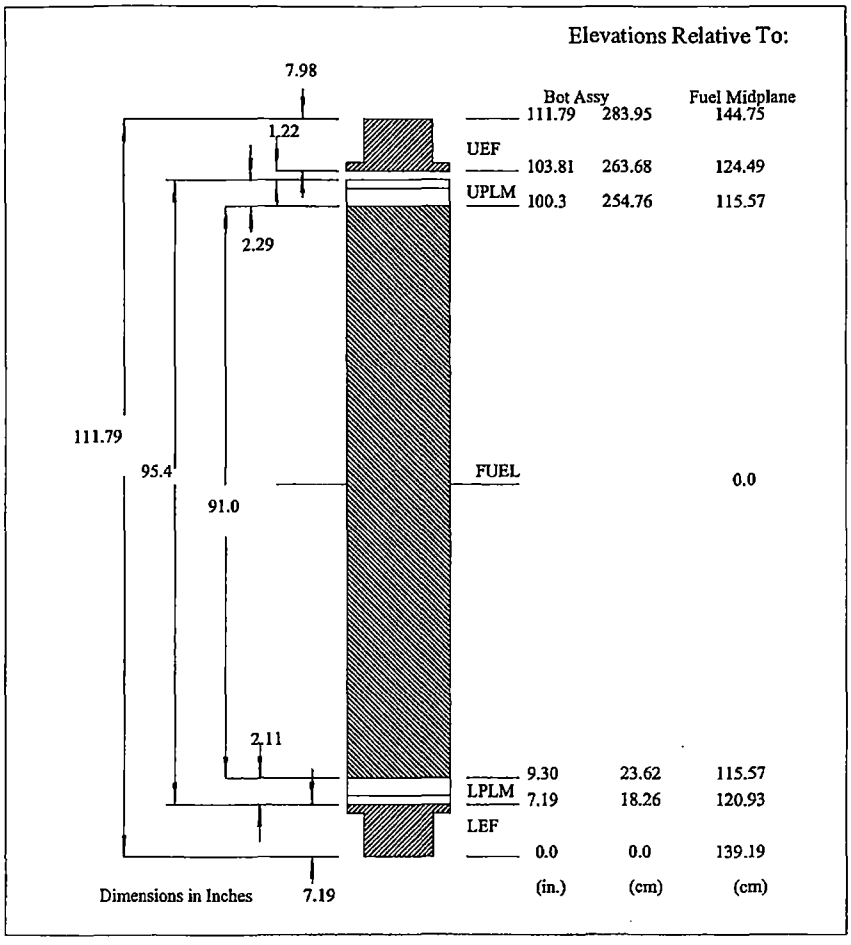
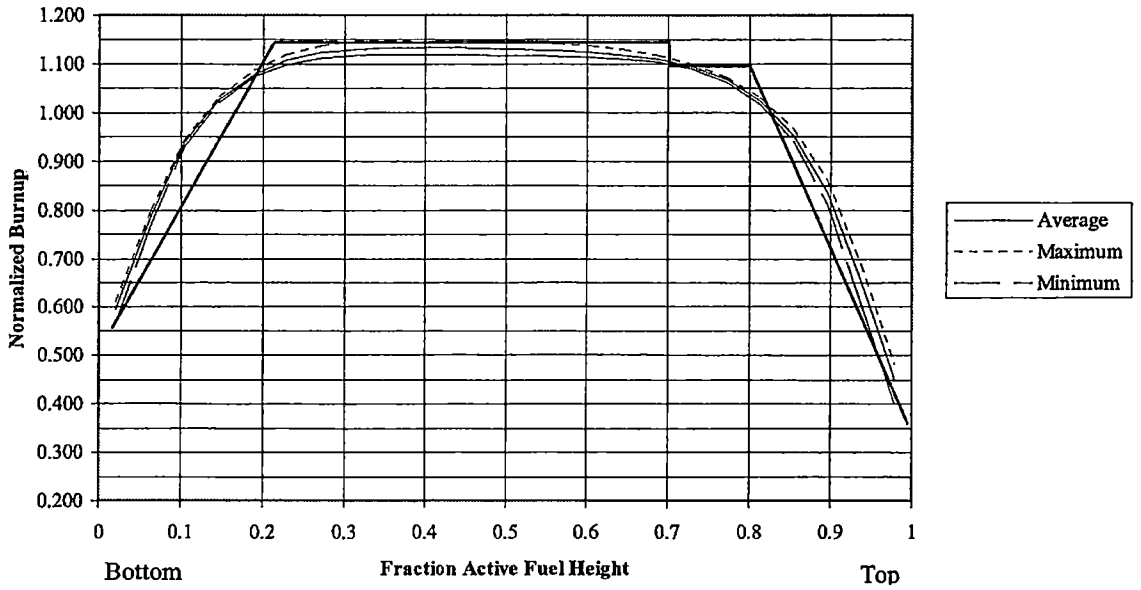


Figure 5.2.1-2 Yankee Class Combustion Engineering Design Basis Fuel Assembly Source Regions and Elevations



SOURCE	REGION
FUEL	Active fuel
UPLM	Upper Plenum
UEF	Upper End Fitting
LPLM	Lower Plenum
LEF	Lower End Fitting

Figure 5.2.1-3 Yankee Class Fuel Design Basis Burnup Profile



Condition: 30,000 - 36,000 MWD/MTU

Figure 5.2.1-4 Yankee Class Fuel Design Basis Neutron and Gamma Source Axial Profiles

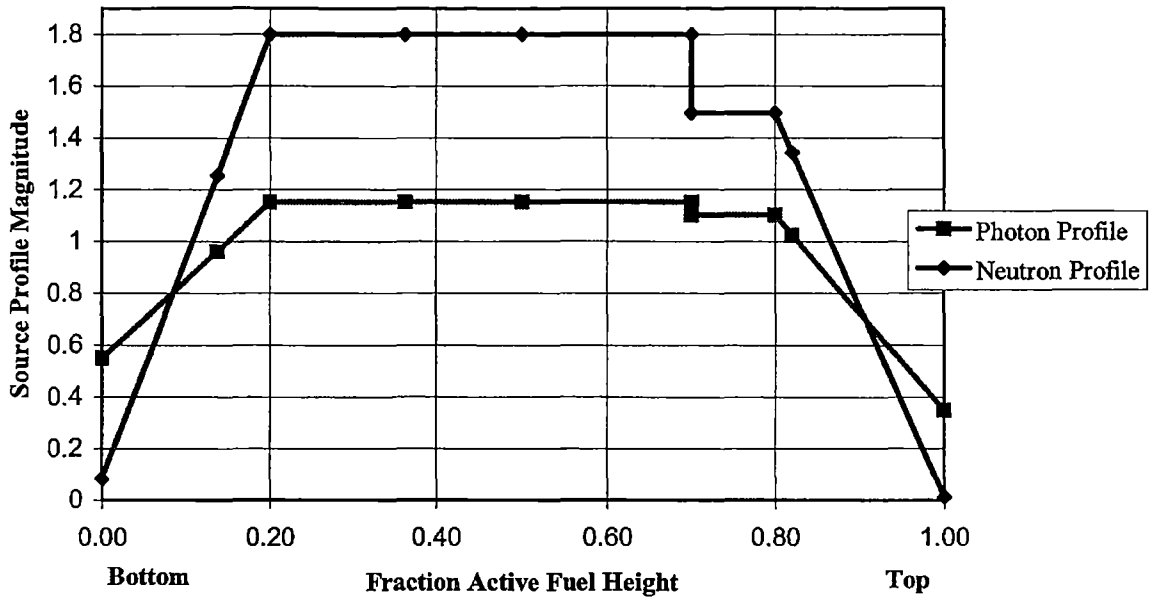


Table 5.2.1-1 Yankee Class Fuel Assembly Physical Parameters

Parameter	CE Type A	CE Type B	Exxon Type A	Exxon Type B	Exxon Type A	Exxon Type B	Westinghouse Type A	Westinghouse Type B	United Nuclear Type A	United Nuclear Type B
Assembly Configuration	-	-	-	-	-	-	-	-	-	-
Assembly Array	16×16	16×16	16×16	16×16	16×16	16×16	18×18	18×18	16×16	16×16
Max. Enrichment[1] (wt % ^{235}U)	3.90	3.90	4.00	4.00	4.00	4.00	4.94	4.94	4.00	4.00
Min. Enrichment[1] (wt % ^{235}U)	3.50	3.50	3.50	3.50	3.50	3.50	4.94	4.94	4.00	4.00
Max. MTU	0.2394	0.2384	0.2394	0.2384	0.2394	0.2384	0.2869	0.2860	0.2456	0.2446
Fuel Rod Configuration	-	-	-	-	-	-	-	-	-	-
Fuel Rod Pitch (cm)	1.1989	1.1989	1.1989	1.1989	1.1989	1.1989	1.0719	1.0719	1.1887	1.1887
Active Fuel Length (cm)	231.1400	231.1400	231.1400	231.1400	231.1400	231.1400	233.9975	233.9975	231.1400	231.1400
Rod OD (cm)	0.9271	0.9271	0.9271	0.9271	0.9271	0.9271	0.8636	0.8636	0.9271	0.9271
Clad ID (cm)	0.8052	0.8052	0.8052	0.8052	0.8052	0.8052	0.7569	0.7569	0.8052	0.8052
Pellet OD (cm)	0.7887	0.7887	0.7887	0.7887	0.7887	0.7887	0.7468	0.7468	0.7887	0.7887
Diametral Gap (cm)	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0102	0.0102	0.0165	0.0165
Rods per Assembly	231	230	231	230	231	230	305	304	237	236
Fuel Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Clad Material	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	SS 348	SS 348	Zircaloy	Zircaloy
Displacement Rod Configuration	-	-	-	-	-	-	-	-	-	-
Displacement Rod Material	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Zircaloy - 4	Zircaloy - 4
Displacement Rod Diameter (cm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.9271	0.9271
Number Per Assembly	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	2
Guide Bar Configuration	-	-	-	-	-	-	-	-	-	-
Guide Bar Material	Zircaloy - 4	Zircaloy - 4	SS 304L	SS 304L	Zircaloy	Zircaloy	N/A	N/A	N/A	N/A
Guide Bar Width (cm)	1.0973	1.0973	1.0566	1.0566	1.0566	1.0566	N/A	N/A	N/A	N/A
Guide Bar Shape (cm)	Square	Square	Square	Square	Square	Square	N/A	N/A	N/A	N/A
Number Per Assembly	8	8	8	8	8	8	N/A	N/A	N/A	N/A
Instrument Tube Configuration	-	-	-	-	-	-	-	-	-	-
Instrument Tube ID (cm)	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970	0.9995	0.9995	0.9995	0.9995
Instrument Tube OD (cm)	1.1481	1.1481	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884
Number Per Assembly	1	1	1	1	1	1	1	1	1	1
Instrument Tube Material	Zircaloy - 4	Zircaloy - 4	SS 304	SS 304	Zircaloy	Zircaloy	SS 304	SS 304	SS 304	SS 304
SS Inert Rod Configuration	-	-	-	-	-	-	-	-	-	-
Inert Rod Material	N/A	N/A	N/A	N/A	SS 304L	SS 304L	N/A	N/A	N/A	N/A
Inert Rod Diameter (cm)	N/A	N/A	N/A	N/A	0.6985	0.6985	N/A	N/A	N/A	N/A
Maximum Per Assembly	N/A	N/A	N/A	N/A	4	4	N/A	N/A	N/A	N/A

1. Nominal enrichments are stated (fuel fabrication tolerances not included).

Table 5.2.1-2 Yankee Class Design Basis Fuel Characteristics for Shielding Evaluations

Parameter	CE Type A
Assembly Configuration	-
Assembly Length (inches)	111.79
Assembly Array	16x16
Minimum Enrichment (wt % ^{235}U)	3.70[3,4]
UO_2 Fuel Mass (kg) at 95% TD	271.6
Fuel Rod Configuration	-
Fuel Rod Pitch (inches)	0.472
Overall Rod Length (inches)	95.4
Active Fuel Length (inches)	91
Rod OD (inches)	0.365
Clad ID (inches)	0.317
Pellet OD (inches)	0.3105
Diametral Gap (inches)	0.0065
Rods per Assembly	231
Clad Material	Zircaloy
Guide Bar Configuration	-
Guide Bar Material	Zircaloy - 4
Guide Bar Width (inches)	0.432
Guide Bar Length (inches)	96.52
Guide Bar Shape	Square
Number Per Assembly	8
Instrument Tube Configuration	-
Instrument Tube ID (inches)	0.3925
Instrument Tube OD (inches)	0.452
Instrument Tube Length (inches)	97.35
Number Per Assembly	1
Instrument Tube Material	Zircaloy - 4
Hardware Configuration	-
Top Nozzle Material	SS 304
Bottom Nozzle Material	SS 304
Upper Plenum Spring Material	SS 302[1]
Top Nozzle Length (inches)	7.98
Bottom Nozzle Length (inches)	7.19
Upper Plenum Length (inches)	1.942
Top Nozzle Mass (kg)	5.5
Bottom Nozzle Mass (kg)	5.18
Upper Plenum Spring Mass (kg)	0.762
Upper Plenum Grid Mass (kg)	0.590
Lower Plenum Material	Stainless Steel and Inconel[1,2]
Lower Plenum Mass (kg)	1.73[2]
Incore Grid Spacers	Zircaloy -4

Notes:
1. For simplicity, all Inconel and steel are modeled as Type 304 stainless steel.
2. Includes Inconel grid and lower plenum spacer.
3. Combustion Engineering fuel may be loaded at a cool time of 8.0 years with a maximum burnup of 32,000 MWD/MTU and a minimum enrichment of 3.5 wt% ^{235}U.
4. The analyzed minimum enrichment for CE fuel is 3.66 wt % ^{235}U for fuel with a maximum burnup of 36,000 MWD/MTU. This reduction in minimum enrichment does not significantly affect calculated dose rates.

Table 5.2.1-3 Yankee Class Design Basis Fuel Reactor Operating Conditions

Assembly Power, MW	8.486
$Temperature_{fuel}$, K	797
$Temperature_{clad}$, K	600
$Temperature_{mod}$, K	551
$Density_{mod}$, g/cc	0.766
Boron, ppm	800
Fuel Burnup, MWD/MTU	36,000
Burnup Cycle, days	2 Cycles of 496.22 days
Down Time, days	60

Table 5.2.1-4 Yankee-MPC Design Basis Fuel Source Terms

Decay Heat, kW	12.5
Active Fuel, photons/sec	6.423+16
Active Fuel, neutrons/sec	2.415+9
Upper End fitting, photons/sec	8.330+13
Upper Plenum, photons/sec	2.309+13
Lower End fitting, photons/sec	7.876+13
Lower Plenum, photons/sec	5.242+13

Condition: 36 Combustion Engineering Yankee Class Fuel Assemblies, 8 Years Cooled, and 36,000 MWD/MTU Burnup.

Table 5.2.1-5 Yankee-MPC Design Basis Fuel Gamma Source Spectra

Group	Gamma Source Spectra[1]	
	Fuel Photons/sec	**Fuel Hardware Photons/sec-kg**
1	3.7701E+04	0.0000E+00
2	1.7759E+05	0.0000E+00
3	9.0547E+05	0.0000E+00
4	2.2566E+06	0.0000E+00
5	6.2676E+08	1.0141E-15
6	5.1211E+09	3.3511E+04
7	1.0789E+11	2.1611E+07
8	9.9933E+10	9.5163E-03
9	4.8070E+12	9.1066E+11
10	3.4718E+13	3.2247E+12
11	6.3503E+13	4.3841E+09
12	8.2333E+14	3.8100E+06
13	1.1897E+14	1.0971E+07
14	1.7831E+13	1.7359E+08
15	2.8386E+13	1.3230E+08
16	1.0201E+14	2.6645E+09
17	1.3136E+14	1.1044E+10
18	4.5899E+14	5.5673E+10
Total	1.7842E+15	4.2095E+12

1. 36,000 MWD/MTU and 8 years cool time.

Table 5.2.1-6 Yankee-MPC Design Basis Fuel Neutron Source Spectra

Group	Neutrons/sec[1]
1	1.2290E+06
2	1.4080E+07
3	1.5760E+07
4	8.7930E+06
5	1.1840E+07
6	1.2870E+07
7	2.5190E+06
8	0.0000E+00
9	0.0000E+00
10	0.0000E+00
11	0.0000E+00
12	0.0000E+00
13	0.0000E+00
14	0.0000E+00
15	0.0000E+00
16	0.0000E+00
17	0.0000E+00
18	0.0000E+00
19	0.0000E+00
20	0.0000E+00
21	0.0000E+00
22	0.0000E+00
23	0.0000E+00
24	0.0000E+00
25	0.0000E+00
26	0.0000E+00
27	0.0000E+00
TOTAL	6.7090E+07

1. 36,000 MWD/MTU and 8-year cool time.

Table 5.2.1-7 MCBEND Three-Dimensional Design Basis Fuel Assembly Description

Parameter	Value
Fuel Rod Height [cm]	242.32
Active Fuel Region Height [cm]	231.14
Lower Plenum Region Height [cm]	5.36
Fuel Rod Diameter [cm]	0.93
Fuel Clad Thickness [cm]	0.06
Fuel Pellet Diameter [cm]	0.79
Fuel Rod Pitch [cm]	1.20
Number of Guide Bars	8
Guide Bar Width [cm]	1.05
Number of Instrument Tubes	1
Instrument Tube OD [cm]	1.15
Instrument Tube Thickness [cm]	0.08
Fuel Assembly Height [cm]	283.95
Fuel Assembly Width [cm]	19.30
Lower Nozzle Height [cm]	18.26
Upper Nozzle Height [cm]	20.27
Gap Fuel Rod to Top Nozzle [cm]	3.10
Upper Plenum Region Height [cm]	5.82
Number of Fuel Rods	231
Calculated MTU [MTU]	0.2394

Table 5.2.1-8 MCBEND Standard 28 Group Neutron Boundaries

Group	E Lower [MeV]	E Upper [MeV]	E Average [MeV]
1	1.360E+01	1.460E+01	1.410E+01
2	1.250E+01	1.360E+01	1.305E+01
3	1.125E+01	1.250E+01	1.188E+01
4	1.000E+01	1.125E+01	1.063E+01
5	8.250E+00	1.000E+01	9.125E+00
6	7.000E+00	8.250E+00	7.625E+00
7	6.070E+00	7.000E+00	6.535E+00
8	4.720E+00	6.070E+00	5.395E+00
9	3.680E+00	4.720E+00	4.200E+00
10	2.870E+00	3.680E+00	3.275E+00
11	1.740E+00	2.870E+00	2.305E+00
12	6.400E-01	1.740E+00	1.190E+00
13	3.900E-01	6.400E-01	5.150E-01
14	1.100E-01	3.900E-01	2.500E-01
15	6.740E-02	1.100E-01	8.870E-02
16	2.480E-02	6.740E-02	4.610E-02
17	9.120E-03	2.480E-02	1.696E-02
18	2.950E-03	9.120E-03	6.035E-03
19	9.610E-04	2.950E-03	1.956E-03
20	3.540E-04	9.610E-04	6.575E-04
21	1.660E-04	3.540E-04	2.600E-04
22	4.810E-05	1.660E-04	1.071E-04
23	1.600E-05	4.810E-05	3.205E-05
24	4.000E-06	1.600E-05	1.000E-05
25	1.500E-06	4.000E-06	2.750E-06
26	5.500E-07	1.500E-06	1.025E-06
27	7.090E-08	5.500E-07	3.105E-07
28	1.000E-11	7.090E-08	3.546E-08

Table 5.2.1-9 MCBEND Standard 22 Group Gamma Boundaries

Group	E Lower [MeV]	E Upper [MeV]	E Average [MeV]
1	1.20E+01	1.40E+01	1.30E+01
2	1.00E+01	1.20E+01	1.10E+01
3	8.00E+00	1.00E+01	9.00E+00
4	6.50E+00	8.00E+00	7.25E+00
5	5.00E+00	6.50E+00	5.75E+00
6	4.00E+00	5.00E+00	4.50E+00
7	3.00E+00	4.00E+00	3.50E+00
8	2.50E+00	3.00E+00	2.75E+00
9	2.00E+00	2.50E+00	2.25E+00
10	1.66E+00	2.00E+00	1.83E+00
11	1.44E+00	1.66E+00	1.55E+00
12	1.22E+00	1.44E+00	1.33E+00
13	1.00E+00	1.22E+00	1.11E+00
14	8.00E-01	1.00E+00	9.00E-01
15	6.00E-01	8.00E-01	7.00E-01
16	4.00E-01	6.00E-01	5.00E-01
17	3.00E-01	4.00E-01	3.50E-01
18	2.00E-01	3.00E-01	2.50E-01
19	1.00E-01	2.00E-01	1.50E-01
20	5.00E-02	1.00E-01	7.50E-02
21	2.00E-02	5.00E-02	3.50E-02
22	1.00E-02	2.00E-02	1.50E-02

Table 5.2.1-10 Design Basis Source Spectra in MCBEND Format

Group	Fuel Neutron [/sec/assy]	Fuel Gamma [/sec/assy]	Hardware [/sec/kg]
1	0.000E+00	0.0000E+00	0.0000E+00
2	4.375E+03	1.9491E+03	0.0000E+00
3	1.823E+04	3.7701E+04	0.0000E+00
4	6.056E+04	1.7759E+05	0.0000E+00
5	1.900E+05	9.0547E+05	0.0000E+00
6	5.100E+05	2.2566E+06	0.0000E+00
7	8.804E+05	6.2676E+08	1.0141E-15
8	2.946E+06	5.1214E+09	3.3511E+04
9	5.031E+06	1.0789E+11	2.1611E+07
10	6.930E+06	9.9933E+10	9.5163E-03
11	1.649E+07	1.6057E+12	5.7445E+00
12	2.523E+07	2.3679E+13	2.0473E+12
13	6.535E+06	1.2298E+13	2.1580E+12
14	2.268E+06	6.3503E+13	4.3841E+09
15	1.082E+02	8.2332E+14	3.8100E+06
16	0.000E+00	1.1897E+14	1.0971E+07
17	0.000E+00	1.7831E+13	1.7359E+08
18	0.000E+00	2.8386E+13	1.3230E+08
19	0.000E+00	1.0201E+14	2.6645E+09
20	0.000E+00	1.3136E+14	1.1044E+10
21	0.000E+00	3.0385E+14	3.1609E+10
22	0.000E+00	2.0898E+14	3.7591E+10
23	0.000E+00		
24	0.000E+00		
25	0.000E+00		
26	0.000E+00		
27	0.000E+00		
28	0.000E+00		
Total	6.709E+07	1.8360E+15	4.2929E+12

5.2.2 Connecticut Yankee Fuel Source Term Specification

The CY-MPC system is designed to safely transfer and store Connecticut Yankee fuel assemblies and non-fuel hardware. The spent fuel inventory consists of both stainless steel clad and Zircaloy clad fuel assemblies. Due to the activation of cobalt impurities present in the stainless steel cladding, these two fuel types are treated separately in the analysis. Based on the fuel inventory, limiting combinations of burnup and cool time for the two fuel types have been identified as shown:

Fuel Type	Maximum Burnup [MWD/MTU]	Minimum Cool Time [yr]
Stainless steel clad	38,000	5
Zircaloy clad	43,000	5

In some cases, additional activated non-fuel hardware, such as Reactor Control Cluster Assemblies and Flow Mixers, will be inserted and stored in CY fuel assemblies. In practice, these insert-containing fuel assemblies are subject to certain additional constraints on either maximum burnup or minimum cool time. In particular, these activated non-fuel components are intended for storage in stainless steel-clad fuel at 38,000 MWd/MTU and 10 years cool time or Zircaloy clad fuel at 20,000 MWd/MTU and 5 years cool time. However, no credit for the reduced source terms of these fuel assemblies is taken here. The non-fuel hardware activation analysis is performed using conservative values for cumulative lifetime exposure. Each Reactor Control Cluster Assembly is assumed to have been positioned in the reactor during operation so as to achieve the maximum possible activation of material throughout its lifetime. Additionally, each flow mixer is assumed to have been in place in the top nozzle of a fuel assembly for every CY plant cycle.

Cross-sectional sketches of the modeled Connecticut Yankee fuel assemblies are shown in Figure 5.2.2-1. The physical parameters of the Connecticut Yankee fuel assemblies are presented in Table 2.1-3.

An evaluation of the Connecticut Yankee spent fuel inventory establishes the Westinghouse 15×15 fuel assembly (Table 5.2.2-1) as the limiting stainless steel clad fuel type based on initial mass loading of uranium. The bounding stainless steel clad fuel in the Connecticut Yankee

inventory has a maximum burnup of 38,000 MWd/MTU, minimum initial enrichment of 3.65 wt. % ^{235}U, and a minimum cooling time of 5 years. Some stainless steel clad fuel assemblies in the Connecticut Yankee inventory have initial enrichments as low as 3.00 wt. % ^{235}U; however, stainless steel clad fuel assemblies with initial enrichments lower than 3.65 wt. % ^{235}U also have lower maximum burnups as shown in the following table.

For Zircaloy clad fuels, the limiting fuel description is based on a maximum burnup of 43,000 MWd/MTU, minimum initial enrichment of 3.59 wt. % ^{235}U, and a minimum cooling time of 5 years. Some Zircaloy clad fuel in the Connecticut Yankee inventory has initial enrichments as low as 2.95 wt. % ^{235}U (see Table 2.1-3); however source terms produced by the design basis combination of burnup and initial enrichment for the limiting Zircaloy clad fuel assemblies bound those of Zircaloy clad fuel assemblies at lower initial enrichments.

The following table provides the acceptable combinations of maximum burnup and minimum initial enrichment that are bounded by the design basis stainless steel and Zircaloy clad fuel assemblies utilized in the dose rate analyses:

Stainless Steel Clad Fuel			**Zircaloy Clad Fuel**		
Enrichment	**Maximum Burnup**	**Minimum Cool Time**	**Enrichment**	**Maximum Burnup**	**Minimum Cool Time**
[wt. % ^{235}U]	**[MWD/MTU]**	**[y]**	**[wt. % ^{235}U]**	**[MWD/MTU]**	**[y]**
$e \geq 3.65$	38,000	5	$e \geq 3.59$	43,000	5
$3.23 \leq e < 3.96$	34,000	5	$3.40 \leq e < 3.59$	40,000	5
$3.00 \leq e < 3.23$	30,000	5	$2.95 \leq e < 3.40$	30,000	5

The SAS2H code sequence (Herman) is used to generate source terms. This code sequence is part of the SCALE 4.3 code package for the PC (ORNL). SAS2H includes an XSDRNPM (Greene) neutronics model of the fuel assembly and ORIGEN-S (Herman) fuel depletion/source term calculations. Reactor operating conditions assumed for the analysis are shown in Table 5.2.2-2. The SAS2H-generated source spectra are rebinned onto the standard 28 group neutron and 22 group gamma scheme used in MCBEND as shown in Table 5.2.2-3 and Table 5.2.2-4, respectively. Source terms are generated for the fuel and fuel assembly hardware. The hardware activation is calculated by light element transmutation using the incore neutron flux spectrum produced by the SAS2H neutronics model.

The Connecticut Yankee design basis fuel source terms are presented in Tables 5.2.2-5 and 5.2.2-6. The activated hardware source term is provided on a per unit mass basis. Source strengths are defined for five source regions: active fuel, upper end fitting, upper plenum, lower end fitting and lower plenum. The fuel assembly length, active fuel region length and fuel assembly hardware lengths are shown for the design basis fuel assemblies in Figure 5.2.2-1.

5.2.2.1 Connecticut Yankee Fuel Gamma Source

The design basis fuel and hardware gamma source spectra are shown in Table 5.2.2-5 and Table 5.2.2-6. The fuel gamma source contains contributions from both fission products and actinides. The spectra are presented in the standard 22 group structure used by MCBEND. The hardware gamma spectra contains contributions primarily from ^{60}Co due to the activation of Type 304 stainless steel with either 0.5 g/kg or 1.2 g/kg ^{59}Co impurity and with some minor contributions from ^{59}Ni and ^{58}Fe. The magnitude of this spectra is based on the irradiation of 1 kg of stainless steel in the incore flux spectrum produced by the SAS2H neutronics calculation.

The activated fuel assembly hardware source strength for a given source region is determined as the product of the hardware source strength per unit mass (Tables 5.2.2-5 and 5.2.2-6), the mass of the hardware (Table 5.2.2-7), a regional flux activation ratio (Table 5.2.2-7), and a mass scale factor (Table 5.2.2-7). The mass scale factor is applied only to the stainless steel fuel assemblies. It accounts for the difference in cobalt concentration of the individual hardware regions and the concentration used in the SAS2H ORIGEN-S burnup evaluation. The stainless steel fuel rod cladding and end-plugs contain a maximum of 0.5 g/kg of ^{59}Co versus the 1.2 g/kg ^{59}Co that is applied to the remaining steel components of the assembly. Rather than running one source term evaluation for the cladding and end-plugs and one source term evaluation for the remaining hardware, a single ORIGEN-S run is made using a concentration of 0.5 g/kg ^{59}Co. In the MCBEND shielding evaluation of the assembly nozzle, plenum and grid spacer sources, the hardware gamma source resulting from the 0.5 g/kg ^{59}Co ORIGEN-S evaluation is increased by a factor of (1.2/0.5 =) 2.4. The factor is applied by directly entering the scaling factor into the MCBEND Monte Carlo shielding input source strength cards. A scale factor of "1.0" is used as the shielding input source strength for the stainless steel cladding and end-plug analysis since the source term for these components is determined at the appropriate cobalt concentration (0.5 g/kg) by the ORIGEN-S run. Similarly, only a single

^{59}Co concentration of 1.2 g/kg ^{59}Co applies to the Zircaloy fuel assemblies, resulting in a scale factor of "1" for all of the activated Zircaloy clad fuel assembly hardware regions.

The regional flux activation ratio accounts for the effects of both magnitude and spectrum variation on hardware activation. These ratios are based on empirical data (Luksic). A flux ratio of 0.2 is applied to hardware regions directly adjacent to the active core region, i.e., upper and lower plenum. A flux ratio of 0.1 is applied to hardware regions once removed from the active core region, i.e., upper and lower end fitting region.

5.2.2.2 Connecticut Yankee Fuel Neutron Source

The neutron source results from actinide spontaneous fission and from (α,n) reactions with the oxygen in UO_2. The isotopes ^{242}Cm and ^{244}Cm characteristically produce all but a few percent of the spontaneous fission neutrons and (α,n) source in light water reactor fuel. The next largest contribution is from (α,n) reactions from ^{238}Pu. The neutron spectra from spontaneous fission is based on fission spectrum measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions is based on Po-α-O source measurements. These spectra are included in the ORIGEN-S nuclear data libraries of the SCALE 4.3 code package. The spectra is automatically collapsed from the energy group structure of the data library into that of the MCBEND 28 group neutron cross-section structure.

The effect of subcritical neutron multiplication is not directly computed in the MCBEND analysis conducted here, due to difficulties in adequately biasing the calculation. Instead, neutron source rates are scaled by a subcritical multiplication factor (scale factor) based on the system multiplication factor, k_{eff}:

$$\text{Scale Factor} = \frac{1}{1 - k_{eff}}$$

For dry cask conditions, the system k_{eff} is taken as 0.4, with a resulting scale factor of 1.67. For wet conditions, the system k_{eff} is assumed to be the maximum allowable value of 0.95, resulting in a scale factor of 20. The scale factor is a direct input value in the MCBEND input file to account for system thermal neutron subcritical multiplication.

5.2.2.3 Connecticut Yankee Non-Fuel Hardware Source

Activated reactor control hardware suitable for storage in the CY–MPC is limited to Reactor Control Cluster Assemblies (RCCA) and Flow Mixer hardware. There are no source term constraints on the selection of the containing assembly; although, in practice, the material will preferentially be placed in lower source term assemblies. In the case of Flow Mixer hardware, a constraint on the permissible number and location of containing assemblies within the basket is imposed. No more than eight assemblies containing Flow Mixers can be loaded into a single canister, and the assemblies must be loaded into fuel assemblies in the centermost basket positions 7, 8, 12, 13, 14, 15, 19 and 20 as shown in Figure 2.1-1.

SAS2H models are developed which reproduce the irradiation history of the RCCA and Flow Mixers in the Connecticut Yankee spent fuel pool inventory. The cycle burnup history for the Connecticut Yankee reactor is shown in Table 5.2.2–8. The Flow Mixers are conservatively assumed to be present in every cycle of operation. The RCCAs are classified into two groups and analyzed separately. The first set of RCCAs was irradiated during operating cycles 1 through 14. The second and more limiting group of RCCAs was irradiated during operating cycles 15 through 19 and are assumed to have been partially inserted into the active core during operation. That is, the bottommost 9 inches of the RCCA is exposed to 60% of the full power flux for the entire irradiation history. The source term analysis for the RCCAs considers activation of both Inconel and Ag-In-Cd material. The resulting source spectra are presented in Table 5.2.2–9 on a per unit mass basis. The modeled mass in each source region is shown in Table 5.2.2–10 for both RCCAs and Flow Mixers.

In general, the dose rates resulting from activation of the non-fuel hardware material are relatively small as compared to that from fuel sources. Results are presented in Section 5.4.2.

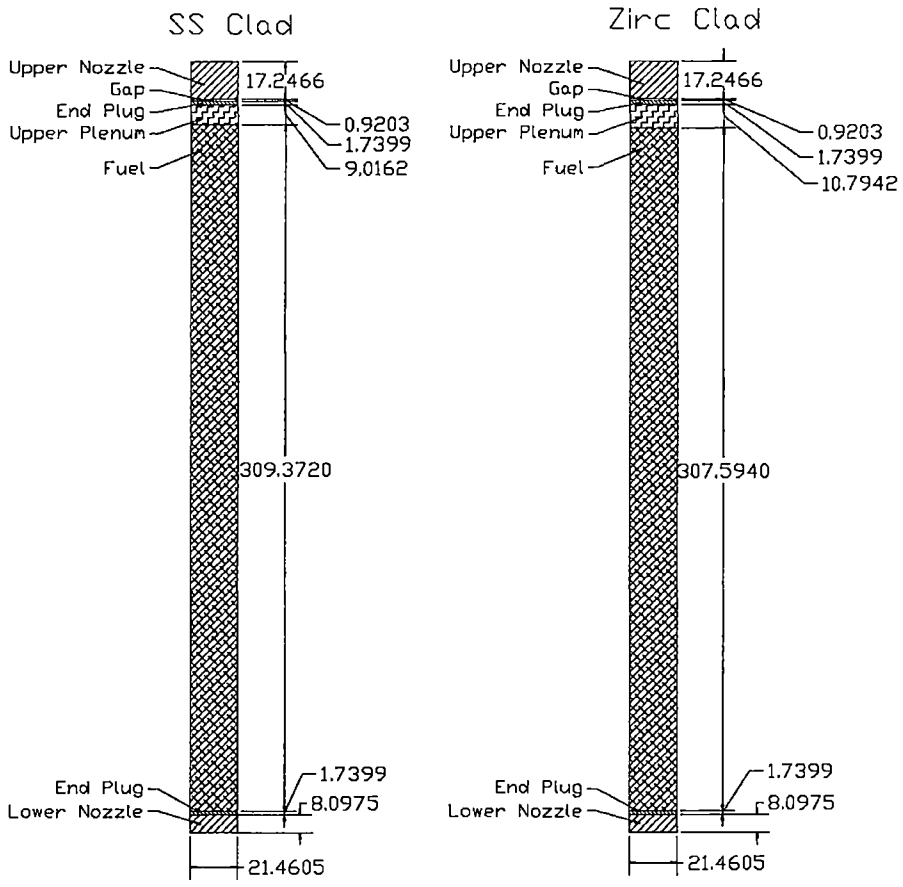
5.2.2.4 Connecticut Yankee Fuel Source Axial Profile

An enveloping axial burnup shape for three-dimensional shielding and thermal evaluations is created based on measured burnup profile data for PWR fuel. Neutron and gamma source profiles are computed based on an assumed relation between burnup, B, and source strength, S, in the form:

$$S = aB^b$$

Parameters a and b are determined by plotting the neutron or gamma source strength calculated by SAS2H against burnup on a log-log scale for various values of burnup. The resulting points are a line having a slope of value "b." The parameter *a* is a scaling factor. For neutron source strengths, which are non-linear with burnup, the value of b is determined by ORIGEN-S SASH evaluations at various burnups and is 4.22 for the system evaluated. For gamma source strengths, the value of b is 1.0, reflecting the linear relation between burnup and source rate. Table 5.2.2–11 gives the resulting source rate profiles for stainless steel clad and Zircaloy clad fuel types. The relative source strength in each axial interval is shown, and these values are used directly in the MCBEND source strength description by defining an axial source mesh within the fuel region at the indicated elevations for each fuel type. A plot of the axial source profiles is shown in Figure 5.2.2–2. The maximum peaking factors produced by these profiles is lower than the peaking factors reported for the Yankee Class fuel assemblies in Section 5.2.1 due to the higher burnup of the CY-class design basis fuel description.

Figure 5.2.2-1 Connecticut Yankee Design Basis Fuel Assembly Source Regions and Elevations



(Dimensions in cm)

Figure 5.2.2-2 Connecticut Yankee Design Basis Fuel Axial Neutron and Gamma Source Profiles in Active Fuel Region

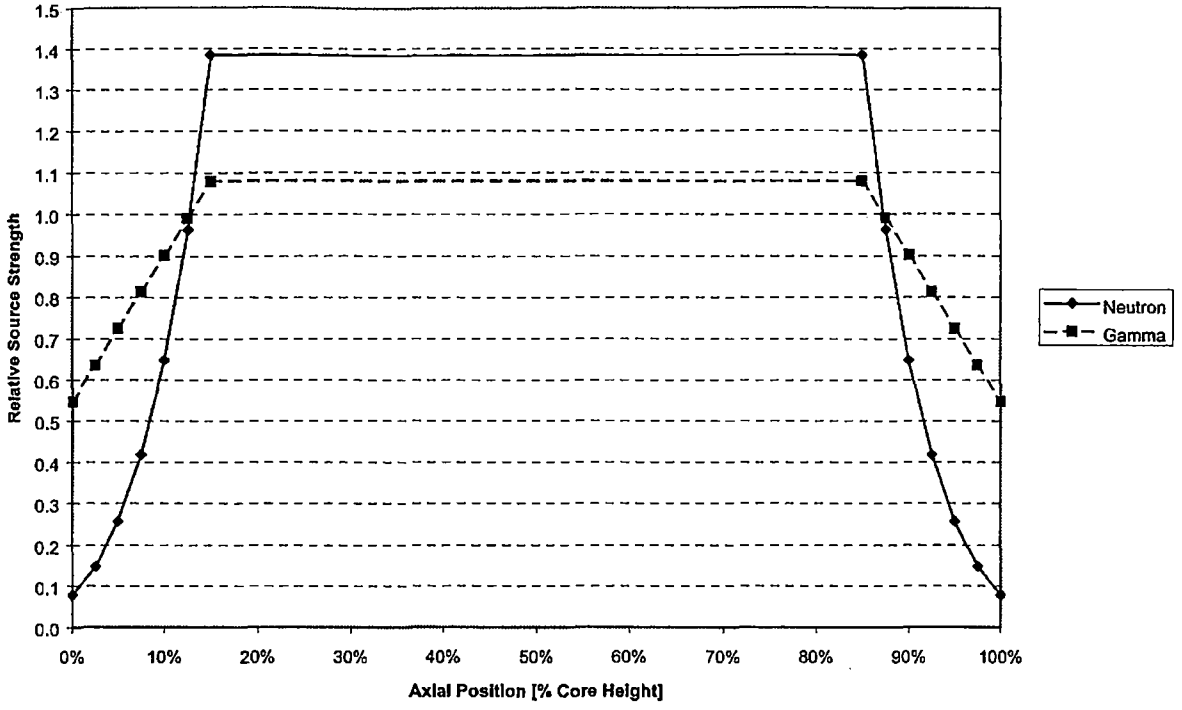


Table 5.2.2-1 Connecticut Yankee Design Basis Fuel Characteristics for Shielding Evaluations

Description	SS Clad [cm]	Zirc Clad [cm]
Fuel Rod Height	321.868	321.868
Top End-Cap Height	1.7399	1.7399
Bottom End-Cap Height	1.7399	1.7399
Active Fuel Region Height	309.372	307.594
Lower Plenum Region Height	0	0
Fuel Rod Diameter	1.0719	1.0757
Fuel Clad Thickness	0.0419	0.0636
Fuel Pellet Diameter	0.9741	0.9347
Array Size for Fuel Assembly	15	15
Fuel Rod Pitch	1.43	1.43
Guide Tube OD	1.3792	1.3538
Guide Tube Thickness	0.0305	0.0432
Instrument Tube OD	1.0719	1.3538
Instrument Tube Thickness	0.0419	0.0432
Fuel Assembly Height	348.1324	348.1324
Fuel Cross Section Width	21.4605	21.4605
Lower Nozzle Height	8.0975	8.0975
Upper Nozzle Height	17.2466	17.2466
Gap Fuel Rod to Bottom Nozzle	0	0
Number of Guide Tubes	20	20
Number of Instrument Tubes	1	1
Number of Fuel Pins	204	204
Upper Plenum Height	9.0162	10.7942
Gap Fuel Rod to Upper Nozzle	0.9203	0.9203

Table 5.2.2-2 Connecticut Yankee Design Basis Fuel Reactor Operating Conditions

Parameter	SS Clad	Zirc Clad
Assembly Power, MW	12.787	12.787
Fuel Temperature, K	900	900
Clad Temperature, K	620	620
Moderator Temperature, K	580	580
Moderator Density, g/cc	0.725	0.725
Boron, ppm	550	550
Fuel Burnup, MWD/MTU	38,000	43,000
Number of Cycles	3	3
Burnup Cycle, days	427.61	442.99
Down Time, days	60	60

Table 5.2.2-3 MCBEND Standard 28 Group Neutron Boundaries

Group	E Lower [MeV]	E Upper [MeV]	E Average [MeV]
1	1.360E+01	1.460E+01	1.410E+01
2	1.250E+01	1.360E+01	1.305E+01
3	1.125E+01	1.250E+01	1.188E+01
4	1.000E+01	1.125E+01	1.063E+01
5	8.250E+00	1.000E+01	9.125E+00
6	7.000E+00	8.250E+00	7.625E+00
7	6.070E+00	7.000E+00	6.535E+00
8	4.720E+00	6.070E+00	5.395E+00
9	3.680E+00	4.720E+00	4.200E+00
10	2.870E+00	3.680E+00	3.275E+00
11	1.740E+00	2.870E+00	2.305E+00
12	6.400E-01	1.740E+00	1.190E+00
13	3.900E-01	6.400E-01	5.150E-01
14	1.100E-01	3.900E-01	2.500E-01
15	6.740E-02	1.100E-01	8.870E-02
16	2.480E-02	6.740E-02	4.610E-02
17	9.120E-03	2.480E-02	1.696E-02
18	2.950E-03	9.120E-03	6.035E-03
19	9.610E-04	2.950E-03	1.956E-03
20	3.540E-04	9.610E-04	6.575E-04
21	1.660E-04	3.540E-04	2.600E-04
22	4.810E-05	1.660E-04	1.071E-04
23	1.600E-05	4.810E-05	3.205E-05
24	4.000E-06	1.600E-05	1.000E-05
25	1.500E-06	4.000E-06	2.750E-06
26	5.500E-07	1.500E-06	1.025E-06
27	7.090E-08	5.500E-07	3.105E-07
28	1.000E-11	7.090E-08	3.546E-08

Table 5.2.2-4 MCBEND Standard 22 Group Gamma Boundaries

Group	E Lower [MeV]	E Upper [MeV]	E Average [MeV]
1	1.200E+01	1.400E+01	1.300E+01
2	1.000E+01	1.200E+01	1.100E+01
3	8.000E+00	1.000E+01	9.000E+00
4	6.500E+00	8.000E+00	7.250E+00
5	5.000E+00	6.500E+00	5.750E+00
6	4.000E+00	5.000E+00	4.500E+00
7	3.000E+00	4.000E+00	3.500E+00
8	2.500E+00	3.000E+00	2.750E+00
9	2.000E+00	2.500E+00	2.250E+00
10	1.660E+00	2.000E+00	1.830E+00
11	1.440E+00	1.660E+00	1.550E+00
12	1.220E+00	1.440E+00	1.330E+00
13	1.000E+00	1.220E+00	1.110E+00
14	8.000E-01	1.000E+00	9.000E-01
15	6.000E-01	8.000E-01	7.000E-01
16	4.000E-01	6.000E-01	5.000E-01
17	3.000E-01	4.000E-01	3.500E-01
18	2.000E-01	3.000E-01	2.500E-01
19	1.000E-01	2.000E-01	1.500E-01
20	5.000E-02	1.000E-01	7.500E-02
21	2.000E-02	5.000E-02	3.500E-02
22	1.000E-02	2.000E-02	1.500E-02

Table 5.2.2-5 Connecticut Yankee Design Basis Stainless Steel Clad Fuel Source Term at 38,000 MWD/MTU and 5 Years Cool Time

Group	Fuel Neutron [n/sec/assy]	Fuel Gamma [g/sec/assy]	Fuel Hardware [g/sec/kg]
1	0.0000E+00	0.0000E+00	0.0000E+00
2	1.1180E+04	4.9793E+03	0.0000E+00
3	4.6600E+04	9.6309E+04	0.0000E+00
4	1.5480E+05	4.5363E+05	0.0000E+00
5	4.8560E+05	2.3127E+06	0.0000E+00
6	1.3040E+06	5.7632E+06	0.0000E+00
7	2.2510E+06	7.8829E+09	1.1585E-15
8	7.5300E+06	6.3481E+10	2.1884E+04
9	1.2830E+07	1.9376E+12	1.4113E+07
10	1.7500E+07	8.5576E+11	3.9579E+02
11	4.1640E+07	5.4210E+12	3.7515E+00
12	6.4300E+07	6.8388E+13	1.3369E+12
13	1.6700E+07	4.4331E+13	1.4092E+12
14	5.7930E+06	2.7622E+14	4.2211E+10
15	2.1670E+02	2.0157E+15	2.4881E+06
16	0.0000E+00	5.9835E+14	7.1902E+06
17	0.0000E+00	5.4394E+13	1.1336E+08
18	0.0000E+00	8.1902E+13	8.6397E+07
19	0.0000E+00	3.0089E+14	1.7400E+09
20	0.0000E+00	3.6139E+14	7.2125E+09
21	0.0000E+00	8.1082E+14	2.0681E+10
22	0.0000E+00	5.5606E+14	2.4715E+10
23	0.0000E+00		
24	0.0000E+00		
25	0.0000E+00		
26	0.0000E+00		
27	0.0000E+00		
28	0.0000E+00		
Total	1.7050E+08	5.1767E+15	2.8430E+12

Table 5.2.2-6 Connecticut Yankee Design Basis Zircaloy Clad Fuel Source Term at 43,000 MWD/MTU and 5 Years Cool Time

Group	Fuel Neutron [n/sec/assy]	Fuel Gamma [g/sec/assy]	Fuel Hardware [g/sec/kg]
1	0.0000E+00	0.0000E+00	0.0000E+00
2	1.6330E+04	7.2619E+03	0.0000E+00
3	6.8020E+04	1.4045E+05	0.0000E+00
4	2.2600E+05	6.6153E+05	0.0000E+00
5	7.0880E+05	3.3725E+06	0.0000E+00
6	1.9030E+06	8.4034E+06	0.0000E+00
7	3.2850E+06	8.4881E+09	1.7794E-15
8	1.0990E+07	6.8189E+10	5.9000E+04
9	1.8680E+07	1.9622E+12	3.8050E+07
10	2.5310E+07	9.0679E+11	3.8679E+02
11	6.0200E+07	5.8277E+12	1.0114E+01
12	9.3640E+07	7.4958E+13	3.6045E+12
13	2.4370E+07	4.8339E+13	3.7994E+12
14	8.4530E+06	3.0517E+14	4.3571E+10
15	2.4950E+02	2.1295E+15	6.7081E+06
16	0.0000E+00	6.5754E+14	1.9341E+07
17	0.0000E+00	5.5897E+13	3.0562E+08
18	0.0000E+00	8.4758E+13	2.3293E+08
19	0.0000E+00	3.1138E+14	4.6912E+09
20	0.0000E+00	3.6951E+14	1.9445E+10
21	0.0000E+00	8.3600E+14	5.5619E+10
22	0.0000E+00	5.7232E+14	6.6046E+10
23	0.0000E+00		
24	0.0000E+00		
25	0.0000E+00		
26	0.0000E+00		
27	0.0000E+00		
28	0.0000E+00		
Total	2.4780E+08	5.4541E+15	7.5939E+12

Table 5.2.2-7 Connecticut Yankee Design Basis Fuel Assembly Activated Hardware Mass and Mass Scale Factors by Source Region

Stainless Steel Clad			
Region	**Mass [kg/assy]**	**Mass Factor**	**Activation Ratio**
Lower Nozzle	8.850	2.4	0.1
Lower End Plug	2.537	1.0	0.2
Fuel Clad	72.933	1.0	1.0
Fuel Grid	12.458	2.4	1.0
Upper Plenum	3.879	2.4	0.2
Upper End Plug	2.537	1.0	0.2
Upper Nozzle	11.240	2.4	0.1
Zircaloy Clad			
Region	**Mass [kg/assy]**	**Mass Factor**	**Activation Ratio**
Lower Nozzle	5.440	1.0	0.1
Lower End Plug	0.000	1.0	0.2
Fuel Grid	19.415	1.0	1.0
Upper Plenum	5.137	1.0	0.2
Upper End Plug	0.000	1.0	0.2
Upper Nozzle	11.840	1.0	0.1

Table 5.2.2-8 Connecticut Yankee Reactor Operational Cycle History

Cycle	Cycle End Date	Cycle Length (days)	Core Loading (MTU)	Avg Cycle Burnup (MWD/MTU)
1	04/17/70	838	65.9	16965
2	04/16/71	295	65.3	7602
3	06/10/72	382	64.7	10201
4	07/08/73	359	64.4	9157
5	05/17/75	519	64.6	13152
6	05/18/76	323	64.6	8738
7	10/15/77	454	64.6	12283
8	01/27/79	423	64.6	11105
9	05/03/80	418	64.7	11044
10	09/26/81	427	64.7	11342
11	01/22/83	437	64.7	11081
12	08/01/84	479	64.6	12987
13	01/04/86	422	64.5	10987
14	07/18/87	435	64.5	10039
15	09/02/89	526	64.5	12982
16	10/17/91	428	64.8	10095
17	05/15/93	426	62.5	12035
18	01/28/95	558	59.9	13588
19	07/22/96	461	58.5	13844

Table 5.2.2-9 Connecticut Yankee Design Basis Non–Fuel Assembly Hardware Source Spectra

Group	RCCA Bot 18 in Fuel [γ/kg/sec]	Flowmixer Upper Plenum [γ/kg/sec]	Flowmixer End Fitting [γ/kg/sec]
1	0.0000E+00	0.0000E+00	0.0000E+00
2	0.0000E+00	0.0000E+00	0.0000E+00
3	0.0000E+00	0.0000E+00	0.0000E+00
4	0.0000E+00	0.0000E+00	0.0000E+00
5	0.0000E+00	0.0000E+00	0.0000E+00
6	0.0000E+00	0.0000E+00	0.0000E+00
7	4.1902E-08	7.0806E-17	3.5403E-17
8	3.1294E+04	2.0779E+04	1.0390E+04
9	1.2285E+07	1.3401E+07	6.7003E+06
10	5.1133E+08	6.4683E+01	3.2341E+01
11	2.8898E+11	3.5620E+00	1.7810E+00
12	5.8569E+11	1.2695E+12	6.3473E+11
13	1.8479E+11	1.3381E+12	6.6906E+11
14	1.8609E+12	6.4313E+09	3.2156E+09
15	6.8080E+12	2.3625E+06	1.1813E+06
16	1.9883E+12	6.8071E+06	3.4035E+06
17	7.0207E+09	1.0764E+08	5.3818E+07
18	8.1621E+09	8.2037E+07	4.1019E+07
19	1.9934E+10	1.6522E+09	8.2610E+08
20	2.1205E+11	6.8486E+09	3.4243E+09
21	1.1162E+12	1.9666E+10	9.8328E+09
22	6.2228E+10	2.3586E+10	1.1793E+10
Total	1.3143E+13	2.6660E+12	1.3330E+12

Table 5.2.2-10 Connecticut Yankee Design Basis Non–Fuel Hardware Masses

Reactor Control Cluster Assemblies			
Source	**Mass [kg]**	**Activation Region**	**Modeled Source Region**
Inconel 625	1.50	Upper Plenum (20% Flux)	Fuel (bottom 18 in)
Ag-In-Cd	5.00	Upper Plenum (20% Flux)	Fuel (bottom 18 in)
Inconel 625	1.50	Active Core (60% Flux)	Fuel (bottom 18 in)
Ag-In-Cd	5.00	Active Core (60% Flux)	Fuel (bottom 18 in)
Total	13.00	--	--

Flow Mixers		
Source	**Mass [kg]**	**Activation and Modeled Source Region**
St. Steel	1.80	Upper Fitting
Inconel	0.42	Upper Fitting
Total Fitting	2.22	--
St. Steel	2.70	Upper Plenum
Total Plenum	2.70	--

Table 5.2.2-11 CY-MPC Axial Gamma and Neutron Source Profiles – Design Basis Stainless Steel and Zircaloy Clad Fuels

% Core Height	SS Clad Elevation [cm]	Zirc Clad Elevation [cm]	Burnup Profile	Gamma Interval	Neutron Interval
0.00%	14.2824	14.2824	0.5470	--	--
2.50%	22.0167	21.9723	0.6358	5.914E-01	1.132E-01
5.00%	29.7510	29.6621	0.7247	6.803E-01	2.024E-01
7.50%	37.4853	37.3520	0.8135	7.691E-01	3.377E-01
10.00%	45.2196	45.0418	0.9023	8.579E-01	5.333E-01
12.50%	52.9539	52.7317	0.9912	9.468E-01	8.057E-01
15.00%	60.6882	60.4215	1.0800	1.036E+00	1.173E+00
85.00%	277.2486	275.7373	1.0800	1.080E+00	1.384E+00
87.50%	284.9829	283.4272	0.9912	1.036E+00	1.173E+00
90.00%	292.7172	291.1170	0.9023	9.468E-01	8.057E-01
92.50%	300.4515	298.8069	0.8135	8.579E-01	5.333E-01
95.00%	308.1858	306.4967	0.7247	7.691E-01	3.377E-01
97.50%	315.9201	314.1866	0.6358	6.803E-01	2.024E-01
100.00%	323.6544	321.8764	0.5470	5.914E-01	1.132E-01

5.3 Model Specification

Different models are used for the evaluation of the Yankee Class and Connecticut Yankee fuel. The Yankee Class fuel is evaluated using one-dimensional SAS1 models for the transfer and storage casks, as described in Section 5.3.1. Three-dimensional evaluations of the transfer and storage casks are performed using SAS4 and MCBEND, respectively. The Connecticut Yankee fuel is evaluated using the three-dimensional MCBEND Monte Carlo transport code. The MCBEND model is described in Section 5.3.2.

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5.3.1 Yankee-MPC Transfer and Storage Cask Model Specifications

Both one-dimensional SAS1 and three-dimensional SAS4 models are used in the shielding evaluations of the Yankee-MPC storage system. The SAS1 radial and axial models are used to estimate the peak and average dose rates on the sides, top and bottom of the storage and transfer casks, and to determine the minimum cool time for the 36,000 MWD/MTU fuel. The one-dimensional models represent the casks as either semi-infinite cylinders or slabs. The method of solution uses the XSDRNPM (Greene) discrete ordinates code and the XSDOSE (Buckholz) flux at a point estimation code. Bucklings are applied to the SAS1 models to account for transverse leakage. One-dimensional analysis also serves as a cross check to the more complex three-dimensional model results.

The SAS4 three-dimensional shielding models are used to estimate the dose profiles at the surfaces of the cask and at streaming paths such as the canister vent and drain ports. The method of solution is adjoint discrete ordinates and Monte Carlo (Tang) using the XSDRNPM and MORSE codes, respectively. The adjoint biasing performed by XSDRNPM is a one-dimensional solution, which may not generate optimal importance maps for geometries that differ from the user-supplied bias map. For example, an importance map optimized for particle acceleration at the concrete cask midplane yields an unoptimized radial importance map at the concrete cask air inlets. This phenomenon has yielded non-converging dose rate results at the inlets, due to high weight, low probability particles passing the detector surface. In order to more effectively estimate air inlet dose rates, the MCBEND code is employed, which has as one of its features the option of a user-supplied three-dimensional importance map. In order to present a consistent seyt of results, the three-dimensional analysis of the concrete cask is performed exclusively using MCBEND.

Since SAS4 requires model symmetry at the fuel midplane, two models are created for each cask, a top and a bottom model. Radial biasing is performed to estimate dose rates on the sides of the cask, and axial biasing is performed to estimate dose rates on the top and bottom surfaces of the cask. Modifications are made to SAS4 to tally dose rates all along the radial, top and bottom surfaces of the cask, as well as any cylindrical surface surrounding the cask. Thus, detailed dose rate profiles are determined that explicitly show peaks due to the fuel burnup profile, activated hardware gamma emission and streaming paths.

In both SAS1 and SAS4 models, the fuel and hardware source regions are homogenized within the volumes defined by the periphery of the basket tubes and by the elevations of the basket heat transfer zone, the active fuel, the plenum and the end fittings (Table 5.3.1-1). Within these volumes, the material masses of the fuel assembly and basket are homogenized (Table 5.3.1-2). The design basis fuel assembly and the Yankee-MPC basket materials are obtained from Table 5.2.1-2 and from Drawings 455-881, 455-891, 455-892, 455-893, 455-894 and 455-895 (Section 1.7). The SCALE 4.3 standard composition library (Landers) default compositions and isotopic distributions are used except for BORAL, NS-4-FR and concrete (Section 5.3.1.2). The resultant material zones and nuclide densities are summarized in Table 5.3.1-3. In all models, the cask and canister shield thicknesses are explicitly represented.

MCBEND Model Description

Three-dimensional MCBEND models are constructed to analyze the concrete cask air inlets and outlets. Detailed models are constructed of the fuel assemblies, basket, and cask shield configurations, including streaming paths.

The MCBEND three-dimensional shielding models are used to estimate the dose profiles at the concrete cask inlets and outlets. MCBEND employs an automated biasing technique for the Monte Carlo calculation based on a three-dimensional adjoint diffusion calculation. Mesh cells for the adjoint solution are selected based on half value thicknesses for each material. Radial biasing is performed to estimate dose rates at the storage cask inlets and outlets, with an additional angular biasing component used to capture the azimuthal variation in bulk shielding properties.

In the MCBEND fuel assembly model, the fuel and hardware source regions are homogenized within a volume defined by the fuel assembly width and height. This volume is subdivided axially into lower end fitting, active fuel, upper plenum, and upper end fitting source regions. Within these axial volumes, the material masses of the fuel assembly are homogenized. In all models, the cask and canister shield thicknesses and axial extents are explicitly represented.

5.3.1.1 Radial and Axial Shielding Configuration for Yankee Class Fuel

The Yankee-MPC storage cask has an interior cavity with a radius of 39.5 inches (100.33 cm). Radial shielding consists of a 3.5-inch (8.89 cm) carbon steel shell surrounded by 21 inches (53.34 cm) of concrete. Gamma shielding is provided by both the carbon steel and concrete, and neutron shielding is provided primarily by the concrete. An additional 0.625 inch (1.59 cm) of stainless steel is provided by the canister shell for radial gamma shielding. The storage cask top shielding comprises 8 inches (20.32 cm) of stainless steel from the canister lids, 4.125 inches (10.48 cm) of carbon steel from the shield plug which encloses 1 inch (2.54 cm) of NS-4-FR and finally, 1.5 inches (3.81 cm) of carbon steel from the storage cask lid. The bottom of the storage cask rests on the concrete pad and is inaccessible. In the case of the storage cask inlets, some shielding is provided by the storage cask structural components. These are 2 inches (5.08 cm) of carbon steel from the pedestal plate, 1 inch (2.54 cm) of carbon steel from the cask base plate and 1 inch (2.54 cm) of stainless steel from the canister bottom plate.

The Yankee-MPC transfer cask has an inside radius of 35.75 inches (90.81 cm) and has a multiwall radial shield design consisting of 0.75 inch (1.91 cm) of carbon steel, 3.5 inches (8.89 cm) of lead, 2 inches (5.08 cm) of a solid borated polymer (NS-4-FR), and 1.25 inches (3.18 cm) of carbon steel. Gamma shielding is provided by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. An additional 0.625 inch (1.59 cm) of stainless steel gamma shielding is provided by the canister shell. The transfer cask bottom shield design comprises carbon steel doors 9.50 inches (24.13 cm) thick. The top shielding of the transfer cask is provided by the 5-inch (12.70 cm) stainless steel shield lid and the 3-inch (7.62 cm) stainless steel structural lid. In addition, a 5-inch (12.70 cm) carbon steel temporary shield is used during welding, draining, drying and transfer operations. This temporary shielding is removed prior to storage.

5.3.1.1.1 One-Dimensional Radial and Axial Shielding Models

Since the fuel assembly and basket features are not explicitly modeled in one-dimensional analysis, the fuel/basket interior is modeled as a set of homogenized material volumes based on equivalent cylindrical volumes. These volumes are defined by the areas created by: the central basket hole; the periphery of the basket tubes and the edge of the steel support disks; and by the

elevations created by the basket heat transfer zone, the active fuel, the fuel assembly plenums and the fuel assembly end fittings.

The Yankee-MPC fuel basket is divided into three radial regions: a central hole (void), fuel/basket region, and a basket/disk region. These regions have equivalent radii of 4.66, 30.63 and 34.51 inches (11.83, 77.80, and 87.66 cm), respectively. Axially, the basket is divided into seven regions: the top, middle and bottom fuel/basket regions; the upper and lower plenum/basket regions; and the upper and lower end fittings/basket regions. For the top models, the top fuel, top plenum and top end fitting regions have elevations with respect to the fuel midplane of 45.50, 49.01, and 56.99 inches (115.57, 124.49 and 144.75 cm), respectively. For the bottom models, the bottom fuel, bottom plenum and bottom end fitting regions have elevations with respect to the fuel midplane of 45.50, 47.61, and 54.80 inches (115.57, 120.93 and 139.19 cm), respectively.

In each of these regions, the relevant fuel assembly material and any basket material present are homogenized. Basket materials include the steel support disks, aluminum heat transfer disks, top and bottom weldments, fuel tubes, BORAL sheets, and BORAL cover sheets. Fuel assembly materials include: UO_2, cladding, grids, plenum springs and spacers, and end-fittings. The resultant material and nuclide densities are described in Section 5.3.1.3.1.

The one-dimensional radial models of the storage cask and the transfer cask are based on the cylindrical representation of the fuel/basket source regions (previously described) surrounded by the explicit canister and cask radial shield dimensions. An axial buckling equal to the active fuel height of 91 inches (231.14 cm) is assumed for all radial models.

The one-dimensional top and bottom axial models of the storage and transfer casks are based on a slab representation of the fuel/basket axial regions covered by the explicitly modeled canister and storage cask axial shield regions. As previously stated, the one-dimensional axial model elevations are specified from the active fuel centerline, which SAS1 automatically establishes as the reflecting boundary. Two models are utilized for each cask: one from the active fuel centerline to the top of the cask; and one from the active fuel centerline to the base plate of the cask. Two transverse bucklings equal to the fuel/basket zone equivalent diameter of 61.26 inches (155.6 cm) are assumed for both axial models.

5.3.1.1.2 Three-Dimensional Top and Bottom Shielding Models

SAS4 three-dimensional shielding analysis allows detailed modeling of the fuel assemblies, basket and cask shield configuration including streaming paths. Some fuel assembly and basket detail is homogenized to simplify model input and improve computational efficiency. Thus, the three-dimensional models maintain the equivalent fuel/basket source volumes developed for the one-dimensional models, but explicitly model the radial and axial extent of the source regions and the cask body details. As in the SAS1 models, the fuel and hardware source regions are homogenized within the volumes defined by the periphery of the basket tubes and by the elevations of the basket heat transfer zone, the active fuel, the plenum and the end fittings. Cask body details include the true axial extent of the cask shields as described by the drawings in Section 1.7, as well as radiation streaming paths such as the storage cask inlets and outlets and the canister vent and drain ports.

SAS4 requires cask model symmetry at the fuel midplane due to the nature of the automated biasing techniques employed and because dose rate tallies from the symmetric halves of the model are averaged together for computational efficiency. Thus, two models are created for each cask, a top and a bottom model. As in the SAS1 models, all three-dimensional shielding models are developed with respect to the fuel midplane as the origin.

The geometry of SAS4 is based on MARS (West) combinatorial geometry embedded in the MORSE code (Emmett). In this geometry, bodies such as cylinders and rectangular parallelepipeds are used to describe the extent of zones of material. Zones are volumes of constant material (cross sections) and are defined by logical operations on geometric bodies.

SAS4 employs an automated biasing technique for the MORSE Monte Carlo calculations based on either a radial or an axial XSDRNPM adjoint calculation. In the case of radial biasing, the adjoint calculation is performed for the radial shields and corresponding fuel/basket regions. In the case of axial biasing, the adjoint calculation is performed for the top or bottom shields and corresponding axial fuel/basket regions. Radial biasing is employed to improve the Monte Carlo computational efficiency and dose rate statistics on the sides of the cask. Axial biasing is employed to improve Monte Carlo computational efficiency and dose rate statistics on the top or bottom surfaces of the cask. The dose rate profiles resulting from both radial and axial biasing calculations yield a complete dose profile of the entire cask with design basis fuel.

MORSE Monte Carlo calculations are performed for each type of source in each source region. In the case of the Yankee-MPC basket and design basis fuel assembly configuration, this leads to eight source terms: middle fuel neutron, gamma and n-gamma; top or bottom fuel neutron, gamma and n-gamma; activated plenum hardware gamma and activated end fitting gamma. Twenty to thirty million histories (gamma and neutron combined) are tracked to yield a dose rate surface profile for each surface.

5.3.1.1.3 Yankee-MPC Storage Cask Three-Dimensional Models

The three-dimensional top model of the Yankee-MPC storage cask containing 36 design basis Yankee Class fuel assemblies is based on the homogenized cylindrical representation of the basket, and the following top features of the storage cask:

- Heat transfer annulus
- Carbon steel shell with four cutouts for outlet vents
- Concrete shield with four cutouts for outlet vents
- Four outlet vents including carbon steel lining
- Carbon steel shield plug
- Shield plug neutron shield
- Carbon steel top lid

Details on the elevations and radii used in creating the three-dimensional top model are taken directly from the drawings in Section 1.7. Elevations associated with the storage cask three-dimensional features are established with respect to the active fuel midplane of the Yankee Class fuel assembly (Figure 5.2.1-2) for the combinatorial model. The three-dimensional storage top model is shown in Figure 5.3.1-1.

The three-dimensional bottom model of the Yankee-MPC storage cask is based on the homogenized cylindrical representation of the fuel/basket and the following bottom features of the storage cask:

- Heat transfer annulus
- Carbon steel shell with four cutouts for inlets
- Concrete shield with four cutouts for inlets
- Four inlets with carbon steel linings
- Carbon steel bottom base plate
- Carbon steel support stand with four cutouts for air flow
- Carbon steel shield ring

- Carbon steel storage cask bottom
- Concrete pad below base plate

The three-dimensional storage cask bottom model is shown in Figure 5.3.1-2. The MARS geometry requires 55 bodies (30 right circular cylinders and 25 rectangular parallelepipeds) to define 50 model zones with combinatorial logic.

5.3.1.1.4 Yankee-MPC Transfer Cask Three-Dimensional Models

Several different three-dimensional models of the top portion of the transfer cask are used in the shielding evaluations. These include wet and dry cavity conditions, as well as the corresponding shield lid and structural lid placement. The top configuration of the transfer cask is evaluated in detail for the welding, draining and drying operations. As with the storage cask models, top models of the NAC-MPC transfer cask containing 36 design basis Yankee fuel assemblies are based on a homogenized representation of the basket, with the rectangular periphery of the basket source region modeled explicitly in order to more accurately estimate vent and drain port dose rates.

The basket disks outside the fuel/basket region are explicitly modeled to more accurately account for basket streaming. The following features of the transfer cask are considered:

- Vent and drain port openings in the shield lid
- Upper weldment shield ring
- Edge tapering and port cutouts in the temporary shielding
- Two lifting trunnions cut through the radial shield to the inner shell
- Lead and neutron shielding overlap at the top as shown on the transfer cask drawings

Details of the elevations and radii used in creating the three-dimensional top model are taken directly from the drawings in Section 1.7. As with the other three-dimensional models, elevations associated with the transfer cask three-dimensional features are established with respect to the active fuel midplane of the Yankee Class fuel assembly for the combinatorial geometry model. The three-dimensional transfer cask top model including shield and structural lid installation is shown in Figure 5.3.1-3.

The three-dimensional bottom model of the Yankee-MPC transfer cask is shown in Figure 5.3.1-4. The three-dimensional bottom model of the Yankee-MPC transfer cask is based on the same homogenized representation of the fuel/basket as the top model. As with the top model of

the transfer cask, the evaluations include both wet and dry canister cavity. The following bottom features of the transfer cask are considered:

- Termination of the radial shields at the bottom doors
- 9.5 inches of carbon steel shielding representing the bottom doors

The MARS geometry requires 69 bodies (56 right circular cylinders and 13 rectangular parallelepipeds) to define 59 model zones with combinatorial logic.

For the damaged fuel can evaluation, additional shielding at the canister vent and drain ports is modeled to maintain dose rates ALARA. In the wet canister model, the port cover zone is modeled with half-density stainless steel to simulate the quick-disconnect fittings at the ports. For both the dry and wet canister models, an inch of lead is modeled above the ports to simulate additional shielding employed during the welding operations. Also included in the models is the lid structure of the damaged fuel cans and the four machined areas in the shield lid required to accommodate the damaged fuel cans. A schematic of the model is shown in Figure 5.3.1-5.

In the damaged fuel analysis of the transfer cask bottom axial and radial dose rates, the source is represented in the homogenized lower end fitting region of the four corner basket positions designated for damaged fuel cans. Material descriptions of the resulting fuel and hardware homogenized region are provided in Section 5.3.1.3. The additional mass due to failed fuel is only represented in the specific analysis of the neutron and gamma dose rate contributions from the failed fuel itself. That is, the self-shielding capability of the additional material is conservatively neglected in the analysis of the remaining source terms from the intact fuel assembly. A schematic of the model with an axial slice through the lower end fitting is shown in Figure 5.3.1-6.

5.3.1.2 MCBEND Three-Dimensional Concrete Cask Models

MCBEND three-dimensional shielding analysis allows detailed modeling of fuel assemblies, basket, and cask shield configuration, including streaming paths. For fuel assembly sources, some fuel assembly detail is homogenized in the model to simplify model input and improve computational efficiency. Thus, the three-dimensional models represent the various fuel assembly source regions as homogenized zones within the basket, but explicitly model the axial extent of the source regions. The fuel and hardware source regions of each assembly are therefore homogenized within the volumes defined by the periphery of the fuel assembly and the

source region axial extents. The basket plate (disks) details are explicitly modeled. Cask details include the axial extent of the cask shield as described by the License Drawings.

The geometric description of a MCBEND model is based on the combinatorial geometry system embedded in the code. In this system, modeling bodies such as cylinders and rectangular parallelepipeds, and their logical intersections and unions, are used to describe the extent of material zones.

MCBEND employs an automated biasing technique for the Monte Carlo calculation based on a three-dimensional adjoint diffusion calculation. Mesh cells for the adjoint solution are selected based on half value thicknesses for each material.

MCBEND Monte Carlo calculations are performed for each source type present in each source region. This approach entails seven separate analyses, encompassing fuel neutron, fuel gamma, fuel n-gamma (secondary gammas arising from neutron interaction in the shield), fuel region hardware, upper plenum, and upper and lower end-fitting gamma sources. Typically, a total of 5 to 20 million histories are tracked to yield dose rate profiles for each model. These cases are analyzed for azimuthally divided radial detectors at the concrete cask air inlets and outlets.

5.3.1.2.1 MCBEND Fuel Assembly Model

Based on the fuel assembly physical parameters provided in Table 5.2.1-7 and the hardware masses in Table 5.2.1-2, homogenized treatments of fuel assembly source regions are developed. The homogenized fuel assembly is represented in the model as a stack of boxes with the width equal to the fuel assembly width. The height of each box corresponds to the modeled height of the corresponding assembly region.

The active fuel region homogenization is shown in Table 5.3.1-4 based on the detailed three-dimensional data in Table 5.2.1-7. Components of the fuel assembly homogenization are subdivided to account for the various area fractions present in the homogenized fuel assembly description. "Interstitial" refers to the space within the fuel assembly array defined by the lattice pitch, but outside the fuel rod or guide/instrument tubes. "Inside tubes" refers to the space inside the instrument and guide tubes and "void" refers to the pellet to clad gap. All three regions are assigned a void material as part of the shielding evaluation since the cask cavity is dry. Combined with the fuel rod clad, fuel material, and guide bar/instrument tube materials the void

accounts for the total fuel region volume. The clad region is Zircaloy (density 6.55 g/cm^3). The resulting regional compositions on an atom/barn-cm basis are shown in Table 5.3.1-6.

Fuel assembly non-fuel regions are homogenized as shown in Table 5.3.1-5. Using the detailed dimensions in Table 5.2.1-7, the axial source regions are modeled as follows: the gap between the lower nozzle and the fuel rod (if present) are assigned to the lower nozzle region, the fuel rod top end-cap and gap to the top nozzle are assigned to the top plenum region, with the top nozzle region height not being modified. Volume fractions of material are based on the modeled regional volume and the volume of stainless steel present as computed from the modeled mass and density (7.92 g/cm^3).

In the damaged fuel evaluation, the equivalent mass of 20 UO_2 rods is added to the lower nozzle material description for the four corner basket locations. No other model changes are necessary in the damaged fuel analysis.

5.3.1.2.2 MCBEND Basket Model

For a given fuel type, the MCBEND description of the basket elements forms a common sub-model employed in the PWR concrete cask analysis. The key feature of the model is the detailed representation of the geometry of the basket support and heat transfer disks.

5.3.1.2.3 MCBEND Concrete Cask Model

The three-dimensional model of the vertical concrete cask containing design basis fuel is based on the explicit modeling of the basket, and the following features of the storage cask:

- Heat transfer annulus.
- Carbon steel weldment with cutouts for inlets and outlets.
- Concrete shield with cutouts for inlets and outlets.
- Air outlet model including carbon steel channel walls.
- Air inlet model including baffle pipes and carbon steel channel walls.
- Carbon steel shield plug with 1.0-inch NS-4-FR.
- Carbon steel top lid.
- Carbon steel bottom base plate.
- Carbon steel support stand with four cutouts for air flow.
- Carbon steel shield ring.

- Carbon steel storage cask bottom.
- Concrete pad below base plate.

Detailed model parameters used in creating the three-dimensional model are taken directly from the License drawings. Elevations associated with the concrete cask three-dimensional features are established with respect to the bottom plate of the canister for the global model. The three-dimensional concrete cask model is shown in Figures 5.3.1-7 and 5.3.1-8.

5.3.1.3 Yankee-MPC Shield Regional Densities

Shield regional densities for the SCALE evaluations of the transfer and concrete casks are discussed in Section 5.3.1.3.1. Shield regional densities for the MCBEND analysis of the storage cask are discussed in Section 5.3.1.3.2.

5.3.1.3.1 SCALE Shield Regional Densities

The SCALE 4.3 standard composition library (Landers) default compositions and isotopic distributions are used unless otherwise indicated. The composition densities before homogenization used in the Yankee-MPC shielding evaluation are:

Material	Density (g/cc)
UO_2 at 95% TD	- 10.412
Zircaloy	- 6.56
H_2O	- 0.9982
Stainless Steel 304	- 7.92
Lead	- 11.344
Aluminum	- 2.702
BORAL (core)	- 2.623 (non-standard)
NS-4-FR	- 1.629 (non-standard)
Concrete	- 2.243 (based on 140 lb/ft^3 design spec. minimum)
Carbon Steel	- 7.821

Reinforcing steel is conservatively ignored in the concrete density. Basket and fuel assembly regional volumes are shown in Table 5.3.1-1 and the regional masses are shown in Table 5.3.1-2.

The resultant regional homogenized densities for the design basis CE fuel assembly and shield densities are provided in Table 5.3.1-3.

For the damaged fuel evaluation, a mass of 20 rods in the bottom endfitting yields a homogenized UO_2 density of 2.4952 g/cm^3, which is added to the stainless steel 304 density of 0.9664 g/cm^3. The damaged fuel material description applies only to the four corner locations. Under wet canister conditions, water at a volume fraction of 0.65 is included in the homogenized region.

5.3.1.3.2 MCBEND Shield Regional Densities

Based on the homogenization described in Section 5.3.1.3.1, the resulting active fuel regional densities are shown in Table 5.3.1-6. Material compositions for remaining structural and shield materials are also shown in Table 5.3.1-6. Compositions for fuel assembly non-fuel regions are equivalent to the stainless steel composition in Table 5.3.1-6 scaled by the material volume fractions shown in Table 5.3.1-5.

Figure 5.3.1-1 Yankee-MPC Storage Cask Three-Dimensional Top Model

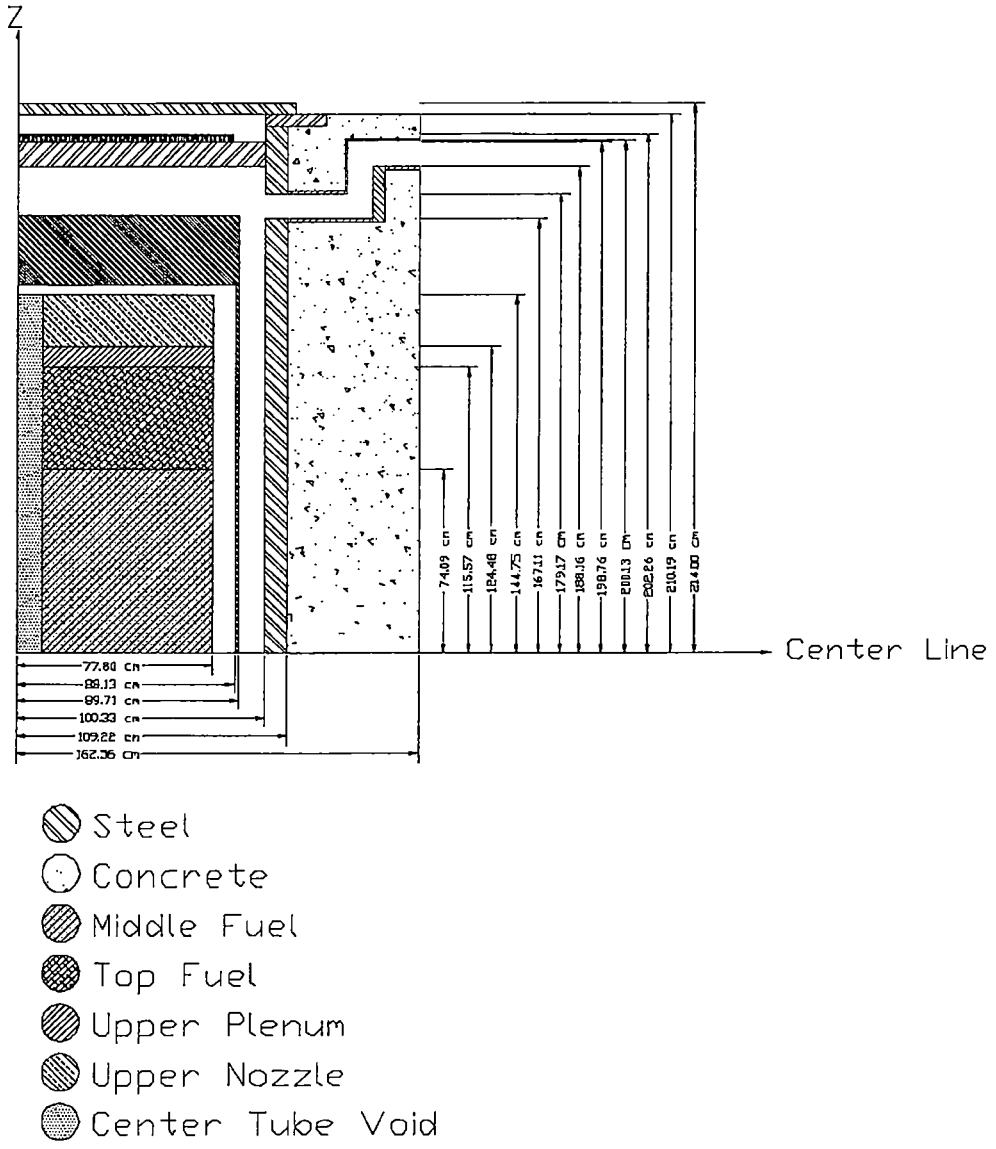


Figure 5.3.1-2 Yankee-MPC Storage Cask Three-Dimensional Bottom Model

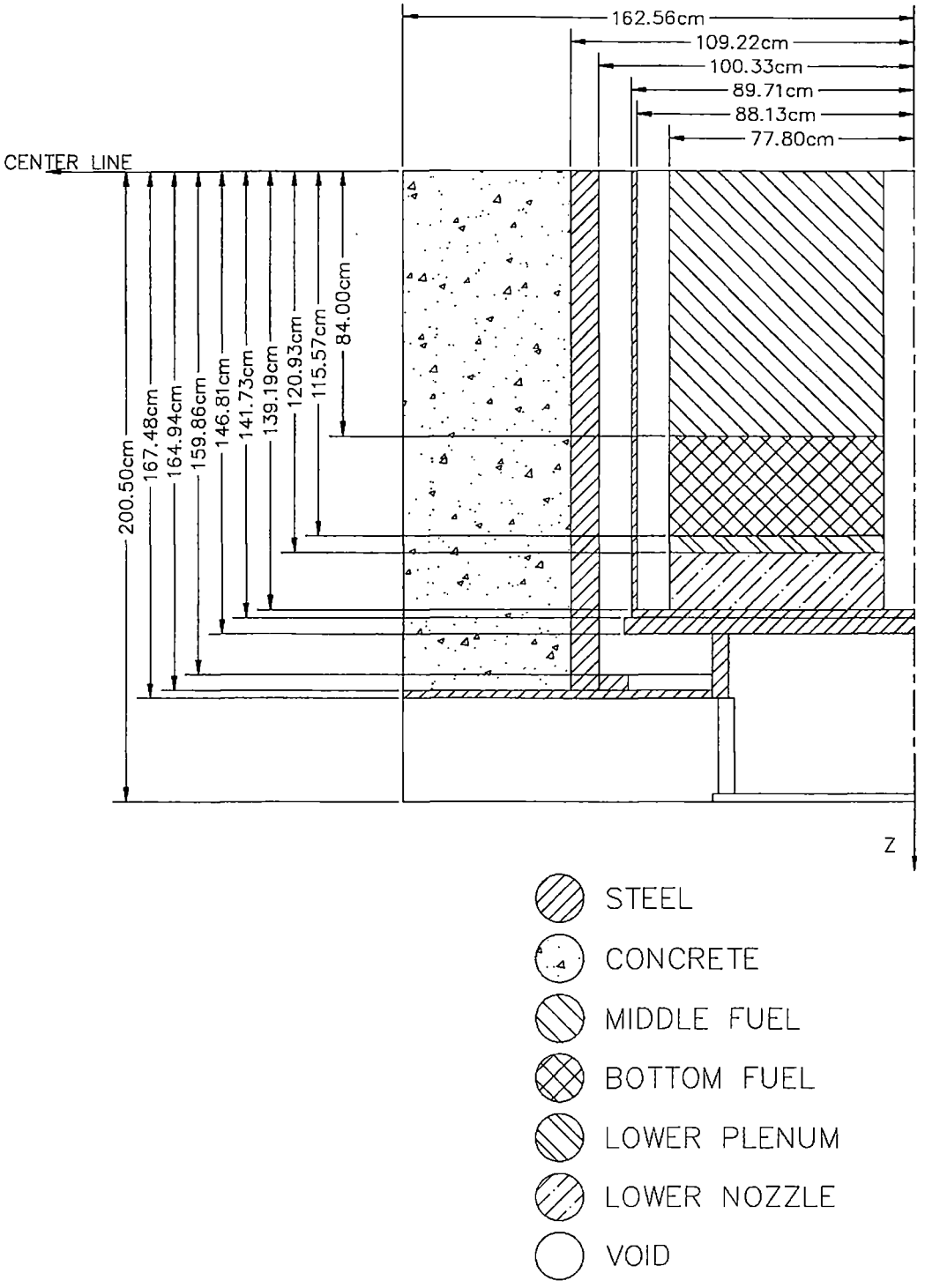


Figure 5.3.1-3 SCALE Transfer Cask Three-Dimensional Top Model Including Shield and Structural Lid

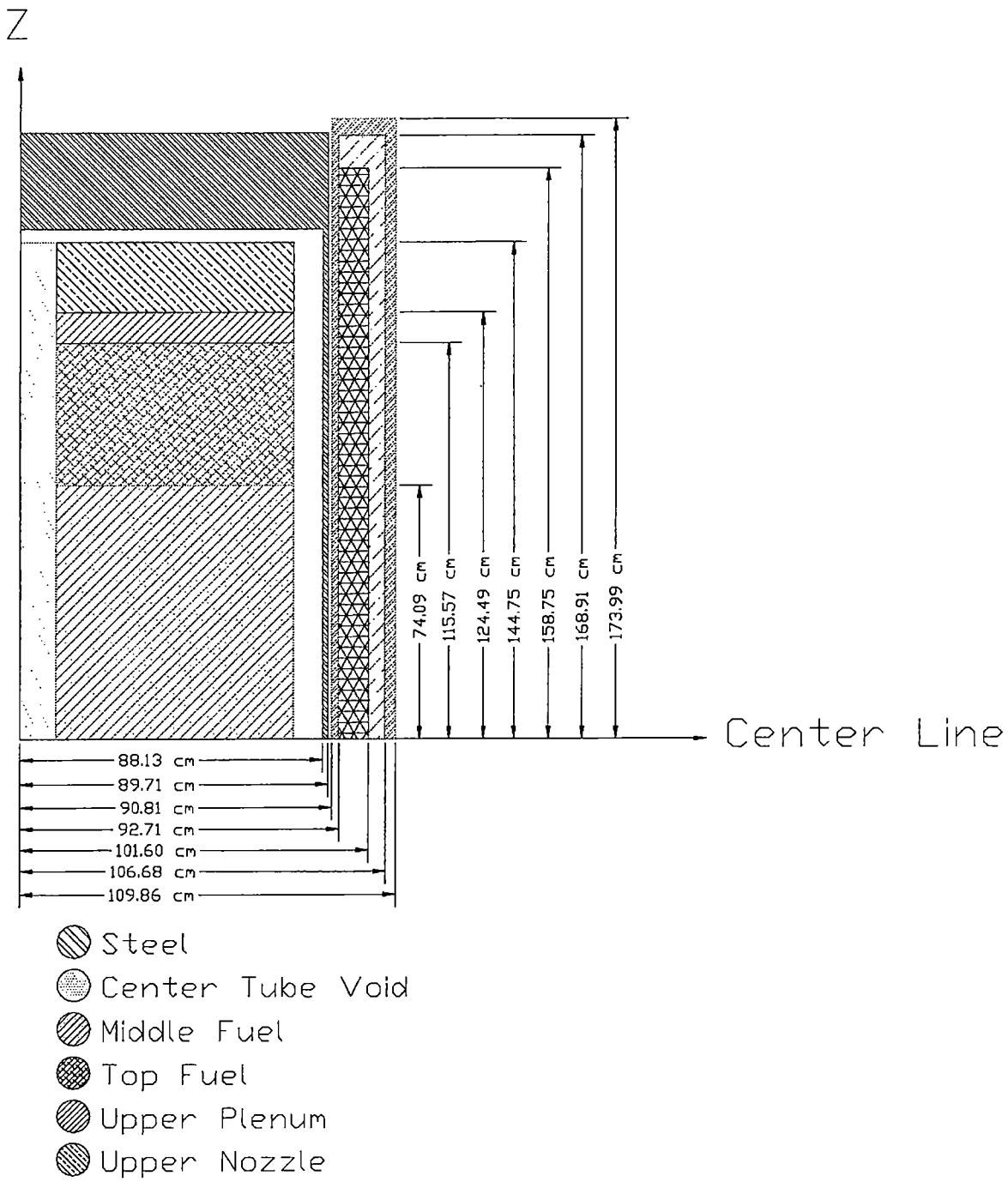


Figure 5.3.1-4 SCALE Transfer Cask Three-Dimensional Bottom Model

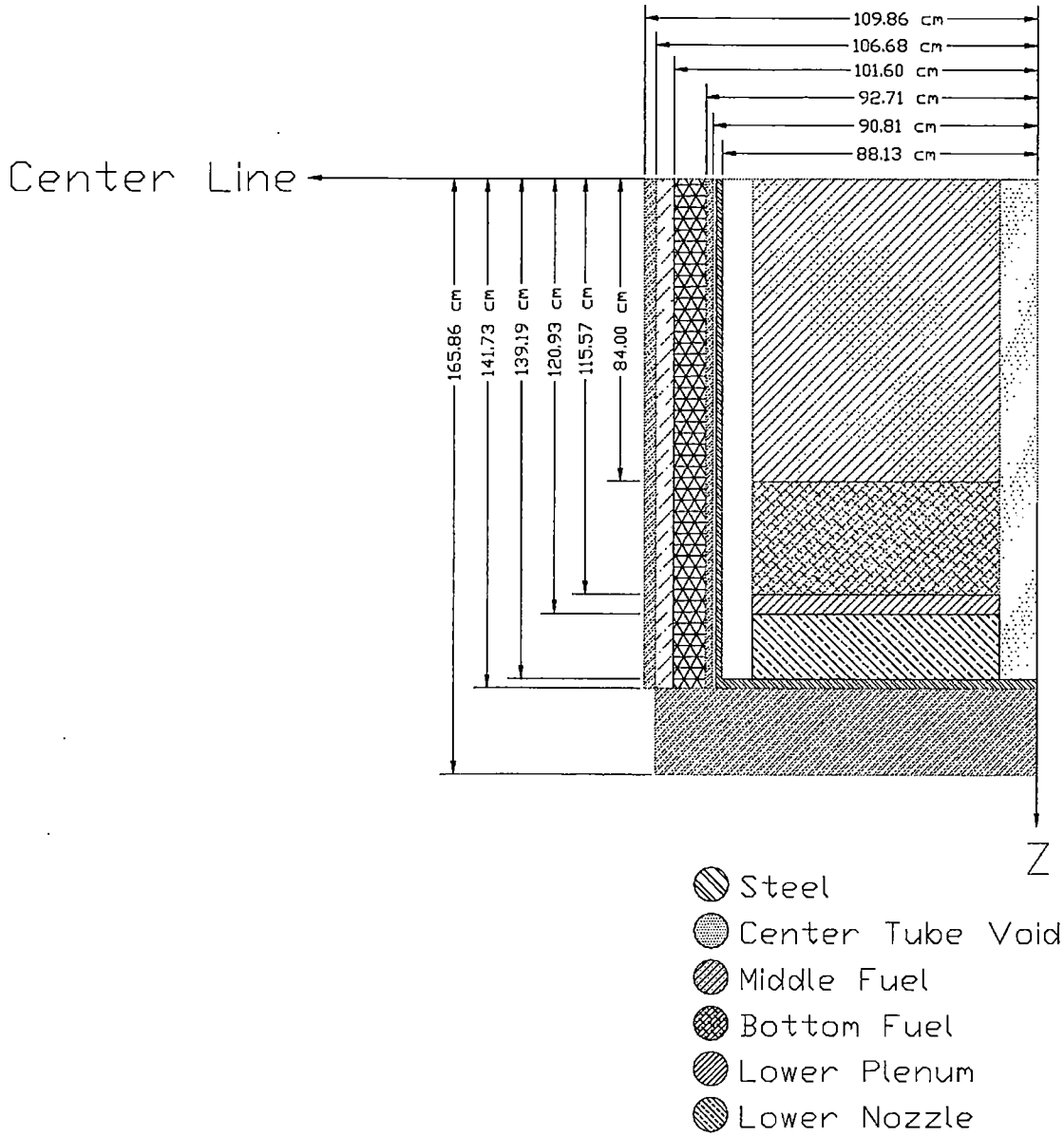


Figure 5.3.1-5 SCALE Transfer Cask Three-Dimensional Damaged Fuel Top Model

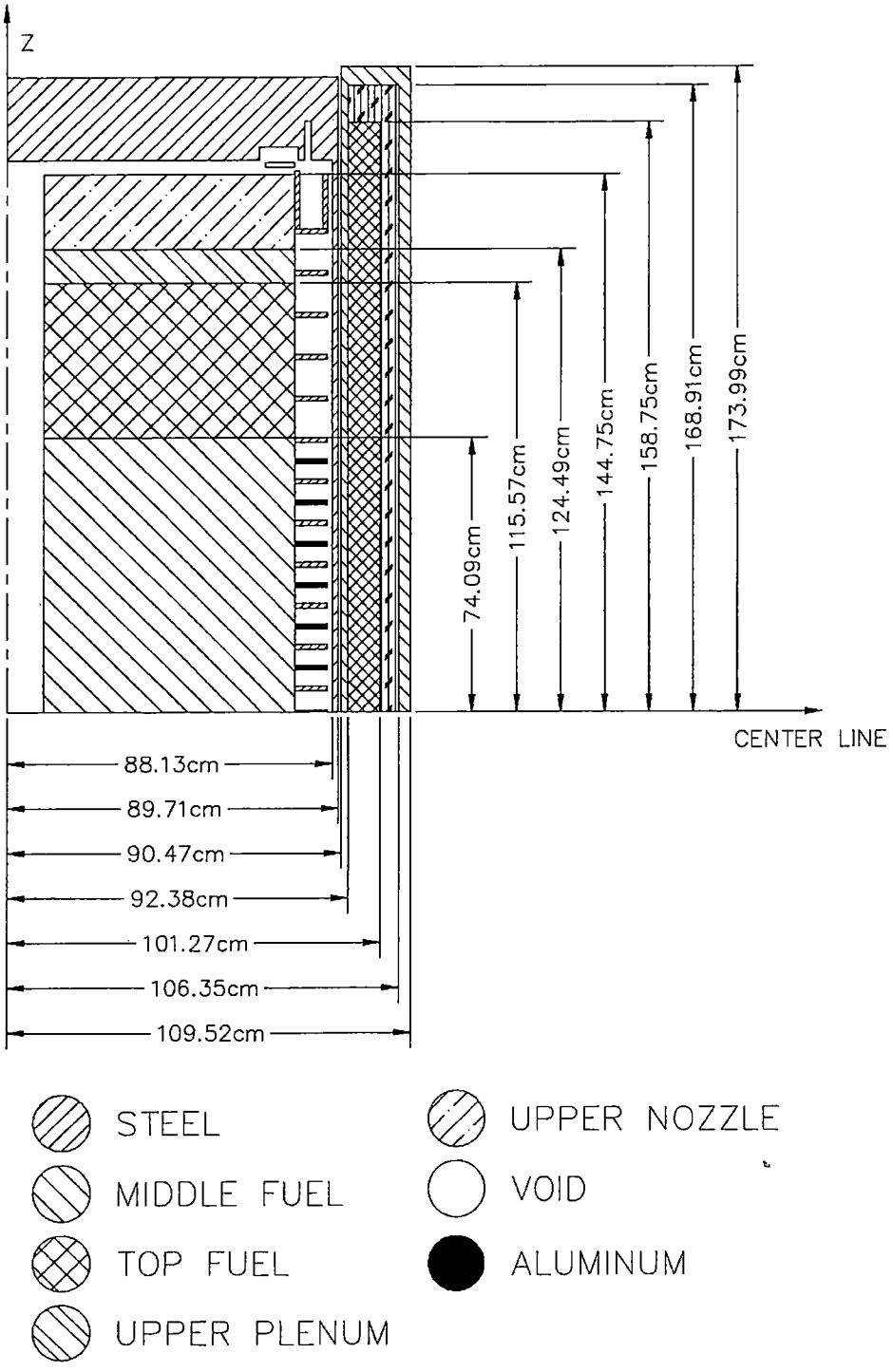


Figure 5.3.1-6 SCALE Transfer Cask Three-Dimensional Damaged Fuel Bottom Model

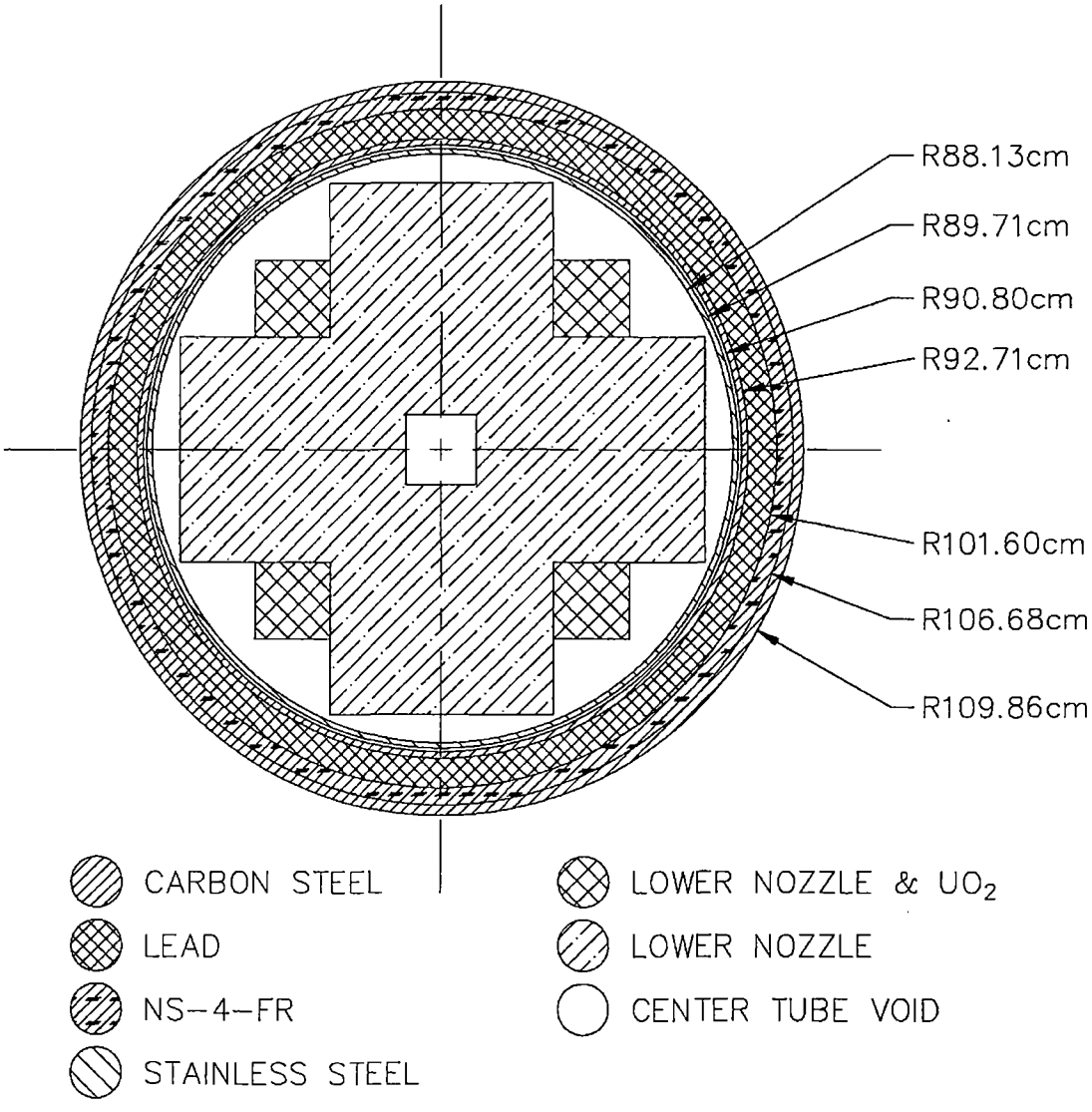
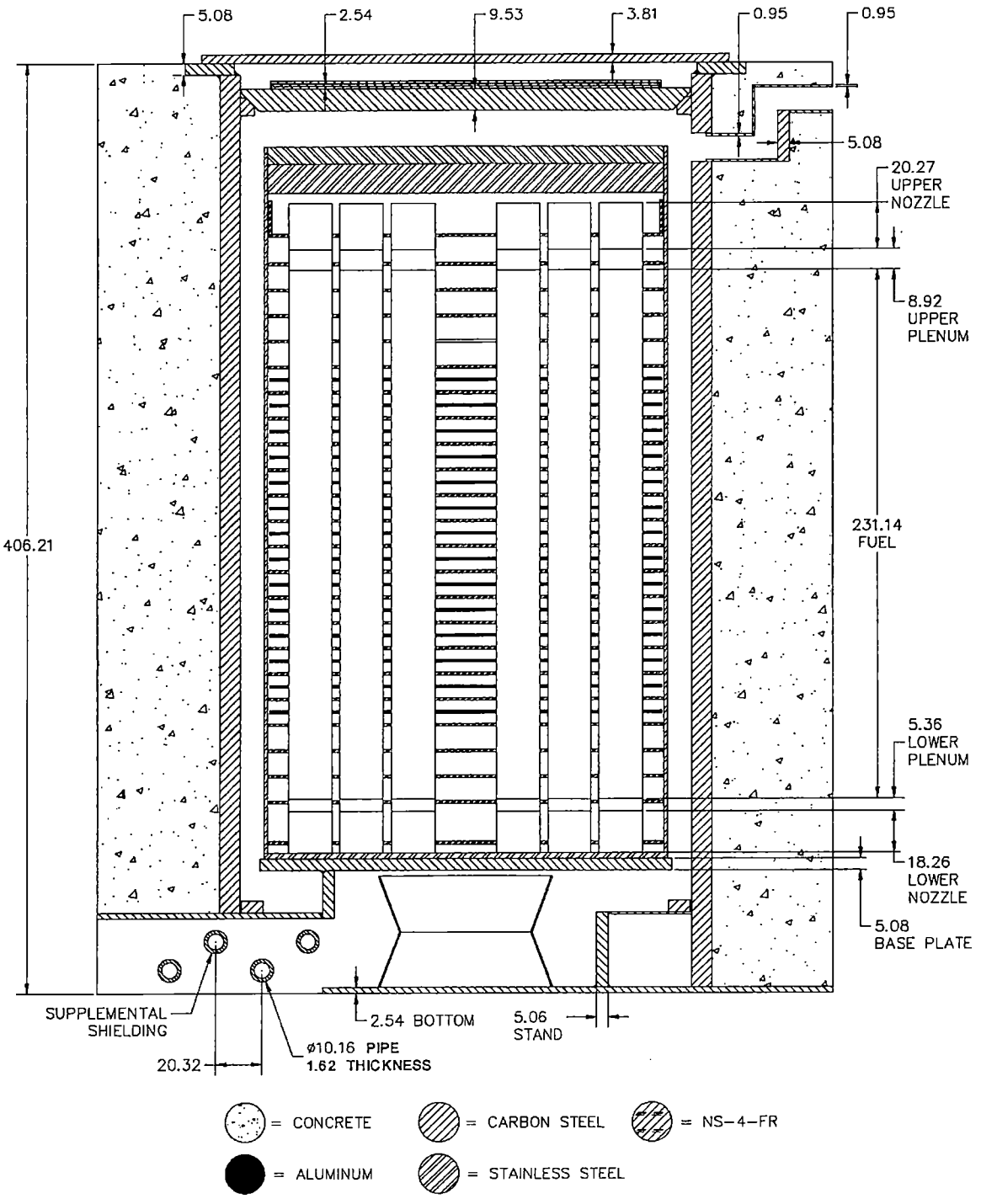
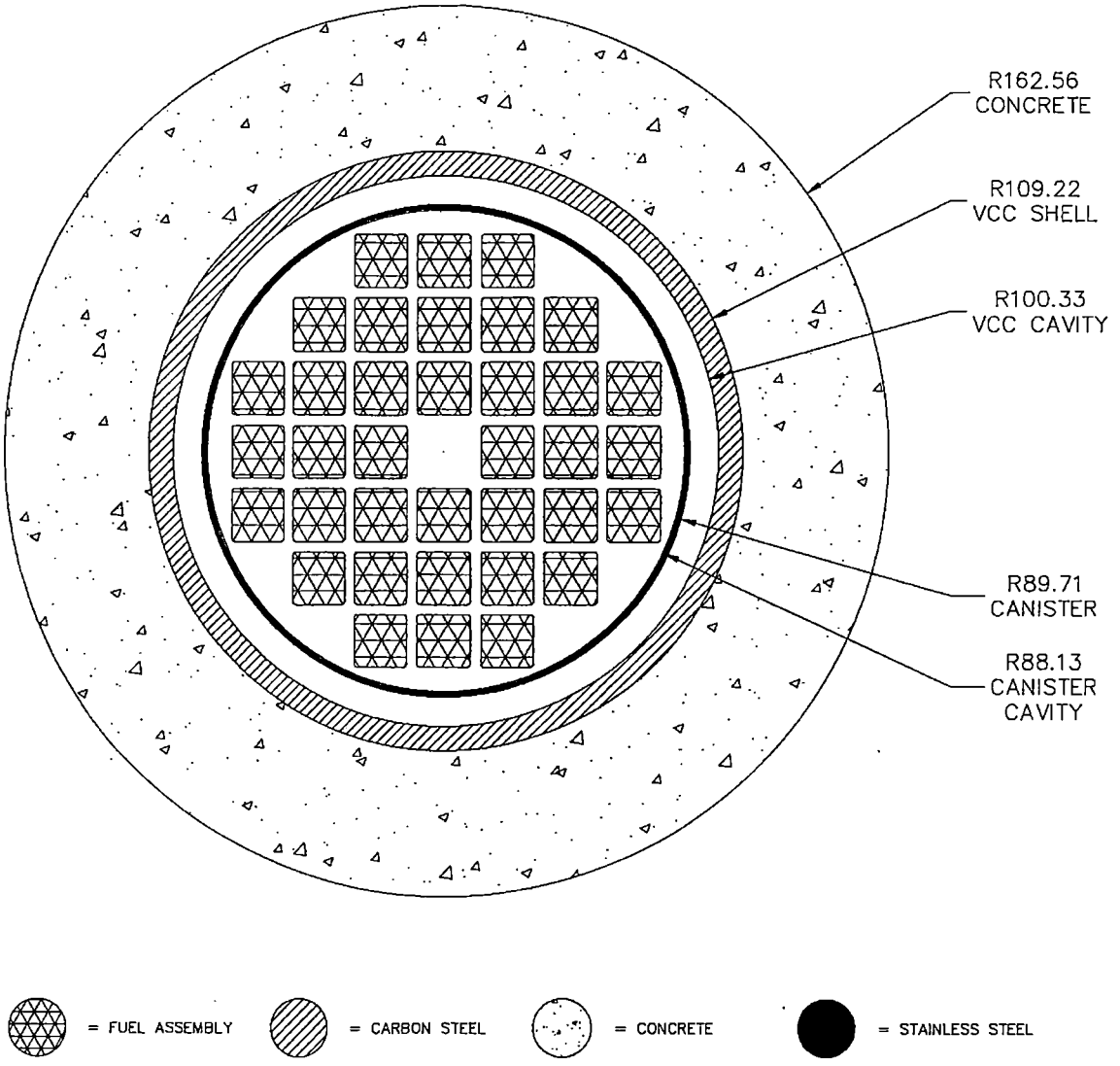


Figure 5.3.1-7 MCBEND Three-Dimensional Vertical Concrete Cask Model – Axial Detail



Dimensions in cm.

Figure 5.3.1-8 MCBEND Three-Dimensional Vertical Concrete Cask Model – Radial Detail



Dimensions in cm.

Table 5.3.1-1 Yankee-MPC SCALE Fuel/Basket Regional Volumes

Axial Zone[1]	Regional Volumes (cm^3)	
	Fuel/Basket Region	Basket/Disk Region
LEF	3.3927E+05	9.3029E+04
LPLM	9.9562E+04	2.7301E+04
$FUEL_{bot}$	5.8652E+05	1.6083E+05
$FUEL_{mid}$	2.9368E+06	8.0530E+05
$FUEL_{top}$	7.7054E+05	2.1129E+05
UPLM	1.6562E+05	4.5415E+04
UEF	3.7654E+05	1.0325E+05

1. See Figure 5.2.1-2 for zone locations.

Table 5.3.1-2 Yankee-MPC SCALE Fuel/Basket Regional Masses

Axial Zone[1]	Fuel/Basket Regional Masses (kg)						Basket/Disk Region	
	Fuel Assembly Contribution			Basket Contribution				
Material	UO_2	Zirc	SS 304	SS 304	Al	B_4C	SS 304	Al
LEF[2]	--	0.00	186.48	141.37	--	--	51.24	--
LPLM	--	61.01	62.28	42.55	--	--	51.24	--
$FUEL_{bot}$	1335.47	359.43	0.00	173.01	36.46	5.90	102.47	--
$FUEL_{mid}$	6687.02	1884.71	0.00	1004.41	320.40	29.55	768.52	235.15
$FUEL_{top}$	1754.48	472.20	0.00	237.61	47.89	7.75	153.70	--
UPLM	--	94.69	27.43	52.41	--	--	51.24	--
UEF	--	0.0000	198.00	56.15	--	--	51.24	--

1. See Figure 5.2.1-2 for zone locations.
2. For the damaged fuel configuration with the mass of 20 fuel rods in the bottom endfitting, the mass of UO_2 is 23.52 kg per assembly.

Table 5.3.1-3 Yankee-MPC SCALE Regional Homogenized Densities and Shield Densities

Zone/Material	Density (g/cc)	Nuclides	Density (atom/b-cm)
Middle Fuel Zone			
UO_2	2.2769	^{234}U	2.793E-07
		^{235}U	3.656E-05
		^{238}U	5.041E-03
		O	1.016E-02
Zircaloy	0.6417	Zr	4.236E-03
SS 304	0.3420	Cr	7.526E-04
		Mn	7.498E-05
		Fe	2.563E-03
		Ni	3.334E-04
Aluminum	0.1091	Al	2.435E-03
B_4C	0.0101	^{10}B	8.764E-05
		^{11}B	3.528E-04
		C	1.101E-04
H_2O Wet Transfer Cask	0.6000	H	4.010E-02
		O	3.021E-02
Middle Basket/Disk Zone			
SS 304	0.9543	Cr	2.100E-03
		Mn	2.092E-04
		Fe	7.152E-03
		Ni	9.303E-04
Aluminum	0.2920	Al	6.517E-03
H_2O Wet Transfer Cask	0.7700	H	5.151E-02
		O	2.575E-02
Steel Shielding			
SS 304	7.9200	Cr	1.743E-02
		Mn	1.736E-03
		Fe	5.9336-02
		Ni	7.721E-03
Carbon Steel Shielding			
Carbon Steel	7.8212	Fe	8.350E-02
		C	3.925E-03
Concrete Shielding			
Concrete	2.2430	Fe	3.386E-04
		H	1.340E-02
		Al	1.702E-03
		Ca	1.483E-03
		O	4.494E-02
		Na	1.704E-03
		N	1.621E-02

Table 5.3.1-3 Yankee-MPC SCALE Regional Homogenized Densities and Shield Densities (Continued)

Material/Zone	Density (g/cc)	Nuclides	Density (atom/b-cm)
Top Fuel/Basket Zone			
UO_2	2.2769	^{234}U	2.793E-07
		^{235}U	3.656E-05
		^{238}U	5.041E-03
		O	1.016E-02
Zircaloy	0.6128	Zr	4.046E-03
SS 304	0.3084	Cr	6.787E-04
		Mn	6.761E-05
		Fe	2.311E-03
		Ni	3.006E-04
Aluminum	0.0622	Al	1.388E-03
B_4C	0.0101	^{10}B	8.764E-05
		^{11}B	3.528E-04
		C	1.101E-04
H_2O Transfer Cask Wet	0.6303	H	4.214E-02
		O	3.123E-02
Top Plenum Zone			
Zircaloy	0.5718	Zr	3.775E-03
SS 304	0.4821	Cr	1.485E-03
		Mn	1.057E-04
		Fe	3.613E-03
		Ni	4.700E-04
H_2O Transfer Cask Wet	0.7019	H	4.695E-02
		O	2.348E-02
Top End Fitting Zone			
SS 304	0.6749	Cr	1.743E-02
		Mn	1.480E-04
		Fe	5.058E-03
		Ni	6.579E-04
H_2O Transfer Cask Wet	0.9132	H	6.108E-02
		O	3.054E-02
Neutron Shield			
NS-4-FR	1.6291	^{10}B	8.553E-05
		^{11}B	3.422E-04
		Al	7.763E-03
		H	5.854E-02
		O	2.609E-02
		N	1.394E-03
		C	2.264E-02

Table 5.3.1-3 Yankee-MPC SCALE Regional Homogenized Densities and Shield Densities (Continued)

Material/Zone	Density (g/cc)	Nuclides	Density (atom/b-cm)
Bottom Fuel/Basket Zone			
UO_2	2.2769	^{234}U	2.793E-07
		^{235}U	3.656E-05
		^{238}U	5.041E-03
		O	1.016E-02
Zircaloy	0.6128	Zr	4.046E-03
SS 304	0.2350	Cr	6.492E-04
		Mn	6.467E-05
		Fe	2.211E-03
		Ni	2.876E-04
Aluminum	0.0622	Al	1.388E-03
B_4C	0.0101	^{10}B	8.764E-05
		^{11}B	3.528E-04
		C	1.101E-04
H_2O Transfer Cask Wet	0.6322	H	4.228E-02
		O	3.130E-02
Bottom Plenum Zone			
Zircaloy	0.6128	Zr	4.046E-03
SS 304	1.0529	Cr	2.317E-03
		Mn	2.308E-03
		Fe	7.891E-03
		Ni	1.026E-03
H_2O Transfer Cask Wet	0.5447	H	3.644E-02
		O	1.822E-02
Bottom End fitting Zone			
SS 304	0.9664	Cr	2.127E-03
		Mn	2.119E-04
		Fe	7.243E-03
		Ni	9.421E-04
H_2O Transfer Cask Wet	0.8764	H	5.862E-02
		O	2.931E-02
UO_2	2.4952	^{234}U	3.061E-07
(Damaged Fuel Only)		^{235}U	4.007E-05
		^{238}U	5.525E-03
		O	1.113E-02
H_2O Transfer Cask Wet	0.8764	H	5.862E-02
(Intact Fuel Only)		O	2.931E-02
H_2O Transfer Cask Wet	0.6503	H	4.342E-02
(Damaged Fuel Only)		O	2.171E-02

Table 5.3.1-4 MCBEND Fuel Region Homogenization

Component	Area [cm^2]	Area Fraction	Volume Fraction of Components			
			UO_2	Void	Clad	Interstitial
Fuel	1.1285E+02	3.0283E-01	3.0283E-01			
Gap	4.7742E+00	1.2812E-02		1.2812E-02		
Clad	3.8317E+01	1.0283E-01			1.0283E-01	
Guide Bar	8.8890E+00	2.3854E-02			2.3854E-02	
Instrument Tube	2.5461E-01	6.8325E-04			6.8325E-04	
Inside Tubes	7.8061E-01	2.0948E-03				2.0948E-03
Interstitial	2.0678E+02	5.5490E-01				5.5490E-01
Total	3.7264E+02		3.0283E-01	1.2812E-02	1.2736E-01	5.5700E-01

Table 5.3.1-5 MCBEND Fuel Assembly Hardware Region Homogenization

Region	Mass SS [kg/assy]	SS Volume [cm3/assy]	Height [cm]	Volume [cm3/assy]	Volume Fraction
Lower Nozzle	5.200	6.5657E+02	18.2626	6.8055E+03	9.6476E-02
Lower Plenum	1.730	2.1843E+02	5.3594	1.9972E+03	1.0937E-01
Upper Plenum	0.762	9.6212E+01	8.9154	3.3223E+03	2.8960E-02
Upper Nozzle	5.500	6.9444E+02	20.2692	7.5532E+03	9.1940E-02

Table 5.3.1-6 MCBEND Regional Densities for Fuel and Concrete Cask Structural and Shield Materials

Material	Element	Density [atom/b-cm]	Density [g/cm^3]
Fuel	CR	9.9241E-06	4.01
	FE	1.8480E-05	
	HF	2.8910E-07	
	NI	8.7917E-07	
	O	1.4096E-02	
	SN	6.5203E-05	
	U	7.0346E-03	
	ZR	5.5480E-03	
Stainless Steel	CR	1.6511E-02	7.92
	FE	6.3199E-02	
	NI	6.5009E-03	
Carbon Steel	C	3.9250E-03	7.82
	FE	8.3498E-02	
Aluminum	AL	6.0263E-02	2.70
NS-4-FR	AL	7.8000E-03	1.63
	B	4.2750E-04	
	C	2.2600E-02	
	H	5.8500E-02	
	N	1.3900E-03	
	O	2.6100E-02	
Concrete	AL	1.7018E-03	2.24
	CA	1.4826E-03	
	FE	3.3857E-04	
	H	1.3401E-02	
	NA	1.7036E-03	
	O	4.4931E-02	
	SI	1.6205E-02	
Lower Nozzle (Damaged Fuel)	CR	1.5933E-03	4.22
	FE	6.0987E-03	
	NI	6.2734E-04	
	O	1.5409E-02	
	U	7.7076E-03	

5.3.2 CY-MPC Transfer and Storage Cask Model Specifications

MCBEND three-dimensional shielding analysis allows detailed modeling of the fuel assemblies, basket, and cask shield configuration, including streaming paths. Some fuel assembly detail is homogenized in the model to simplify model input and improve computational efficiency. Thus, the three-dimensional models represent the various fuel assembly source regions as homogenized zones within the fuel tubes in the basket, but explicitly model the axial extent of the source regions. The basket details, including support disks, heat transfer disks, top and bottom weldments, and shielding beneath the canister vent and drain ports, are explicitly modeled.

The fuel and hardware source regions of each assembly are homogenized within the volumes defined by the periphery of the fuel assembly and the source region axial extents. Cask body details include the true axial extent of the cask shield as described by the drawings in Section 1.7, as well as radiation streaming paths such as the storage cask inlets and outlets and the canister vent and drain ports.

The geometric description of a MCBEND model is based on the Fractal Geometry combinatorial geometry system embedded in the code. In this system, bodies such as cylinders and rectangular parallelepipeds, and their logical intersections and unions, are used to describe the extent of material zones.

MCBEND employs an automated biasing technique for the Monte Carlo calculation based on a three-dimensional adjoint diffusion calculation. Mesh cells for the adjoint solution are selected based on half value thicknesses for each material.

MCBEND Monte Carlo calculations are performed for each source type present in each source region. This approach entails seven separate analyses, encompassing fuel neutron, fuel gamma, fuel n-gamma (secondary gammas arising from neutron interaction in the shield), fuel hardware, upper plenum, and upper and lower end-fitting gamma sources. Typically, a total of some 30 to 50 million histories are tracked to yield dose rate profiles for each model. These cases are analyzed for both radial and axial detector locations. Furthermore, the transfer cask axial model is analyzed for a number of operational configurations of the top lids and temporary shielding, and for both wet and dry conditions. In addition, dose rates on the bottom surface of the transfer cask are reported.

The vertical concrete cask has an interior cavity with a radius of 39.50 inches. Radial shielding consists of a 3.50-inch carbon steel shell surrounded by 21.00 inches of concrete. Gamma shielding is provided by both the carbon steel and concrete, and neutron shielding is provided primarily by the concrete. An additional 0.625 inch of stainless steel is provided by the canister shell for radial gamma shielding. The concrete cask top shielding comprises 8.00 inches of stainless steel from the canister lids, 1.5 inches of carbon steel from the cask lid, and 3.75 inches of carbon steel from the shield plug. A 0.375-inch thick carbon steel cover encloses 2 inches of NS-3 or NS-4-FR on the shield plug. The bottom of the cask rests on the concrete pad and is inaccessible. The concrete cask air inlets are shielded by the cask lower weldment structural components. These components include 4.00 inches of carbon steel from the pedestal plate, 1.00 inch of carbon steel from the cask base plate, and 2.25 inches of carbon steel in the inlet channel top plate. There are also 1.75 inches of stainless steel from the canister bottom plate.

The top axial neutron shield evaluation is based on a 1-inch layer of NS-4-FR, or a 1.5-inch layer of NS-3, attached to the underside of the concrete cask lid using a 3/8-inch carbon steel shell enclosure. The dose rates calculated for either neutron shield configuration are conservative with respect to the design incorporating 2 inches of neutron shielding in the concrete cask shield plug.

The transfer cask has an inside radius of 35.75 inches and has a multiwall radial shield design consisting of 0.75 inch of low alloy steel, 4.00 inches of lead, 2.75 inches of a solid borated polymer (NS-4-FR), and 1.25 inches of low alloy steel in an outer shell. Gamma shielding is provided by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. An additional 0.625-inch of stainless steel gamma shielding is provided by the canister shell. The transfer cask bottom shield design is comprised of carbon steel doors 9.50 inches thick. The top shielding of the transfer cask is provided by the 5.00-inch stainless steel shield lid and the 3.00-inch stainless steel structural lid. In addition, a 5.00-inch carbon steel temporary shield is used during welding, draining, and drying operations. This temporary shielding is assumed to be removed prior to moving the cask.

5.3.2.1 Connecticut Yankee Fuel Assembly Model

Based on the fuel assembly parameters provided in Tables 5.2.2–1 and 5.2.2–7, homogenized treatments are developed for the stainless steel and Zircaloy clad fuel assembly source regions. Grid mass is conservatively neglected in the material homogenization. The homogenized fuel assembly is represented in the model as a stack of boxes with width equal to the fuel assembly

width. The height of each box corresponds to the modeled height of the corresponding assembly region, as shown in Figure 5.2.2–1.

The active fuel region homogenizations for stainless steel and Zircaloy clad fuel are shown in Tables 5.3.2–1 and 5.3.2–2, respectively. The interstitial material is a void under dry canister conditions and is water (density 0.9982 g/cm^3) under wet canister conditions. The clad region is either stainless steel (density 7.92 g/cm^3) or Zircaloy (density 6.55 g/cm^3), depending on the fuel type.

Non-fuel assembly regions are homogenized as shown in Tables 5.3.2–3 and 5.3.2–4 for stainless steel and Zircaloy clad fuel types, respectively. The only material included in the homogenized region is stainless steel. Volume fractions of material are based on the modeled region volume and the volume of stainless steel present as computed from the modeled mass and density (7.92 g/cm^3).

Although the geometry of the fuel end plug regions is modeled explicitly, the radiation source from activated fuel pin end plug material is assigned to adjacent source regions. For upper end plugs, the activation source term is assigned to the upper plenum source region, and for lower end plugs the source term is assigned to the lower nozzle source region. This simplifying assumption reduces the number of source cases required and has little impact on computed dose rates.

The resulting regional compositions on an atom/barn-cm unit basis are shown in Table 5.3.2-6.

5.3.2.2 CY-MPC Canister and Basket Model

For a given fuel type, the MCBEND description of the canister and basket elements forms a common sub-model employed in all storage and transfer cask analyses. The key features of the model are the detailed representation of fuel tubes, basket support and heat transfer disks, and weldment structures; the inclusion of the vent and drain ports in the canister shield lid; and explicit modeling of the shielding installed beneath the lid ports.

The vent and drain ports in the canister shield lid are modeled as a series of three stacked cylinders. The port cover is also modeled, but may or may not be in place depending on the particular operational condition specified. In the axial analysis of the transfer cask, the vent and

drain port covers are assumed to be installed when the canister is in a dry condition, and removed when the canister is modeled in a wet condition. Port covers are in place in all storage cask model analyses. The port cover is modeled as a solid piece of stainless steel.

5.3.2.3 Description of the CY-MPC Transfer Cask Model

In order to estimate occupational dose rates associated with the canister sealing operation, a number of operational configurations of the transfer cask are considered for the three-dimensional model of the upper cask region. These include wet and dry canister conditions and various shield lid, structural lid, and temporary shielding configurations. The temporary shield is modeled as a 5.00-inch thick truncated cone carbon steel plate with a bottom radius two inches shorter than the canister inner radius. The temporary shield is assumed to have 6.00-inch diameter cutouts to permit access to the canister vent ports and a 45-degree taper around the circumference to permit the automated welding machine access to the canister lid/canister wall interface. This configuration amounts to an assumed temporary shielding configuration. In reality, the temporary shield may be supplemented with additional shielding materials on site, although no credit for such material is taken here.

The top configuration of the transfer cask is evaluated in detail for the welding, draining, and drying operations. Model features include:

- Vent and drain port openings in the canister shield lid.
- Edge tapering and port cutouts in the temporary shielding.
- Upper trunnions cut through the radial shield and extend from the inner shell to the outer shell. No credit for the radial extent of the trunnions outside the cask outer shell is taken.
- Lead and neutron shielding overlap at the top as per the transfer cask drawings.
- Termination of the radial shields at the bottom plate.
- An explicit model of the bottom door assembly.

Details of the elevations and radii used in creating the three-dimensional top model are taken directly from the drawings in Section 1.7. As with the other three-dimensional models, elevations associated with the transfer cask three-dimensional features are established with respect to the center bottom of the canister bottom plate for the MCBEND combinatorial

geometry model. The three-dimensional transfer cask model including shield and structural lids is shown in Figure 5.3.2-1.

5.3.2.4 Description of the CY-MPC Storage Cask Model

The three-dimensional model of the vertical concrete cask containing design basis fuel assemblies is based on the following features of the storage cask:

- Heat transfer annulus.
- Carbon steel weldment with cutouts for inlets and outlets.
- Concrete shield with cutouts for inlets and outlets.
- Inlet and outlet models including carbon steel channel walls.
- Carbon steel shield plug with neutron shield.
- Carbon steel top lid.
- Carbon steel bottom base plate.
- Carbon steel support stand with four cutouts for air flow.
- Carbon steel shield ring.
- Carbon steel storage cask bottom.
- Concrete pad below base plate.

Detailed model parameters used in creating the three-dimensional model are taken directly from the drawings in Section 1.7. Elevations associated with the concrete cask three-dimensional features are established with respect to the center bottom of the canister for the MCBEND combinatorial model. The three-dimensional concrete cask model is shown in Figure 5.3.2-2.

A detailed sketch of the cask outlet model is shown in Figure 5.3.2-3 in terms of labeled key points in the model. Dimensions for the key points are shown in Table 5.3.2-5.

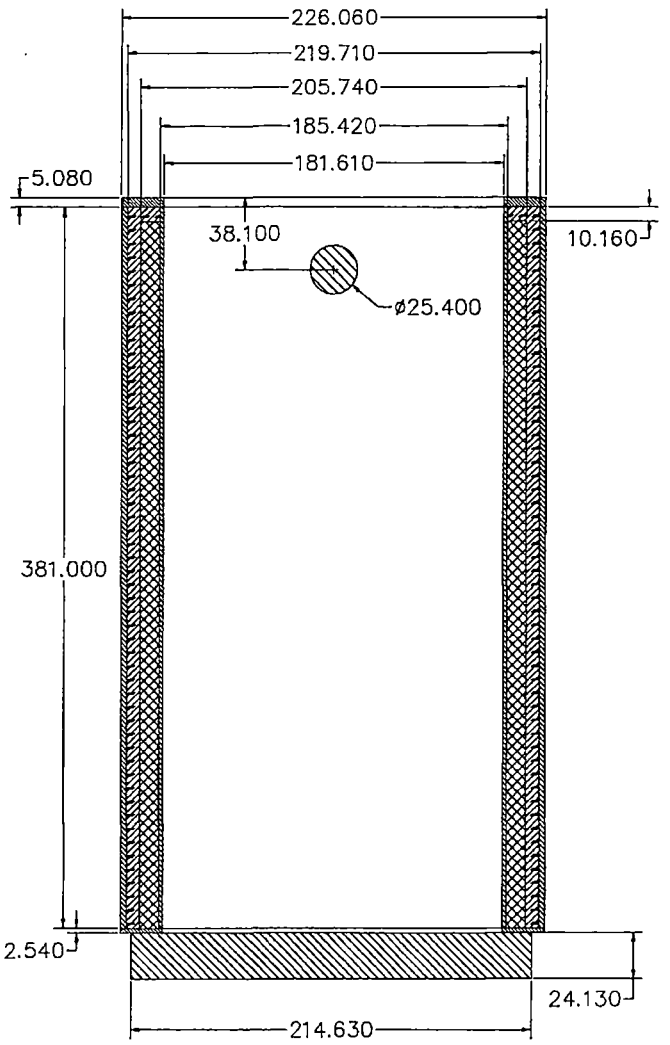
The bottom weldment model is detailed in Figure 5.3.2-4. The figure shows two sections through the bottom weldment assembly model. The portion of the figure to the left of the centerline is a section through an inlet location. The portion to the right of the centerline is a section through a non-inlet location.

The canister model employed in both the transfer and storage analyses is identical, except for variations in lid configuration in the various transfer cask cases. The relevant canister model dimensions are shown in Figure 5.3.2-5.

5.3.2.5 CY-MPC Shield Regional Densities

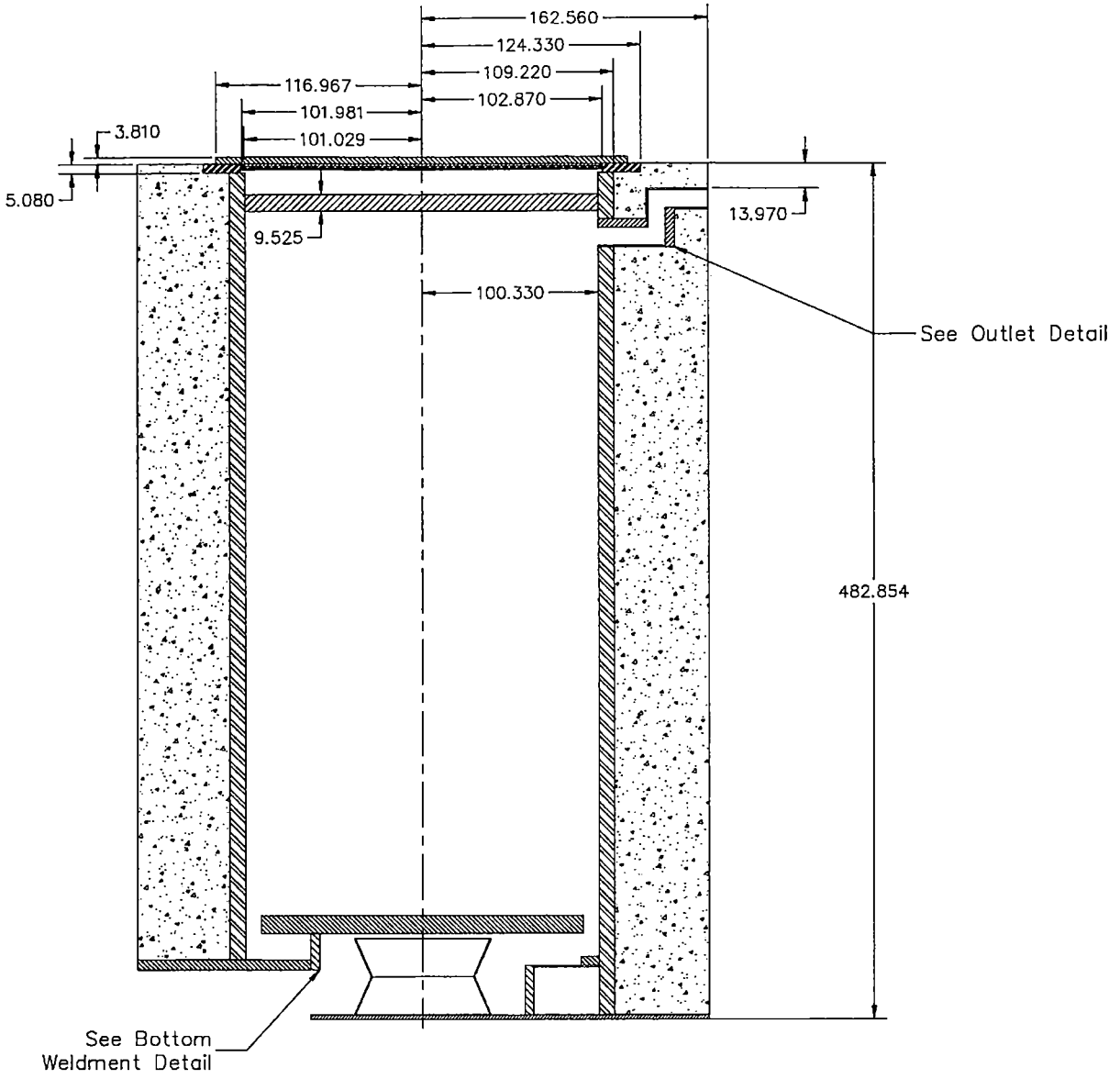
Based on the homogenization described in Section 5.3.2.1, the resulting active fuel regional densities are shown in Table 5.3.2-6 for stainless steel and Zircaloy clad fuel types. Material compositions for remaining structural and shield materials are shown in Table 5.3.2-7. Compositions for fuel assembly non-fuel regions are equivalent to the stainless steel composition in Table 5.3.2-7 scaled by the material volume fractions shown in Tables 5.3.2-3 and 5.3.2-4.

Figure 5.3.2-1 CY-MPC Three-Dimensional Transfer Cask Model



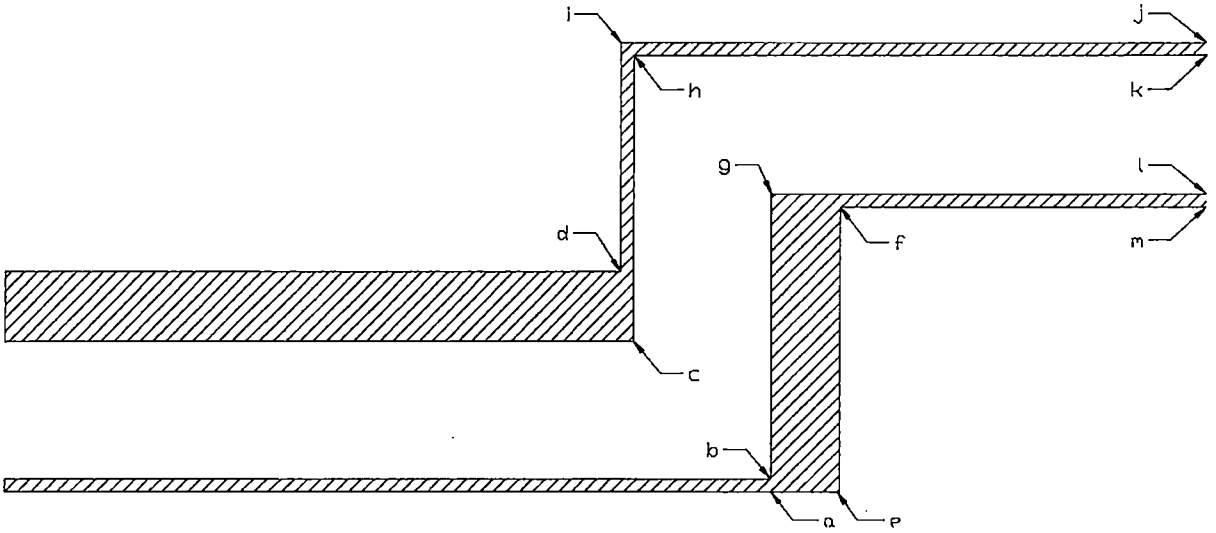
(Dimensions in centimeters)

Figure 5.3.2-2 CY-MPC Three-Dimensional Storage Cask Model



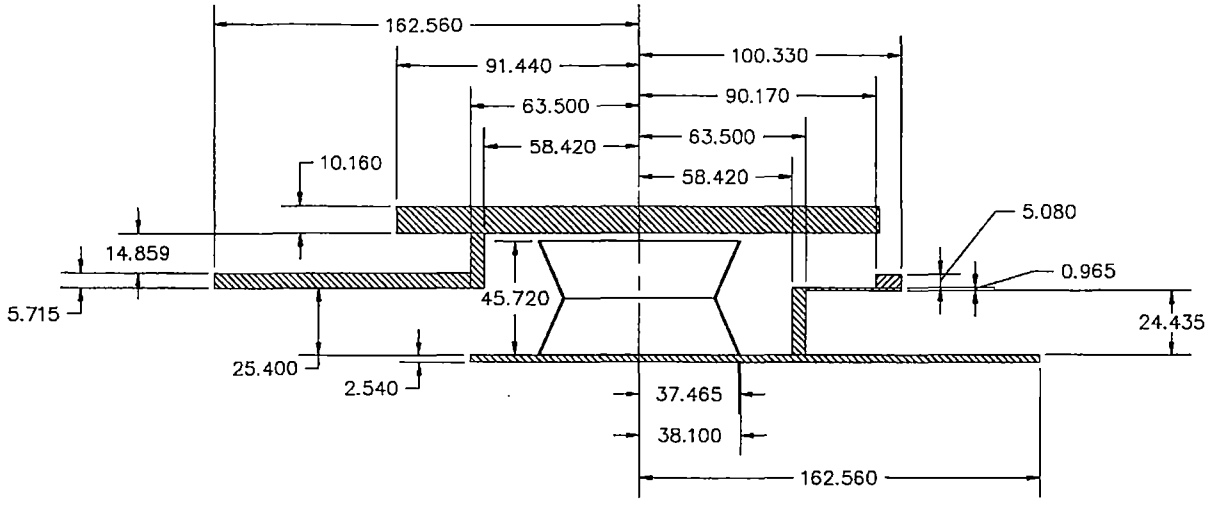
(Dimensions in centimeters)

Figure 5.3.2-3 CY-MPC Three-Dimensional Storage Cask Outlet Model Detail



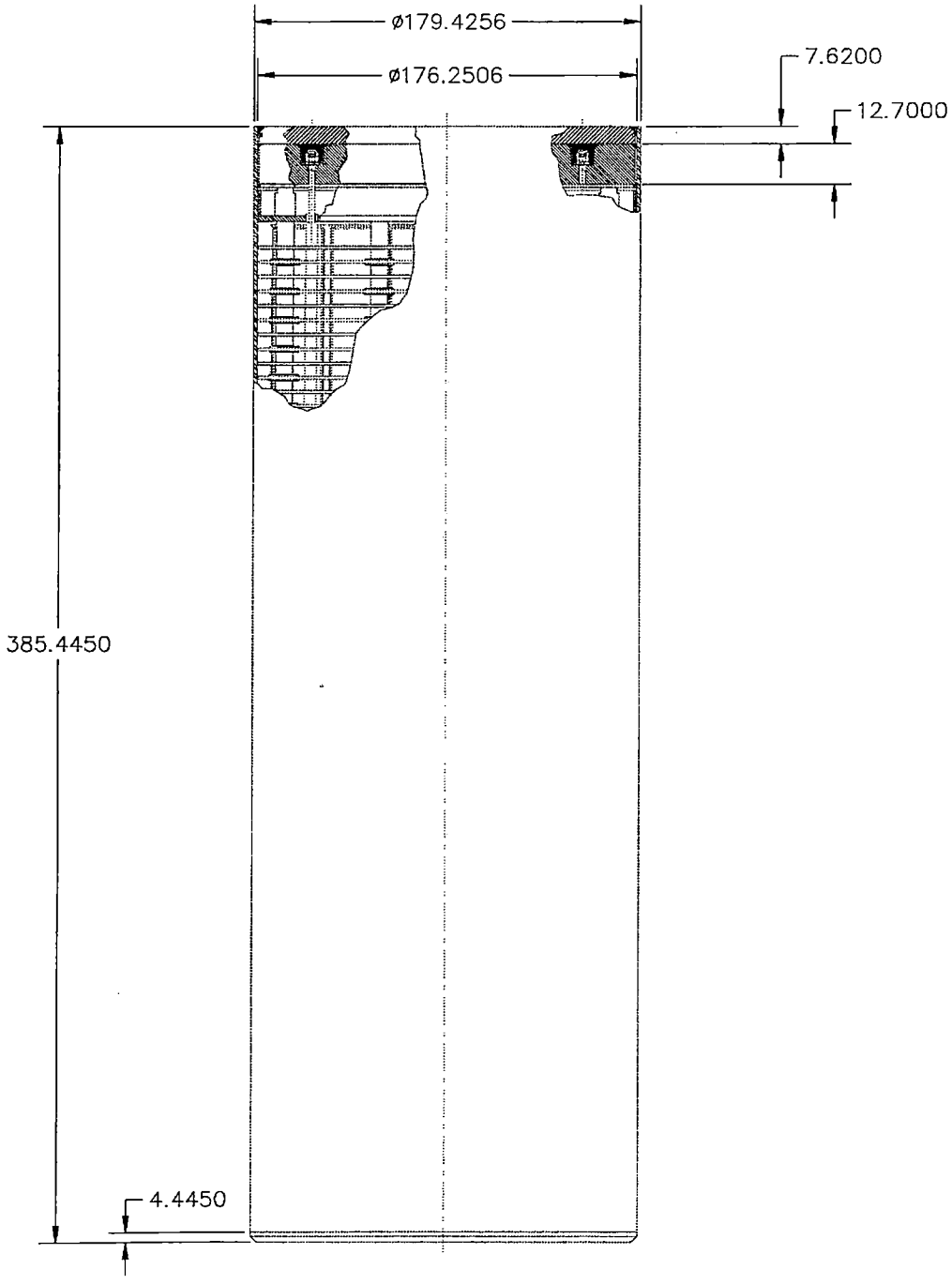
(See Table 5.3.2–5 for dimensions)

Figure 5.3.2-4 CY-MPC Three-Dimensional Storage Cask Bottom Weldment Model Detail



(Dimensions in centimeters)

Figure 5.3.2-5 CY-MPC Three-Dimensional Canister Model Detail



(Dimensions in centimeters)

Table 5.3.2-1 Connecticut Yankee Stainless Steel Clad Fuel Region Homogenization

Component	Volume Fraction of Components			
	UO_2	Void	Clad	Interstitial
Fuel	3.3010E-01	--	--	--
Gap	--	9.5568E-03	--	--
Clad	--	--	6.0055E-02	--
Guide Tube	--	--	5.6120E-03	--
Instrument Tube	--	--	2.9439E-04	--
Inside Tubes	--	--	--	6.0931E-02
Interstitial	--	--	--	5.3345E-01
Total	3.3010E-01	9.5568E-03	6.5962E-02	5.9438E-01

Table 5.3.2-2 Connecticut Yankee Zircaloy Clad Fuel Region Homogenization

Component	Volume Fraction of Components			
	UO_2	Void	Clad	Interstitial
Fuel	3.0394E-01	--	--	--
Gap	--	9.0410E-03	--	--
Clad	--	--	8.9574E-02	--
Guide Tube	--	--	7.7242E-03	--
Instrument Tube	--	--	3.8621E-04	--
Inside Tubes	--	--	--	5.7525E-02
Interstitial	--	--	--	5.3181E-01
Total	3.0394E-01	9.0410E-03	9.7684E-02	5.8934E-01

Table 5.3.2-3 Connecticut Yankee Stainless Steel Clad Fuel Assembly Hardware Region Homogenization

Region	Mass SS [kg/cask]	SS Volume [cm^3]	Height [cm]	Volume [cm^3]	Volume Fraction
Lower Nozzle	230.10	2.9053E+04	8.0975	9.6963E+04	2.9963E-01
Lower End Plug	65.96	8.3277E+03	1.7399	2.0834E+04	3.9971E-01
Upper Plenum	100.85	1.2734E+04	9.0162	1.0796E+05	1.1795E-01
Upper End Plug	65.96	8.3277E+03	1.7399	2.0834E+04	3.9971E-01
Upper Nozzle	292.24	3.6899E+04	17.2466	2.0652E+05	1.7867E-01

Table 5.3.2-4 Connecticut Yankee Zircaloy Clad Fuel Assembly Hardware Region Homogenization

Region	Mass SS [kg/cask]	SS Volume [cm^3]	Height [cm]	Volume [cm^3]	Volume Fraction
Lower Nozzle	141.44	1.7859E+04	8.0975	9.6963E+04	1.8418E-01
Lower End Plug	0.0	0.0000E+00	1.7399	2.0834E+04	0.0000E+00
Upper Plenum	133.56	1.6864E+04	10.7942	1.2925E+05	1.3047E-01
Upper End Plug	0.0	0.0000E+00	1.7399	2.0834E+04	0.0000E+00
Upper Nozzle	307.84	3.8869E+04	17.2466	2.0652E+05	1.8821E-01

Table 5.3.2-5 Connecticut Yankee Storage Cask Outlet Model Parameters

Key Point[1]	Radial Dimension		Axial Dimension[2]	
	[in]	[cm]	[in]	[cm]
a	54.450	138.303	148.625	377.508
b	54.450	138.303	149.000	378.460
c	50.570	128.448	152.880	388.315
d	50.195	127.495	154.880	393.395
e	56.450	143.383	148.625	377.508
f	56.450	143.383	156.845	398.386
g	54.450	138.303	157.220	399.339
h	50.570	128.448	161.100	409.194
i	50.195	127.495	161.475	410.147
j	64.000	162.560	161.475	410.147
k	64.000	162.560	161.100	409.194
l	64.000	162.560	157.220	399.339
m	64.000	162.560	156.845	398.386

1. Refer to Figure 5.3.2-3.
2. Dimension with respect to bottom of canister bottom plate.

Table 5.3.2-6 Connecticut Yankee Homogenized Fuel Regional Densities

Stainless Steel Clad		Zircaloy Clad	
Element	**Density [atom/b-cm]**	**Element**	**Density [atom/b-cm]**
CR	1.08911E-03	CR	7.41045E-06
FE	4.16871E-03	FE	1.37989E-05
NI	4.28815E-04	HF	2.15875E-07
O	1.53301E-02	NI	6.56487E-07
U	7.66861E-03	O	1.41392E-02
--	--	SN	4.86877E-05
--	--	U	7.06088E-03
--	--	ZR	4.14273E-03

Table 5.3.2-7 Regional Densities for CY-MPC Structural and Shield Materials

Material	Element	Density [atom/b-cm]
Stainless Steel	CR	1.65112E-02
	FE	6.31986E-02
	NI	6.50094E-03
Carbon Steel	C	3.92500E-03
	FE	8.34980E-02
BORAL Aluminum Clad	AL	3.35910E-02
	B	4.63378E-02
	C	1.21776E-02
Aluminum	AL	6.02626E-02
Lead	PB	3.20871E-02
NS-4-FR	AL	7.80000E-03
	B	4.27500E-04
	C	2.26000E-02
	H	5.85000E-02
	N	1.39000E-03
	O	2.61000E-02
NS-3	AL	6.59115E-03
	C	7.73839E-03
	CA	1.39147E-03
	FE	8.52616E-04
	H	4.15720E-02
	O	3.40389E-02
	SI	1.18926E-03
Concrete	AL	1.70180E-03
	CA	1.48260E-03
	FE	3.38570E-04
	H	1.34010E-02
	NA	1.70360E-03
	O	4.49310E-02
	SI	1.62050E-02
Water	H	6.67364E-02
	O	3.33677E-02

5.4 Shielding Evaluation

This section evaluates the shielding design of NAC-MPC transfer and storage casks. The calculational methods are described for the Yankee-MPC and CY-MPC configurations.

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5.4.1 Yankee-MPC Shielding Evaluation

Yankee-MPC shielding calculations are performed with design basis Yankee Class fuel source terms at 36,000 MWD/MTU and eight years cooling time. Dose rate profiles are reported as a function of distance from the sides, top, and bottom of the NAC-MPC storage and transfer casks. Storage cask outgoing neutron and gamma directional source strengths (neutron and gamma fluxes at the cask surface) are provided for ISFSI controlled area boundary dose evaluations.

5.4.1.1 SCALE Package Calculational Methods

Shielding evaluations of the transfer and storage casks are performed with SCALE 4.3 for the PC. In particular, SCALE shielding analysis sequence SAS2H is used to generate source terms for the design basis fuel. SAS1 is used to perform one-dimensional radial and axial shielding analysis, and a modified version of SAS4 is used to perform three-dimensional shielding analysis of the transfer cask. The coupled 27-group neutron, 18-group gamma ENDF/B-IV (27N-18COUPLE) cross section library is used in all SCALE shielding evaluations. Source terms include fuel neutron, fuel gamma, and gamma contributions from activated hardware. Dose rate evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms. The SCALE shielding analysis sequences and cross section libraries recently have been benchmarked to measurements of light water reactor fuel source terms, shielding material dose rate attenuation, and spent fuel storage and transport cask dose rates (Broadhead).

The SAS2H code sequence is used to generate source terms for the Yankee Class design basis fuel. SAS2H includes an XSDRNPM neutronics model of the fuel assembly and ORIGEN-S fuel depletion/source terms calculations. The 27 energy group ENDF/B-IV neutron cross section library, 27GROUPNDF4, is used in the source terms calculations. Source terms are generated for both UO_2 fuel and fuel assembly hardware. The hardware activation is calculated by ORIGEN-S using the incore neutron flux spectrum produced by the SAS2H neutronics model. The hardware is assumed to be Type 304 stainless steel with 1.2 g/kg ^{59}Co impurity. The effects of axial flux spectrum and magnitude variation on hardware activation are estimated by flux ratios based on empirical data (Luskic). Both the one-dimensional SAS1 and the three-dimensional SAS4 shielding models are used in the evaluations of the NAC-MPC storage system. The SAS1 radial and axial models are used to estimate the peak and average dose rates on the sides, top, and bottom of the storage and transfer casks. The models represent the cask as

either semi-infinite cylinders or slabs. The method of solution is XSDRNPM discrete ordinates. Bucklings are applied to the one-dimensional models to account for transverse leakage. One-dimensional analysis also serves as a cross check of the three-dimensional model results and is employed to establish the minimum cool time for the loading of 32,000 MWD/MTU burnup assemblies and the Exxon 36,000 MWD/MTU assemblies (Table 5.4.1-6).

The SAS4 shielding models are used to estimate the dose profiles along the surfaces of the transfer and storage casks and to estimate doses in and around streaming paths such as the storage cask inlets and outlets, and the canister vent and drain ports. The SAS4 models represent the cask body and any streaming paths with combinatorial logic. The method of solution is adjoint discrete ordinates and Monte Carlo using the XSDRNPM and MORSE codes, respectively. Since SAS4 requires model symmetry at the fuel midplane, two models are created for each cask, a top and a bottom model. Radial biasing is performed to estimate dose rate on the sides of the cask, and axial biasing is performed to estimate dose rates on the top and bottom surfaces of the cask. Modifications are made to SAS4 to determine dose rates all along the radial, top and bottom surfaces of the cask, as well as any cylindrical surface surrounding the cask. Thus, detailed dose profiles are determined that explicitly show peaks due to the fuel burnup profile, activated hardware gamma emission and any streaming paths.

In both the SAS1 and SAS4 models, the fuel and hardware source regions are homogenized within the volumes described by the periphery of the basket tubes and defined by the fuel assembly active fuel, plenum, and end fitting elevations. Within these volumes, the material masses of the fuel assembly and basket are preserved.

5.4.1.2 MCBEND Calculational Methods

The shielding evaluation of the storage cask is performed with MCBEND version 9E. Source terms include fuel neutron, fuel gamma, and gamma contributions from activated hardware. As described in Section 5.2.1, these evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

The MCBEND shielding models described in Section 5.3.1 are utilized with the source terms described in Section 5.2.1.2 to estimate the dose rate profiles at the surface of the concrete cask and at the air inlets and outlets. The method of solution is continuous energy Monte Carlo with an adjoint diffusion solution for generating importance meshes. Radial and top axial biasing are

performed within the MCBEND code, with an additional azimuthal component added to the splitting mesh to account for the angular variations in the bulk shielding properties of the concrete cask at the inlets and outlets.

The MCBEND code has been validated against various classical shielding problems, including fast and thermal neutron sources penetrating through single material slab geometries of iron, graphite and water. The validation suite also includes fast neutron transmission through alternating slabs of iron and water. Of particular interest is a benchmark of MCBEND to gamma and neutron dose rates outside a metal transport cask, where agreement between measurement and calculation is within 20% for the majority of dose locations.

MCBEND results are calculated using the JEF2.2 neutron cross-section library and the ANSWERS gamma library.

5.4.1.3 Flux-to-Dose Rate Conversion Factors

The ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors are used in all NAC-MPC shielding evaluations. These factors are default for SCALE 4.3 and user input in the MCBEND evaluations. Tables 5.4.1-1 and 5.4.1-2 show the group flux-to-dose rate factors associated with the coupled 27-group neutron and 18-group gamma cross-section library used in the SCALE shielding evaluations.

5.4.1.4 Dose Rates

This section provides detailed dose rate profiles for the Yankee-MPC storage and transfer cask based on the source terms presented in Section 5.2.1. Design basis fuel source terms include contributions from fuel neutron, fuel gamma and activated hardware gamma. The fuel assembly activated hardware gamma source terms include: steel and inconel in the upper and lower fuel assembly end fittings, and upper and lower fuel rod plenum hardware. Peaking factors of 1.15 and 1.80 are applied to the one-dimensional radial fuel gamma and neutron dose rates, respectively. The three-dimensional model dose rates include the axial profiles for neutron and gamma source distributions shown in Figure 5.2.1-4.

Three-dimensional dose rates for the concrete cask are calculated using MCBEND. Three-dimensional dose rates for the transfer cask are calculated using SAS4.

5.4.1.4.1 One-Dimensional Yankee-MPC Storage Cask Dose Rates

One-dimensional radial dose rates with design basis fuel were found to be in good agreement with the three-dimensional models at the radial midplane. However, the peaks in the radial dose rates, due to activated endfittings, cannot be captured by one-dimensional analysis. One-dimensional dose rates at the top of the storage cask are significantly lower than those calculated using three-dimensional analysis. This is primarily due to the neutron component of the dose rates and the transverse bucklings applied in the one-dimensional axial model, as well as streaming effects caused by the heat transfer annulus and top vents. Except for the neutron component of the top axial model and obvious limitations in geometry, one-dimensional analysis is found to support the results of the more complicated three-dimensional models. Except for the storage cask loss of concrete accident radial dose rates shown in Table 5.4.1-3, the dose rate results from three-dimensional analysis are reported.

One-dimensional radial surface dose rates are also used to determine the minimum cool times, based on the design basis fuel values, for CE, UN, and WE fuel types with a maximum burnup of 32,000 MWD/MTU and Exxon assemblies at 36,000 MWD/MTU. The calculated minimum cool times for CE, UN, and WE fuel at 32,000 MWD/MTU are 8, 13 and 24 years, respectively. Exxon assemblies with steel hardware require 16 years cooling while the Exxon assemblies with Zircaloy hardware require only 10 years cooling. The 10-year cool time for Exxon fuel assemblies with Zircaloy fuel region hardware includes the activation of four hollow Zircaloy replacement rods with stainless steel slugs. One-dimensional dose rates at the minimum cool times listed above are summarized in Table 5.4.1-6.

5.4.1.4.2 Three-Dimensional Yankee-MPC Storage Cask Dose Rates

The Yankee-MPC storage cask three-dimensional model dose rates are presented in Figures 5.4.1-1 through 5.4.1-6 for intact fuel. Approximately 50 million particle histories (neutron and gamma) are tracked to yield the dose rate profiles presented in these figures. The average standard deviation for the side total dose rate shown in Figures 5.4.1-1 and 5.4.1-2 is less than ± 2% and the average standard deviation for the top total dose rate shown in Figure 5.4.1-6 is less than. ± 1%. The standard deviations for the peak inlet and outlet vent total dose rates are shown in Figures 5.4.1-3 and 5.4.1-4 and are less than ± 2%.

The vertical profile along the radial surface of the storage cask, as well as at distances of 30.48 cm (1 foot), and 1 meter are plotted in Figure 5.4.1-1 as a function of elevation. Each datum represents the circumferentially average dose rate at the corresponding distance and elevations. The negative elevations are the dose rates at locations below the base plate. In the vertical dose profile, peaking is observed at the fuel midplane. The average and maximum side surface dose rates for the storage cask are 35.7 (1.1%) and 44.1 (1.2%) mrem/hr, respectively.

The radial surface dose profile is further described by source component in Figure 5.4.1-2. The source components in both models contribute to the radial doses largely as one would expect, i.e., at the elevations where they are located. Since these doses are circumferential averages, the detailed circumferential dose rate profile at the top vent elevation and the bottom vent inlet are shown radially in Figure 5.4.1-3 and Figure 5.4.1-4, respectively. Average dose rates of 116 mrem/hr (1.1%) and 191 mrem/hr (1.2%) are calculated at the surface of the outlet vent at the entrance of the inlet vent with supplemental shielding, respectively. The calculated air inlet dose rate without supplemental shielding is 803 (<1%) mrem/hr.

The dose rate profiles on the top surface of the storage cask and at distances of 1 foot and 1 meter above the lid are shown in Figure 5.4.1-5. The dose rates are plotted radially out from the centerline of the storage cask. Two dose rate peaks are observed on the storage cask top surface: one in the vicinity of 90 to 100 cm, which corresponds to the location of the heat transfer annular gap, and another at approximately 130 cm resulting from streaming through the air outlet gap in the cask liner. The dose rate profile on the top surface of the storage cask is shown by source component in Figure 5.4.1-6 and indicates that the peak dose rate above the annular gap is caused by neutrons streaming up the gap. The component profile also indicates that the second peak is created by gammas from the upper end fitting, fuel, and upper plenum source regions. This peak occurs at approximately the same radial location as the vertical leg in the upper outlet vent. Thus, it is a result of a decrease in effective shield thickness caused by the void in the concrete and cask liner due to the outlet vents. The average dose rate over the top of the storage cask is computed to be 34.9 mrem/hr (<1%), while the peak dose on top of the storage cask is 75.5 mrem/hr (<1%).

Three-dimensional model dose rate additions due to the damaged fuel located at the bottom-end fitting region of the corner basket locations are presented in Figures 5.4.1-7 and 5.4.1-8.

The additive radial dose rates due to the presence of the mass of 20 fuel rods in the bottom-end fitting yields a maximum side dose rate of 2.7 mrem/hr at the bottom of the cask. The additional

dose, however, does not affect the calculated maximum dose rate on the side of the cask and the average dose rate increases by less than 0.5%. The total air inlet dose rate due to both intact and damaged fuel with supplemental shielding in the outlet is 219 (1%) mrem/hr, based on a statistical combination of the symmetric air inlet dose rate results. Air inlet damaged fuel results are calculated with supplemental shielding included in the air inlets.

5.4.1.3.3 One-Dimensional Yankee-MPC Transfer Cask Dose Rates

One-dimensional radial dose rates with design basis fuel are in good agreement with the three-dimensional models at the radial midplane. As with the storage cask one-dimensional radial model, the peaks in the radial dose rates due to activated endfittings cannot be captured by one-dimensional analysis. One-dimensional top dose rates at the top and bottom of the transfer cask were significantly lower than three-dimensional analysis. This was primarily due to the neutron component of the dose rates and the transverse bucklings applied in the one-dimensional axial model, as well as streaming effects around the temporary shielding. Except for the neutron component of the top axial model, one-dimensional analysis supports the results of the more complicated three-dimensional models.

5.4.1.3.4 Three-Dimensional Yankee-MPC Transfer Cask Dose Rates

The transfer cask three-dimensional model dose rates for intact fuel are presented in Figures 5.4.1-9 through 5.4.1-16. Approximately 100 million particle histories (neutron and gamma) are tracked to yield the dose rate profiles presented in theses figures. The average standard deviation for the side total dose rates shown in Figures 5.4.1-9 through 5.4.1-12 is less than ± 2%, and the average standard deviation for the top total dose rates shown in Figures 5.4.1-13 and 5.4.1-14 is less than ± 2%.

The transfer cask side dose rate profiles with a wet cavity are shown in Figure 5.4.1-9 as a function of elevation and distance, and in Figure 5.4.1-10 as a function of source component. In this condition, the majority of the dose rate is from fuel gamma and activated end fitting gamma. It is assumed in the model that the water level in the canister is lowered for welding operations, thus, the top end fitting is uncovered and causes a large peak in dose rate at the top of the transfer cask due to the gamma source from the activated top end fitting. In this condition, the peak and average dose rates on the side of the transfer cask are 210.2 (0.8%) and 79.5 (0.3%) mrem/hr,

respectively, and the peak and average dose rates at 1 meter are 40.5 (0.7%) and 26.4 (0.2%) mrem/hr, respectively.

The transfer cask side dose rate profiles with a dry cavity are shown in Figure 5.4.1-11 as a function of elevation and distance and in Figure 5.4.1-12 as a function of source component. In this condition, the majority of the dose rate is from fuel neutron and gamma source, but significant peaks are shown from the activated end fittings. The peak and average dose rates on the side of the transfer cask are 413.4 (1.5%) and 226.3 (0.2%) mrem/hr, respectively, and the peak and average dose rates at 1 meter are 103.4 (0.6%) and 72.2 (0.2 %) mrem/hr, respectively.

The transfer cask peak and average dose rate on the temporary shield surface are 188.7 (1.1%) and 172.0 (0.3%) mrem/hr, respectively. In this condition, the majority of the dose rate is from the activated top end fitting. The peak and average dose rate at 1 meter are 389.1 (5.1%) and 263.7 (1.5%) mrem/hr, respectively.

In the final configuration, the canister cavity is dry, the shield lid and structural lid are in place, and 5 inches of temporary steel shielding are installed. In this condition, the transfer cask top dose rate is shown in Figure 5.4.1-13 as a function of distance and in Figure 5.4.1-14 as a function of component. The majority of the dose rate is from the fuel neutron. The dose rate peaks at the lid edge due to gamma streaming around the tapered edge of the temporary shield. The peak and average dose rates on the top of the transfer cask are 358.9 (2.6%) and 224.6 (0.9%) mrem/hr, respectively, and the peak and average dose rates at 1 meter are 39.6 (4.5%) and 34.2 (1.3 %) mrem/hr, respectively.

The transfer cask bottom dose rate profiles with the cavity wet and dry are shown in Figures 5.4.1-15 and 5.4.1-16, respectively. In the wet cavity situation, the peak and average dose rates on the bottom of the transfer cask are 77.2 (0.7%) and 55.9 (0.2 %) mrem/hr, respectively, and the peak and average dose rates at 1 meter are 19.0 (2.1%) and 12.2 (0.3 %) mrem/hr, respectively. In the dry cavity situation, the peak and average dose rates on the bottom of the transfer cask are 398.4 (1.0%) and 278.9 (0.2 %) mrem/hr, respectively, and the peak and average dose rates at one meter are 66.7 (1.2%) and 46.7 (0.3 %) mrem/hr, respectively.

The transfer cask three-dimensional model dose rates are presented in Figures 5.4.1-17 through 5.4.1-19 for the canister containing damaged fuel cans.

For the damaged fuel can wet canister cavity configuration, the transfer cask peak and average dose rates on the temporary shield surface are 214.1 (0.1%) and 194.7 (<0.1%) mrem/hr, respectively. In this condition, the majority of the dose rate is from the activated top end fitting. The peak and average dose rates at 1 meter are 387.4 (0.7%) and 296.1 (0.2%) mrem/hr, respectively. Top axial dose rates are shown as a function of distance from the temporary shield in Figure 5.4.1-17. Significant local peaking occurs at the port radius due to the proximity of the shield lid machined areas to the vent and drain ports. Figure 5.4.1-18 shows the local peaking of 4 rem/hr (0.6%).

In the damaged fuel can dry canister configuration, the damaged fuel shield lid and structural lid are in place, and 5 inches of temporary steel shielding is installed. In this condition, the transfer cask top dose rates are shown in Figure 5.4.1-19 as a function of distance from the temporary shield. The majority of the dose rate is from the fuel neutron source. The dose rate peaks at the lid edge due to gamma streaming around the tapered edge of the temporary shield. The peak and average dose rates on the top of the transfer cask are 387.9 (0.6%) and 173.7 (0.3%) mrem/hr, respectively, and the peak and average dose rates at 1 meter are 90.9 (15.4%) and 71.3 (0.7 %) mrem/hr, respectively. Note that the damaged fuel shield lid is only used with the basket configuration having damaged fuel cans in the corner locations.

The maximum additional dose rate contribution due to damaged fuel sources in the lower endfitting region is no greater than 40 mrem/hr at any point on the surface of the transfer cask. Comparisons of intact and damaged fuel dose rate profiles on the side of the cask are shown in Figure 5.4.1-20 and Figure 5.4.1-21 for dry and wet canister conditions, respectively. The damaged fuel maximum radial surface dose rate is 444.8 (1.6%) mrem/hr under dry conditions. Under wet canister conditions, the location of the maximum radial surface dose rate is unchanged from the intact fuel case since the peak occurs near the top of the cask. The maximum bottom axial dose rates for the damaged fuel case are 435.7 (0.9%) mrem/hr and 96.3 (0.6%) mrem/hr for dry and wet conditions, respectively.

5.4.1.4 Yankee-MPC Storage Cask Shielded Source Terms

The storage cask shielded source terms are provided in this section for use in the ISFSI controlled area boundary dose evaluations. These shielded source terms are the neutron and gamma directional source strengths at the surface of the concrete storage cask due to the neutron and gamma sources specified in Section 5.2 and obtained from the three-dimensional MCBEND shielding evaluation for intact fuel. As stated in Section 5.4.1.4.2, the calculated maximum dose rate is identical for intact and damaged fuel while the increase in average dose rate with damaged fuel is less than 1%.

Surface directional source strengths are output in the 28 group neutron and 22 group gamma energy group structure employed in the MCBEND evaluations. Source strengths are listed in MCBEND group structure in Table 5.4.1-4 for the side and the top of the storage cask. This source strength, in the case of the radial component, is based on the surface area of the storage cask side and, in the case of the top axial component, is based on the surface area of the top lid. The total source strengths (Table 5.4.1-5) and spectra are used in the SKYSHINE-III direct and air-scatter dose evaluations presented in Chapter 10 for an array of NAC-MPC storage casks at an ISFSI.

Figure 5.4.1-1 Yankee-MPC Storage Cask Radial Dose Rate Profile

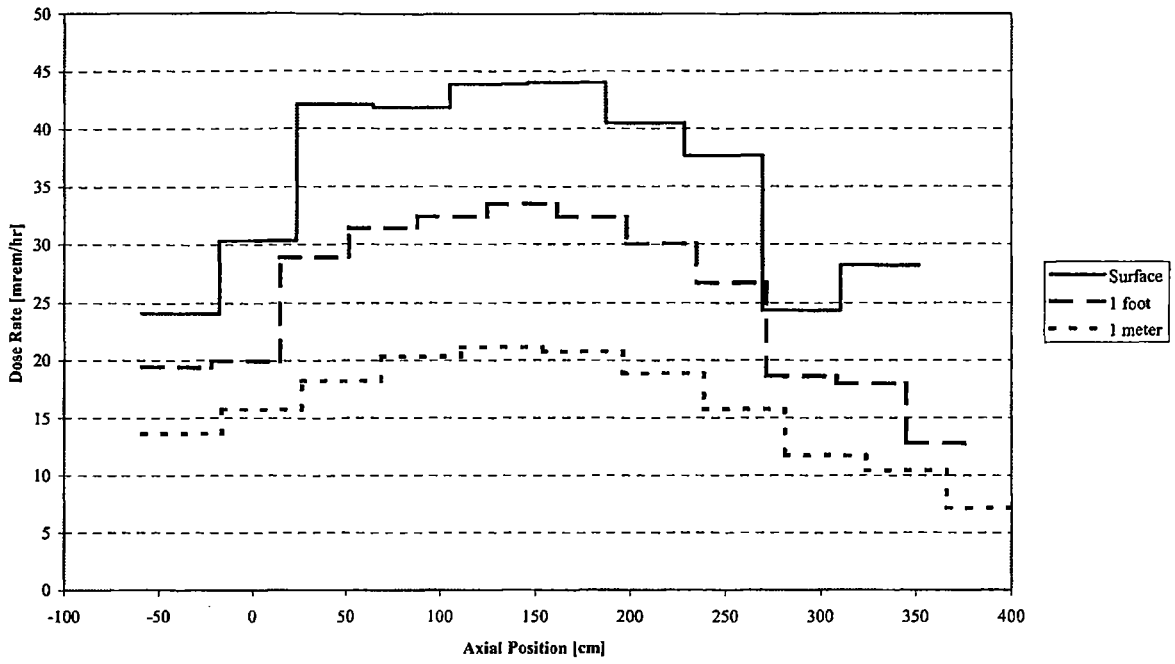


Figure 5.4.1-2 Yankee-MPC Storage Cask Three-Dimensional Model Surface Dose Rate Profile by Source Component

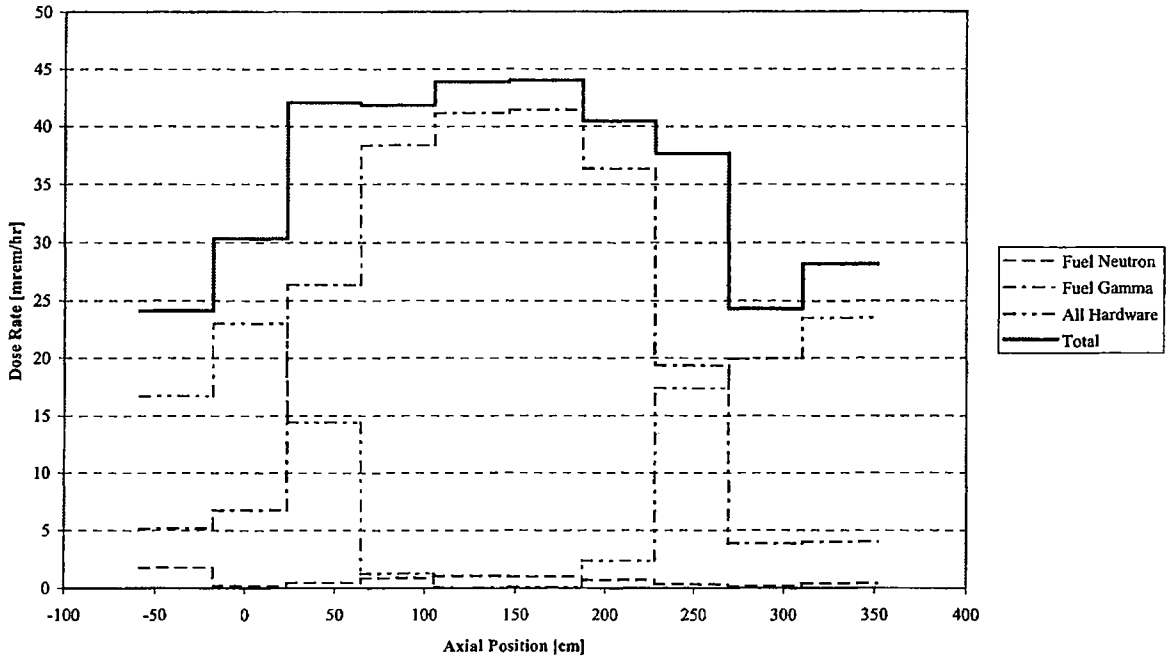


Figure 5.4.1-3 Yankee-MPC Storage Cask Top Outlet Vent Dose Rate Profile

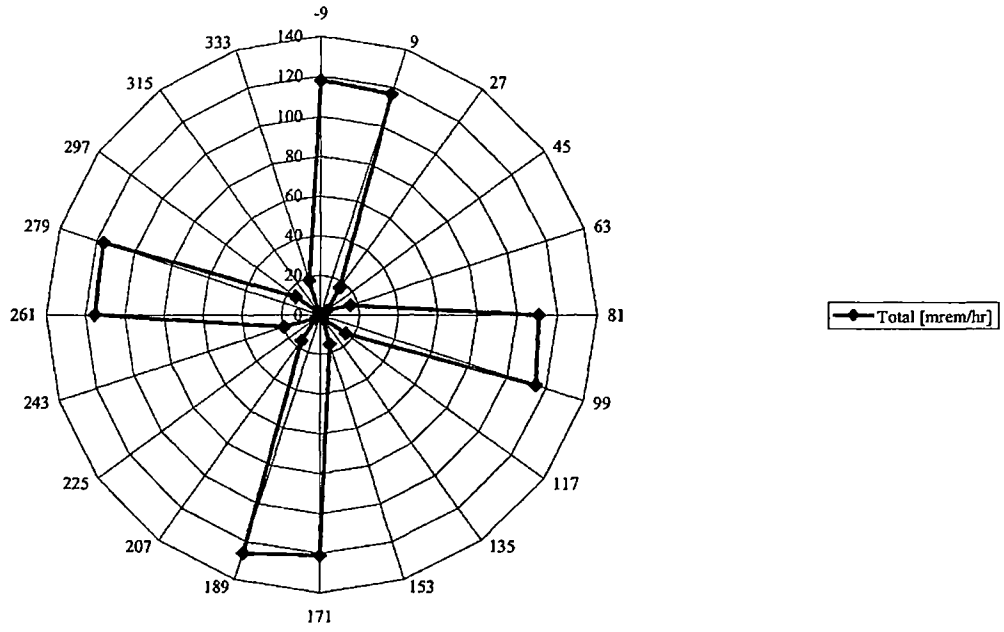


Figure 5.4.1-4 Yankee-MPC Storage Cask Bottom Inlet Vent Dose Rate Profile

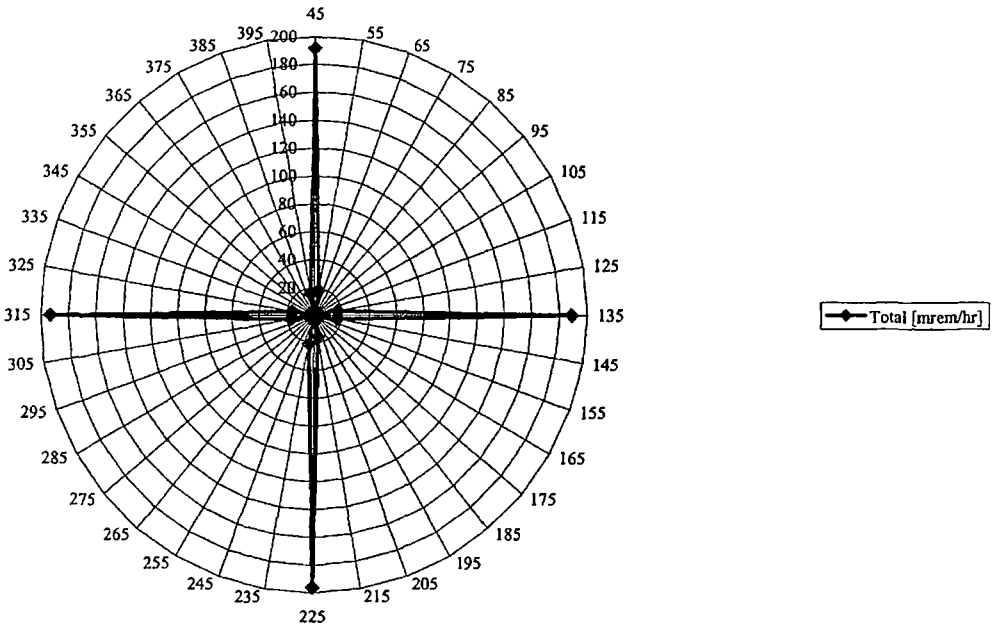


Figure 5.4.1-5 Yankee-MPC Storage Cask Top Dose Rate Profile as a Function of Radius from the Centerline and Distance from Surface

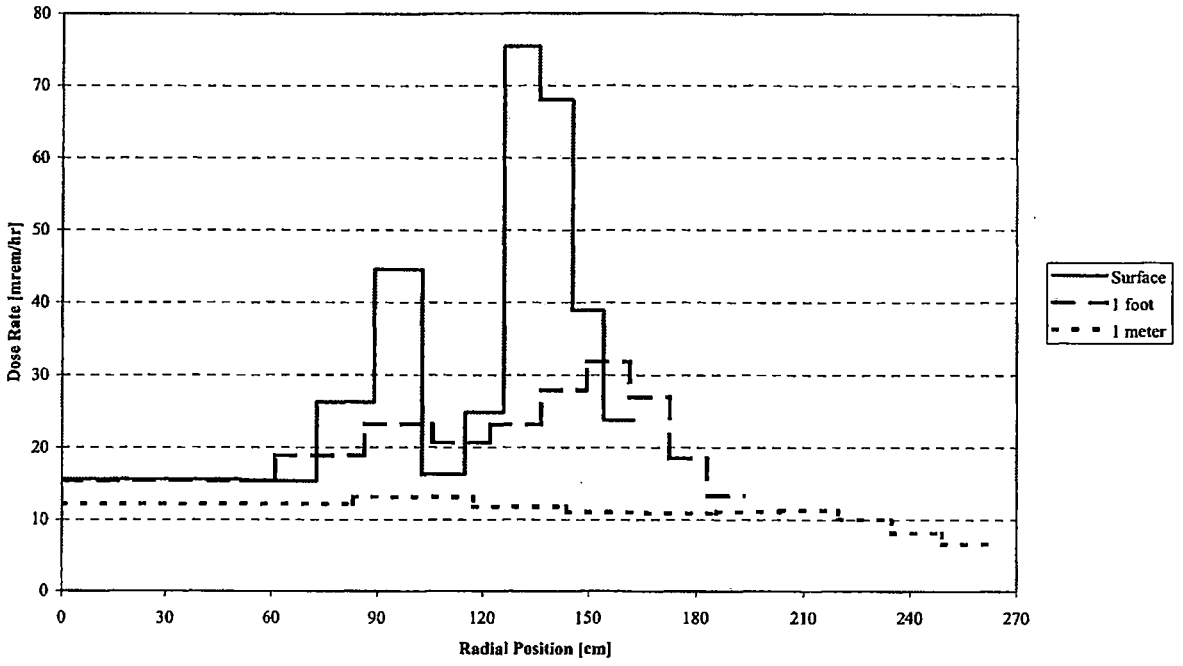


Figure 5.4.1-6 Yankee-MPC Storage Cask Top Surface Dose Rate Profile by Source Component

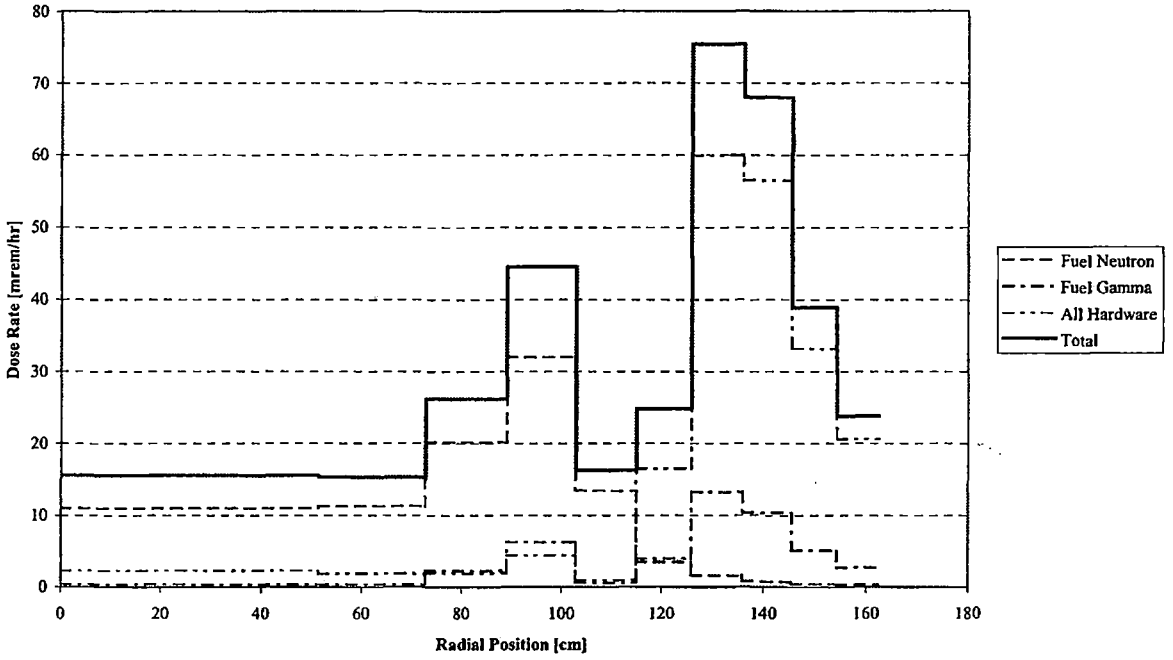


Figure 5.4.1-7 Yankee-MPC Storage Cask Radial Dose Rate Profile – Intact/Damaged Fuel Comparison

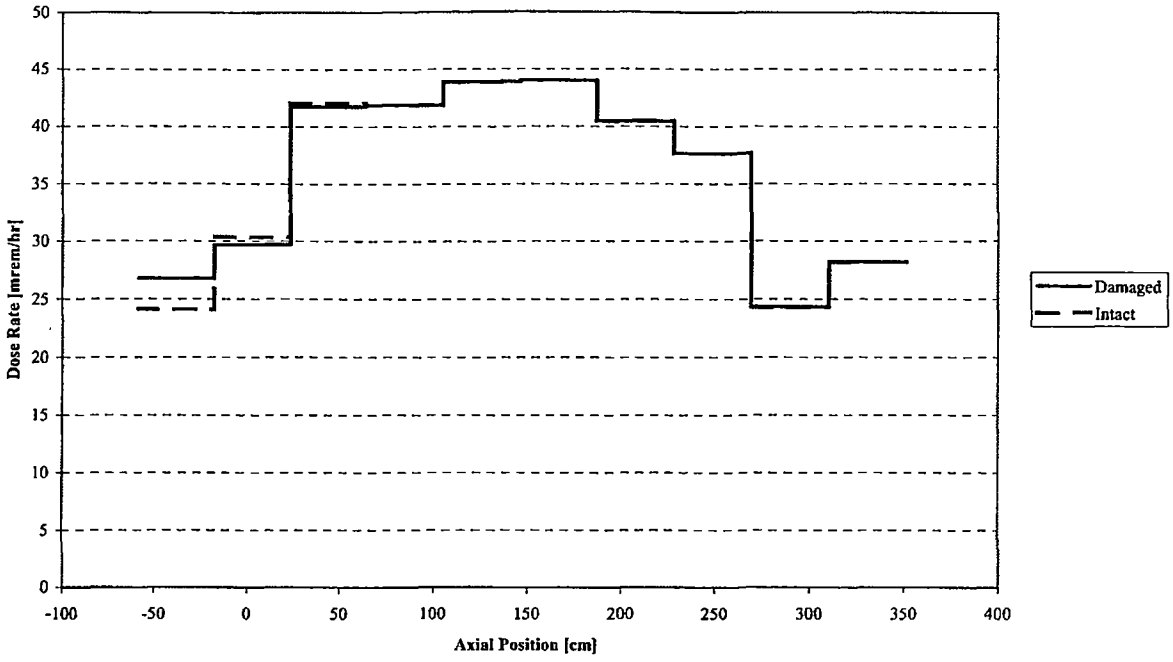


Figure 5.4.1-8 Yankee-MPC Storage Cask Bottom Inlet Vent Dose Rate Profile – Damaged Fuel

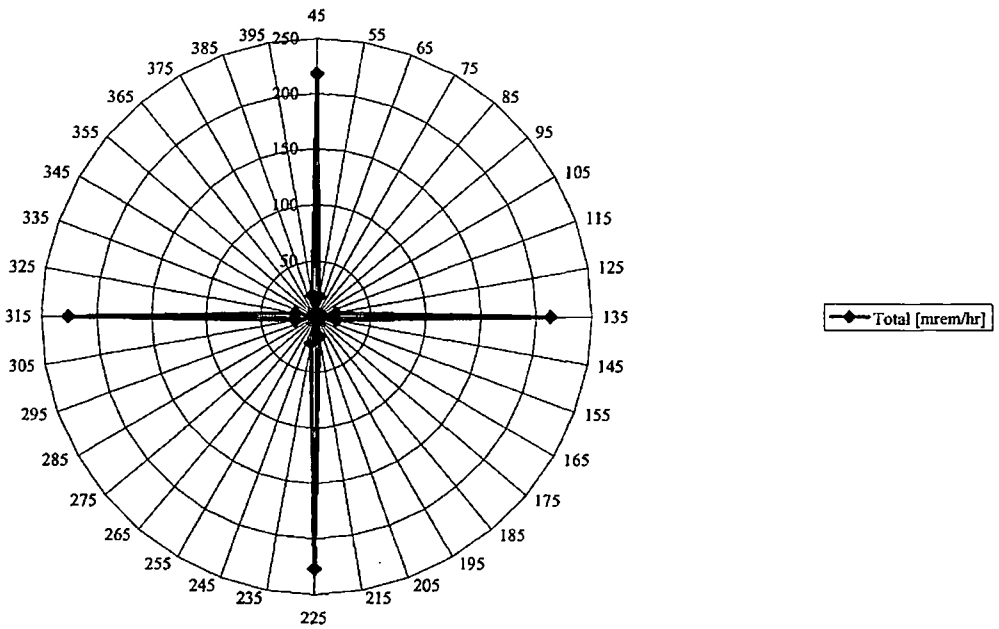


Figure 5.4.1-9 Yankee-MPC Transfer Cask Side Dose Rate Profile as a Function of Elevation and Distance, Wet Cavity

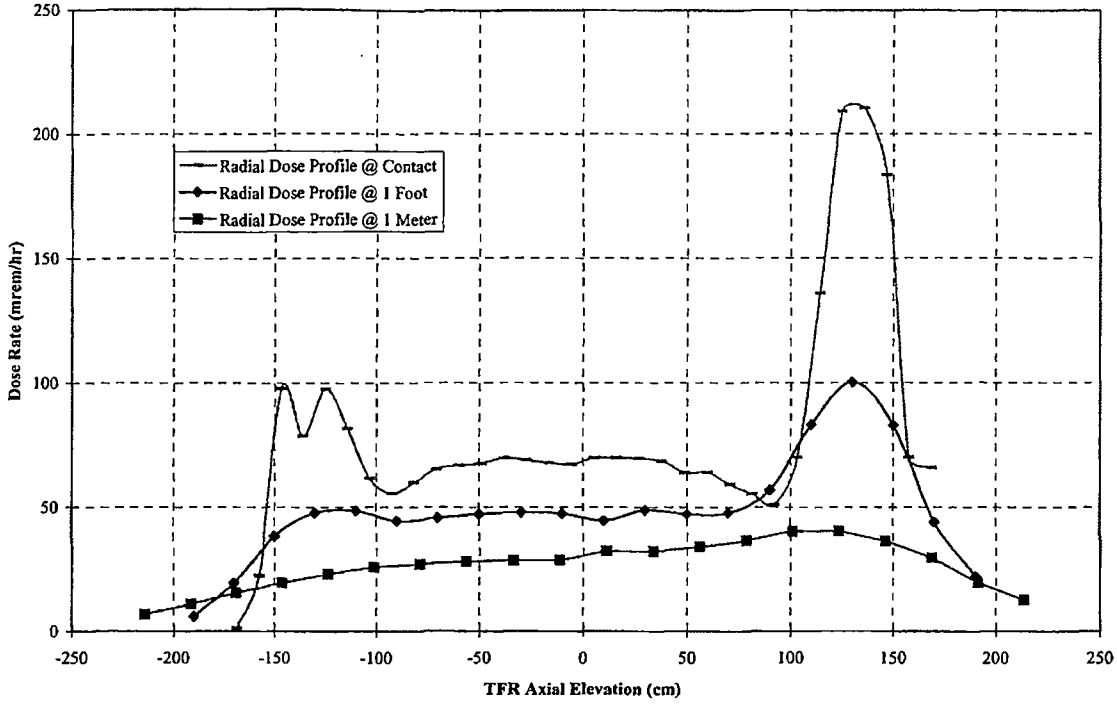
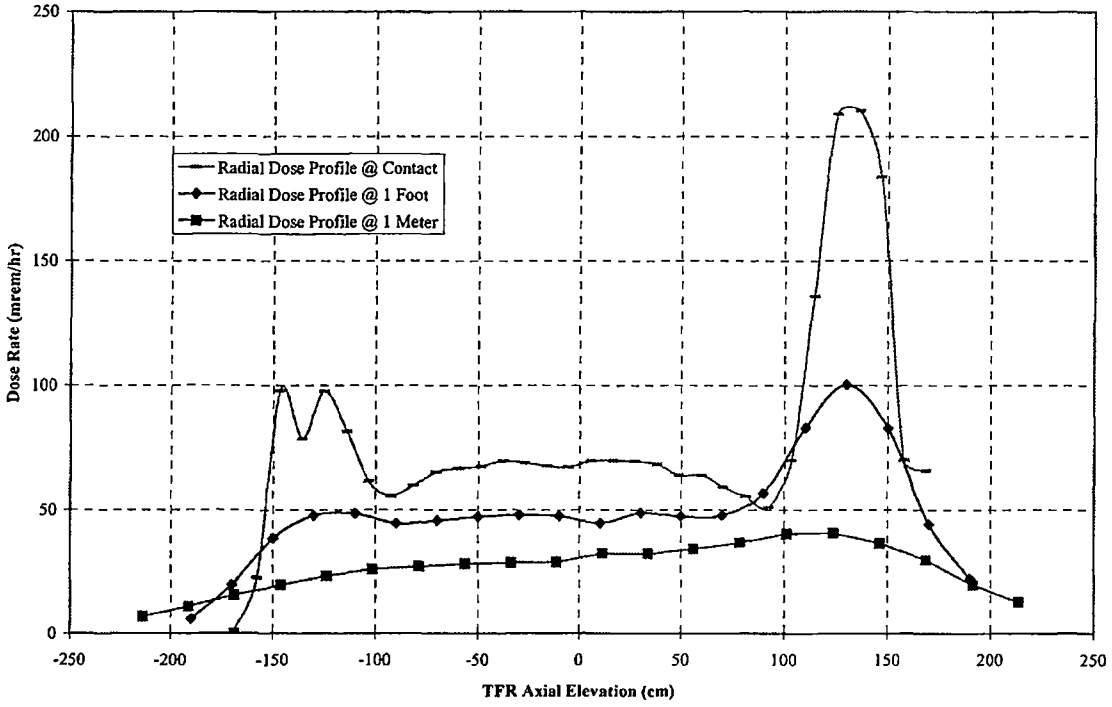


Figure 5.4.1-10 Yankee-MPC Transfer Cask Side Dose Rate Profile by Source Component, Wet Cavity



Note: Peak in nozzle dose at 135 cm is due to draining 50 gallons of water which uncovers the nozzle.

Figure 5.4.1-11 Yankee-MPC Transfer Cask Side Dose Rate Profile as a Function of Elevation and Distance, Dry Cavity

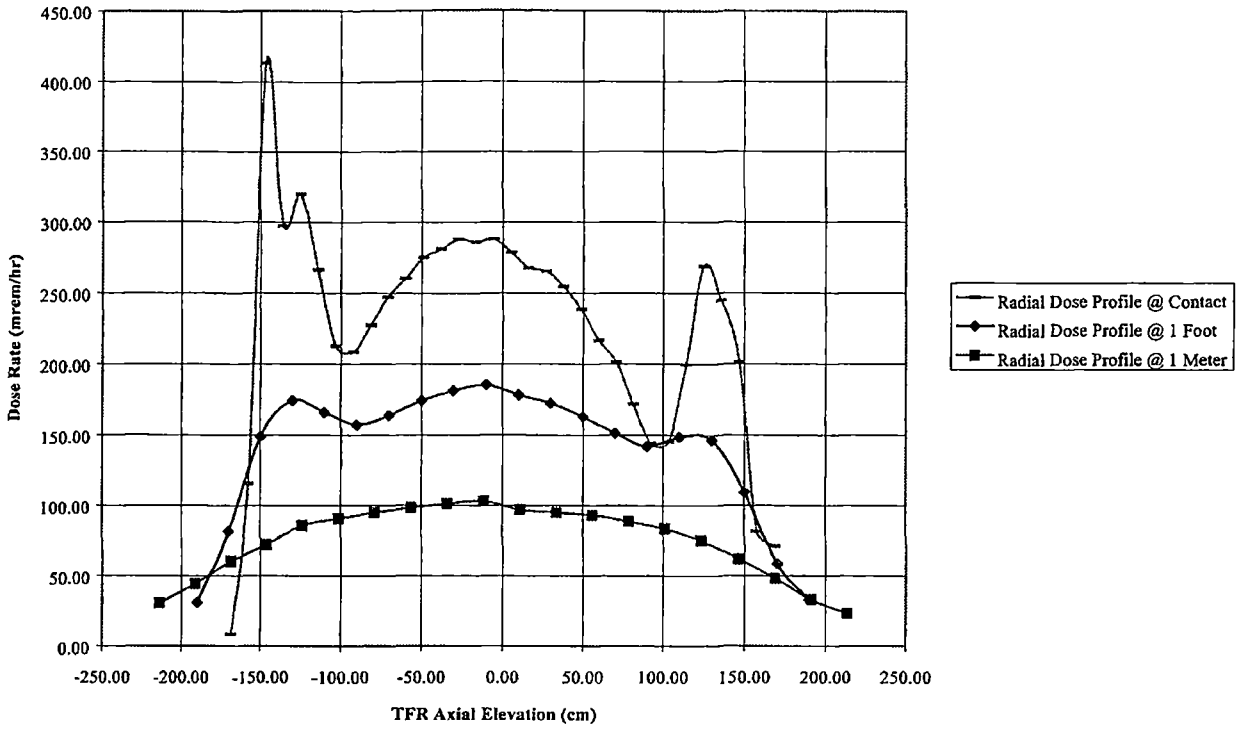


Figure 5.4.1-12 Yankee-MPC Transfer Cask Side Dose Rate Profile by Source Component, Dry Cavity

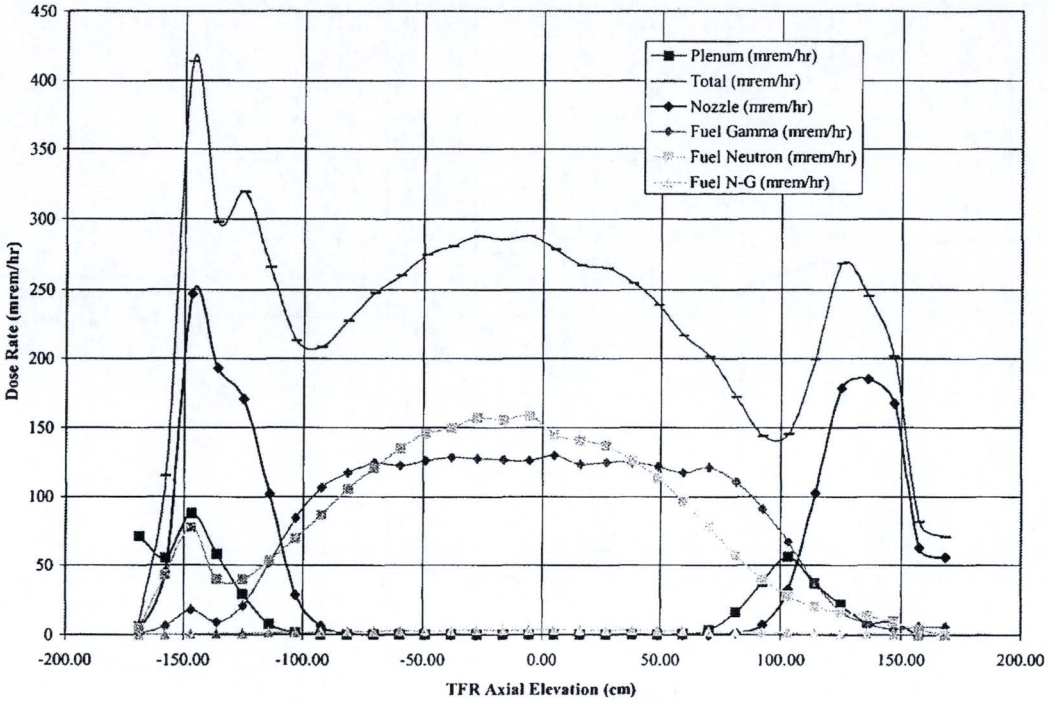
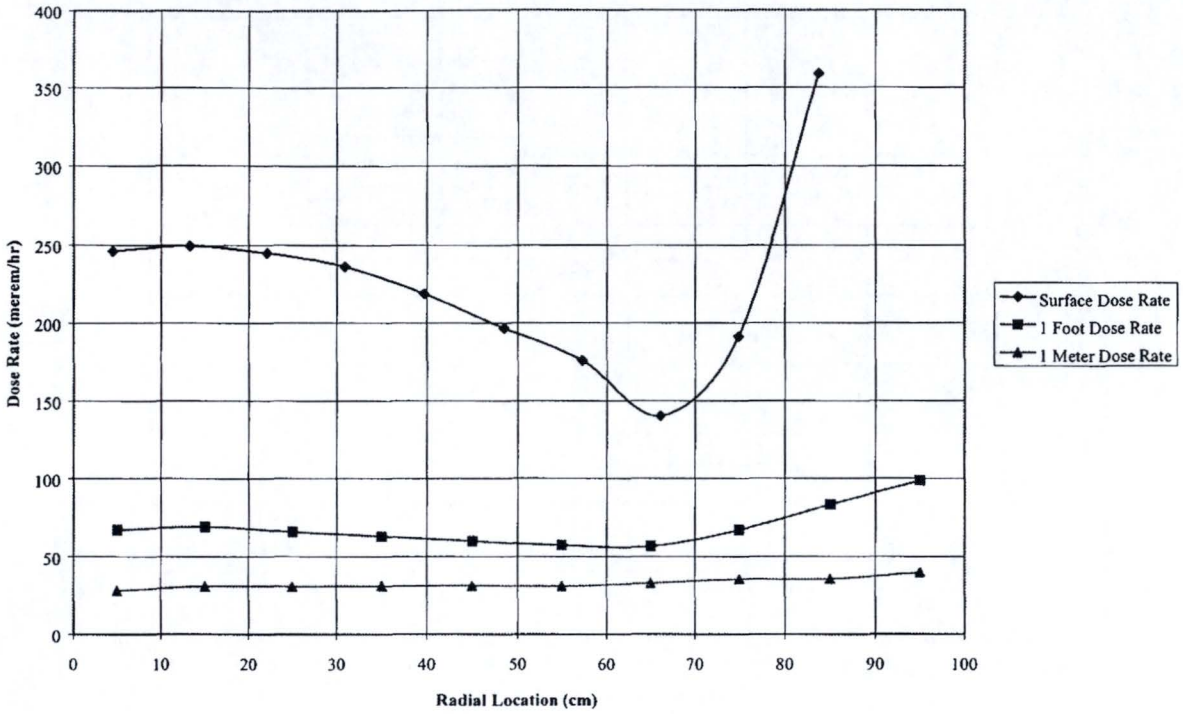
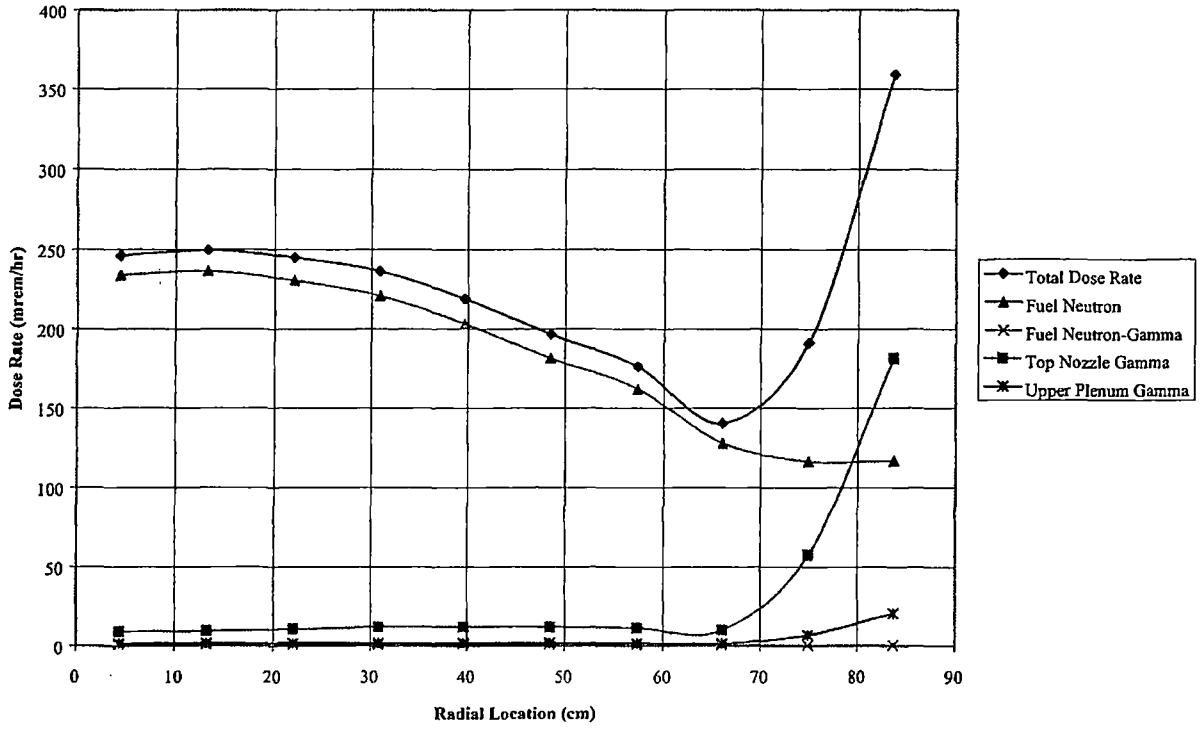


Figure 5.4.1-13 Yankee-MPC Transfer Cask Top Surface Dose Rate as a Function of Radius and Distance from Surface, Shield Lid, Structural Lid, and Temporary Shield On, Dry Cavity



Condition: Shield Lid, Structural Lid, and Temporary Shield On, Dry Cavity

Figure 5.4.1-14 Yankee-MPC Transfer Cask Top Surface Dose Rate by Source Component, Shield Lid, Structural Lid, and Temporary Shield On, Dry Cavity



Condition: Shield Lid, Structural Lid, and Temporary Shield On, Dry Cavity

Figure 5.4.1-15 Yankee-MPC Transfer Cask Bottom Surface Dose Rate, Wet Cavity

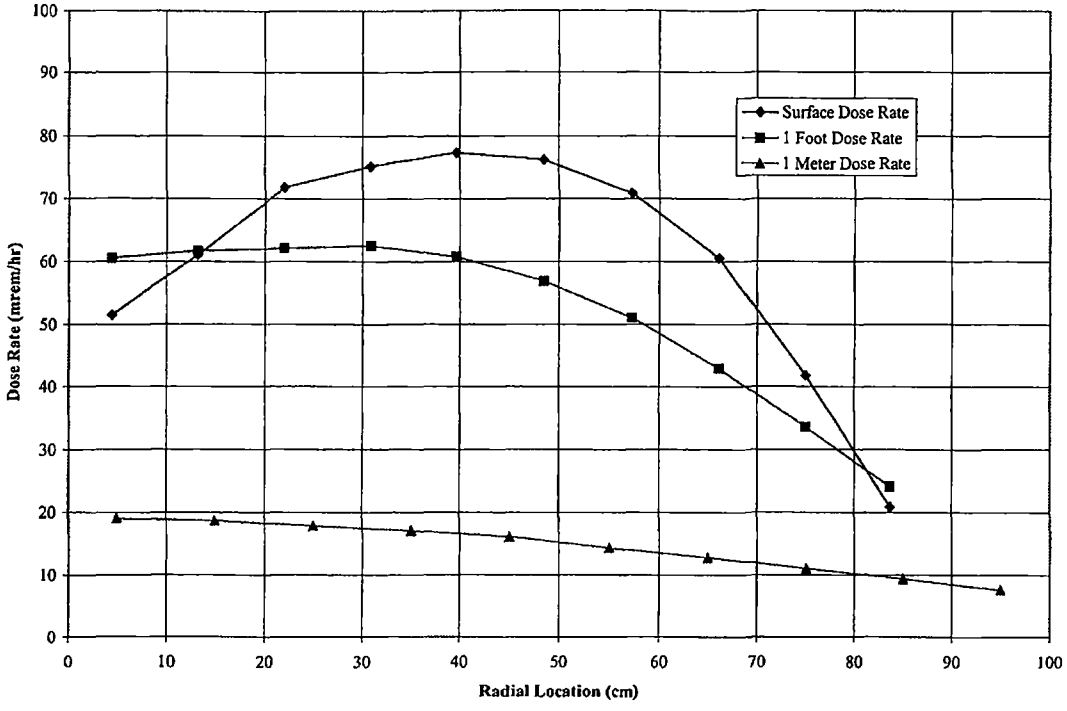


Figure 5.4.1-16 Yankee-MPC Transfer Cask Bottom Surface Dose Rate, Dry Cavity

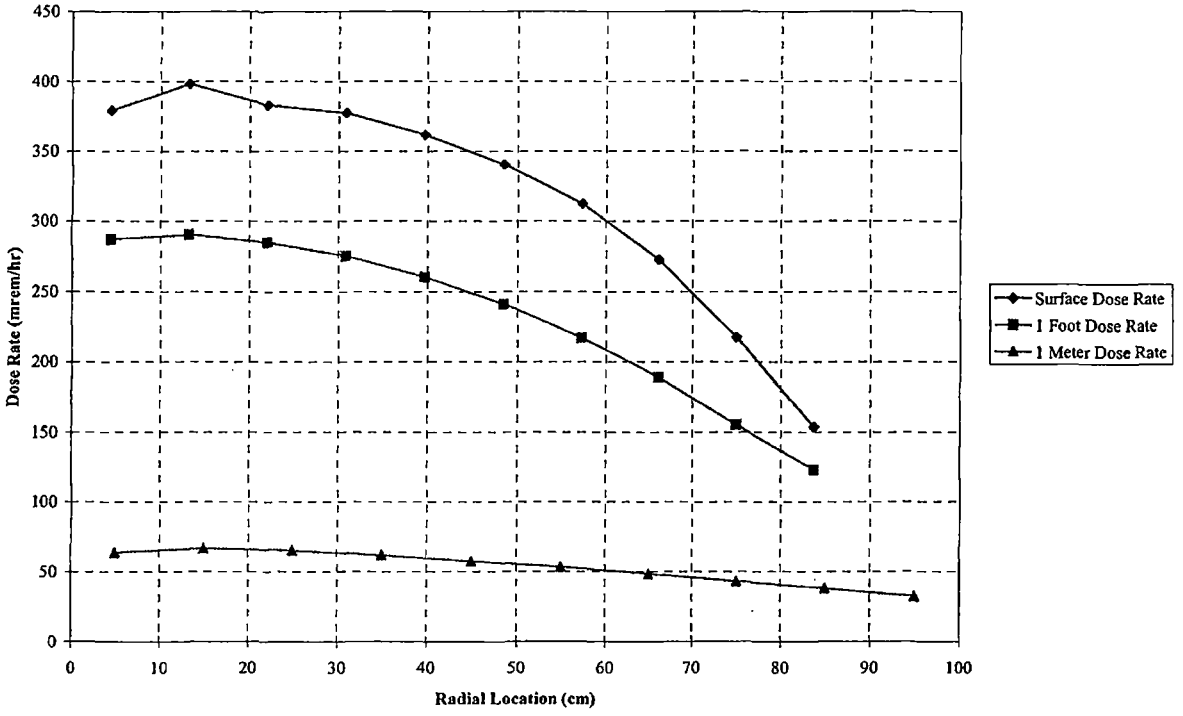
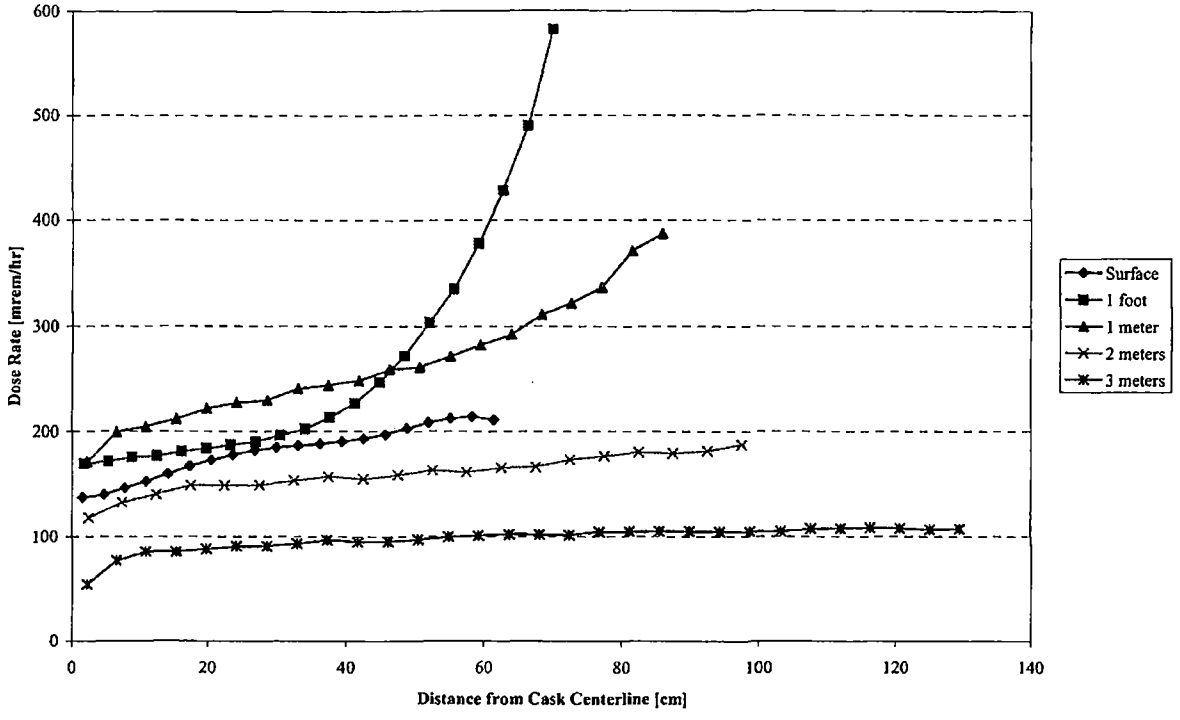
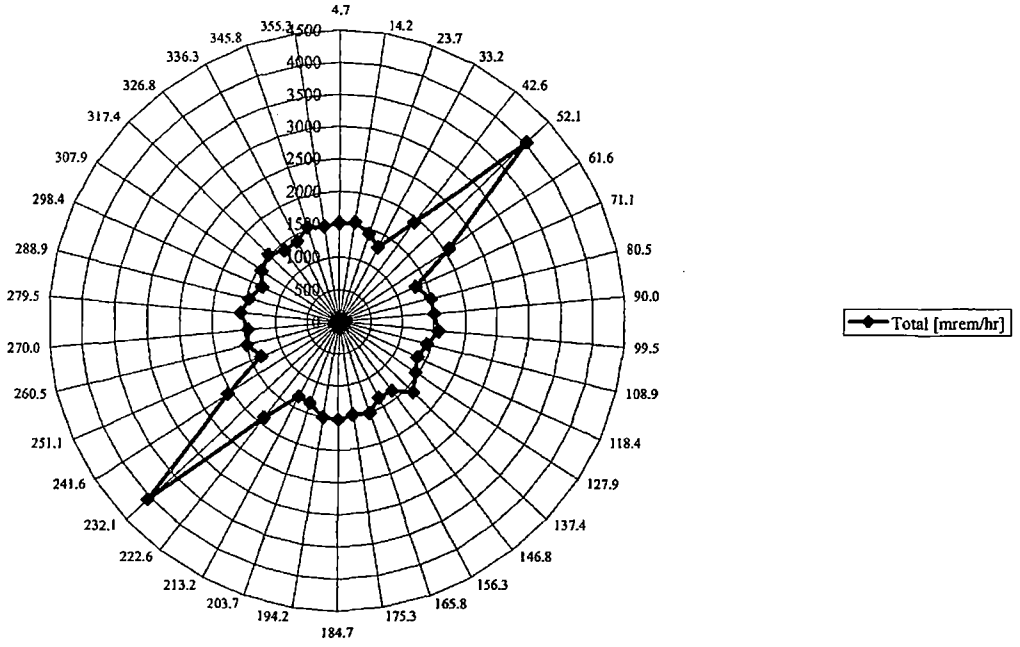


Figure 5.4.1-17 Yankee-MPC Transfer Cask Top Surface Dose Rate Due to Damaged Fuel as a Function of Radius and Distance from Surface (Wet Cavity)



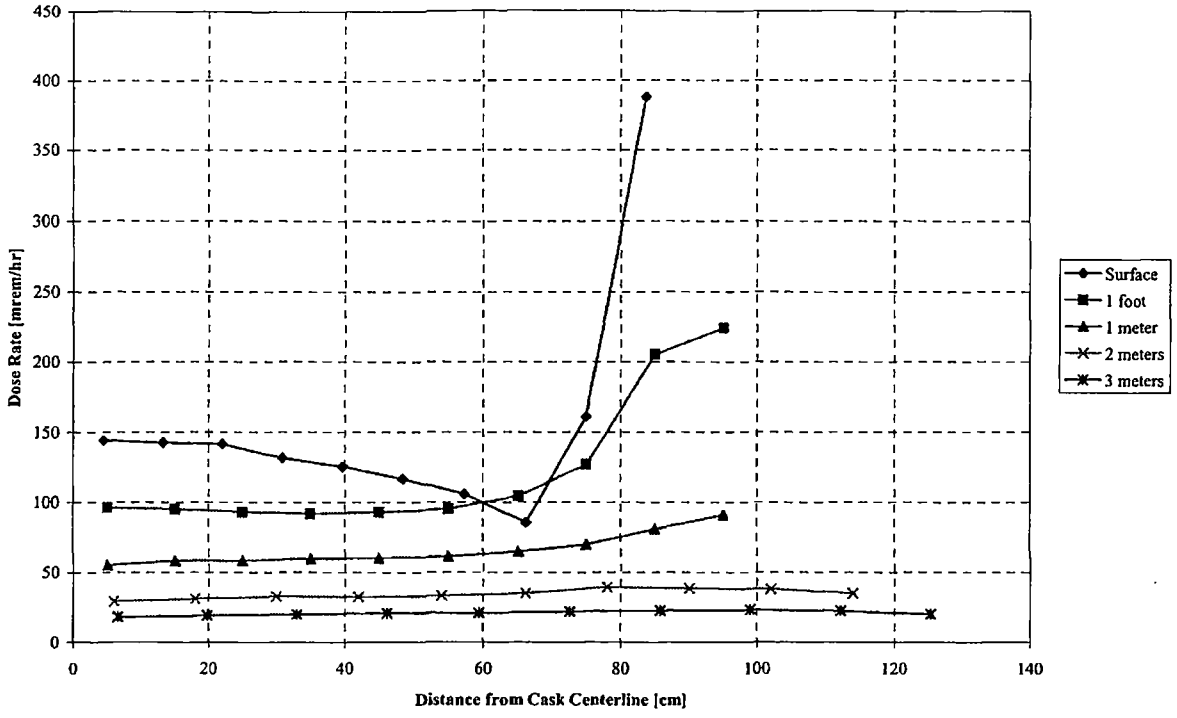
Condition: Damaged Fuel Shield Lid with Temporary Shield On, Wet Cavity

Figure 5.4.1-18 Yankee-MPC Transfer Cask Top Surface Dose Rate Profile Due to Damaged Fuel at Port Radius



Condition: Damaged Fuel Shield Lid with Temporary Shield On, Wet Cavity

Figure 5.4.1-19 Yankee-MPC Transfer Cask Top Surface Dose Rate Due to Damaged Fuel as a Function of Radius and Distance from Surface (Dry Cavity)



Condition: Damaged Fuel Shield Lid, Structural Lid, and Temporary Shield On, Dry Cavity

Figure 5.4.1-20 Yankee-MPC Transfer Cask Radial Surface Dose Rate Comparison of Intact and Damaged Fuel under Dry Conditions

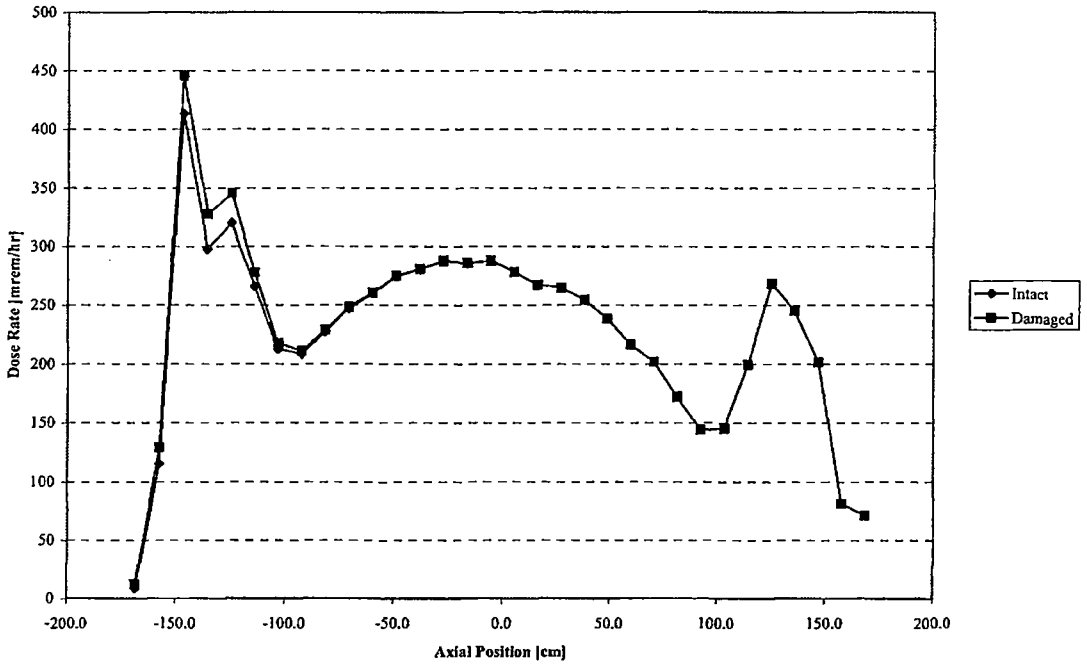


Figure 5.4.1-21 Yankee-MPC Transfer Cask Radial Surface Dose Rate Comparison of Intact and Damaged Fuel under Wet Conditions

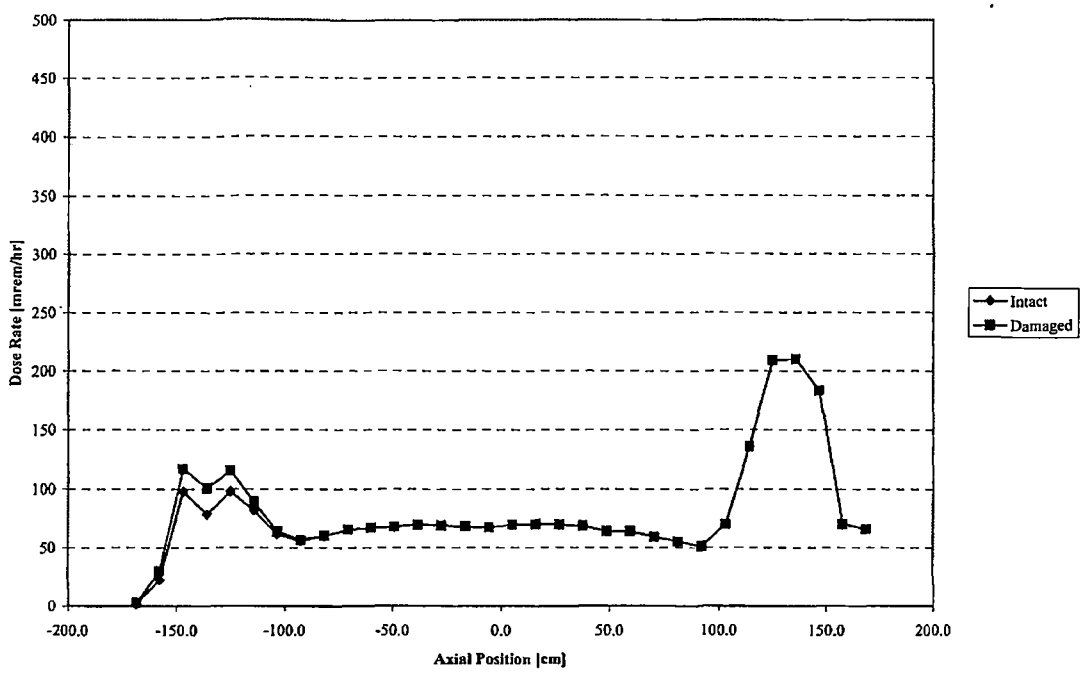


Table 5.4.1-1 ANSI Standard Neutron Flux-To-Dose Rate Factors

Group	(Rem/Hr)/(N/cm^2/Sec)
1	1.49160E-04
2	1.44640E-04
3	1.27010E-04
4	1.28110E-04
5	1.29770E-04
6	1.02810E-04
7	5.11830E-05
8	1.23189E-05
9	3.83650E-06
10	3.72469E-06
11	4.01500E-06
12	4.29259E-06
13	4.47439E-06
14	4.56760E-06
15	4.55809E-06
16	4.51850E-06
17	4.48790E-06
18	4.46649E-06
19	4.43450E-06
20	4.32709E-06
21	4.19750E-06
22	4.09759E-06
23	3.83900E-06
24	3.67480E-06
25	3.67480E-06
26	3.67480E-06
27	3.67480E-06

Table 5.4.1-2 ANSI Standard Gamma Flux-To-Dose Rate Factors

Group	(Rem/Hr)/(N/cm^2/Sec)
1	8.77160E-06
2	7.47849E-06
3	6.37479E-06
4	5.41360E-06
5	4.62209E-06
6	3.95960E-06
7	3.46860E-06
8	3.01920E-06
9	2.62759E-06
10	2.20510E-06
11	1.83260E-06
12	1.52280E-06
13	1.17250E-06
14	8.75940E-07
15	6.30610E-07
16	3.83380E-07
17	2.66930E-07
18	9.34720E-07

Table 5.4.1-3 Yankee-MPC Storage Cask One-Dimensional Projectile Accident Radial Dose Rates

Source	Surface (mrem/hr)	1 meter (mrem/hr)
Fuel Neutron	4.1	1.5
Fuel Gamma	306.0	136.0
Fuel N-Gamma	4.5	1.8
Total	315	139

Table 5.4.1-4 Yankee-MPC Shielded Source Strengths

Energy Group	Radial		Top Axial	
	Neutron [n/cm^2-sec]	Gamma [γ/cm^2-sec]	Neutron [n/cm^2/sec]	Gamma [γ/cm^2/sec]
1	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2.5268E-05	2.5983E-02	1.2783E-04	2.5933E-02
3	2.7705E-04	3.9198E-01	0.0000E+00	9.0691E-01
4	1.1249E-03	4.7461E+00	7.3289E-04	1.2192E+01
5	3.9129E-03	9.8062E+00	2.5605E-03	7.4486E+00
6	8.7000E-03	1.3791E+01	2.4885E-03	6.0701E+00
7	2.3879E-02	1.3859E+01	5.7983E-03	9.4972E+00
8	5.8428E-02	1.7074E+01	1.9028E-02	8.2025E+00
9	6.3752E-02	6.8938E+01	3.4308E-02	1.8064E+01
10	8.3143E-02	5.5855E+01	8.2955E-02	1.7030E+01
11	6.0677E-01	1.0837E+02	5.9184E-01	2.1923E+01
12	7.0152E-01	9.2009E+02	8.5406E+00	7.9339E+02
13	4.8958E-01	1.3893E+03	1.1656E+01	1.1981E+03
14	1.7963E+00	1.8432E+03	6.7402E+01	1.4050E+03
15	6.0393E-01	2.8554E+03	1.8354E+01	1.9887E+03
16	8.7709E-01	4.5308E+03	2.1042E+01	2.7634E+03
17	1.1112E+00	4.7071E+03	3.3713E+01	1.8660E+03
18	7.7665E-01	3.3158E+03	1.0823E+01	2.1494E+03
19	7.9137E-01	5.0082E+03	1.1769E+01	2.8596E+03
20	6.8111E-01	2.8484E+03	8.1445E+00	1.4007E+03
21	5.5738E-01	9.2449E+01	5.6148E+00	2.7050E+01
22	7.8014E-01	3.1811E+00	8.8005E+00	4.0151E-02
23	6.2232E-01	-	7.6159E+00	-
24	9.3380E-01	-	7.9751E+00	-
25	5.6667E-01	-	4.6169E+00	-
26	5.8562E-01	-	3.7205E+00	-
27	1.1425E+01	-	6.1280E+00	-
28	2.5510E+01	-	5.7576E+00	-
Total	4.9660E+01	2.7807E+04	2.4241E+02	1.6553E+04

Table 5.4.1-5 Yankee-MPC Shielded Neutron Total SKYSHINE-III Source Strengths Flux

Surface Source	Neutron [n/sec]	Gamma [γ/sec]
Radial[1]	2.092E+07	1.171E+10
Top Axial[2]	2.012E+07	1.374E+09

1. Total radial source is total flux multiplied by radial surface area of 4.213E+5 cm^2.
2. Total axial source is total flux multiplied by axial surface area of 8.302E+4 cm^2.

Table 5.4.1-6 Minimum Cool Time Determination Based on Storage Cask One-Dimensional Dose Rates

Source Spectrum	CE 36 GWD/MTU 8 Years	CE 32 GWD/MTU 8 Years	Exxon (Zr Hw) 36 GWD/MTU 10 Years	Exxon (SS Hw) 36 GWD/MTU 16 Years	UN 32 GWD/MTU 13 Years	Westinghouse 32 GWD/MTU 24 Years
Neutron	2.2	1.5	2.3	1.8	1.0	0.6
Gamma	37.3	31.8	28.3	17.0	17.9	10.0
Hardware	0.0	0.0	5.9	18.9	18.9	26.9
Total	39.5	33.3	36.5	37.7	37.8	37.4

5.4.2 Connecticut Yankee Fuel Shielding Evaluation

Shielding calculations are performed for the transfer cask and storage cask designs using the source terms from the two design basis fuel types described in Section 5.2.2: Stainless steel clad fuel at 38,000 MWD/MTU and a 5-year cool time, and Zircaloy clad fuel at 43,000 MWd/MTU and a 5-year cool time. The resulting dose rate profiles are reported as a function of distance from the radial and axial surfaces of the CY-MPC storage cask and transfer cask.

5.4.2.1 CY-MPC Calculational Methods

The shielding evaluations of the transfer and storage casks are performed with MCBEND version 9D. Source terms include fuel neutron, fuel gamma, and gamma contributions from activated hardware. As described in Section 5.2.2, these evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

The MCBEND shielding models described in Section 5.3.2 are utilized with the source terms described in Section 5.2.2 to estimate the dose rate profiles along the surfaces of the transfer and storage casks, and to estimate doses in and around streaming paths such as the storage cask inlets and outlets, and the canister vent and drain ports. The method of solution is continuous energy Monte Carlo with an adjoint diffusion solution for generating importance meshes. Radial biasing is performed within the MCBEND code to estimate dose rates on the sides of the transfer cask and storage cask, and axial biasing is performed to estimate dose rates on the top surfaces of the casks.

5.4.2.2 MCBEND Flux-to-Dose Rate Conversion Factors

The ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors are used in all CY-MPC shielding evaluations. Tables 5.4.2-1 and 5.4.2-2 show the regrouped flux-to-dose conversion factors on the MCBEND standard 28 group neutron and 22 group gamma energy boundaries

5.4.2.3 CY-MPC Storage Cask Three-Dimensional Dose Rates

For the design basis 5-year cooled stainless steel clad fuel, the CY-MPC storage cask side three-dimensional model dose rates are presented in Figure 5.4.2–1. The figure shows the dose profile

at various radial distances from the cask surface. Figure 5.4.2–2 shows the contributions to the surface dose rate from each source component. Maximum dose rates are summarized in Table 5.4.2–3, while average dose rates are summarized in Table 5.4.2-12. The maximum radial surface dose rate for the storage cask is 167 (1.7%) mrem/hr. At the inlet locations, the average dose rate of the four symmetric inlet openings is 85 (3.2%) mrem/hr. At the outlets, the average dose rate at the four symmetric outlet locations is 60 (1.5%) mrem/hr.

Figure 5.4.2–3 shows the corresponding top axial dose profile at various axial distances from the cask surface for stainless steel clad fuel, and Figure 5.4.2–4 gives the contributions to the surface dose rate from each source type. The azimuthal dose profile at the air inlet elevation is shown in Figure 5.4.2–5. Similarly, the azimuthal dose rate profile at the cask air outlets is shown in Figure 5.4.2–6.

Similar results are presented for the design basis Zircaloy clad fuel in Figures 5.4.2–7 through 5.4.2–12. The maximum radial surface dose rate for Zircaloy clad fuel is 140 (1.0%) mrem/hr. The maximum top axial surface dose rate is 36 (0.7%) mrem/hr. The dose rate average over the four air inlets is 83 (4.0%) mrem/hr. At the air outlets, the average dose rate at the four symmetric outlet locations is 66 (1.5%). Maximum and average dose rates are summarized in Tables 5.4.2–4 and 5.4.2-13, respectively.

Note that the stainless steel clad fuel bounds the radial and the inlet results, while the Zircaloy clad fuel results bound the top axial and air outlet dose rate results.

Two dose rate peaks are observed on the storage cask top surface: one in the vicinity of 90 to 100 cm, which corresponds to the location of the annular gap between the canister and the storage cask liner, and another at approximately 130 cm. The peak dose rate above the annular gap is caused by neutrons streaming up the gap. The second peak is created by gammas from the end fitting, top fuel, and top plenum source regions. This peak occurs at approximately the same radial location as the vertical leg in the upper outlet. Thus, it is a result of a decrease in effective shield thickness caused by the void in the concrete due to the outlets.

Additional dose rates due to inclusion of up to eight activated flow mixers inserted into the top nozzles of fuel assemblies in the centermost basket locations (positions 7, 8, 12, 13, 14, 15, 19 and 20) is small. The radial surface dose rate contribution from the flow mixers is a maximum of 3.0 (0.2%) mrem/hr and the maximum top surface dose rate increase is 1.3 (0.7%) mrem/hr, as

shown in Figures 5.4.2–13 and 5.4.2–14, respectively. The small dose rate increase is due to the effective self-shielding of the material by the surrounding fuel assemblies and the limited radial extent of the material with respect to the canister lids. The dose rate contribution at the outlets due to the flow mixer source term is 2.5 (1.5%) mrem/hr. Figure 5.4.2–15 shows an azimuthal plot of the dose rate at the air outlet vent elevations due to the eight flow mixer source term.

The dose rate contributions from the activated Reactor Control Cluster Assemblies (RCCAs) are small compared to those from the fuel sources. A full complement of 26 RCCAs cooled a minimum of 5 years leads to an additional maximum radial surface dose rate of 35 (0.4%) mrem/hr at an axial position adjacent to the bottom of the fuel. The contribution of the RCCAs to the dose rate at the axial position adjacent to the fuel midplane is less than 1 mrem/hr, as shown in Figure 5.4.2-16. Hence, no significant increase in cask radial maximum dose rate occurs from the cluster assemblies. Since the activated portion of the RCCA resides in the bottom of the fuel, no significant increase in top axial dose rates is observed. In addition, placement of the RCCAs increases the dose rate at the cask inlets by 18.4 (7.5%) mrem/hr. An azimuthal plot of the total dose rate due to the RCCA source at the air inlet elevation is shown in Figure 5.4.2–17. Hence, for the stainless steel fuel at the design basis conditions of 38,000 MWD/MTU burnup and 5 years cooling, with a full complement of 26 five-year cooled RCCAs, the maximum inlet dose rate is no greater than 105 mrem/hr. Maximum and average dose rates from activated non-fuel material are summarized in Tables 5.4.2–5 and 5.4.2-14, respectively.

To ensure that the worst case configuration is considered, two damaged fuel configurations are evaluated. The first assumes the damaged fuel collects over the active fuel length of the fuel assembly. For conservatism, this configuration is modeled by doubling the UO_2 density and doubling the source strength for the fuel neutron, gamma, and n-gamma sources produced by 204 fuel rods. A comparison of dose rate profiles for the 26-assembly results and 22-assembly with 4 damaged fuel cans results shows that the top axial dose rates slightly increase (<5 mrem/hr for the maximum and <1 mrem/hr for the average), while the radial dose rates are essentially identical. The inlet and outlet dose rates are slightly less. In the second case, damaged fuel is assumed to migrate from the active fuel into the lower hardware region of the fuel assembly, filling all the modeled void space. In this case, the combined gamma and neutron sources result in a maximum radial dose rate increase less than 4.5 mrem/hr (average increase <1 mrem/hr). The inlet dose rate increase is less than 14 mrem/hr. Conservatively, no credit is taken for the reduction in lower nozzle hardware dose rate due to the added UO_2 mass and self-shielding. These cases bound the worst case configuration of the damaged fuel can containing a complete

fuel assembly, lattice, or failed rod storage canister because the source material densities and source strengths are increased without increasing the density of the lattice hardware or consideration of the shielding provided by the failed rod storage canister.

5.4.2.4 CY-MPC Transfer Cask Three-Dimensional Dose Rates

The CY–MPC transfer cask is analyzed for various lid configurations and under wet and dry conditions corresponding to the operational configurations associated with loading the canister with spent fuel assemblies in a fuel pool environment. Under wet conditions, the canister is assumed to be filled with water to an axial elevation 3.05 inches (7.76 cm) below the base of the shield lid. This distance accounts for the removal of water from the canister prior to welding the shield lid to the canister in order to prevent water contamination of the shield lid weld.

Some lid configuration scenarios include a model of a temporary weld shield to be installed during lid welding operations. This weld shield is modeled as a truncated cone 5 inches thick with a bottom radius of 32.695 inches (two inches less than the canister inner radius). The sides of the weld shield are sloped at a 45-degree angle, and two 6-inch diameter holes are cut through the shield at positions centered over the canister vent and drain ports in order to allow access to the ports. This model of the weld shield represents the minimum required shielding for canister lid welding operations. In practice, the weld shield will be supplemented with additional temporary shielding, although no credit is taken for additional shielding here.

Top axial dose rates are calculated for two lid configurations. The first configuration consists of the shield lid and weld shield (referred to as model "Shw"). This case is analyzed with the canister in the wet condition, and no covers over the vent and drain ports are present. The second configuration consists of the shield lid, structural lid, and weld shield. The canister is modeled in the dry condition and port covers are assumed to be installed. This model is referred to as "Stw." Additionally, radial dose rates are presented for a third configuration. This configuration is referred to as "Stl," and consists of the transfer cask with a dry canister, after completion of all welding activities on the shield and structural lids.

For the shield lid welding configuration, including a wet canister cavity, shield lid and weld shield (model Shw), the top axial surface dose rate profiles are shown in Figures 5.4.2–18 and 5.4.2-19 for the design basis stainless steel and Zircaloy clad fuels, respectively. As shown in the figures, a localized peak appears in the annular region between the weld shield and canister inner

wall, with the Zircaloy clad fuel source term producing the highest peak dose rate. Figure 5.4.2-20 shows the surface dose rate profile by source component for the design basis Zircaloy clad fuel. For the wet cavity configurations, the primary contributor to dose rate is the activated hardware component. The radial surface dose rate profiles are shown in Figures 5.4.2–21 and 5.4.2–22 for the design basis stainless steel and Zircaloy clad fuels, respectively. While the dose rate results are nearly equal for the two design basis fuels, the Zircaloy clad fuel source term produces slightly higher results. The component dose rates produced by the design basis stainless steel clad fuel are shown in Figure 5.4.2–23 for the radial surface dose rate response. The maximum dose rate results for the Shw model are summarized in Tables 5.4.2–6 and 5.4.2-7 for the design basis stainless steel and Zircaloy clad fuels, respectively.

For the structural lid welding configuration, including a dry canister cavity, shield lid, structural lid and weld shield (model Stw) the top axial dose rate profiles are shown in Figures 5.4.2–24 and 5.4.2-25 for the design basis stainless steel and Zircaloy clad fuels, respectively. A peak similar to that observed in the Shw model results is evident at the canister inner wall, although the peak dose rate is reduced by the additional attenuation provided by the structural lid. The maximum dose rate results for the Stw model are summarized in Tables 5.4.2–8 and 5.4.2-9 for the design basis stainless steel and Zircaloy clad fuels, respectively.

Radial dose rate results for the transfer cask, after completion of welding operations (model Stl), are presented in Figures 5.4.2–26 and 5.4.2-27 for the design basis stainless steel and Zircaloy clad fuels, respectively. These values are higher than those reported for the shield lid welding operations (model Shw) because the water has been removed from the canister cavity. While the dose rate results are nearly equal for the two design basis fuels, the stainless steel clad fuel source term produces slightly higher results. A breakdown of the radial surface dose rate profile by source component for the stainless steel clad fuel is shown in Figure 5.4.2–28. Summaries of the maximum radial dose rate results for the Stl model are presented in Tables 5.4.2–10 and 5.4.2-11.

Summaries of the detector average dose rate results for each of the three model configurations are shown in Tables 5.4.2–15 and 5.4.2-16 for the design basis stainless steel and Zircaloy clad fuels, respectively.

The dose rate profiles produced by the Reactor Control Cluster Assembly and Flow Mixer source terms are presented in Figures 5.4.2-29 through 5.4.2-32.

Figure 5.4.2–1 CY–MPC Storage Cask Radial Dose Rate Profile at Various Radial Positions – Azimuthal Average – Design Basis Stainless Steel Clad Fuel

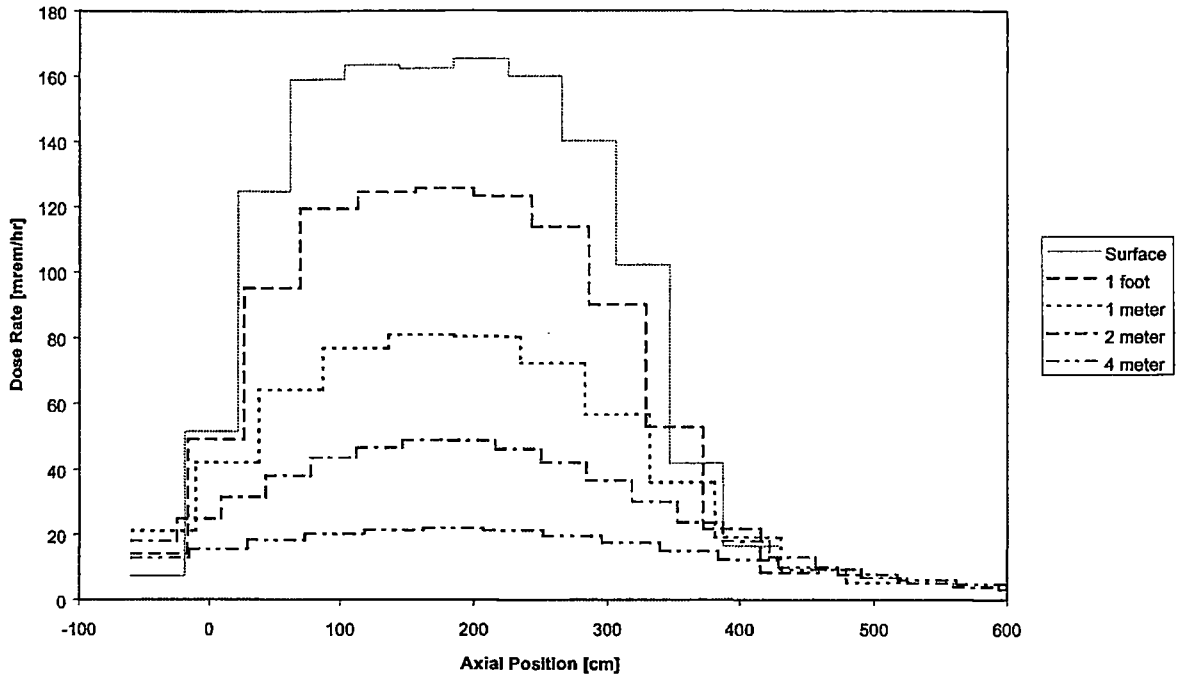


Figure 5.4.2–2 CY–MPC Storage Cask Radial Surface Dose Rate Profile by Source Component – Azimuthal Average – Design Basis Stainless Steel Clad Fuel

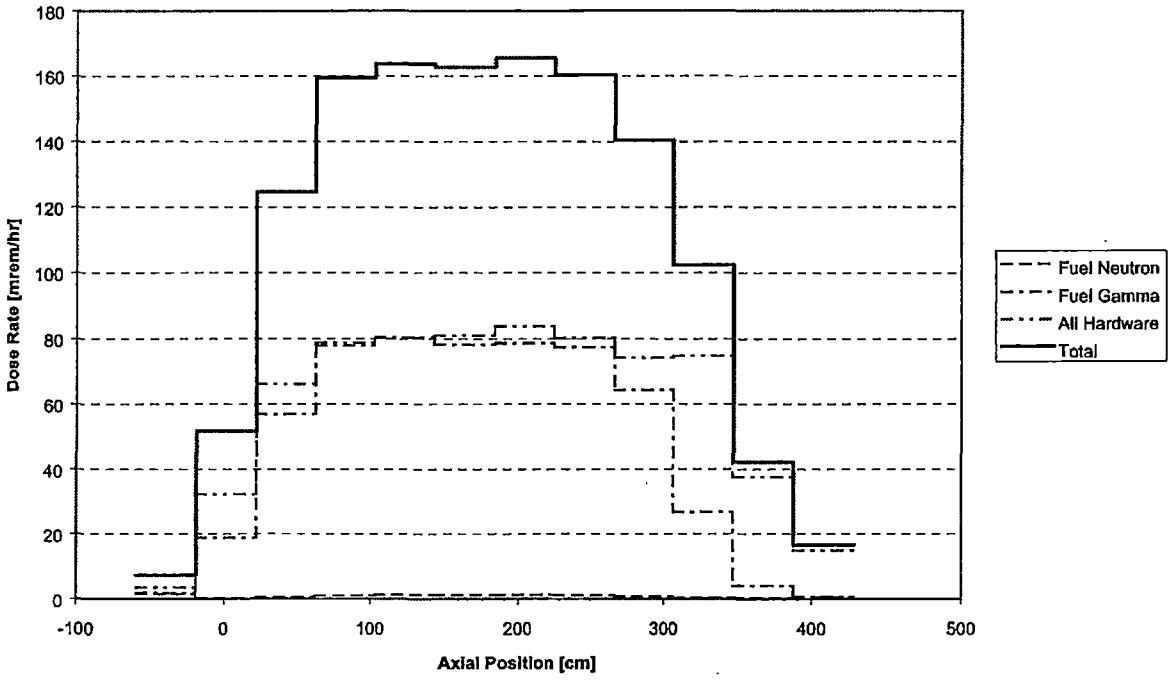


Figure 5.4.2–3 CY–MPC Storage Cask Top Axial Dose Rate Radial Profile at Various Axial Positions– Azimuthal Average – Design Basis Stainless Steel Clad Fuel

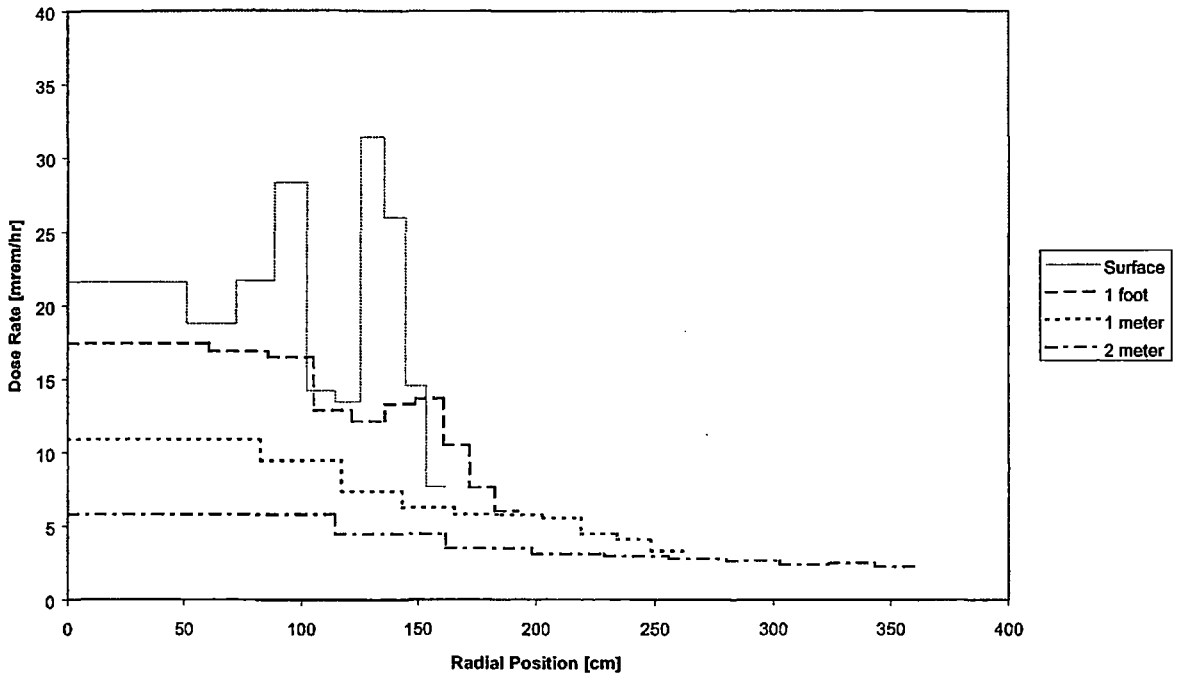


Figure 5.4.2–4 CY–MPC Storage Cask Top Axial Dose Rate Radial Profile by Source Component – Azimuthal Average – Design Basis Stainless Steel Clad Fuel

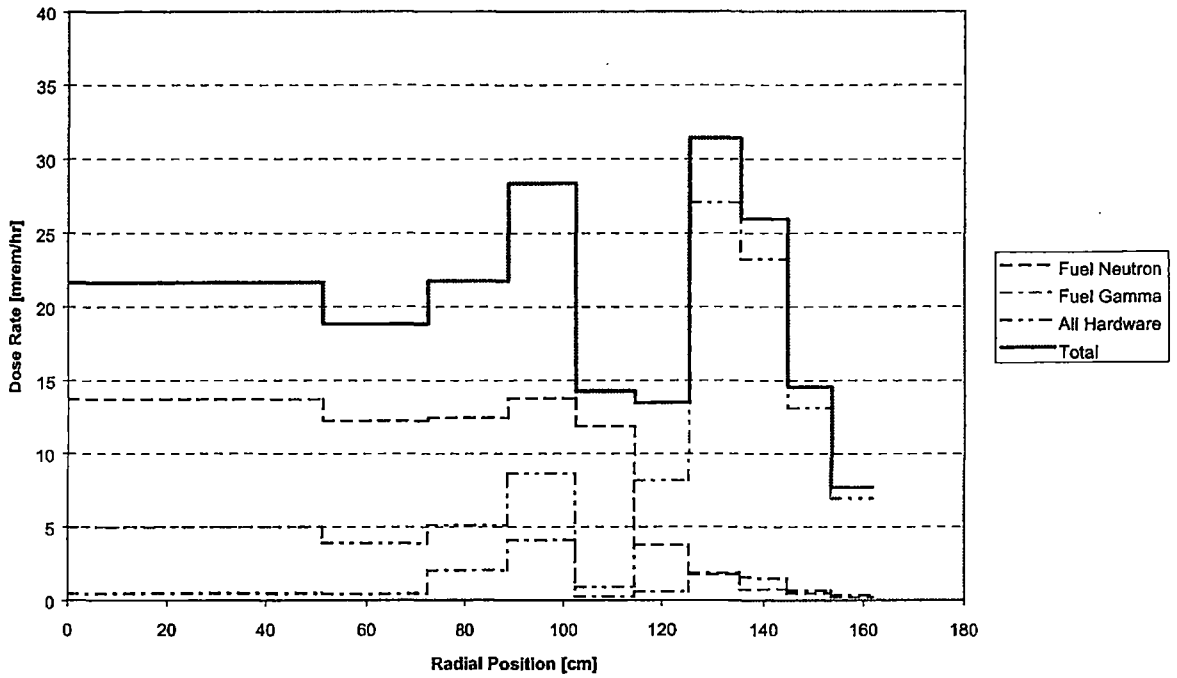


Figure 5.4.2–5 CY–MPC Storage Cask Azimuthal Dose Rate Profile at Air Inlet Elevation – Design Basis Stainless Steel Clad Fuel

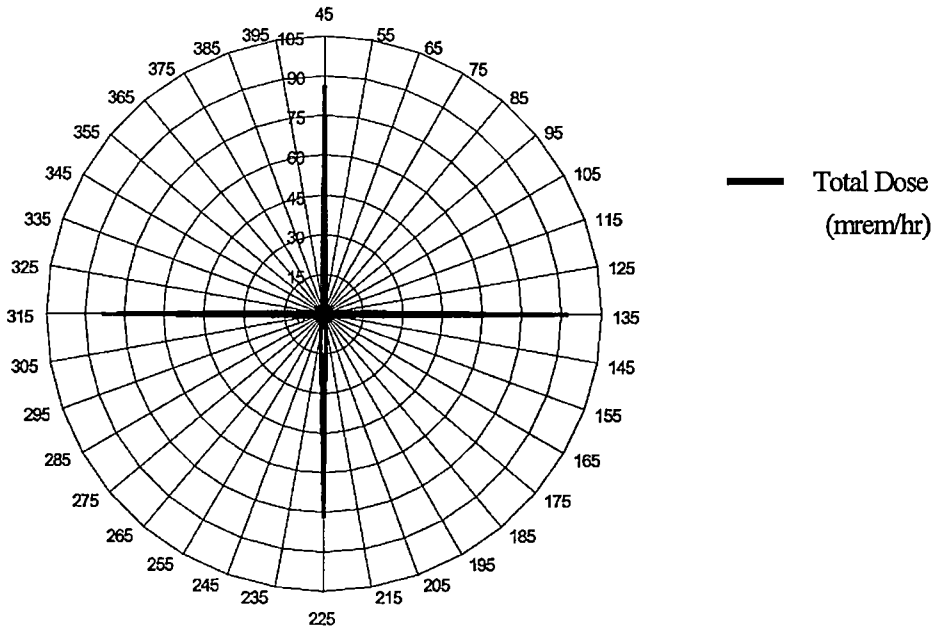


Figure 5.4.2–6 CY–MPC Storage Cask Azimuthal Dose Rate Profile at Air Outlet Elevation – Design Basis Stainless Steel Clad Fuel

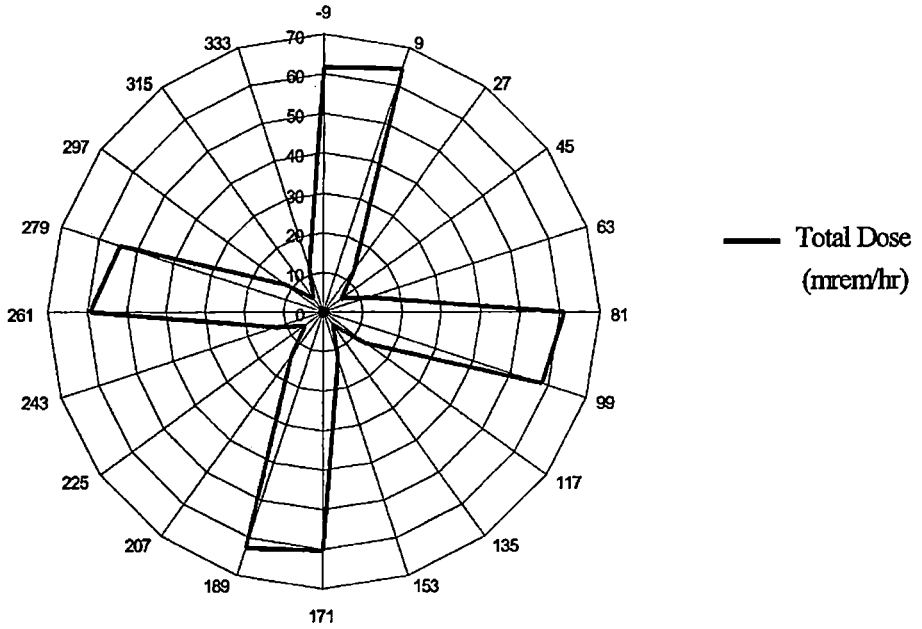


Figure 5.4.2–7 CY–MPC Storage Cask Radial Dose Rate Profile at Various Radial Positions – Azimuthal Average – Design Basis Zircaloy Clad Fuel

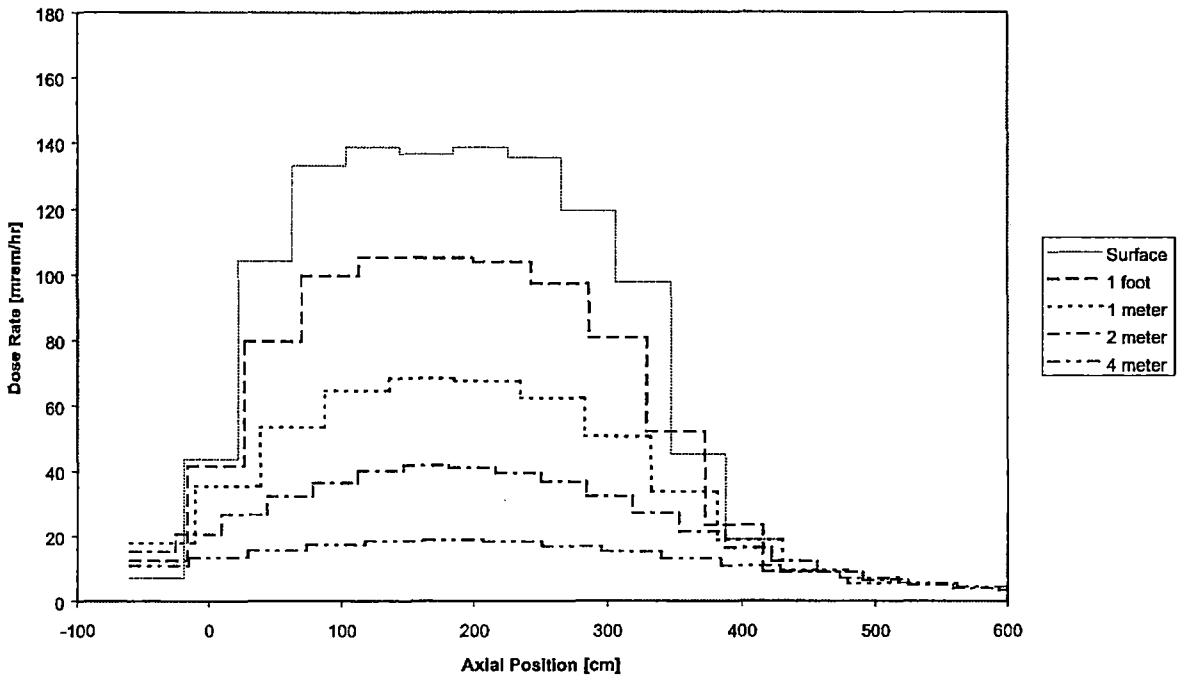


Figure 5.4.2–8 CY–MPC Storage Cask Radial Surface Dose Rate Profile by Source Component – Azimuthal Average – Design Basis Zircaloy Clad Fuel

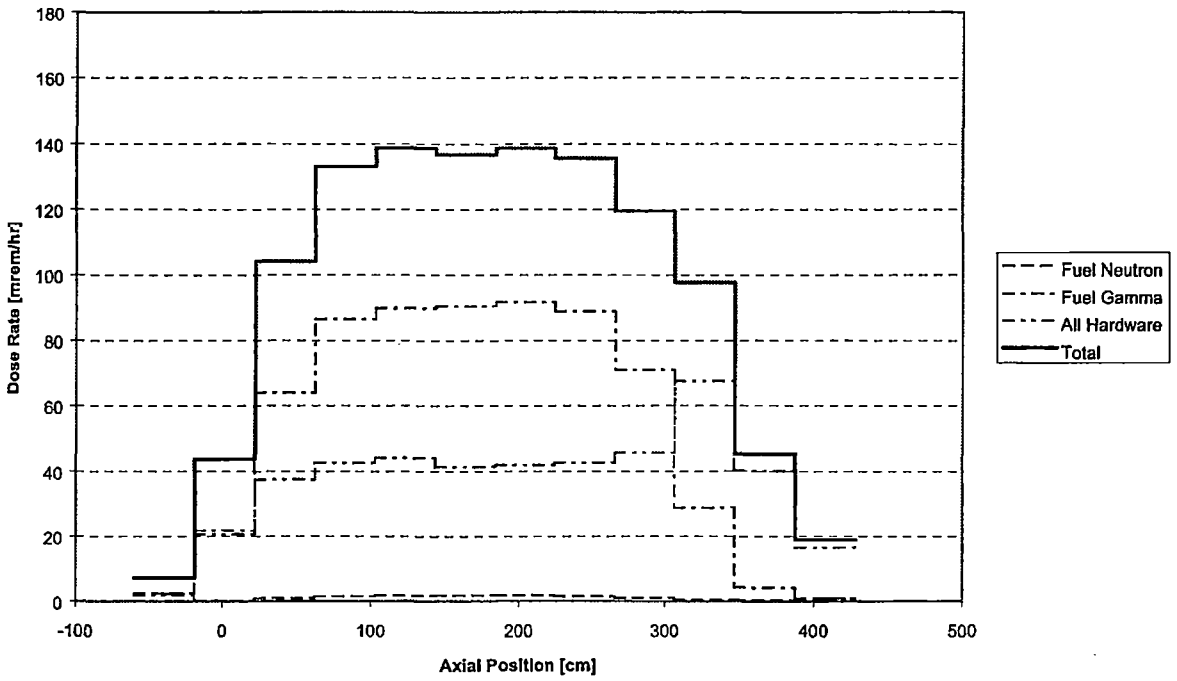


Figure 5.4.2–9 CY–MPC Storage Cask Top Axial Dose Rate Radial Profile at Various Axial Positions – Azimuthal Average – Design Basis Zircaloy Clad Fuel

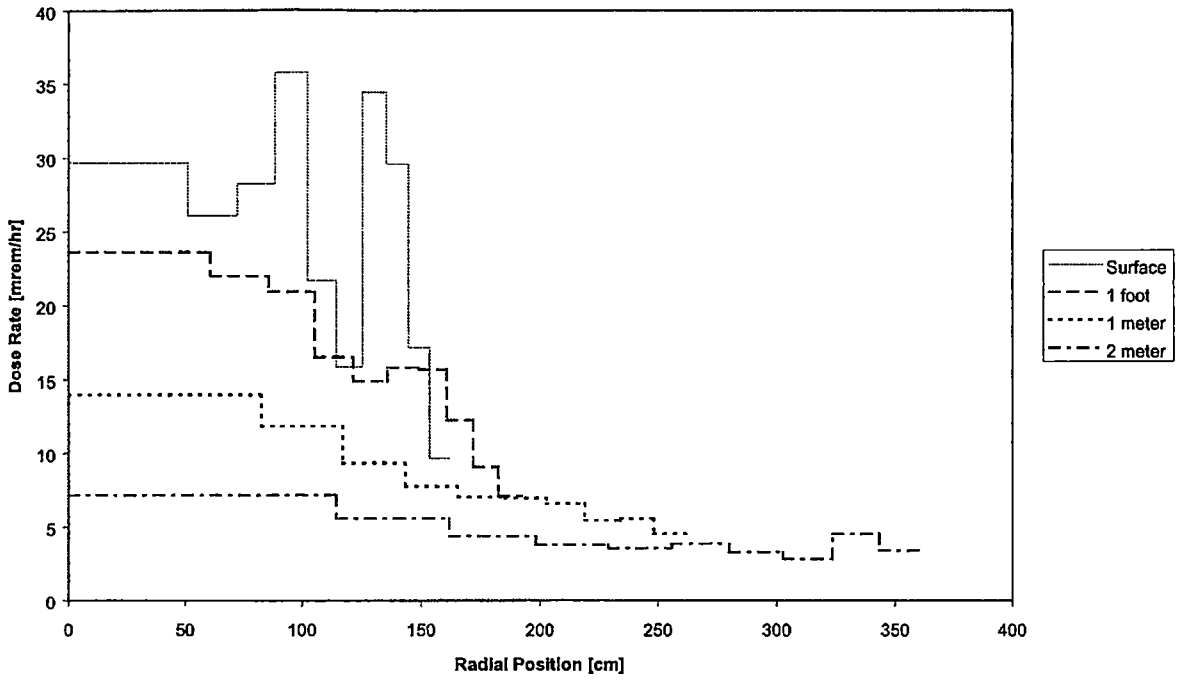


Figure 5.4.2–10 CY–MPC Storage Cask Top Axial Surface Dose Rate Radial Profile by Source Component – Azimuthal Average – Design Basis Zircaloy Clad Fuel

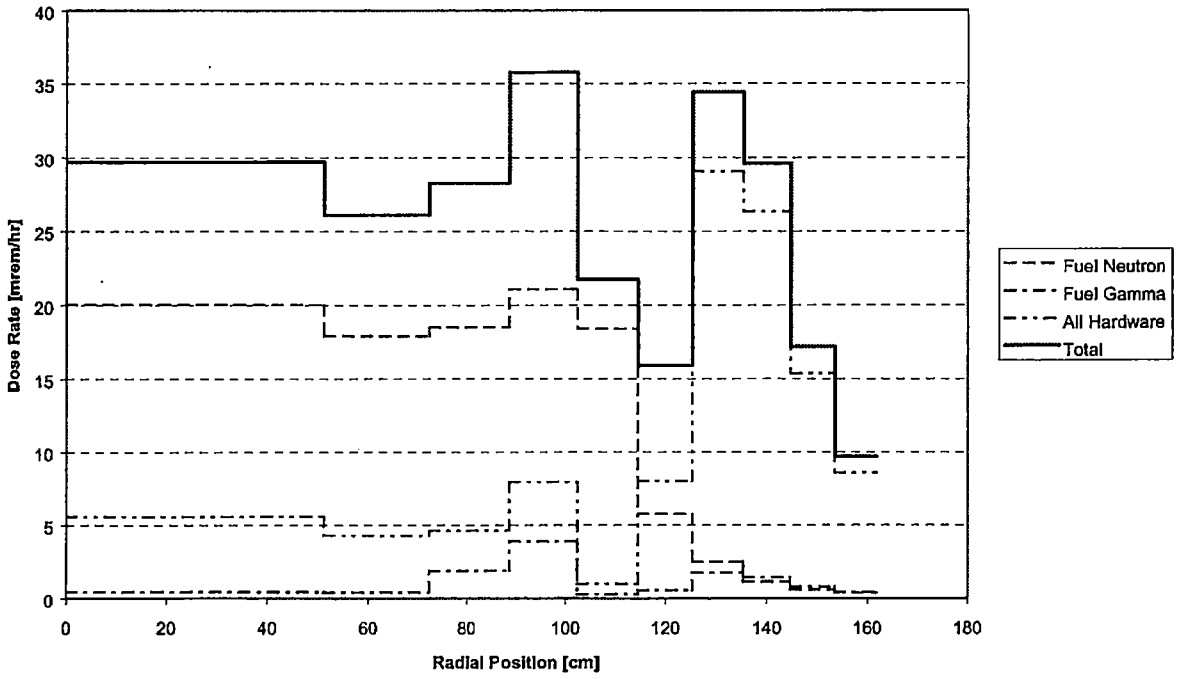


Figure 5.4.2–11 CY–MPC Storage Cask Azimuthal Dose Rate Profile at Air Inlet Elevation – Design Basis Zircaloy Clad Fuel

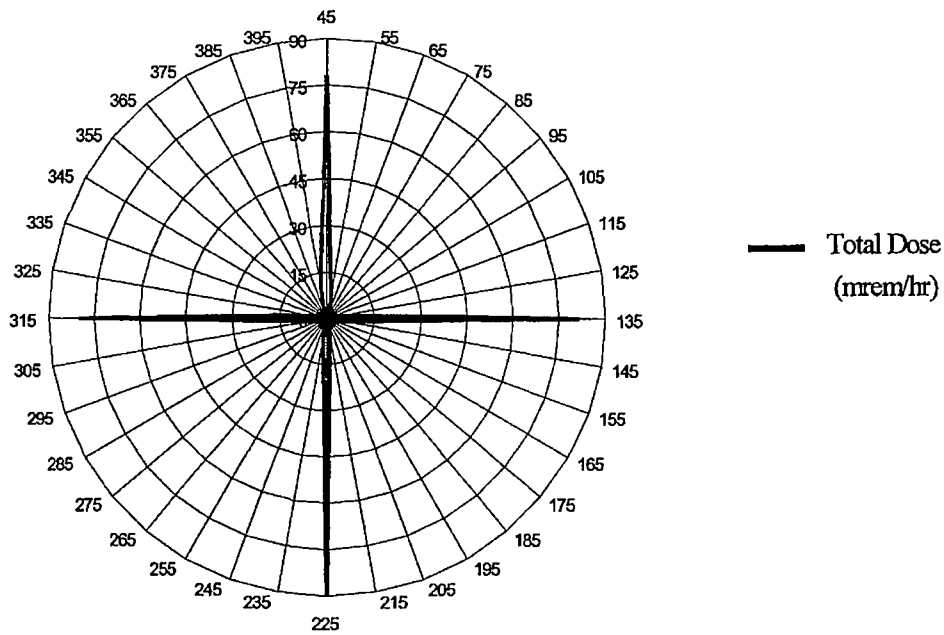


Figure 5.4.2–12 CY–MPC Storage Cask Azimuthal Dose Rate Profile at Air Outlet Elevation – Design Basis Zircaloy Clad Fuel

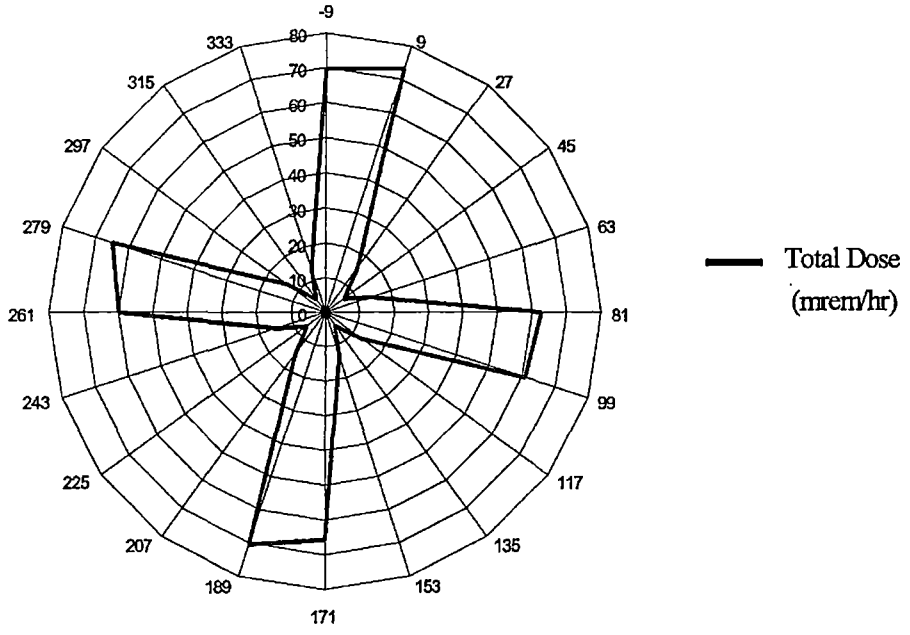


Figure 5.4.2–13 CY–MPC Storage Cask Radial Dose Rate Profile at Various Radial Positions – Azimuthal Average – 8 Flow Mixer Source

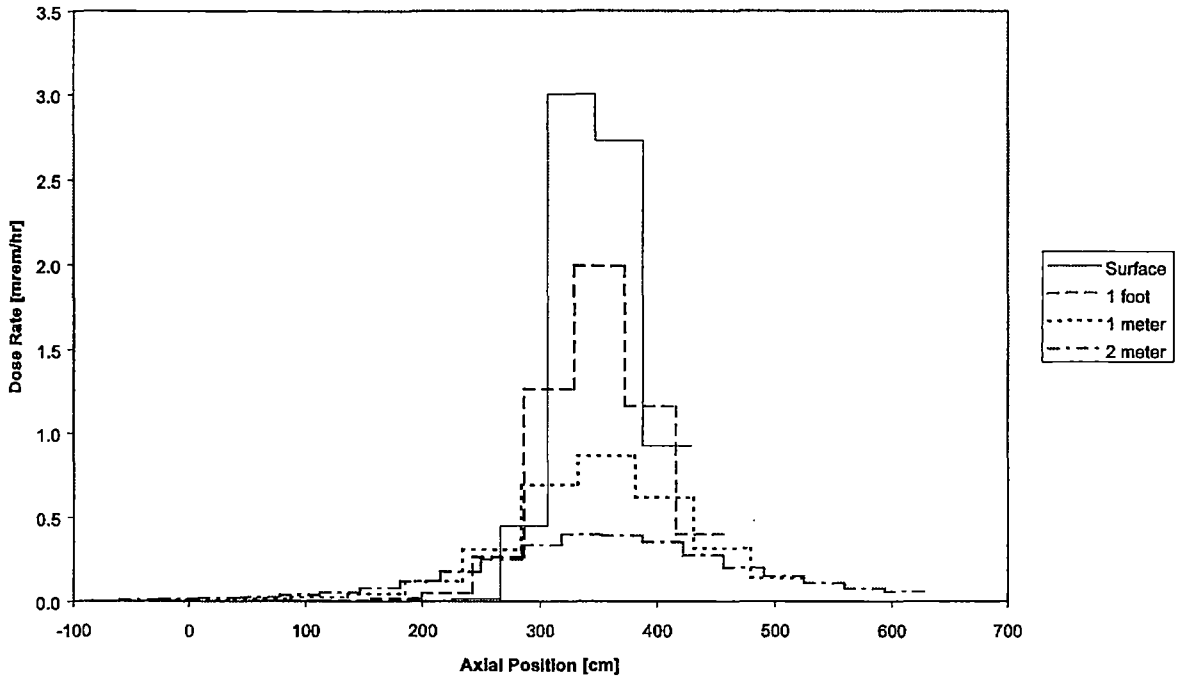


Figure 5.4.2–14 CY–MPC Storage Cask Top Axial Dose Rate Profile at Various Axial Positions – Azimuthal Average – 8 Flow Mixer Source

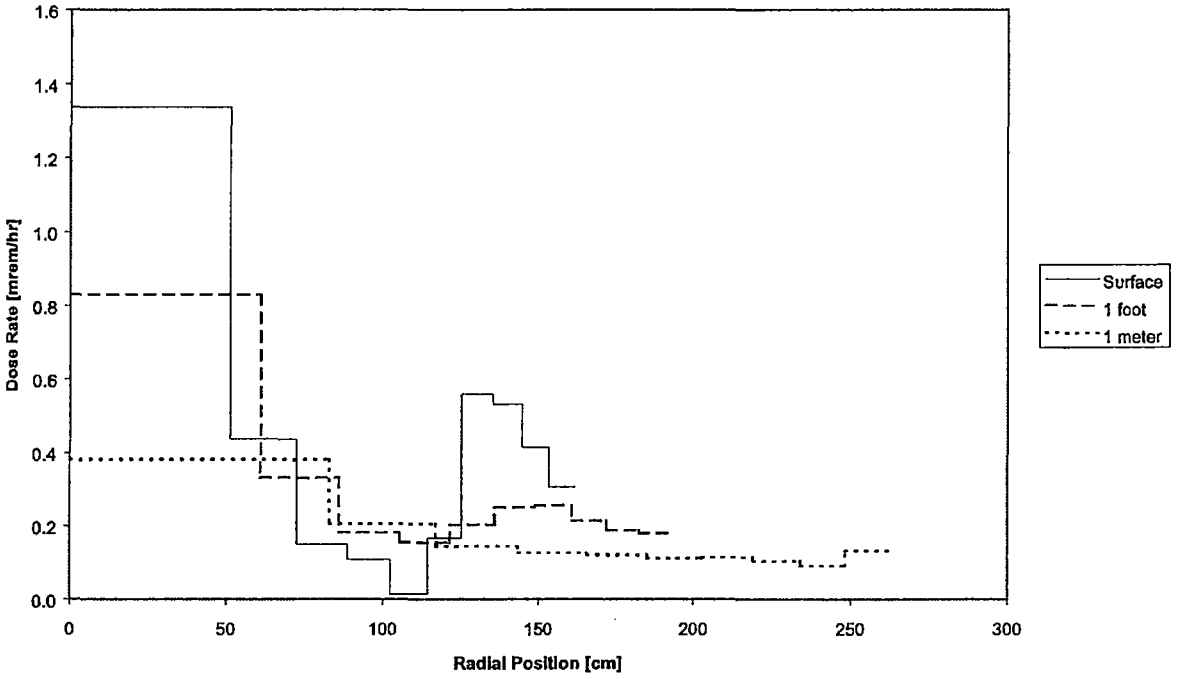


Figure 5.4.2–15 CY–MPC Storage Cask Radial Dose Rate Profile at Air Outlet Elevation – 8 Flow Mixer Source

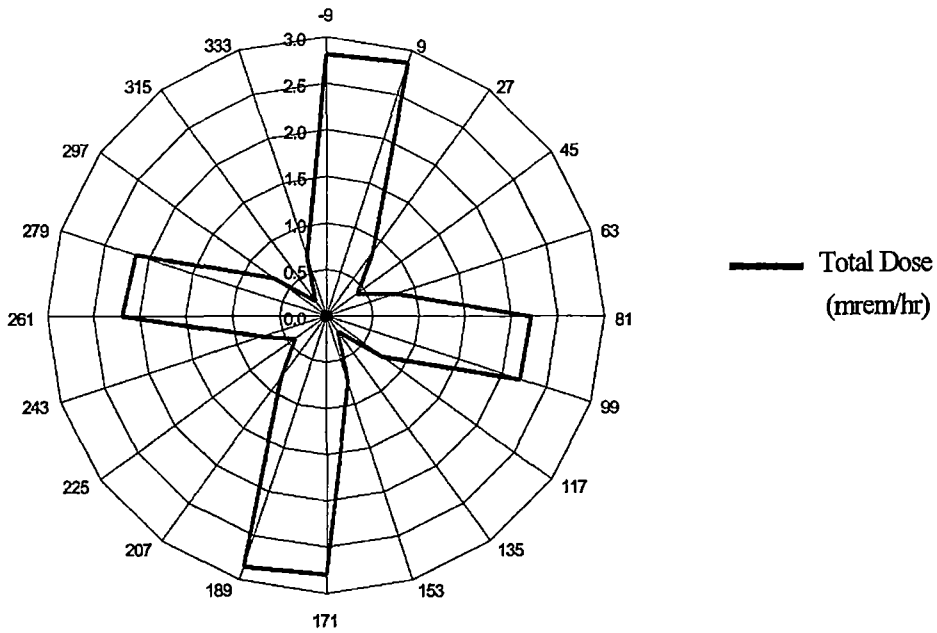


Figure 5.4.2–16 CY–MPC Storage Cask Radial Dose Rate Profile at Various Radial Positions – Azimuthal Average – Design Basis RCCA Source

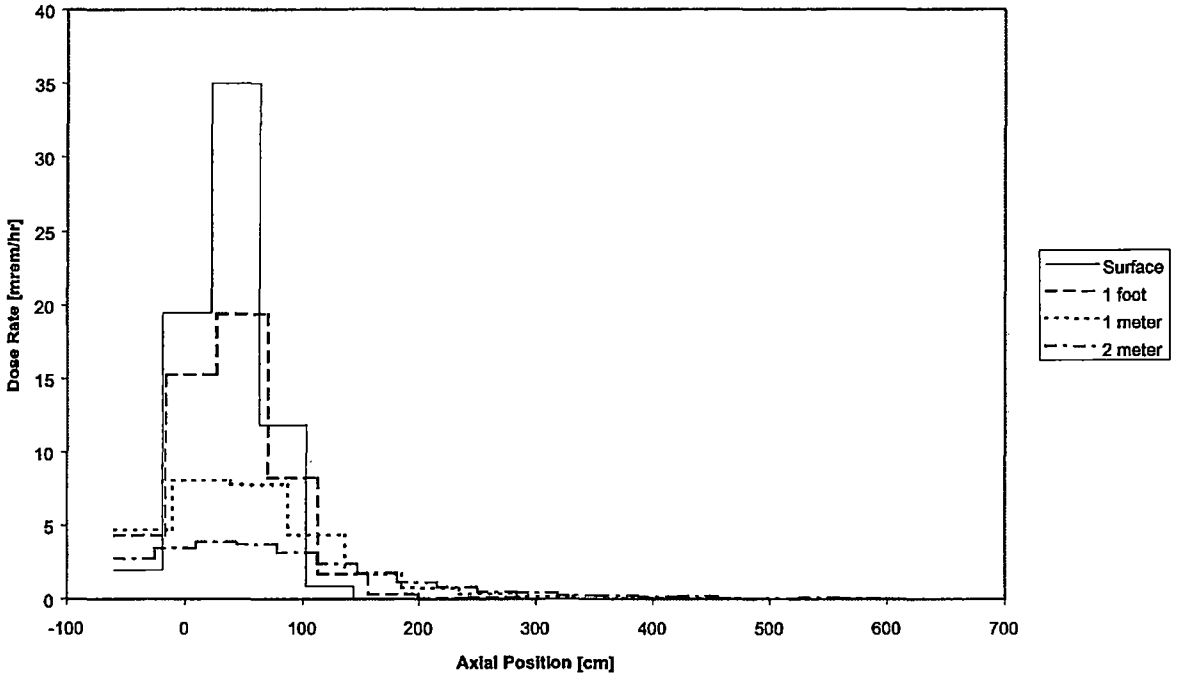


Figure 5.4.2–17 CY–MPC Storage Cask Azimuthal Dose Rate Profile at Air Inlet Elevation – Design Basis RCCA Source

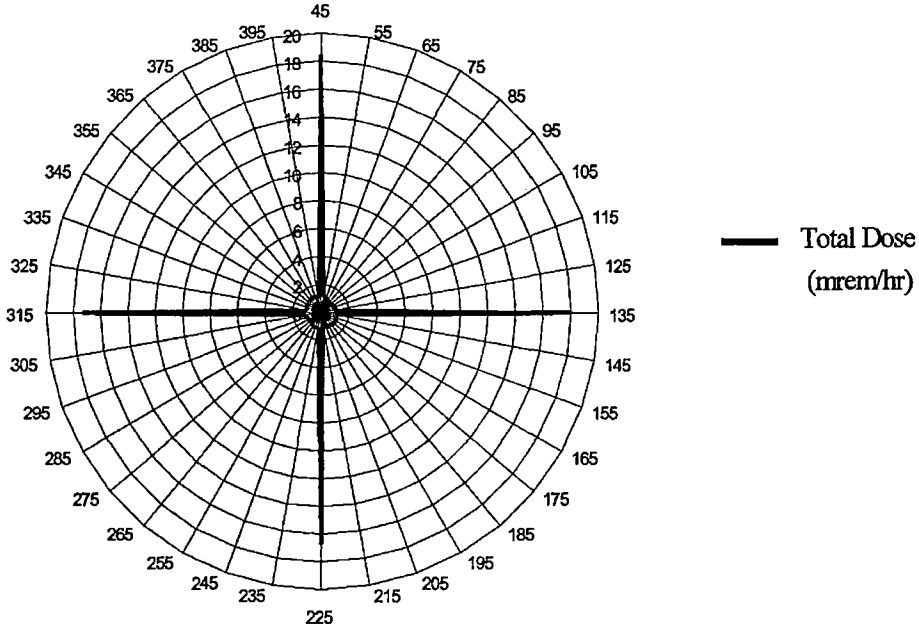


Figure 5.4.2–18 CY-MPC Transfer Cask Top Axial Surface Dose Rate Profile – Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Stainless Steel Clad Fuel

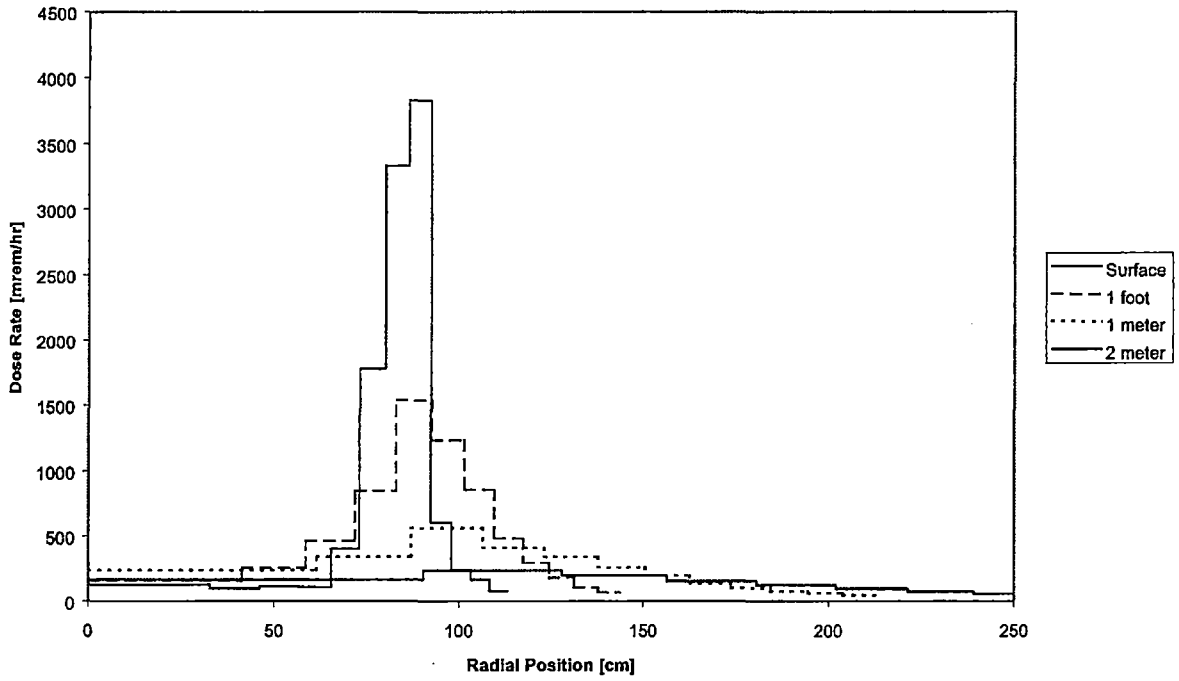


Figure 5.4.2–19 CY-MPC Transfer Cask Top Axial Dose Rate Profile – Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Zircaloy Clad Fuel

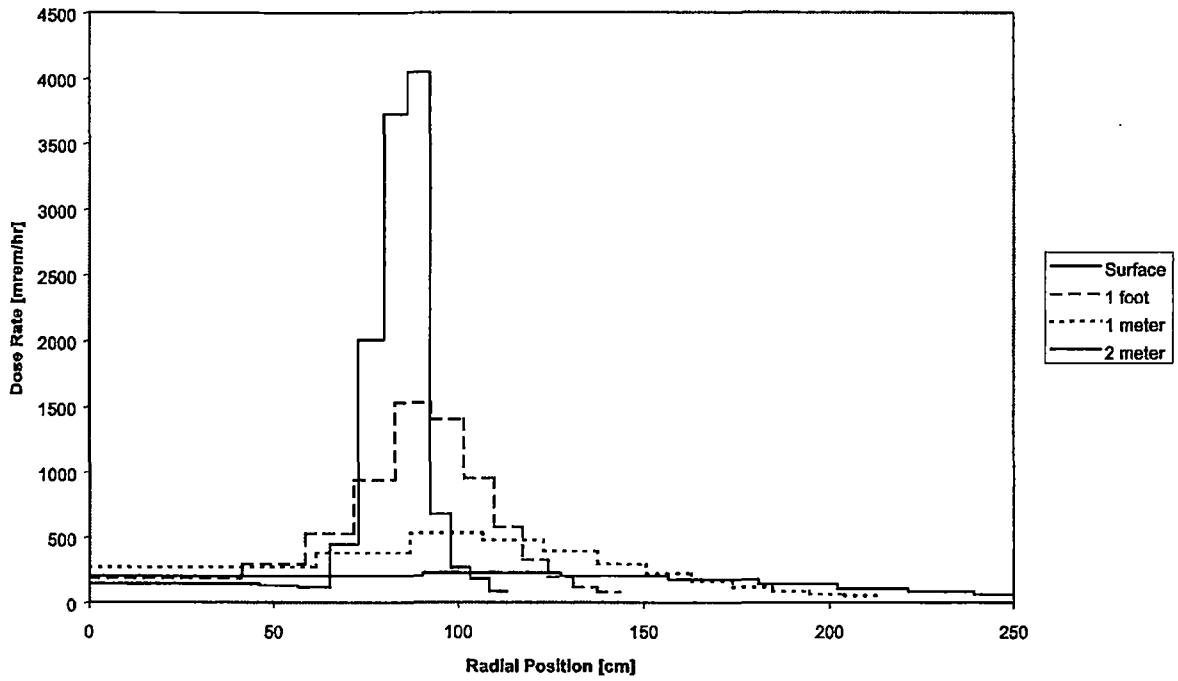


Figure 5.4.2–20 CY-MPC Transfer Cask Top Axial Surface Dose Rate Profile by Source Type – Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Zircaloy Clad Fuel

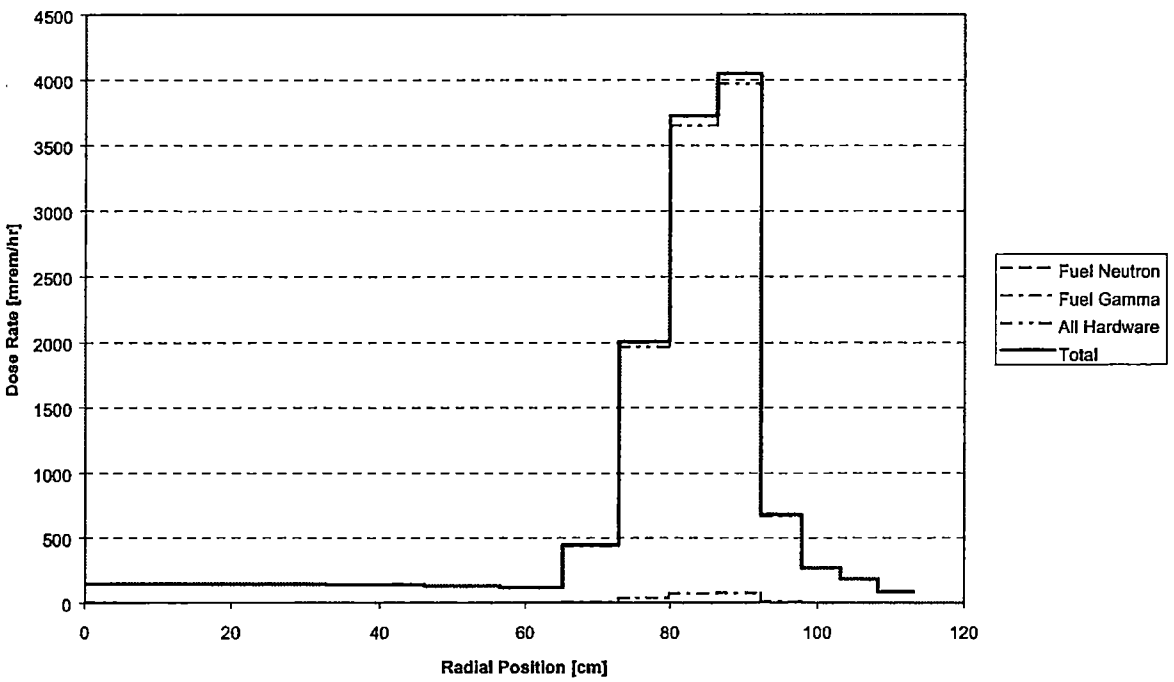


Figure 5.4.2–21 CY-MPC Transfer Cask Radial Surface Dose Rate Profiles – Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Stainless Steel Clad Fuel

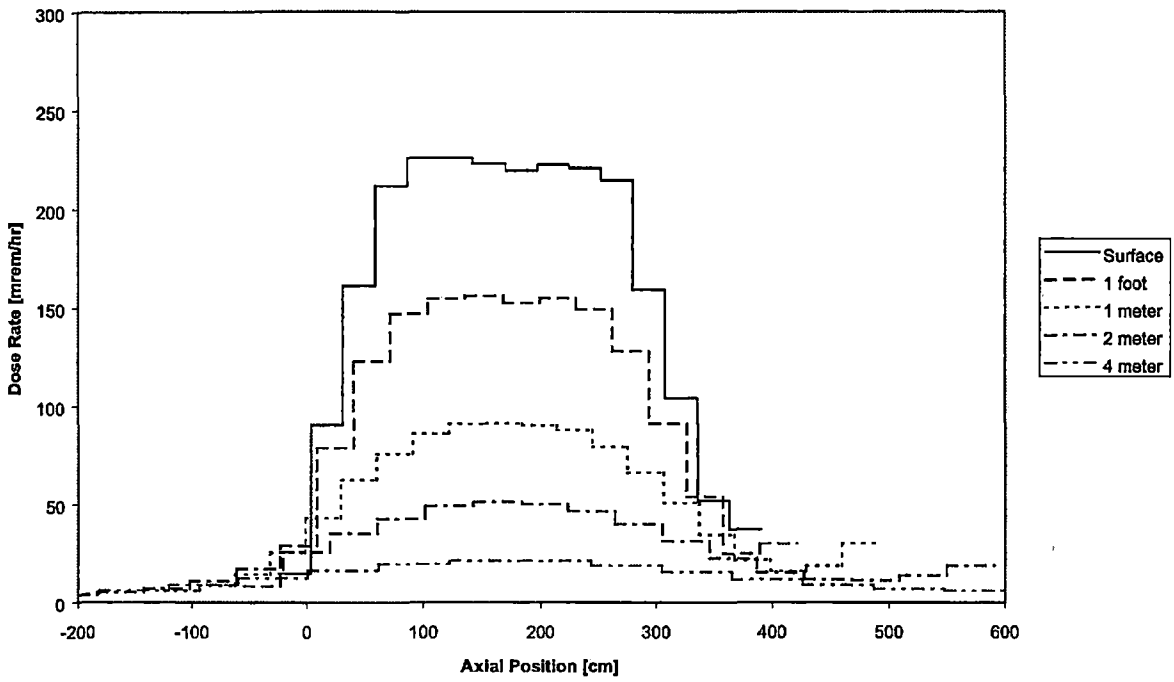


Figure 5.4.2–22 CY-MPC Transfer Cask Radial Surface Dose Rate Profiles – Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Zircaloy Clad Fuel

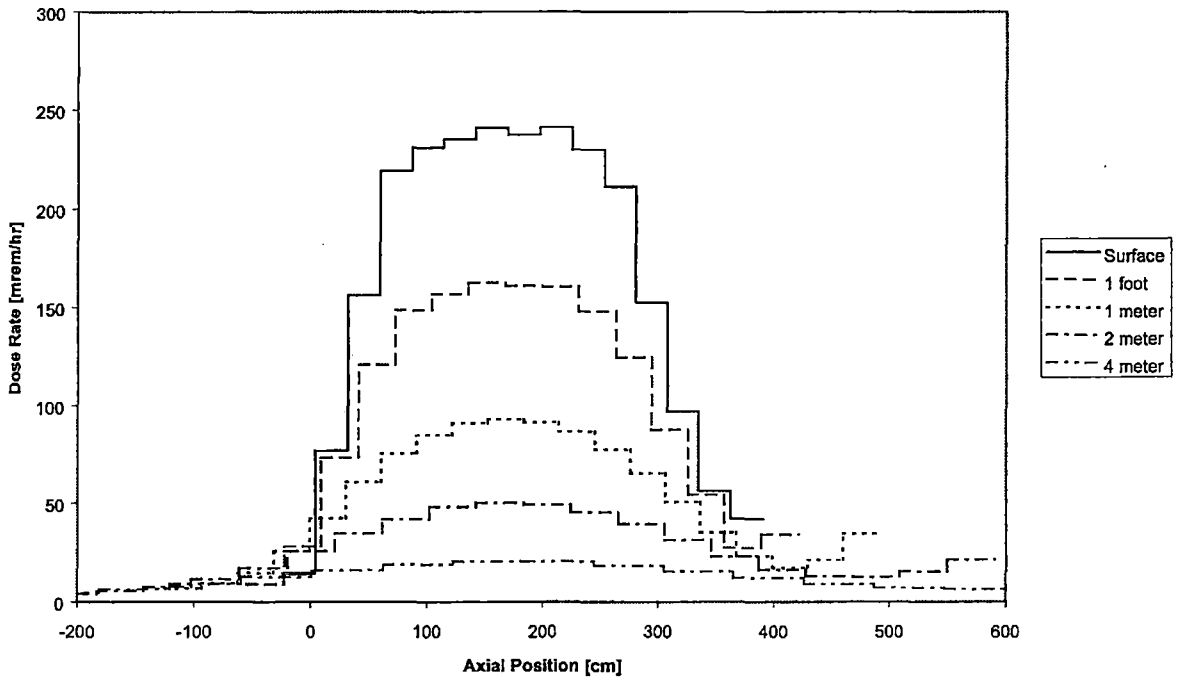


Figure 5.4.2–23 CY-MPC Transfer Cask Radial Surface Dose Rate Profile by Source Type– Shield Lid with Weld Shield Model (Shw) – Wet Conditions – Design Basis Stainless Steel Clad Fuel

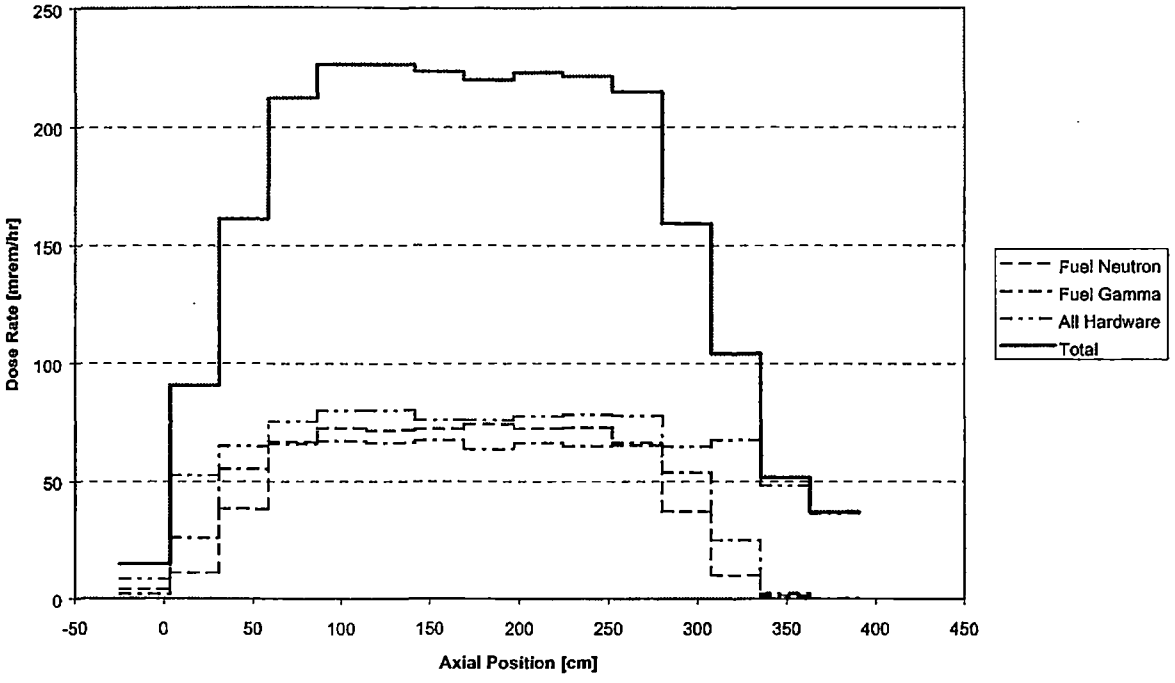


Figure 5.4.2–24 CY-MPC Transfer Cask Top Axial Dose Rate Profile – Structural Lid with Weld Shield Model (Stw) – Dry Conditions – Design Basis Stainless Steel Clad Fuel

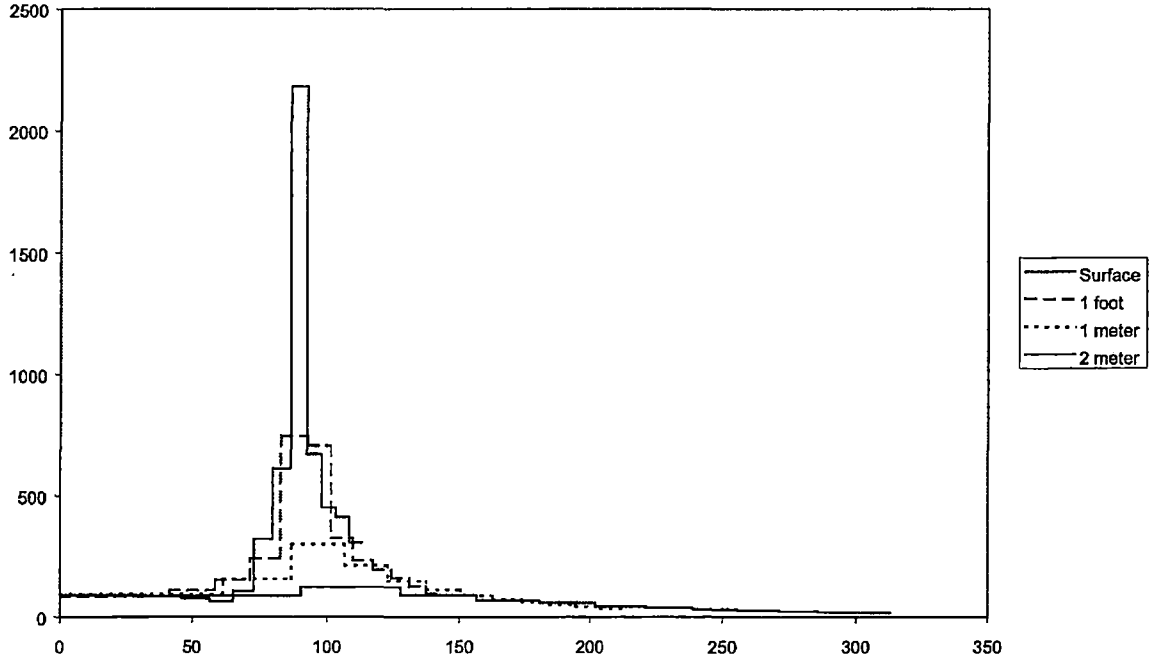


Figure 5.4.2–25 CY-MPC Transfer Cask Top Axial Dose Rate Profile – Structural Lid with Weld Shield Model (Stw) – Dry Conditions – Design Basis Zircaloy Clad Fuel

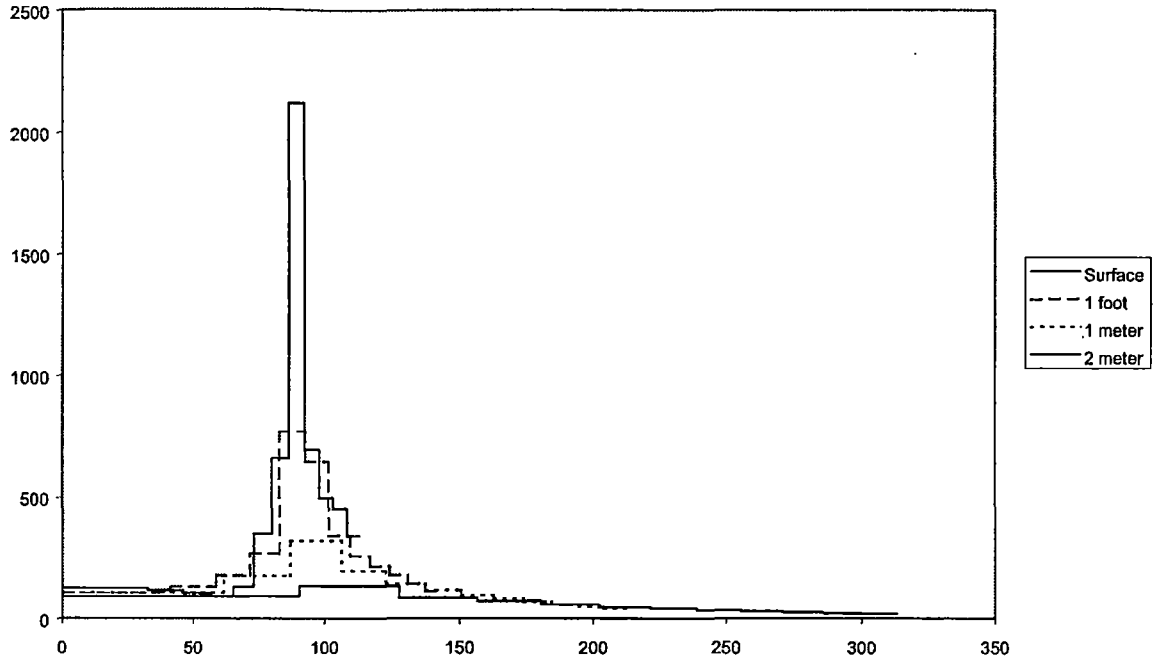


Figure 5.4.2–26 CY-MPC Transfer Cask Radial Surface Dose Rate Profile – Structural Lid Model (Stl) – Dry Conditions – Design Basis Stainless Steel Clad Fuel

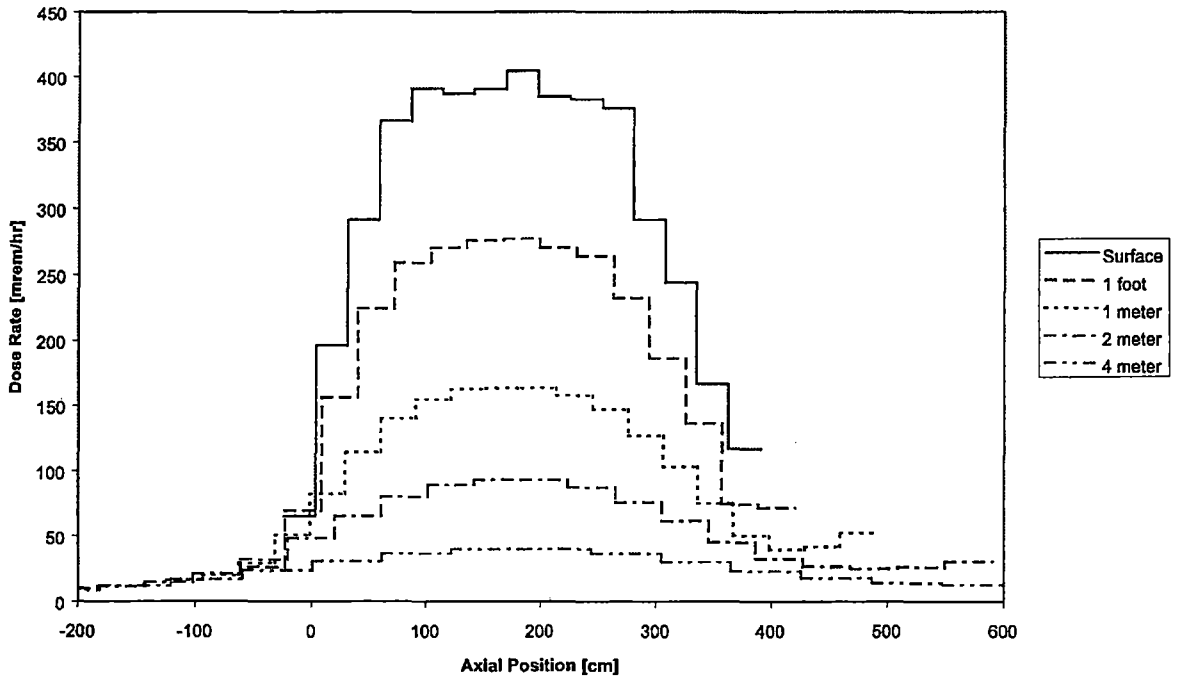


Figure 5.4.2–27 CY-MPC Transfer Cask Radial Surface Dose Rate Profile – Structural Lid Model (Stl) – Dry Conditions – Design Basis Zircaloy Clad Fuel

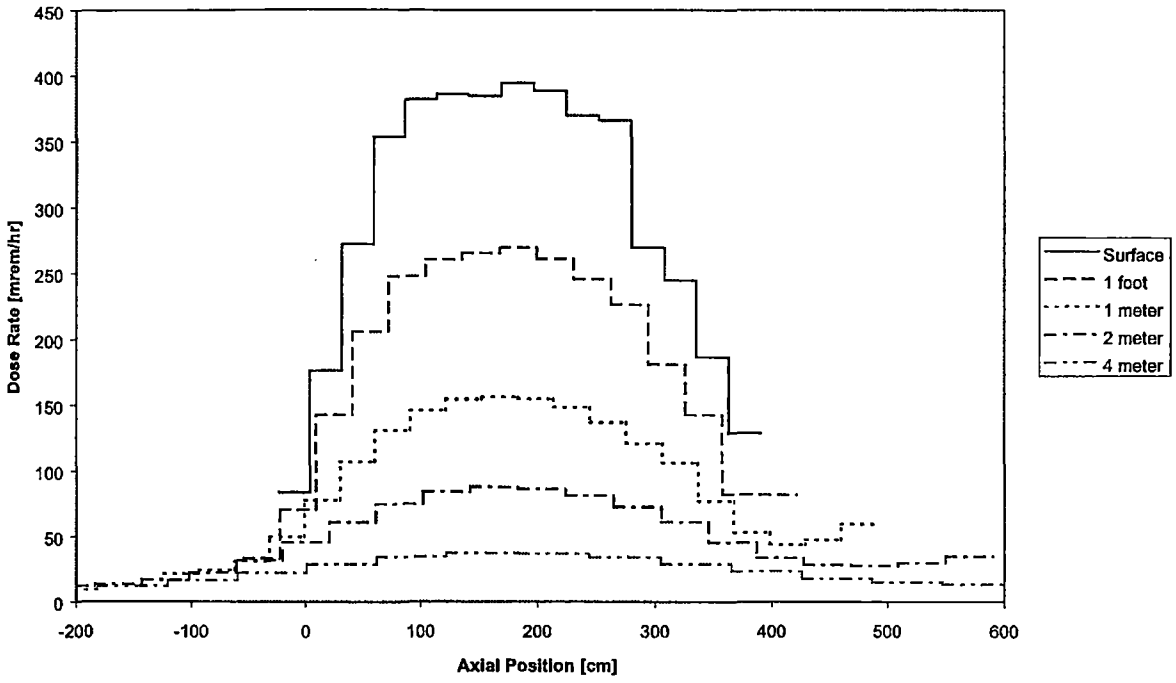


Figure 5.4.2–28 CY-MPC Transfer Cask Radial Surface Dose Rate Profile by Source Type– Structural Lid Model (Stl) – Dry Conditions – Design Basis Stainless Steel Clad Fuel

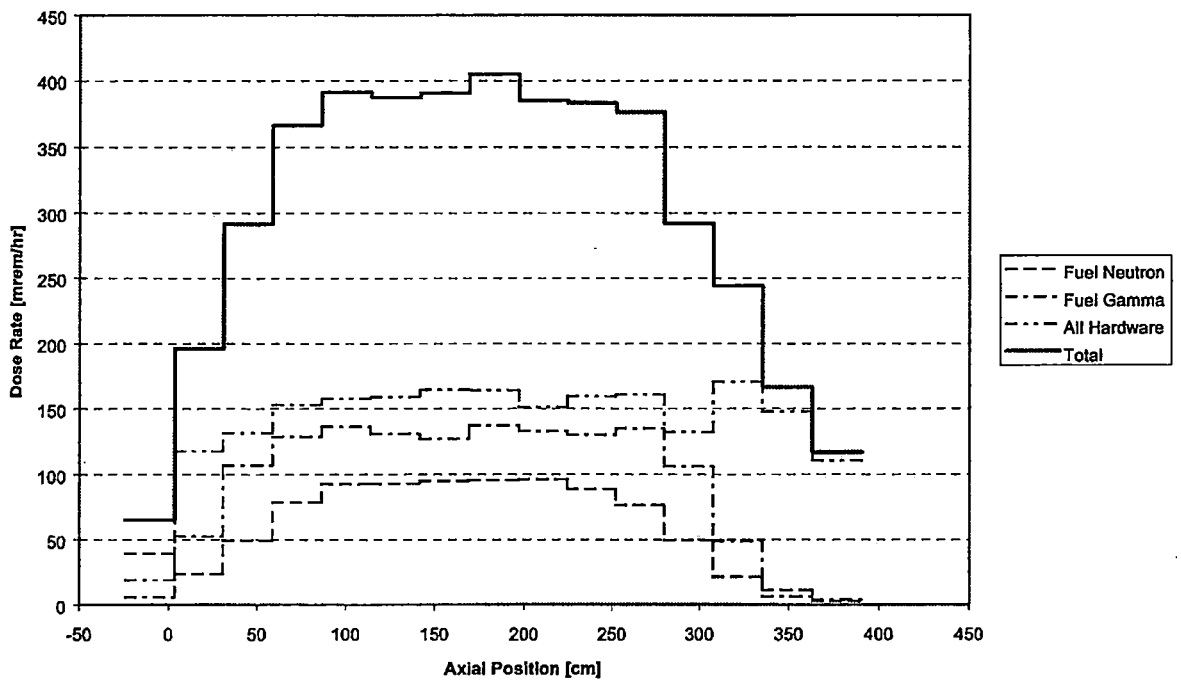


Figure 5.4.2–29 CY-MPC Transfer Cask Radial Dose Rate Profile – Shield Lid with Weld Shield (Model Shw) – Wet Conditions – Reactor Control Cluster Assembly Source

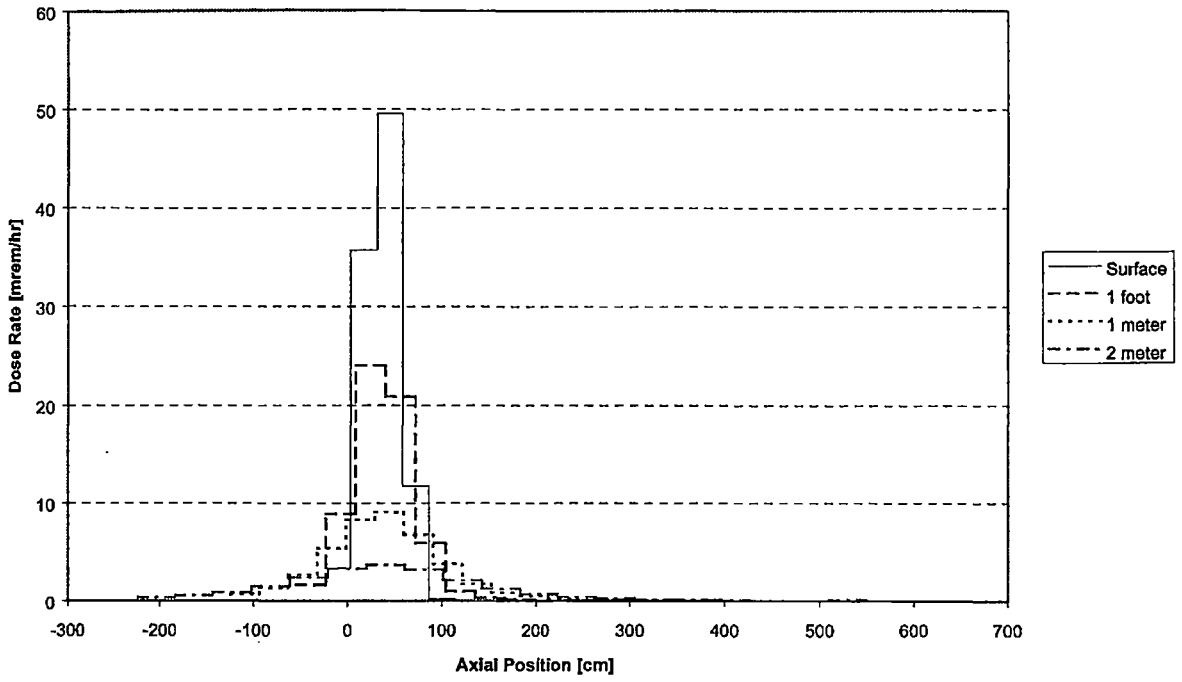


Figure 5.4.2–30 CY-MPC Transfer Cask Radial Dose Rate Profile – Structural Lid (Model Stl) – Dry Conditions – Reactor Control Cluster Assembly Source

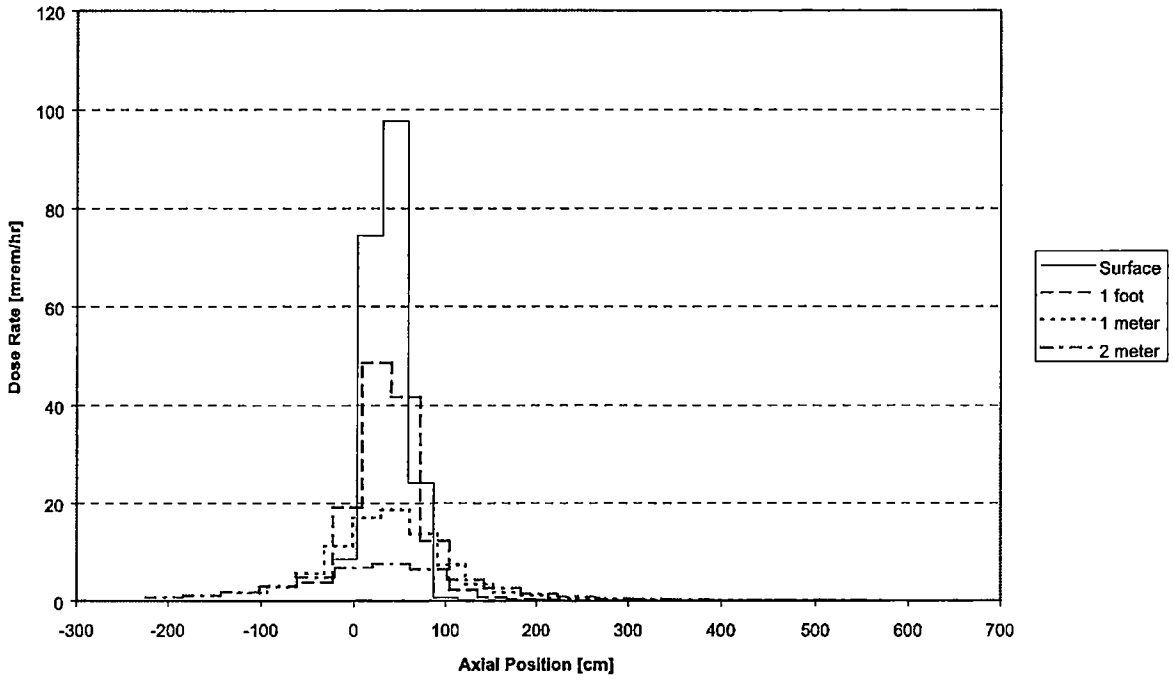


Figure 5.4.2–31 CY-MPC Transfer Cask Top Axial Dose Rate Profile – Shield Lid with Weld Shield (Model Shw) – Wet Conditions – Flow Mixer Source

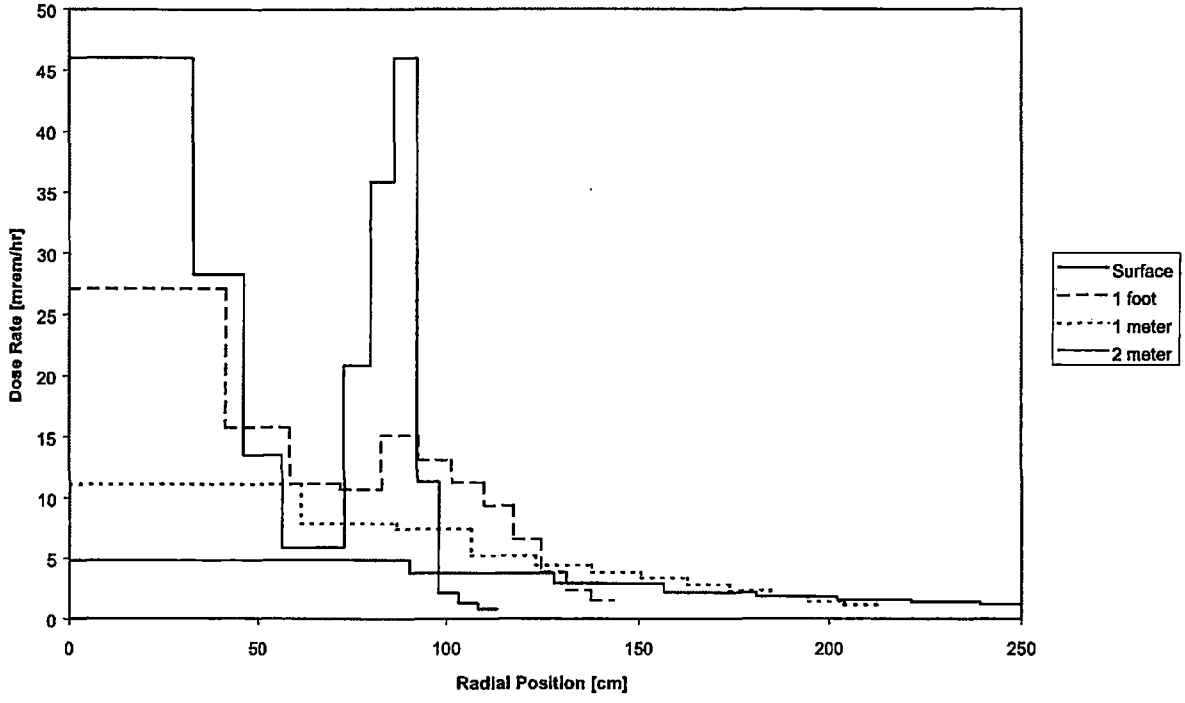


Figure 5.4.2–32 CY-MPC Transfer Cask Top Axial Dose Rate Profile – Structural Lid with Weld Shield (Model Stw) – Dry Conditions – Flow Mixer Source

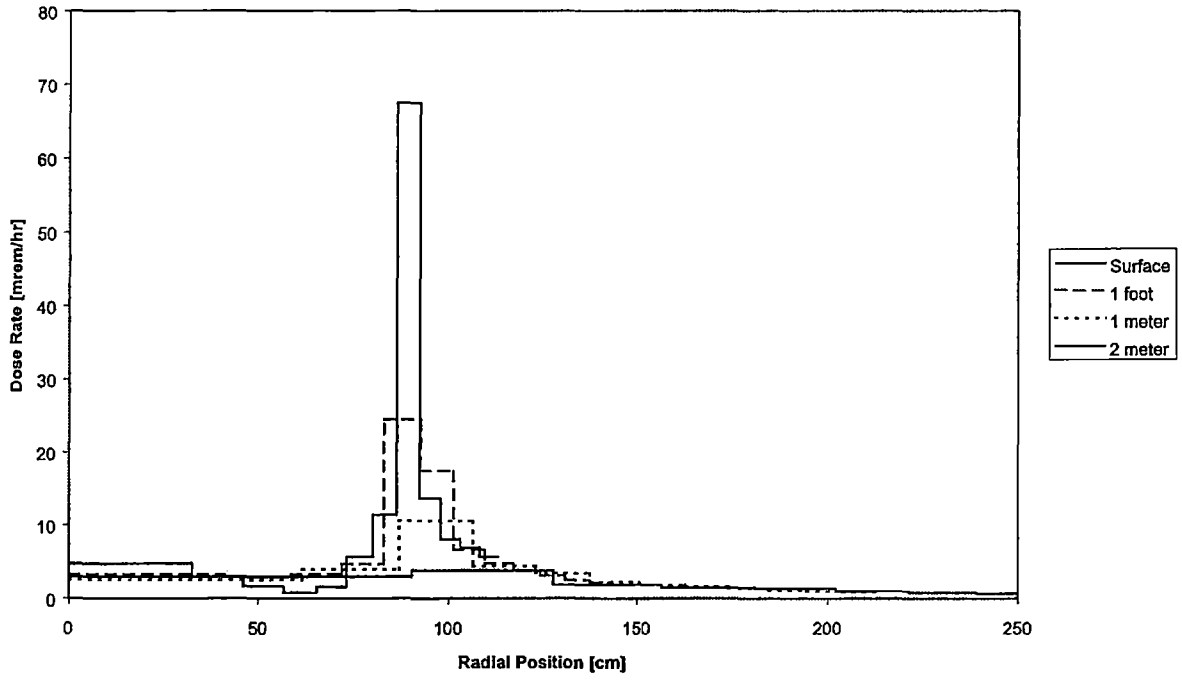


Table 5.4.2–1 CY-MPC Neutron Flux-to-Dose Conversion Factors

Group	Upper E [MeV]	Lower E [MeV]	Response [(mrem/hr)/(n/cm^2/sec)]
1	1.46E+01	1.36E+01	2.0533E-01
2	1.36E+01	1.25E+01	1.8999E-01
3	1.25E+01	1.13E+01	1.7250E-01
4	1.13E+01	1.00E+01	1.5399E-01
5	1.00E+01	8.25E+00	1.4700E-01
6	8.25E+00	7.00E+00	1.4700E-01
7	7.00E+00	6.07E+00	1.4929E-01
8	6.07E+00	4.72E+00	1.5348E-01
9	4.72E+00	3.68E+00	1.4580E-01
10	3.68E+00	2.87E+00	1.3478E-01
11	2.87E+00	1.74E+00	1.2657E-01
12	1.74E+00	6.40E-01	1.2570E-01
13	6.40E-01	3.90E-01	8.8205E-02
14	3.90E-01	1.10E-01	4.6004E-02
15	1.10E-01	6.74E-02	1.8108E-02
16	6.74E-02	2.48E-02	1.0774E-02
17	2.48E-02	9.12E-03	4.9057E-03
18	9.12E-03	2.95E-03	3.6168E-03
19	2.95E-03	9.61E-04	3.7152E-03
20	9.61E-04	3.54E-04	3.8611E-03
21	3.54E-04	1.66E-04	4.0252E-03
22	1.66E-04	4.81E-05	4.1919E-03
23	4.81E-05	1.60E-05	4.3795E-03
24	1.60E-05	4.00E-06	4.5200E-03
25	4.00E-06	1.50E-06	4.4895E-03
26	1.50E-06	5.50E-07	4.3924E-03
27	5.50E-07	7.09E-08	3.9685E-03
28	7.09E-08	0.00E+00	2.3759E-03

Table 5.4.2–2 CY–MPC Gamma Flux-to-Dose Conversion Factors

Group	Upper E [MeV]	Lower E [MeV]	Response [(mrem/hr)/(γ/cm^2/sec)]
1	1.40E+01	1.20E+01	1.1728E-02
2	1.20E+01	1.00E+01	1.0225E-02
3	1.00E+01	8.00E+00	8.7164E-03
4	8.00E+00	6.50E+00	7.4457E-03
5	6.50E+00	5.00E+00	6.3551E-03
6	5.00E+00	4.00E+00	5.3991E-03
7	4.00E+00	3.00E+00	4.5984E-03
8	3.00E+00	2.50E+00	3.9449E-03
9	2.50E+00	2.00E+00	3.4485E-03
10	2.00E+00	1.66E+00	2.9982E-03
11	1.66E+00	1.44E+00	2.6706E-03
12	1.44E+00	1.22E+00	2.3929E-03
13	1.22E+00	1.00E+00	2.1055E-03
14	1.00E+00	8.00E-01	1.8164E-03
15	8.00E-01	6.00E-01	1.5143E-03
16	6.00E-01	4.00E-01	1.1686E-03
17	4.00E-01	3.00E-01	8.6947E-04
18	3.00E-01	2.00E-01	6.2398E-04
19	2.00E-01	1.00E-01	3.8050E-04
20	1.00E-01	5.00E-02	2.7163E-04
21	5.00E-02	2.00E-02	5.8620E-04
22	2.00E-02	1.00E-02	2.3540E-03

Table 5.4.2–3 Summary of CY-MPC Storage Cask Maximum Dose Rates – Design Basis Stainless Steel Clad Fuel

	Cask Surface (mrem/hr with relative uncertainty)				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
Source	**Side**		**Top**		**Side**		**Top**	
Neutron	2	2.4%	2	3.2%	1	1.4%	6	0.5%
Gamma	165	1.7%	30	1.0%	81	0.8%	6	1.9%
Total	167	1.7%	32	1.0%	82	0.8%	12	1.0%

Table 5.4.2–4 Summary of CY-MPC Storage Cask Maximum Dose Rates – Design Basis Zircaloy Clad Fuel

	Cask Surface (mrem/hr with relative uncertainty)				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
Source	**Side**		**Top**		**Side**		**Top**	
Neutron	2	1.7%	3	3.1%	1	1.4%	8	0.5%
Gamma	138	1.1%	33	0.8%	68	0.9%	6	0.7%
Total	140	1.0%	36	0.7%	69	0.9%	14	0.4%

Table 5.4.2–5 Summary of CY-MPC Storage Cask Maximum Dose Rates – Non Fuel Sources

	Cask Surface (mrem/hr with relative uncertainty)				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
Source	**Side**		**Top**		**Side**		**Top**	
8 Flow Mixer	3.0	0.2%	1.3	0.7%	0.9	0.3%	0.4	0.7%
26 RCCA	35	0.4%	–	–	8	0.3%	–	–

Table 5.4.2–6 CY-MPC Transfer Cask Detector Maximum Dose Rates – Shield Lid with Weld Shield (Model Shw) – Wet Conditions – Design Basis Stainless Steel Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	1	6.1%	<1	7.7%	<1	7.2%
	Fuel Gamma	102	11.0%	17	18.2%	8	18.3%
	Fuel Hardware	194	39.4%	44	48.9%	19	51.1%
	Fuel N-Gamma	<1	36.6%	<1	34.0%	<1	33.8%
	Upper Plenum	525	23.1%	95	35.9%	28	11.4%
	Upper Nozzle	3008	5.2%	409	10.8%	184	11.1%
	Lower Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Total	3830	5.5%	565	10.6%	239	9.6%
Radial	Fuel Neutron	73	1.0%	24	1.0%	12	0.9%
	Fuel Gamma	67	2.3%	30	2.5%	17	2.0%
	Fuel Hardware	80	2.3%	34	2.4%	20	2.0%
	Fuel N-Gamma	7	16.1%	2	13.7%	1	12.1%
	Upper Plenum	<1	0.0%	<1	6.5%	<1	3.1%
	Upper Nozzle	<1	0.0%	<1	9.1%	<1	4.4%
	Lower Nozzle	<1	0.0%	<1	7.2%	<1	3.1%
	Total	226	1.2%	91	1.3%	51	1.1%
Bottom Axial	Fuel Neutron	20	2.6%	5	1.4%	2	1.4%
	Fuel Gamma	7	7.8%	3	3.2%	1	2.8%
	Fuel Hardware	8	8.0%	3	3.5%	1	3.1%
	Fuel N-Gamma	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Plenum	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Lower Nozzle	61	3.0%	26	1.3%	11	1.2%
	Total	95	2.2%	36	1.0%	15	0.9%

Table 5.4.2–7 CY-MPC Transfer Cask Detector Maximum Dose Rates – Shield Lid with Weld Shield (Model Shw) – Design Basis Zircaloy Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	1	14.6%	0	16.6%	0	15.8%
	Fuel Gamma	78	4.0%	12	6.2%	5	2.9%
	Fuel Hardware	39	8.0%	6	13.4%	3	9.0%
	Fuel N-Gamma	<1	22.1%	<1	69.1%	<1	59.7%
	Upper Plenum	392	0.9%	54	1.1%	24	1.0%
	Upper Nozzle	3540	2.2%	460	4.2%	194	1.8%
	Lower Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Total	4050	1.9%	532	3.6%	226	1.6%
Radial	Fuel Neutron	111	1.7%	37	1.0%	18	0.9%
	Fuel Gamma	81	4.1%	34	2.3%	19	1.8%
	Fuel Hardware	40	3.8%	18	2.2%	10	1.8%
	Fuel N-Gamma	9	37.7%	3	17.8%	2	15.5%
	Upper Plenum	<1	0.0%	<1	6.6%	<1	3.2%
	Upper Nozzle	<1	0.0%	<1	10.4%	<1	4.7%
	Lower Nozzle	<1	0.0%	<1	6.7%	<1	2.9%
	Total	241	2.2%	93	1.2%	50	1.0%
Bottom Axial	Fuel Neutron	29	2.6%	7	1.3%	3	1.3%
	Fuel Gamma	12	7.8%	5	3.5%	2	3.1%
	Fuel Hardware	5	7.3%	2	3.0%	1	2.7%
	Fuel N-Gamma	1	52.0%	<1	30.0%	<1	31.9%
	Upper Plenum	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Lower Nozzle	37	2.7%	15	1.2%	7	1.1%
	Total	84	2.0%	29	0.9%	12	0.9%

Table 5.4.2–8 CY-MPC Transfer Cask Detector Maximum Dose Rates – Structural Lid with Weld Shield (Model Stw) – Design Basis Stainless Steel Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	54	0.6%	14	0.7%	6	0.7%
	Fuel Gamma	226	21.0%	22	11.1%	8	9.5%
	Fuel Hardware	120	17.5%	22	26.3%	8	23.8%
	Fuel N-Gamma	2	8.4%	<1	6.5%	<1	6.6%
	Upper Plenum	427	13.3%	52	6.5%	21	5.9%
	Upper Nozzle	1350	8.8%	191	13.4%	78	14.9%
	Lower Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Total	2179	6.5%	301	8.8%	122	9.8%

Table 5.4.2–9 CY-MPC Transfer Cask Detector Maximum Dose Rates – Structural Lid with Weld Shield (Model Stw) – Design Basis Zircaloy Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	79	0.6%	20	0.8%	9	0.8%
	Fuel Gamma	195	14.0%	31	21.4%	12	22.8%
	Fuel Hardware	65	7.6%	10	10.9%	4	11.6%
	Fuel N-Gamma	3	9.1%	1	8.5%	<1	8.4%
	Upper Plenum	422	4.8%	64	6.3%	26	6.4%
	Upper Nozzle	1353	4.8%	194	8.2%	81	8.7%
	Lower Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Total	2117	3.5%	319	5.6%	132	5.8%

Table 5.4.2–10 CY-MPC Transfer Cask Detector Maximum Dose Rates – Structural Lid with No Weld Shield (Model Stl) – Design Basis Stainless Steel Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Radial	Fuel Neutron	96	1.9%	32	1.1%	16	1.0%
	Fuel Gamma	137	4.1%	58	2.0%	34	1.6%
	Fuel Hardware	164	7.1%	71	2.9%	40	2.3%
	Fuel N-Gamma	8	38.2%	2	5.7%	1	7.3%
	Upper Plenum	<1	0.0%	1	3.8%	1	1.9%
	Upper Nozzle	<1	0.0%	1	3.4%	1	1.5%
	Lower Nozzle	<1	0.0%	<1	4.8%	1	2.0%
	Total	405	3.3%	164	1.5%	93	1.2%
Bottom Axial	Fuel Neutron	208	1.0%	53	0.6%	20	0.6%
	Fuel Gamma	14	6.5%	6	2.9%	3	2.5%
	Fuel Hardware	16	6.3%	6	2.8%	3	2.5%
	Fuel N-Gamma	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Plenum	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Lower Nozzle	71	2.6%	29	1.2%	13	1.1%
	Total	307	1.0%	94	0.6%	38	0.5%

Table 5.4.2–11 CY-MPC Transfer Cask Detector Maximum Dose Rates – Structural Lid with No Weld Shield (Model Stl) – Design Basis Zircaloy Clad Fuel

Detector	Source	Surface		1 meter		2 meter	
		mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Radial	Fuel Neutron	149	1.8%	49	1.0%	24	0.9%
	Fuel Gamma	148	4.1%	64	1.8%	37	1.4%
	Fuel Hardware	87	4.4%	38	2.1%	22	1.7%
	Fuel N-Gamma	11	23.3%	3	24.2%	1	19.4%
	Upper Plenum	<1	0.0%	1	4.5%	1	2.2%
	Upper Nozzle	<1	0.0%	1	3.9%	1	1.7%
	Lower Nozzle	<1	0.0%	<1	4.6%	1	1.9%
	Total	394	2.0%	156	1.0%	88	0.8%
Bottom Axial	Fuel Neutron	326	0.9%	83	0.6%	31	0.6%
	Fuel Gamma	24	5.4%	9	2.3%	4	2.1%
	Fuel Hardware	11	4.6%	5	3.1%	2	2.9%
	Fuel N-Gamma	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Plenum	<1	0.0%	<1	0.0%	<1	0.0%
	Upper Nozzle	<1	0.0%	<1	0.0%	<1	0.0%
	Lower Nozzle	46	2.5%	19	1.0%	8	1.0%
	Total	407	0.8%	116	0.5%	45	0.5%

Table 5.4.2–12 Summary of CY-MPC Storage Cask Average Dose Rates – Design Basis Stainless Steel Clad Fuel

Cask Surface (mrem/hr with relative uncertainty)				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
Side		**Top**		**Side**		**Top**	
108	1.2%	20	1.5%	47	0.8%	6	2.0%

Table 5.4.2–13 Summary of CY-MPC Storage Cask Average Dose Rates – Design Basis Zircaloy Clad Fuel

Cask Surface (mrem/hr with relative uncertainty)						**1 Meter From Surface (mrem/hr with relative uncertainty)**					
Side		**Top NS-4-FR**		**Top NS-3**		**Side**		**Top NS-4-FR**		**Top NS-3**	
93	1.2%	24	0.9%	24	1.3%	41	0.8%	8	6.8%	8	5.7%

Table 5.4.2–14 Summary of CY-MPC Storage Cask Average Dose Rates – Non Fuel Sources

Source	**Cask Surface (mrem/hr with relative uncertainty)**				**1 Meter From Surface (mrem/hr with relative uncertainty)**			
	Side		**Top**		**Side**		**Top**	
8 Flow Mixer	0.6	0.9%	0.4	2.2%	0.3	0.7%	0.2	7.7%
26 RCCA	5.8	1.0%	-	-	8	0.3%	-	-

Table 5.4.2–15 Summary of CY-MPC Transfer Cask Detector Average Dose Rates – Design Basis Stainless Steel Clad Fuel

Model	Condition	Detector	Surface		1 meter		2 meter	
			Mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Shw	Wet	Top Axial	907	6.9%	231	7.6%	103	7.9%
		Radial	159	1.9%	50	1.3%	25	1.3%
		Bottom	46	1.9%	12	1.3%	6	1.5%
Stw	Dry	Top Axial	448	9.3%	115	10.0%	52	10.2%
Stl	Dry	Radial	297	1.9%	95	1.2%	48	1.1%
		Bottom	162	0.8%	36	0.9%	16	1.0%

Table 5.4.2–16 Summary of CY-MPC Transfer Cask Detector Average Dose Rates – Design Basis Zircaloy Clad Fuel

Model	Condition	Detector	Surface		1 meter		2 meter	
			mrem/hr	RSD	mrem/hr	RSD	mrem/hr	RSD
Shw	Wet	Top Axial	999	2.4%	254	2.5%	113	2.6%
		Radial	163	2.0%	50	1.3%	26	1.3%
		Bottom	41	1.7%	11	1.3%	5	1.6%
Stw	Dry	Top Axial	472	4.5%	120	4.9%	54	5.0%
Stl	Dry	Radial	293	1.8%	92	1.5%	48	1.4%
		Bottom	218	0.7%	47	0.8%	20	1.0%

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5.6 Appendices

5.6.1 Yankee-MPC Sample Input Files

This section contains sample input files employed in the shielding evaluations of the Yankee-MPC.

5.6.1.1 SAS2H Sample Input Files

Sample SAS2H input for the design basis CE fuel is shown in Figure 5.6.1.1-1. ORIGEN-S is employed to rebin the calculated sources into the MCBEND neutron and gamma energy group structures.

Figure 5.6.1.1-1 SAS2H Input File for Design Basis CE Fuel at 36,000 MWD/MTU and 3.7 wt % ^{235}U in MCBEND Group Format

```
=SAS2H    PARM=(HALT02,SKIPSHIPDATA)
YNPS - CE Type A - 36000 MWD/MTU 6 TO 10 YEARS COOLING 3.7wt%235U
27GROUPNDF4 LATTICECELL
UO2     1 0.95 797 92235 3.7 92238 96.3 END
ZIRCALLOY 2 1.0 600 END
H2O     3 DEN=0.766 1.0 551 END
ARBM-BORMOD 0.766 1 1 0 0 5000 100 3 800.0E-6 551 END
END COMP
SQUAREPITCH 1.1989 0.7887 1 3 0.9271 2 0.8052 0 END
NPIN=231 FUEL=231.14 NCYC=2 NLIB=1 PRIN=6 LIGH=5
INPL=1 NUMH=1 NUMI=0 ORTU=0.5740 SRTU=0.4985 END
POWER=8.684 BURN=496.22 DOWN=60 END
POWER=8.684 BURN=496.22 DOWN=1826.25 END
FE 0.672 CR 0.190 NI 0.115 MN 0.020 CO 0.0012
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING TO 10 YEARS AND FISSION PRODUCT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  5.0 E T
COOLING TO 10 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60**  6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.01
81$$  2 51 26 1 E
82$$  F6
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
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FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA 22 GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING TO 10 YEARS AND ACTINIDE GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  5.0 E T
COOLING TO 10 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60**  6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.01
81$$  2 51 26 1 E
82$$  F5
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA 22 GROUPS
56$$ F0  T
END
```

Figure 5. 6.1.1-1 SAS2H Input File for Design Basis CE Fuel at 36,000 MWD/MTU and 3.7 wt % ^{235}U in MCBEND Group Format (Continued)

```
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING TO 10 YEARS AND STEEL GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  5.0 E T
COOLING TO 10 YEARS AND STEEL GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60**  6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.01
81$$  2 51 26 1 E
82$$  P4
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
STEEL GAMMA SPECTRA IN AEA 22 GROUPS
56$$ F0  T
END
```

5.6.1.2 MCBEND Sample Input Files

Sample MCBEND input storage cask files are shown in Figure 5.6.1.2-1 through Figure 5.6.1.2-3. The modeled geometry includes the supplemental air inlet shields.

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing

```
columns 1 200
*
* Yankee-MPC VCC - ce16y_36b37e08y - Fuel Gamma - Radial
*   Shield Lid - Ports - With Covers
*   Structural Lid - No Weld Shield
*   Dry Conditions
*
*   Model Revision v1.6.0.0
*

*
* Parameters
*
@samps =    20000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit    1000m
    seeds    97329    92281
    chime every    [@samps/10]    samples
*    chime every    60m
    report interim results
    sbd    10s
    dump intervals    1
end

*
* Unit 3 Output Control
*
*begin output control
*    suppress inflows
*end

*
* Unit 4 Material Geometry
*
begin material geometry
* Fuel Assembly Type A - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    1    NEST
BOX    M5        0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6        0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1    S    0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8        0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7        0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* Fuel Assembly Type B - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    2    NEST
BOX    M5        0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6        0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1    S    0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8        0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7        0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* BORAL and Cover for Standard Opening v1.0
PART    3    NEST
BOX    BH1    0.0457    0.0000    0.3556    0.1905    18.2880    244.3480    ! BORAL Sheet - Axial offset from cover sheet bottom
BOX    M0    0.0457    0.0000    0.0000    0.1905    18.2880    248.9200    ! Space under cover sheet that allows sheet to shift
under cover
BOX    M11    0.0000    0.0000    0.0000    0.2362    18.2880    248.9200    ! SS cover sheet for BORAL
* Fuel Assembly in Tube (Type A) v1.0
PART    4
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.0
PART    5
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.0
PART    6    CLUSTER
BOX    P4    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type A with fuel assy
BOX    P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX    P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX    P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
        ZROT    90.0000
BOX     P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
        ZROT    270.0000
BOX     H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
*  Type B Disk Opening with Tube v1.0
PART    7     CLUSTER
BOX     P5    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type B with fuel assy
BOX     P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX     P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX     P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
        ZROT    90.0000
BOX     P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
        ZROT    270.0000
BOX     H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
* Basket v1.0
PART    8
BOX     1    -33.6702    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 1
BOX     2    -10.4826    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 2
BOX     3    12.7051    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 3
BOX     4    -56.6928    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 4
BOX     5    -33.6702    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 5
BOX     6    -10.4826    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 6
BOX     7    12.7051    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 7
BOX     8    35.7276    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 8
BOX     9    -79.5630    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 9
BOX     10    -56.6928    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 10
BOX     11    -33.6702    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 11
BOX     12    -10.4826    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 12
BOX     13    12.7051    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 13
BOX     14    35.7276    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 14
BOX     15    58.5978    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 15
BOX     16    -79.5630    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 16
BOX     17    -56.6928    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 17
BOX     18    -33.6702    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 18
BOX     19    -10.4826    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Middle Opening
BOX     20    12.7051    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 19
BOX     21    35.7276    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 20
BOX     22    58.5978    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 21
BOX     23    -79.5630    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 22
BOX     24    -56.6928    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 23
BOX     25    -33.6702    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 24
BOX     26    -10.4826    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 25
BOX     27    12.7051    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 26
BOX     28    35.7276    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 27
BOX     29    58.5978    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 28
BOX     30    -56.6928    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 29
BOX     31    -33.6702    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 30
BOX     32    -10.4826    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 31
BOX     33    12.7051    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 32
BOX     34    35.7276    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 33
BOX     35    -33.6702    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 34
BOX     36    -10.4826    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 35
BOX     37    12.7051    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 36
BOX     38    33.6703    -78.6004    270.5100    28.4480    21.9075    16.0020    ! Drain Baffle Box A
BOX     39    35.2578    -78.6004    270.5100    26.8605    20.3200    16.0020    ! Drain Baffle Box B
ZROD    40    46.2405    -61.3632    0.0000    2.6035    288.2900    ! Drain Baffle Hole
BOX     41    -62.1182    56.6929    270.5100    28.4480    21.9075    16.0020    ! Vent Baffle Box A
BOX     42    -62.1182    58.2804    270.5100    26.8605    20.3200    16.0020    ! Vent Baffle Box B
ZROD    43    -46.2405    61.3632    0.0000    2.6035    288.2900    ! Vent Baffle Hole
ZROD    44    0.0000    0.0000    0.0000    86.3346    288.2900    ! Baffle limiting radius
CONTAINER
ZROD    45    0.0000    0.0000    0.0000    87.4649    288.2900    ! Basket stack to cavity height
ZONES
/Opening01/    P6    +1
/Opening02/    P6    +2
/Opening03/    P6    +3
/Opening04/    P7    +4
/Opening05/    P6    +5
/Opening06/    P6    +6
/Opening07/    P6    +7
/Opening08/    P7    +8
/Opening09/    P6    +9
/Opening10/    P6    +10
/Opening11/    P6    +11
/Opening12/    P6    +12
/Opening13/    P6    +13
/Opening14/    P6    +14
/Opening15/    P6    +15
/Opening16/    P6    +16
/Opening17/    P6    +17
/Opening18/    P6    +18
/Opening19/    P6    +20
/Opening20/    P6    +21
/Opening21/    P6    +22
/Opening22/    P6    +23
/Opening23/    P6    +24
/Opening24/    P6    +25
/Opening25/    P6    +26
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
/Opening26/    P6    +27
/Opening27/    P6    +28
/Opening28/    P6    +29
/Opening29/    P7    +30
/Opening30/    P6    +31
/Opening31/    P6    +32
/Opening32/    P6    +33
/Opening33/    P7    +34
/Opening34/    P6    +35
/Opening35/    P6    +36
/Opening36/    P6    +37
/Center/    H2    +19
/DrainBfl/    M17    +38    -39    +44
/DrainBflHole/    H6    +40
/DrainBflInner/    H2    +39    -40    +44
/VentBfl/    M17    +41    -42    +44
/VentBflHole/    H6    +43
/VentBflInner/    H2    +42    -43    +44
/Basket/    H2    +45    -1    -2    -3    -4    -5
        -6    -7    -8    -9    -10    -11
        -12    -13    -14    -15    -16    -17
        -18    -19    -20    -21    -22    -23
        -24    -25    -26    -27    -28    -29
        -30    -31    -32    -33    -34    -35
        -36    -37    -38    -40    -41    -43
/BasketDrain/    H2    +45    +38    -44
/BasketVent/    H2    +45    +41    -44

VOLUMES    UNITY
* Basket in Canister Cavity v1.0
PART    9    NEST
ZROD    P8    0.0000    0.0000    0.0000    87.4649    288.2900        ! Basket inserted - Includes gap to lid
        ZROT    0.0000
ZROD    H6    0.0000    0.0000    0.0000    88.1253    288.2900        ! Inserts flood matl to canister shell
* Canister - Structural Lid - No Weld Shield v1.0
PART    10
ZROD    1    0.0000    0.0000    0.0000    88.1253    288.2900        ! Canister cavity contents
ZROD    2    0.0000    0.0000    -2.5400    89.7128    2.5400        ! Canister Bottom Plate
ZROD    3    0.0000    0.0000    288.2900    88.1253    12.7000        ! Shield Lid
ZROD    4    0.0000    0.0000    300.9900    88.1253    7.6200        ! Structural Lid
ZROD    5    0.0000    0.0000    0.0000    88.1253    308.6100        ! Canister Shell Inner
ZROD    6    0.0000    0.0000    0.0000    89.7128    308.6100        ! Canister Shell Outer
ZROD    7    0.0000    0.0000    -2.5400    89.7128    311.1500        ! Inner Detector Surface
ZONES
/Cavity/    P9    +1
/BottomPlate/    M17    +2
/ShieldLid/    P11    +3
/StructLid/    M17    +4
/Shell/    M17    +6    -5
/Canister/    M0    +7    -6    -4    -2
VOLUMES    UNITY
* Shield Lid - With Ports v1.0
PART    11    CLUSTER
ZROD    P12    -46.2405    61.3632    0.0000    7.6200    12.7000        ! Vent port
ZROD    P12    46.2405    -61.3632    0.0000    7.6200    12.7000        ! Drain port
ZROD    M17    0.0000    0.0000    0.0000    88.1253    12.7000        ! Shield Lid
* Vent Port Model - With Covers v1.0
PART    12    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.3843    4.6228        ! Bottom Cylinder
ZROD    M17    0.0000    0.0000    4.6228    5.0800    6.6548        ! Middle Cyclinder
ZROD    M17    0.0000    0.0000    11.2776    7.6200    1.4224        ! Top Cylinder
ZROD    M17    0.0000    0.0000    0.0000    7.6200    12.7000        ! Shield lid material
* Storage Cask Air Inlet PIM Model
PART    13
YROD    1    5.0800    0.0000    22.8600    5.0800    30.4800        ! Pipe A Outer
YROD    2    5.0800    0.0000    22.8600    3.4646    30.4800        ! Pipe A Inner
YROD    3    25.4000    0.0000    10.1600    5.0800    30.4800        ! Pipe B Outer
YROD    4    25.4000    0.0000    10.1600    3.4646    30.4800        ! Pipe B Inner
YROD    5    45.7200    0.0000    22.8600    5.0800    30.4800        ! Pipe C Outer
YROD    6    45.7200    0.0000    22.8600    3.4646    30.4800        ! Pipe C Inner
YROD    7    66.0400    0.0000    10.1600    5.0800    30.4800        ! Pipe D Outer
YROD    8    66.0400    0.0000    10.1600    3.4646    30.4800        ! Pipe D Inner
BOX    9    0.0000    0.0000    0.0000    71.1200    30.4800    33.0200        ! Container
ZONES
/Pipe A Steel/    M18    +1    -2
/Pipe A Void/    M0    +2
/Pipe A Steel/    M18    +3    -4
/Pipe A Void/    M0    +4
/Pipe A Steel/    M18    +5    -6
/Pipe A Void/    M0    +6
/Pipe A Steel/    M18    +7    -8
/Pipe A Void/    M0    +8
/Container/    M0    +9    -1    -3    -5    -7
VOLUMES UNITY
*Storage Cask Top Geometry v1.6.0.0
PART    14
ZROD    1    0.0000    0.0000    347.4720    116.9670    3.8100        ! VCC lid
ZROD    2    0.0000    0.0000    342.3920    124.3330    5.0800        ! Top flange outer
ZROD    3    0.0000    0.0000    342.3920    102.8700    5.0800        ! Top flange inner
ZROD    4    0.0000    0.0000    324.6120    100.3300    7.6200        ! Support ring outer
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
ZROD    5    0.0000    0.0000    324.6120    93.9800    7.6200            ! Support ring inner
ZROD    6    0.0000    0.0000    0.0000    109.2200    342.3920            ! VCC shell outer
ZROD    7    0.0000    0.0000    0.0000    100.3300    342.3920            ! VCC shell inner
ZROD    8    0.0000    0.0000    304.2920    109.2200    12.0650            ! VCC shell opening
ZROD    9    0.0000    0.0000    0.0000    162.5600    347.4720            ! Concrete
ZCONE   10    0.0000    0.0000    326.5170    92.0750    99.6950    7.6200        ! Shield plug cone
ZROD    11    0.0000    0.0000    334.1370    99.6950    1.9050            ! Shield plug cylinder
ZROD    12    0.0000    0.0000    336.0420    86.9950    3.4925            ! NS cover plate
ZROD    13    0.0000    0.0000    336.0420    86.0425    2.5400            ! NS
ZROD    14    0.0000    0.0000    304.2920    106.6800    12.0650            ! Air outlet inner radius
BOX     15    -54.2290    -162.5600    304.2920    108.4580    325.1200    33.1470        ! Air outlet A channel box
BOX     16    -53.2765    -162.5600    305.2445    106.5530    325.1200    31.2420        ! Air outlet A void box
BOX     17    -53.2765    -162.5600    304.2920    106.5530    325.1200    33.1470        ! Air outlet A wall box
BOX     18    -162.5600    -54.2290    304.2920    325.1200    108.4580    33.1470        ! Air outlet B channel box
BOX     19    -162.5600    -53.2765    305.2445    325.1200    106.5530    31.2420        ! Air outlet B void box
BOX     20    -162.5600    -53.2765    304.2920    325.1200    106.5530    33.1470        ! Air outlet B wall box
BOX     21    -162.5600    -162.5600    336.4865    325.1200    325.1200    0.9525        ! Box H8-H7 R5
BOX     22    -162.5600    -162.5600    326.3265    325.1200    325.1200    10.1600        ! Box H7-H6 R5
BOX     23    -162.5600    -162.5600    325.3740    325.1200    325.1200    0.9525        ! Box H6-H5 R5
BOX     24    -162.5600    -162.5600    304.2920    325.1200    325.1200    21.0820        ! Box H5-H1 R5
BOX     25    -128.0160    -128.0160    316.3570    256.0320    256.0320    21.0820        ! Box H8-H4 R2
BOX     26    -127.0635    -127.0635    316.3570    254.1270    254.1270    21.0820        ! Box H8-H4 R1
BOX     27    -143.2560    -143.2560    304.2920    286.5120    286.5120    21.0820        ! Box H5-H1 R4
BOX     28    -143.2560    -143.2560    304.2920    286.5120    286.5120    22.0345        ! Box H6-H1 R4
BOX     29    -128.0160    -128.0160    315.4045    256.0320    256.0320    0.9525        ! Box H4-H3 R2
BOX     30    -138.1760    -138.1760    305.2445    276.3520    276.3520    21.0820        ! Box H6-H2 R3
BOX     31    -128.0160    -128.0160    305.2445    256.0320    256.0320    10.1600        ! Box H3-H2 R2
BOX     32    -138.1760    -138.1760    304.2920    276.3520    276.3520    0.9525        ! Box H2-H1 R3
BOX     33    -138.1760    -138.1760    304.2920    276.3520    276.3520    22.0345        ! Box H6-H1 R3
BOX     34    -128.0160    -128.0160    305.2445    256.0320    256.0320    21.0820        ! Box H6-H2 R2
ZROD    35    0.0000    0.0000    0.0000    100.3300    342.3920            ! Cavity
ZROD    36    0.0000    0.0000    0.0000    162.5600    351.2820            ! Container
ZROD    37    0.0000    0.0000    0.0000    89.7128    311.1500            ! Canister
ZROD    38    0.0000    0.0000    311.1500    31.7271    1.0000            ! Canister Det 01
ZROD    39    0.0000    0.0000    311.1500    44.8689    1.0000            ! Canister Det 02
ZROD    40    0.0000    0.0000    311.1500    54.9530    1.0000            ! Canister Det 03
ZROD    41    0.0000    0.0000    311.1500    63.4543    1.0000            ! Canister Det 04
ZROD    42    0.0000    0.0000    311.1500    70.9440    1.0000            ! Canister Det 05
ZROD    43    0.0000    0.0000    311.1500    77.7153    1.0000            ! Canister Det 06
ZROD    44    0.0000    0.0000    311.1500    83.9421    1.0000            ! Canister Det 07
ZROD    45    0.0000    0.0000    311.1500    89.7379    1.0000            ! Canister Det 08
ZROD    46    0.0000    0.0000    311.1500    95.1814    1.0000            ! Canister Det 09
ZROD    47    0.0000    0.0000    311.1500    100.3300    1.0000            ! Canister Det 10
ZROD    48    0.0000    0.0000    312.1500    100.3300    1.0000            ! Can Azi Det Container
ZSEC    49    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 01
        345.0000    375.0000
ZSEC    50    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 02
        15.0000    45.0000
ZSEC    51    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 03
        45.0000    75.0000
ZSEC    52    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 04
        75.0000    105.0000
ZSEC    53    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 05
        105.0000    135.0000
ZSEC    54    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 06
        135.0000    165.0000
ZSEC    55    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 07
        165.0000    195.0000
ZSEC    56    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 08
        195.0000    225.0000
ZSEC    57    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 09
        225.0000    255.0000
ZSEC    58    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 10
        255.0000    285.0000
ZSEC    59    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 11
        285.0000    315.0000
ZSEC    60    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 12
        315.0000    345.0000
ZROD    61    0.0000    0.0000    339.5345    31.7271    1.0000            ! Shield Plug Det 01
ZROD    62    0.0000    0.0000    339.5345    44.8689    1.0000            ! Shield Plug Det 02
ZROD    63    0.0000    0.0000    339.5345    54.9530    1.0000            ! Shield Plug Det 03
ZROD    64    0.0000    0.0000    339.5345    63.4543    1.0000            ! Shield Plug Det 04
ZROD    65    0.0000    0.0000    339.5345    70.9440    1.0000            ! Shield Plug Det 05
ZROD    66    0.0000    0.0000    339.5345    77.7153    1.0000            ! Shield Plug Det 06
ZROD    67    0.0000    0.0000    339.5345    83.9421    1.0000            ! Shield Plug Det 07
ZROD    68    0.0000    0.0000    339.5345    89.7379    1.0000            ! Shield Plug Det 08
ZROD    69    0.0000    0.0000    339.5345    95.1814    1.0000            ! Shield Plug Det 09
ZROD    70    0.0000    0.0000    339.5345    100.3300    1.0000            ! Shield Plug Det 10
ZONES
/VCCLid/    M18    +1
/TopFlange/    M18    +2    -3
/SupportRing/    M18    +4    -5    -10
/ShieldPlugCone/    M18    +10
/ShieldPlugCyl/    M18    +11
/NScover/    M18    +12    -13
/NS/    M20    +13
/VCC Shell1/    M18    +6    -7    -8                    ! Outside air outlet opening
/VCC Shell2/    M18    +8    -7    -15    -18                ! Outside air outlet channel
/Concrete1/    M23    +9    -6    -2    -15    -18            ! Non air outlet concrete
/Concrete2/    M23    +9    +24    -27    +15                ! Bot air outlet concrete
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
/Concrete3/    M23    +9    +24    -27    +18                    ! Bot air outlet concrete
/Concrete4/    M23    +9    -6    +26    +15                     ! Top air outlet concrete
/Concrete5/    M23    +9    -6    +26    +18                     ! Top air outlet concrete
/AirOutTop1/    M18    +15    +21    -25    +9
/AirOutTop2/    M18    +18    +21    -25    +9
/AirOutMid1/    M18    +15    +23    -28    +9
/AirOutMid2/    M18    +18    +23    -28    +9
/AirOutBack1/    M18    +15    +25    -26
/AirOutBack2/    M18    +18    +25    -26
/AirOutBot1/    M18    +15    +32    -14
/AirOutBot2/    M18    +18    +32    -14
/AirOutBot3/    M18    +32    +15    +14    -7    -17
/AirOutBot4/    M18    +32    +18    +14    -7    -20
/AirOutShieldPlate1/    M18    +15    +28    -33
/AirOutShieldPlate2/    M18    +18    +28    -33
/AirOutTopThick1/    M18    +15    +29    -14
/AirOutTopThick2/    M18    +18    +29    -14
/AirOutTopThick3/    M18    +29    +15    +14    -7    -16
/AirOutTopThick4/    M18    +29    +18    +14    -7    -19
/AirOutTopVoid1/    M0    +16    +22    -25    +9
/AirOutTopVoid2/    M0    +19    +22    -25    +9
/AirOutMidVoid1/    M0    +16    +30    -34
/AirOutMidVoid2/    M0    +19    +30    -34
/AirOutBotVoid1/    M0    +16    +31    -14
/AirOutBotVoid2/    M0    +19    +31    -14
/AirOutWallTop1/    M18    +15    -16    +22    -25    +9
/AirOutWallTop2/    M18    +18    -19    +22    -25    +9
/AirOutWallMid1/    M18    +15    -16    +30    -34
/AirOutWallMid2/    M18    +18    -19    +30    -34
/AirOutWallBot1/    M18    +15    -16    +31    -7
/AirOutWallBot2/    M18    +18    -19    +31    -7
/ShellOpeningVoid1/    M0    +14    -7    +16    -29
/ShellOpeningVoid2/    M0    +14    -7    +19    -29
/ShellOpeningVoid3/    M0    +32    +14    -7    +17
/ShellOpeningVoid4/    M0    +32    +14    -7    +20
/ShellOpeningVoid5/    M0    +29    +14    -7    +16
/ShellOpeningVoid6/    M0    +29    +14    -7    +19
/FlangeVoid/    M0    +3    -12
/Cavity1/    M0    +35    -4    -10    -11    -12    -37        ! Outside support ring
        -47    -48    -70
/Cavity2/    M0    +35    +5    -10    -12                ! Inside support ring
/TSC/    P10    +37
/Container/    M0    +36    -9    -1
/TSCLid01/    M0    +38
/TSCLid02/    M0    +39    -38
/TSCLid03/    M0    +40    -39
/TSCLid04/    M0    +41    -40
/TSCLid05/    M0    +42    -41
/TSCLid06/    M0    +43    -42
/TSCLid07/    M0    +44    -43
/TSCLid08/    M0    +45    -44
/TSCLid09/    M0    +46    -45
/TSCLid10/    M0    +47    -46
/CanAziVoid/    M0    +48    -49    -50    -51    -52    -53
        -54    -55    -56    -57    -58    -59
        -60
/CanAziDet01/    M0    +49
/CanAziDet02/    M0    +50
/CanAziDet03/    M0    +51
/CanAziDet04/    M0    +52
/CanAziDet05/    M0    +53
/CanAziDet06/    M0    +54
/CanAziDet07/    M0    +55
/CanAziDet08/    M0    +56
/CanAziDet09/    M0    +57
/CanAziDet10/    M0    +58
/CanAziDet11/    M0    +59
/CanAziDet12/    M0    +60
/PlugTop01/    M0    +61
/PlugTop02/    M0    +62    -61
/PlugTop03/    M0    +63    -62
/PlugTop04/    M0    +64    -63
/PlugTop05/    M0    +65    -64
/PlugTop06/    M0    +66    -65
/PlugTop07/    M0    +67    -66
/PlugTop08/    M0    +68    -67
/PlugTop09/    M0    +69    -68
/PlugTop10/    M0    +70    -69
VOLUMES    53*1.0        10*3.1624E+03        1.0    12*2.6353E+02        10*3.1624E+03
*Storage Cask Bottom Geometry v1.6.0.0
PART    15
ZROD    1    0.0000    0.0000    53.5940    91.4400    5.0800            ! Base plate
ZCONE    2    0.0000    0.0000    2.5400    38.1000    29.2100    24.1300        ! Baffle weldment bot
ZCONE    3    0.0000    0.0000    2.5400    37.4543    28.5643    24.1300        ! Baffle weldment bot void
ZCONE    4    0.0000    0.0000    26.6700    29.2100    38.1000    24.1300        ! Baffle weldment top
ZCONE    5    0.0000    0.0000    26.6700    28.5643    37.4543    24.1300        ! Baffle weldment top void
ZROD    6    0.0000    0.0000    2.5400    63.5000    51.054            ! Stand outer
ZROD    7    0.0000    0.0000    2.5400    58.4200    51.054            ! Stand inner
ZP    8    33.0200                    ! Cut plane for stand
BOX    9    104.1710    -125.7236    0.0000    30.4800    325.1200    33.0200        ! Air inlet A void
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
        ZROT    -45.0000
BOX     10   103.4975    -126.3971    0.0000    32.3850    325.1200    35.5600        ! Air inlet A channel
        ZROT    -45.0000
BOX     11   -104.1710    -125.7236    0.0000    325.1200    30.4800    33.0200        ! Air inlet B void
        ZROT    -45.0000
BOX     12   -103.4975    -126.3971    0.0000    325.1200    32.3850    35.5600        ! Air inlet B channel
        ZROT    -45.0000
ZROD    13    0.0000    0.0000    0.0000    162.5600    2.5400            ! Bottom plate outer
ZROD    14    0.0000    0.0000    0.0000    63.5000    2.5400            ! Bottom plate inner
ZROD    15    0.0000    0.0000    2.5400    109.2200    56.1340            ! VCC shell outer
ZROD    16    0.0000    0.0000    2.5400    100.3300    56.1340            ! VCC shell inner
ZROD    17    0.0000    0.0000    2.5400    162.5600    56.1340            ! Concrete
ZROD    18    0.0000    0.0000    32.0675    99.6950    0.9525            ! Cover
BOX     19   -25.6540    -99.6950    33.0200    51.3080    199.3900    20.5740        ! Stand top cut box A
BOX     20   -99.6950    -25.6540    33.0200    199.3900    51.3080    20.5740        ! Stand top cut box B
ZROD    21    0.0000    0.0000    33.0200    99.6950    5.0800            ! Shield ring outer
ZROD    22    0.0000    0.0000    33.0200    90.1700    5.0800            ! Shield ring inner
BOX     23   35.2026    -56.7552    0.0000    71.1200    30.4800    33.0200        ! +x -y
        ZROT    45.0000
BOX     24   56.7552    35.2026    0.0000    71.1200    30.4800    33.0200        ! +x +y
        ZROT    -45.0000
BOX     25   -35.2026    56.7552    0.0000    71.1200    30.4800    33.0200        ! -x +y
        ZROT    -135.0000
BOX     26   -56.7552    -35.2026    0.0000    71.1200    30.4800    33.0200        ! -x -y
        ZROT    135.0000
ZROD    27    0.0000    0.0000    0.0000    162.5600    58.6740            ! Container
ZONES
/Container/    M0    +27    -17    -13
/BasePlate/    M18    +1
/BaffleTop/    M18    +4    -5
/BaffleTopVoid/    M0    +5
/BaffleBot/    M18    +2    -3
/BaffleBotVoid/    M0    +3
/InletAVoid/    M0    +9    -14    -7    +27    -23    -25        ! Outside of stand inner
/InletBVoid/    M0    +11    -14    -7    +27    -24    -26        ! Outside of stand inner
/PIM+x-y/    P13    +23                    ! PIM at +x - y
/PIM+x+y/    P13    +24                    ! PIM at +x + y
/PIM-x+y/    P13    +25                    ! PIM at -x + y
/PIM-x-y/    P13    +26                    ! PIM at -x - y
/InletAWalls/    M18    +10    -9    -6    +27    -14            ! Outside of stand outer
/InletBWalls/    M18    +12    -11    -6    +27    -14            ! Outside of stand outer
/VCCShell/    M18    +15    -16    -10    -12
/BotPlateInner/    M18    +14
/BotPlateOuter/    M18    +13    -14    -9    -11
/BaseVoid/    M0    +7    -2    -4                    ! Inside stand inner
/Concrete/    M23    +17    -15    -10    -12
/Cover/    M18    +18    -6    -10    -12
/StandBot/    M18    +6    -7    -8    -9    -11
/StandTop/    M18    +6    -7    +8    -19    -20
/ShieldRing/    M18    +21    -22    -10    -12
/StandTopVoid1/    M0    +6    +8    -7    +19
/StandTopVoid2/    M0    +6    +8    -7    +20
/ShieldRingVoid1/    M0    +22    -6    -10    -12                ! Inside the shield ring
/xyVoid/    M0    +16    -6    -10    -12    -8    -18
/OuterVoid/    M0    +16    -6    +8    -21    -1    -10    -12
VOLUMES UNITY
*Storage Cask Combined Geometry
PART    16
ZROD    1    0.0000    0.0000    -58.6740    162.5600    58.6740            ! Bottom
ZROD    2    0.0000    0.0000    0.0000    162.5600    351.2820            ! Top
ZROD    3    0.0000    0.0000    -158.6740    162.5600    100.0000            ! Concrete Pad
ZROD    4    0.0000    0.0000    -158.6740    162.5600    509.9560            ! Container
ZONES
/Bottom/    P15    +1
/Top/    P14    +2
/Concrete Pad/    M23    +3
/Container/    M0    +4    -3    -2    -1
VOLUMES UNITY
* Storage Cask Detector Description v1.6.0.0
PART    17
* Radial Detector DRA (Surface) Bodies
ZROD    1    0.0000    0.0000    -158.6740 162.5600  509.9560
ZROD    2    0.0000    0.0000    -58.6740  163.5600  40.9956
ZROD    3    0.0000    0.0000    -17.6784  163.5600  40.9956
ZROD    4    0.0000    0.0000    23.3172   163.5600  40.9956
ZROD    5    0.0000    0.0000    64.3128   163.5600  40.9956
ZROD    6    0.0000    0.0000    105.3084  163.5600  40.9956
ZROD    7    0.0000    0.0000    146.3040  163.5600  40.9956
ZROD    8    0.0000    0.0000    187.2996  163.5600  40.9956
ZROD    9    0.0000    0.0000    228.2952  163.5600  40.9956
ZROD    10   0.0000    0.0000    269.2908  163.5600  40.9956
ZROD    11   0.0000    0.0000    310.2864  163.5600  40.9956
* Radial Detector DRAA (Outlet) Bodies
ZROD    12   0.0000    0.0000    -159.6740 163.5600  511.9560
*   Band 1 Bodies
ZSEC    13   0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   342.0000  360.0000
ZSEC    14   0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   0.0000    18.0000
ZSEC    15   0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   18.0000   36.0000
ZSEC    16   0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   36.0000   54.0000
ZSEC    17   0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   54.0000   72.0000
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
ZSEC      18                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   72.0000   90.0000
ZSEC      19                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   90.0000   108.0000
ZSEC      20                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   108.0000  126.0000
ZSEC      21                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   126.0000  144.0000
ZSEC      22                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   144.0000  162.0000
ZSEC      23                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   162.0000  180.0000
ZSEC      24                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   180.0000  198.0000
ZSEC      25                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   198.0000  216.0000
ZSEC      26                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   216.0000  234.0000
ZSEC      27                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   234.0000  252.0000
ZSEC      28                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   252.0000  270.0000
ZSEC      29                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   270.0000  288.0000
ZSEC      30                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   288.0000  306.0000
ZSEC      31                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   306.0000  324.0000
ZSEC      32                  0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   324.0000  342.0000
* Radial Detector DRAB (Inlet) Bodies
ZROD      33                  0.0000    0.0000    -160.6740 164.5600  513.9560
*   Band 1 Bodies
ZSEC      34                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   40.0000   50.0000
ZSEC      35                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   50.0000   60.0000
ZSEC      36                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   60.0000   70.0000
ZSEC      37                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   70.0000   80.0000
ZSEC      38                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   80.0000   90.0000
ZSEC      39                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   90.0000   100.0000
ZSEC      40                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   100.0000  110.0000
ZSEC      41                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   110.0000  120.0000
ZSEC      42                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   120.0000  130.0000
ZSEC      43                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   130.0000  140.0000
ZSEC      44                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   140.0000  150.0000
ZSEC      45                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   150.0000  160.0000
ZSEC      46                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   160.0000  170.0000
ZSEC      47                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   170.0000  180.0000
ZSEC      48                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   180.0000  190.0000
ZSEC      49                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   190.0000  200.0000
ZSEC      50                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   200.0000  210.0000
ZSEC      51                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   210.0000  220.0000
ZSEC      52                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   220.0000  230.0000
ZSEC      53                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   230.0000  240.0000
ZSEC      54                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   240.0000  250.0000
ZSEC      55                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   250.0000  260.0000
ZSEC      56                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   260.0000  270.0000
ZSEC      57                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   270.0000  280.0000
ZSEC      58                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   280.0000  290.0000
ZSEC      59                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   290.0000  300.0000
ZSEC      60                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   300.0000  310.0000
ZSEC      61                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   310.0000  320.0000
ZSEC      62                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   320.0000  330.0000
ZSEC      63                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   330.0000  340.0000
ZSEC      64                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   340.0000  350.0000
ZSEC      65                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   350.0000  360.0000
ZSEC      66                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   360.0000  370.0000
ZSEC      67                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   10.0000   20.0000
ZSEC      68                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   20.0000   30.0000
ZSEC      69                  0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   30.0000   40.0000
* Radial Detector DRAC (RadAzi) Bodies
ZROD      70                  0.0000    0.0000    -161.6740 165.5600  515.9560
*   Band 1 Bodies
ZSEC      71                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   40.0000   50.0000
ZSEC      72                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   50.0000   60.0000
ZSEC      73                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   60.0000   70.0000
ZSEC      74                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   70.0000   80.0000
ZSEC      75                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   80.0000   90.0000
ZSEC      76                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   90.0000   100.0000
ZSEC      77                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   100.0000  110.0000
ZSEC      78                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   110.0000  120.0000
ZSEC      79                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   120.0000  130.0000
ZSEC      80                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   130.0000  140.0000
ZSEC      81                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   140.0000  150.0000
ZSEC      82                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   150.0000  160.0000
ZSEC      83                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   160.0000  170.0000
ZSEC      84                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   170.0000  180.0000
ZSEC      85                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   180.0000  190.0000
ZSEC      86                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   190.0000  200.0000
ZSEC      87                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   200.0000  210.0000
ZSEC      88                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   210.0000  220.0000
ZSEC      89                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   220.0000  230.0000
ZSEC      90                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   230.0000  240.0000
ZSEC      91                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   240.0000  250.0000
ZSEC      92                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   250.0000  260.0000
ZSEC      93                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   260.0000  270.0000
ZSEC      94                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   270.0000  280.0000
ZSEC      95                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   280.0000  290.0000
ZSEC      96                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   290.0000  300.0000
ZSEC      97                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   300.0000  310.0000
ZSEC      98                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   310.0000  320.0000
ZSEC      99                  0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   320.0000  330.0000
ZSEC      100                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   330.0000  340.0000
ZSEC      101                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   340.0000  350.0000
ZSEC      102                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   350.0000  360.0000
ZSEC      103                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   360.0000  370.0000
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
ZSEC      104                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   10.0000   20.0000
ZSEC      105                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   20.0000   30.0000
ZSEC      106                 0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   30.0000   40.0000
* Radial Detector DRB (1ft) Bodies
ZROD      107                 0.0000    0.0000    -162.6740 193.0400  544.4360
ZROD      108                 0.0000    0.0000    -58.6740  194.0400  36.7030
ZROD      109                 0.0000    0.0000    -21.9710  194.0400  36.7030
ZROD      110                 0.0000    0.0000    14.7320   194.0400  36.7030
ZROD      111                 0.0000    0.0000    51.4350   194.0400  36.7030
ZROD      112                 0.0000    0.0000    88.1380   194.0400  36.7030
ZROD      113                 0.0000    0.0000    124.8410  194.0400  36.7030
ZROD      114                 0.0000    0.0000    161.5440  194.0400  36.7030
ZROD      115                 0.0000    0.0000    198.2470  194.0400  36.7030
ZROD      116                 0.0000    0.0000    234.9500  194.0400  36.7030
ZROD      117                 0.0000    0.0000    271.6530  194.0400  36.7030
ZROD      118                 0.0000    0.0000    308.3560  194.0400  36.7030
ZROD      119                 0.0000    0.0000    345.0590  194.0400  36.7030
* Radial Detector DRC (1m) Bodies
ZROD      120                 0.0000    0.0000    -163.6740 262.5600  614.9560
ZROD      121                 0.0000    0.0000    -58.6740  263.5600  42.4963
ZROD      122                 0.0000    0.0000    -16.1777  263.5600  42.4963
ZROD      123                 0.0000    0.0000    26.3187   263.5600  42.4963
ZROD      124                 0.0000    0.0000    68.8150   263.5600  42.4963
ZROD      125                 0.0000    0.0000    111.3113  263.5600  42.4963
ZROD      126                 0.0000    0.0000    153.8077  263.5600  42.4963
ZROD      127                 0.0000    0.0000    196.3040  263.5600  42.4963
ZROD      128                 0.0000    0.0000    238.8003  263.5600  42.4963
ZROD      129                 0.0000    0.0000    281.2967  263.5600  42.4963
ZROD      130                 0.0000    0.0000    323.7930  263.5600  42.4963
ZROD      131                 0.0000    0.0000    366.2893  263.5600  42.4963
ZROD      132                 0.0000    0.0000    408.7857  263.5600  42.4963
* Radial Detector DRD (2m) Bodies
ZROD      133                 0.0000    0.0000    -164.6740 362.5600  715.9560
ZROD      134                 0.0000    0.0000    -58.6740  363.5600  30.4978
ZROD      135                 0.0000    0.0000    -28.1762  363.5600  30.4978
ZROD      136                 0.0000    0.0000    2.3216    363.5600  30.4978
ZROD      137                 0.0000    0.0000    32.8194   363.5600  30.4978
ZROD      138                 0.0000    0.0000    63.3172   363.5600  30.4978
ZROD      139                 0.0000    0.0000    93.8150   363.5600  30.4978
ZROD      140                 0.0000    0.0000    124.3128  363.5600  30.4978
ZROD      141                 0.0000    0.0000    154.8106  363.5600  30.4978
ZROD      142                 0.0000    0.0000    185.3084  363.5600  30.4978
ZROD      143                 0.0000    0.0000    215.8062  363.5600  30.4978
ZROD      144                 0.0000    0.0000    246.3040  363.5600  30.4978
ZROD      145                 0.0000    0.0000    276.8018  363.5600  30.4978
ZROD      146                 0.0000    0.0000    307.2996  363.5600  30.4978
ZROD      147                 0.0000    0.0000    337.7974  363.5600  30.4978
ZROD      148                 0.0000    0.0000    368.2952  363.5600  30.4978
ZROD      149                 0.0000    0.0000    398.7930  363.5600  30.4978
ZROD      150                 0.0000    0.0000    429.2908  363.5600  30.4978
ZROD      151                 0.0000    0.0000    459.7886  363.5600  30.4978
ZROD      152                 0.0000    0.0000    490.2864  363.5600  30.4978
ZROD      153                 0.0000    0.0000    520.7842  363.5600  30.4978
* Radial Detector DRE (4m) Bodies
ZROD      154                 0.0000    0.0000    -165.6740 562.5600  916.9560
ZROD      155                 0.0000    0.0000    -58.6740  563.5600  40.4978
ZROD      156                 0.0000    0.0000    -18.1762  563.5600  40.4978
ZROD      157                 0.0000    0.0000    22.3216   563.5600  40.4978
ZROD      158                 0.0000    0.0000    62.8194   563.5600  40.4978
ZROD      159                 0.0000    0.0000    103.3172  563.5600  40.4978
ZROD      160                 0.0000    0.0000    143.8150  563.5600  40.4978
ZROD      161                 0.0000    0.0000    184.3128  563.5600  40.4978
ZROD      162                 0.0000    0.0000    224.8106  563.5600  40.4978
ZROD      163                 0.0000    0.0000    265.3084  563.5600  40.4978
ZROD      164                 0.0000    0.0000    305.8062  563.5600  40.4978
ZROD      165                 0.0000    0.0000    346.3040  563.5600  40.4978
ZROD      166                 0.0000    0.0000    386.8018  563.5600  40.4978
ZROD      167                 0.0000    0.0000    427.2996  563.5600  40.4978
ZROD      168                 0.0000    0.0000    467.7974  563.5600  40.4978
ZROD      169                 0.0000    0.0000    508.2952  563.5600  40.4978
ZROD      170                 0.0000    0.0000    548.7930  563.5600  40.4978
ZROD      171                 0.0000    0.0000    589.2908  563.5600  40.4978
ZROD      172                 0.0000    0.0000    629.7886  563.5600  40.4978
ZROD      173                 0.0000    0.0000    670.2864  563.5600  40.4978
ZROD      174                 0.0000    0.0000    710.7842  563.5600  40.4978
* World
ZROD      175                 0.0000    0.0000    -215.6740 612.5600  1016.9560
* External Void
ZROD      176                 0.0000    0.0000    -265.6740 662.5600  1116.9560

ZONES
/StorageCask/       P16       +1
* Detector DRA (Surface)
/DRA01/   M0        +2        -1
/DRA02/   M0        +3        -1
/DRA03/   M0        +4        -1
/DRA04/   M0        +5        -1
/DRA05/   M0        +6        -1
/DRA06/   M0        +7        -1
/DRA07/   M0        +8        -1
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
/DRA08/   M0        +9        -1
/DRA09/   M0        +10       -1
/DRA10/   M0        +11       -1
/Void/    M0        +12       -1
                    -2        -3        -4        -5        -6        -7
                    -8        -9        -10       -11
* Detector DRAA (Outlet)
/DRAA0101/          M0        +13
/DRAA0102/          M0        +14
/DRAA0103/          M0        +15
/DRAA0104/          M0        +16
/DRAA0105/          M0        +17
/DRAA0106/          M0        +18
/DRAA0107/          M0        +19
/DRAA0108/          M0        +20
/DRAA0109/          M0        +21
/DRAA0110/          M0        +22
/DRAA0111/          M0        +23
/DRAA0112/          M0        +24
/DRAA0113/          M0        +25
/DRAA0114/          M0        +26
/DRAA0115/          M0        +27
/DRAA0116/          M0        +28
/DRAA0117/          M0        +29
/DRAA0118/          M0        +30
/DRAA0119/          M0        +31
/DRAA0120/          M0        +32
/Void/    M0        +33       -12
                    -13       -14       -15       -16       -17       -18
                    -19       -20       -21       -22       -23       -24
                    -25       -26       -27       -28       -29       -30
                    -31       -32
* Detector DRAB (Inlet)
/DRAB0101/          M0        +34
/DRAB0102/          M0        +35
/DRAB0103/          M0        +36
/DRAB0104/          M0        +37
/DRAB0105/          M0        +38
/DRAB0106/          M0        +39
/DRAB0107/          M0        +40
/DRAB0108/          M0        +41
/DRAB0109/          M0        +42
/DRAB0110/          M0        +43
/DRAB0111/          M0        +44
/DRAB0112/          M0        +45
/DRAB0113/          M0        +46
/DRAB0114/          M0        +47
/DRAB0115/          M0        +48
/DRAB0116/          M0        +49
/DRAB0117/          M0        +50
/DRAB0118/          M0        +51
/DRAB0119/          M0        +52
/DRAB0120/          M0        +53
/DRAB0121/          M0        +54
/DRAB0122/          M0        +55
/DRAB0123/          M0        +56
/DRAB0124/          M0        +57
/DRAB0125/          M0        +58
/DRAB0126/          M0        +59
/DRAB0127/          M0        +60
/DRAB0128/          M0        +61
/DRAB0129/          M0        +62
/DRAB0130/          M0        +63
/DRAB0131/          M0        +64
/DRAB0132/          M0        +65
/DRAB0133/          M0        +66
/DRAB0134/          M0        +67
/DRAB0135/          M0        +68
/DRAB0136/          M0        +69
/Void/    M0        +70       -33
                    -34       -35       -36       -37       -38       -39
                    -40       -41       -42       -43       -44       -45
                    -46       -47       -48       -49       -50       -51
                    -52       -53       -54       -55       -56       -57
                    -58       -59       -60       -61       -62       -63
                    -64       -65       -66       -67       -68       -69
* Detector DRAC (RadAzi)
/DRAC0101/          M0        +71
/DRAC0102/          M0        +72
/DRAC0103/          M0        +73
/DRAC0104/          M0        +74
/DRAC0105/          M0        +75
/DRAC0106/          M0        +76
/DRAC0107/          M0        +77
/DRAC0108/          M0        +78
/DRAC0109/          M0        +79
/DRAC0110/          M0        +80
/DRAC0111/          M0        +81
/DRAC0112/          M0        +82
/DRAC0113/          M0        +83
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
/DRAC0114/          M0        +84
/DRAC0115/          M0        +85
/DRAC0116/          M0        +86
/DRAC0117/          M0        +87
/DRAC0118/          M0        +88
/DRAC0119/          M0        +89
/DRAC0120/          M0        +90
/DRAC0121/          M0        +91
/DRAC0122/          M0        +92
/DRAC0123/          M0        +93
/DRAC0124/          M0        +94
/DRAC0125/          M0        +95
/DRAC0126/          M0        +96
/DRAC0127/          M0        +97
/DRAC0128/          M0        +98
/DRAC0129/          M0        +99
/DRAC0130/          M0        +100
/DRAC0131/          M0        +101
/DRAC0132/          M0        +102
/DRAC0133/          M0        +103
/DRAC0134/          M0        +104
/DRAC0135/          M0        +105
/DRAC0136/          M0        +106
/Void/    M0        +107      -70
                    -71       -72       -73       -74       -75       -76
                    -77       -78       -79       -80       -81       -82
                    -83       -84       -85       -86       -87       -88
                    -89       -90       -91       -92       -93       -94
                    -95       -96       -97       -98       -99       -100
                    -101      -102      -103      -104      -105      -106
* Detector DRB (1ft)
/DRB01/   M0        +108      -107
/DRB02/   M0        +109      -107
/DRB03/   M0        +110      -107
/DRB04/   M0        +111      -107
/DRB05/   M0        +112      -107
/DRB06/   M0        +113      -107
/DRB07/   M0        +114      -107
/DRB08/   M0        +115      -107
/DRB09/   M0        +116      -107
/DRB10/   M0        +117      -107
/DRB11/   M0        +118      -107
/DRB12/   M0        +119      -107
/Void/    M0        +120      -107
                    -108      -109      -110      -111      -112      -113
                    -114      -115      -116      -117      -118      -119
* Detector DRC (1m)
/DRC01/   M0        +121      -120
/DRC02/   M0        +122      -120
/DRC03/   M0        +123      -120
/DRC04/   M0        +124      -120
/DRC05/   M0        +125      -120
/DRC06/   M0        +126      -120
/DRC07/   M0        +127      -120
/DRC08/   M0        +128      -120
/DRC09/   M0        +129      -120
/DRC10/   M0        +130      -120
/DRC11/   M0        +131      -120
/DRC12/   M0        +132      -120
/Void/    M0        +133      -120
                    -121      -122      -123      -124      -125      -126
                    -127      -128      -129      -130      -131      -132
* Detector DRD (2m)
/DRD01/   M0        +134      -133
/DRD02/   M0        +135      -133
/DRD03/   M0        +136      -133
/DRD04/   M0        +137      -133
/DRD05/   M0        +138      -133
/DRD06/   M0        +139      -133
/DRD07/   M0        +140      -133
/DRD08/   M0        +141      -133
/DRD09/   M0        +142      -133
/DRD10/   M0        +143      -133
/DRD11/   M0        +144      -133
/DRD12/   M0        +145      -133
/DRD13/   M0        +146      -133
/DRD14/   M0        +147      -133
/DRD15/   M0        +148      -133
/DRD16/   M0        +149      -133
/DRD17/   M0        +150      -133
/DRD18/   M0        +151      -133
/DRD19/   M0        +152      -133
/DRD20/   M0        +153      -133
/Void/    M0        +154      -133
                    -134      -135      -136      -137      -138      -139
                    -140      -141      -142      -143      -144      -145
                    -146      -147      -148      -149      -150      -151
                    -152      -153
* Detector DRE (4m)
/DRE01/   M0        +155      -154
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
/DRE02/   M0        +156      -154
/DRE03/   M0        +157      -154
/DRE04/   M0        +158      -154
/DRE05/   M0        +159      -154
/DRE06/   M0        +160      -154
/DRE07/   M0        +161      -154
/DRE08/   M0        +162      -154
/DRE09/   M0        +163      -154
/DRE10/   M0        +164      -154
/DRE11/   M0        +165      -154
/DRE12/   M0        +166      -154
/DRE13/   M0        +167      -154
/DRE14/   M0        +168      -154
/DRE15/   M0        +169      -154
/DRE16/   M0        +170      -154
/DRE17/   M0        +171      -154
/DRE18/   M0        +172      -154
/DRE19/   M0        +173      -154
/DRE20/   M0        +174      -154
/Void/    M0        +175      -154
                    -155      -156      -157      -158      -159      -160
                    -161      -162      -163      -164      -165      -166
                    -167      -168      -169      -170      -171      -172
                    -173      -174
/ExtVoid/ M-2000    +176      -175
Volumes
                    1.0       10*4.2001E+04       1.0       20*5.2366E+02       1.0       36*9.5125E+02
                    1.0       36*8.6949E+02       1.0       12*4.4633E+04       1.0       12*7.0240E+04
                    1.0       20*6.9571E+04       1.0       20*1.4327E+05       1.0       1.0
end

*
* Unit 5 Splitting Geometry for Radial Detectors - Gamma
*
begin splitting geometry
    r    39    fill    0.0000
                  n    10    87.4649
                  n    2    100.3300
                  n    7    109.2200
                  n    18    162.5600
                  n    1    163.5600
                  n    1    168.5600

    z    66    fill    -158.6740
                  n    1    -68.6740
                  n    4    -58.6740
                  n    2    -56.1340
                  n    4    -5.0800
                  n    4    0.0000
                  n    2    2.5400
                  n    2    26.1620
                  n    13    257.3020
                  n    1    266.2174
                  n    2    286.4866
                  n    1    290.8300
                  n    9    303.5300
                  n    6    311.1500
                  n    1    326.5170
                  n    7    336.0420
                  n    1    338.5820
                  n    1    339.5345
                  n    1    347.4720
                  n    3    351.2820
                  n    1    352.2820

end
*
* Unit 6 - Source Geometry for Fuel Gamma
*
begin source geometry
    r    11    fill    0.0000    n    11    87.4649
    z    13
        26.1620    33.8667    41.5713    49.2760    56.9807    64.6853
        72.3900    187.9600    211.0740    220.3196    229.5652
        238.8108    248.0564    257.3020
end

*
* Unit 7
*
begin energy data
    gamma    dice
    importance    standard    22    groups
    scoring    as    importance
    simple    source    histogram    weighting    automatic
end

*
* Unit 8 Importance Map - Radial
*
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
begin importance map
    calculate
    targets    10
    part    17
    zones
        2    3    4    5    6
        7    8    9    10    11
    strengths
        1.0E+02    1.0E+01    1.0E+00    1.0E+00    1.0E+00
        1.0E+00    1.0E+00    1.0E+00    1.0E+01    1.0E+02
    defer mixing
    void density    0.10
    track
!    coupled source
!    write gamma importances to 32
!    write unformatted file to 31
!    use method d
end

*
* Unit 9 Scoring Data - Radial
*
begin scoring data
    flux
    part    17
    from    2    to    11    ! DRA
    from    13    to    32    ! DRAA
    from    34    to    69    ! DRAB
    from    71    to    106    ! DRAC
    from    108    to    119    ! DRB
    from    121    to    132    ! DRC
    from    134    to    153    ! DRD
    from    155    to    174    ! DRE
    responses    sos    ditto
    contributions to responses        ditto
    ! score distribution for response
    ! weight distribution    total
end

*
* Unit 10 Response Data
*
begin response data
* Scaled to mrem/hr
/ansi ans-6.1.1-1977 photon flux-dose conversion factors - mcnp table h.2 - mrem/
          function pairs
          1.5000E+01          1.3300E-02
          1.4787E+01          1.3142E-02
          1.4577E+01          1.2985E-02
          1.4370E+01          1.2831E-02
          1.4166E+01          1.2678E-02
          1.3964E+01          1.2528E-02
          1.3766E+01          1.2379E-02
          1.3570E+01          1.2231E-02
          1.3377E+01          1.2086E-02
          1.3187E+01          1.1942E-02
          1.3000E+01          1.1800E-02
          1.2785E+01          1.1641E-02
          1.2573E+01          1.1483E-02
          1.2365E+01          1.1328E-02
          1.2160E+01          1.1175E-02
          1.1958E+01          1.1025E-02
          1.1760E+01          1.0876E-02
          1.1565E+01          1.0729E-02
          1.1374E+01          1.0584E-02
          1.1185E+01          1.0441E-02
          1.1000E+01          1.0300E-02
          1.0781E+01          1.0136E-02
          1.0567E+01          9.9740E-03
          1.0357E+01          9.8149E-03
          1.0152E+01          9.6583E-03
          9.9499E+00          9.5043E-03
          9.7522E+00          9.3526E-03
          9.5585E+00          9.2035E-03
          9.3686E+00          9.0566E-03
          9.1824E+00          8.9122E-03
          9.0000E+00          8.7700E-03
          8.8374E+00          8.6521E-03
          8.6777E+00          8.5358E-03
          8.5210E+00          8.4211E-03
          8.3670E+00          8.3079E-03
          8.2158E+00          8.1962E-03
          8.0674E+00          8.0861E-03
          7.9216E+00          7.9774E-03
          7.7785E+00          7.8701E-03
          7.6380E+00          7.7644E-03
          7.5000E+00          7.6600E-03
          7.4214E+00          7.6031E-03
          7.3436E+00          7.5467E-03
          7.2666E+00          7.4907E-03
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
7.1905E+00          7.4351E-03
7.1151E+00          7.3799E-03
7.0406E+00          7.3251E-03
6.9668E+00          7.2707E-03
6.8937E+00          7.2167E-03
6.8215E+00          7.1632E-03
6.7500E+00          7.1100E-03
6.6983E+00          7.0721E-03
6.6469E+00          7.0344E-03
6.5959E+00          6.9969E-03
6.5454E+00          6.9596E-03
6.4952E+00          6.9225E-03
6.4454E+00          6.8856E-03
6.3960E+00          6.8489E-03
6.3469E+00          6.8124E-03
6.2983E+00          6.7761E-03
6.2500E+00          6.7400E-03
6.1981E+00          6.7021E-03
6.1466E+00          6.6643E-03
6.0956E+00          6.6268E-03
6.0450E+00          6.5895E-03
5.9948E+00          6.5524E-03
5.9450E+00          6.5155E-03
5.8956E+00          6.4788E-03
5.8467E+00          6.4423E-03
5.7981E+00          6.4061E-03
5.7500E+00          6.3700E-03
5.6979E+00          6.3331E-03
5.6463E+00          6.2963E-03
5.5952E+00          6.2598E-03
5.5445E+00          6.2235E-03
5.4943E+00          6.1874E-03
5.4446E+00          6.1515E-03
5.3953E+00          6.1158E-03
5.3464E+00          6.0803E-03
5.2980E+00          6.0451E-03
5.2500E+00          6.0100E-03
5.2244E+00          5.9887E-03
5.1990E+00          5.9674E-03
5.1737E+00          5.9462E-03
5.1485E+00          5.9251E-03
5.1235E+00          5.9041E-03
5.0985E+00          5.8831E-03
5.0737E+00          5.8622E-03
5.0490E+00          5.8414E-03
5.0245E+00          5.8207E-03
5.0000E+00          5.8000E-03
4.9744E+00          5.7797E-03
4.9490E+00          5.7594E-03
4.9236E+00          5.7393E-03
4.8985E+00          5.7192E-03
4.8734E+00          5.6991E-03
4.8485E+00          5.6792E-03
4.8237E+00          5.6593E-03
4.7990E+00          5.6394E-03
4.7744E+00          5.6197E-03
4.7500E+00          5.6000E-03
4.6975E+00          5.5619E-03
4.6455E+00          5.5240E-03
4.5941E+00          5.4863E-03
4.5433E+00          5.4490E-03
4.4931E+00          5.4118E-03
4.4434E+00          5.3750E-03
4.3942E+00          5.3384E-03
4.3456E+00          5.3020E-03
4.2975E+00          5.2659E-03
4.2500E+00          5.2300E-03
4.1971E+00          5.1886E-03
4.1449E+00          5.1474E-03
4.0934E+00          5.1066E-03
4.0425E+00          5.0662E-03
3.9922E+00          5.0260E-03
3.9425E+00          4.9862E-03
3.8935E+00          4.9467E-03
3.8451E+00          4.9075E-03
3.7972E+00          4.8686E-03
3.7500E+00          4.8300E-03
3.6967E+00          4.7863E-03
3.6442E+00          4.7429E-03
3.5924E+00          4.7000E-03
3.5414E+00          4.6574E-03
3.4911E+00          4.6152E-03
3.4415E+00          4.5734E-03
3.3926E+00          4.5320E-03
3.3444E+00          4.4910E-03
3.2968E+00          4.4503E-03
3.2500E+00          4.4100E-03
3.2019E+00          4.3683E-03
3.1546E+00          4.3269E-03
3.1079E+00          4.2860E-03
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
3.0619E+00          4.2454E-03
3.0166E+00          4.2052E-03
2.9720E+00          4.1655E-03
2.9280E+00          4.1260E-03
2.8847E+00          4.0870E-03
2.8420E+00          4.0483E-03
2.8000E+00          4.0100E-03
2.7793E+00          3.9906E-03
2.7588E+00          3.9713E-03
2.7384E+00          3.9520E-03
2.7182E+00          3.9329E-03
2.6981E+00          3.9138E-03
2.6782E+00          3.8949E-03
2.6585E+00          3.8760E-03
2.6388E+00          3.8573E-03
2.6193E+00          3.8386E-03
2.6000E+00          3.8200E-03
2.5569E+00          3.7780E-03
2.5146E+00          3.7364E-03
2.4729E+00          3.6953E-03
2.4319E+00          3.6547E-03
2.3917E+00          3.6145E-03
2.3520E+00          3.5747E-03
2.3131E+00          3.5354E-03
2.2747E+00          3.4965E-03
2.2371E+00          3.4580E-03
2.2000E+00          3.4200E-03
2.1563E+00          3.3744E-03
2.1135E+00          3.3293E-03
2.0715E+00          3.2849E-03
2.0303E+00          3.2410E-03
1.9900E+00          3.1978E-03
1.9504E+00          3.1551E-03
1.9117E+00          3.1130E-03
1.8737E+00          3.0714E-03
1.8365E+00          3.0304E-03
1.8000E+00          2.9900E-03
1.7553E+00          2.9381E-03
1.7118E+00          2.8872E-03
1.6693E+00          2.8371E-03
1.6279E+00          2.7879E-03
1.5875E+00          2.7395E-03
1.5481E+00          2.6920E-03
1.5096E+00          2.6453E-03
1.4722E+00          2.5994E-03
1.4356E+00          2.5543E-03
1.4000E+00          2.5100E-03
1.3537E+00          2.4512E-03
1.3089E+00          2.3937E-03
1.2656E+00          2.3376E-03
1.2237E+00          2.2828E-03
1.1832E+00          2.2293E-03
1.1441E+00          2.1771E-03
1.1062E+00          2.1260E-03
1.0696E+00          2.0762E-03
1.0342E+00          2.0275E-03
1.0000E+00          1.9800E-03
9.7793E-01          1.9477E-03
9.5635E-01          1.9160E-03
9.3525E-01          1.8848E-03
9.1461E-01          1.8541E-03
8.9443E-01          1.8238E-03
8.7469E-01          1.7941E-03
8.5539E-01          1.7649E-03
8.3651E-01          1.7361E-03
8.1805E-01          1.7078E-03
8.0000E-01          1.6800E-03
7.8939E-01          1.6633E-03
7.7892E-01          1.6467E-03
7.6859E-01          1.6303E-03
7.5839E-01          1.6141E-03
7.4833E-01          1.5980E-03
7.3841E-01          1.5821E-03
7.2861E-01          1.5663E-03
7.1895E-01          1.5507E-03
7.0941E-01          1.5353E-03
7.0000E-01          1.5200E-03
6.9483E-01          1.5118E-03
6.8970E-01          1.5037E-03
6.8461E-01          1.4955E-03
6.7955E-01          1.4875E-03
6.7454E-01          1.4795E-03
6.6956E-01          1.4715E-03
6.6461E-01          1.4635E-03
6.5971E-01          1.4557E-03
6.5483E-01          1.4478E-03
6.5000E-01          1.4400E-03
6.4482E-01          1.4318E-03
6.3968E-01          1.4236E-03
6.3458E-01          1.4155E-03
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
6.2952E-01          1.4075E-03
6.2450E-01          1.3994E-03
6.1952E-01          1.3915E-03
6.1458E-01          1.3835E-03
6.0968E-01          1.3756E-03
6.0482E-01          1.3678E-03
6.0000E-01          1.3600E-03
5.9480E-01          1.3507E-03
5.8965E-01          1.3415E-03
5.8454E-01          1.3324E-03
5.7948E-01          1.3233E-03
5.7446E-01          1.3142E-03
5.6948E-01          1.3053E-03
5.6455E-01          1.2964E-03
5.5966E-01          1.2875E-03
5.5481E-01          1.2787E-03
5.5000E-01          1.2700E-03
5.4478E-01          1.2596E-03
5.3962E-01          1.2493E-03
5.3450E-01          1.2391E-03
5.2943E-01          1.2290E-03
5.2440E-01          1.2190E-03
5.1943E-01          1.2090E-03
5.1450E-01          1.1991E-03
5.0962E-01          1.1893E-03
5.0479E-01          1.1796E-03
5.0000E-01          1.1700E-03
4.9476E-01          1.1607E-03
4.8957E-01          1.1514E-03
4.8444E-01          1.1422E-03
4.7937E-01          1.1331E-03
4.7434E-01          1.1241E-03
4.6937E-01          1.1151E-03
4.6445E-01          1.1062E-03
4.5958E-01          1.0974E-03
4.5477E-01          1.0887E-03
4.5000E-01          1.0800E-03
4.4473E-01          1.0701E-03
4.3952E-01          1.0603E-03
4.3438E-01          1.0506E-03
4.2929E-01          1.0409E-03
4.2426E-01          1.0314E-03
4.1930E-01          1.0220E-03
4.1439E-01          1.0126E-03
4.0953E-01          1.0033E-03
4.0474E-01          9.9411E-04
4.0000E-01          9.8500E-04
3.9469E-01          9.7374E-04
3.8946E-01          9.6260E-04
3.8429E-01          9.5160E-04
3.7920E-01          9.4072E-04
3.7417E-01          9.2996E-04
3.6920E-01          9.1933E-04
3.6431E-01          9.0882E-04
3.5947E-01          8.9843E-04
3.5470E-01          8.8815E-04
3.5000E-01          8.7800E-04
3.4465E-01          8.6531E-04
3.3937E-01          8.5279E-04
3.3418E-01          8.4046E-04
3.2907E-01          8.2831E-04
3.2404E-01          8.1633E-04
3.1908E-01          8.0453E-04
3.1420E-01          7.9290E-04
3.0939E-01          7.8143E-04
3.0466E-01          7.7014E-04
3.0000E-01          7.5900E-04
2.9458E-01          7.4511E-04
2.8926E-01          7.3147E-04
2.8403E-01          7.1809E-04
2.7890E-01          7.0495E-04
2.7386E-01          6.9205E-04
2.6891E-01          6.7938E-04
2.6405E-01          6.6695E-04
2.5928E-01          6.5474E-04
2.5460E-01          6.4276E-04
2.5000E-01          6.3100E-04
2.4448E-01          6.1661E-04
2.3909E-01          6.0255E-04
2.3381E-01          5.8881E-04
2.2865E-01          5.7538E-04
2.2361E-01          5.6226E-04
2.1867E-01          5.4943E-04
2.1385E-01          5.3690E-04
2.0913E-01          5.2466E-04
2.0451E-01          5.1269E-04
2.0000E-01          5.0100E-04
1.9433E-01          4.8721E-04
1.8882E-01          4.7380E-04
1.8346E-01          4.6076E-04
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
          1.7826E-01          4.4808E-04
          1.7321E-01          4.3575E-04
          1.6829E-01          4.2376E-04
          1.6352E-01          4.1210E-04
          1.5888E-01          4.0075E-04
          1.5438E-01          3.8973E-04
          1.5000E-01          3.7900E-04
          1.4404E-01          3.6809E-04
          1.3832E-01          3.5749E-04
          1.3282E-01          3.4720E-04
          1.2754E-01          3.3721E-04
          1.2247E-01          3.2750E-04
          1.1761E-01          3.1807E-04
          1.1293E-01          3.0892E-04
          1.0845E-01          3.0002E-04
          1.0414E-01          2.9139E-04
          1.0000E-01          2.8300E-04
          9.6496E-02          2.8039E-04
          9.3115E-02          2.7781E-04
          8.9852E-02          2.7526E-04
          8.6704E-02          2.7272E-04
          8.3666E-02          2.7021E-04
          8.0734E-02          2.6772E-04
          7.7906E-02          2.6526E-04
          7.5176E-02          2.6282E-04
          7.2542E-02          2.6040E-04
          7.0000E-02          2.5800E-04
          6.7684E-02          2.6103E-04
          6.5444E-02          2.6410E-04
          6.3279E-02          2.6721E-04
          6.1185E-02          2.7035E-04
          5.9161E-02          2.7353E-04
          5.7203E-02          2.7675E-04
          5.5311E-02          2.8000E-04
          5.3481E-02          2.8330E-04
          5.1711E-02          2.8663E-04
          5.0000E-02          2.9000E-04
          4.7510E-02          3.1092E-04
          4.5144E-02          3.3335E-04
          4.2896E-02          3.5740E-04
          4.0760E-02          3.8318E-04
          3.8730E-02          4.1083E-04
          3.6801E-02          4.4047E-04
          3.4968E-02          4.7224E-04
          3.3227E-02          5.0631E-04
          3.1572E-02          5.4284E-04
          3.0000E-02          5.8200E-04
          2.6879E-02          7.0502E-04
          2.4082E-02          8.5404E-04
          2.1577E-02          1.0346E-03
          1.9332E-02          1.2532E-03
          1.7321E-02          1.5181E-03
          1.5518E-02          1.8390E-03
          1.3904E-02          2.2277E-03
          1.2457E-02          2.6986E-03
          1.1161E-02          3.2690E-03
          1.0000E-02          3.9600E-03
end

*
* Unit 13 Hole Data
*
begin hole data
* Canister Hole Description v1.0
* Hole    1    BORAL Core
PLATE
1    0    0
2
0.1905    13
0.0000    12
13

* Hole    2    General Basket Structure
PLATE
0    0    1
7
286.5120    0            ! Top of Basket
258.0894    -3            ! Top of Highest Support Disk
212.0138    -8            ! Resume support disk only
55.1942    -5            ! Start of support+heat disk region
21.5900    -7            ! Bottom of Lowest Support Disk
0.0000    -4            ! Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole    3    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
86.3346
87.6046
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
5                 ! number of axial intervals
258.0894                ! Top of diskstack
269.2400                ! Bottom of weldment
270.5100                ! Top of weldment plate
270.5100                ! Ullage
283.9720                ! Flange
286.5120                ! Void to top of basket
0    0             ! Material below weldment
15    15             ! Plate Material
0    15             ! Ullage
0    15             ! Flange
0    0             ! Void to top of basket
0                 ! Outside material

* Hole    4    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                 ! number of radial points
87.6046
1                 ! number of axial intervals
3.8100
5.0800                ! Coordinates inherited from PLATE Hole
15                ! Plate Material
0                 ! Outside material

* Hole    5    Support disk and heat transfer disk stack
PLATE
origin    0    0    55.1942    ! Origin
0    0    1
4
CELL    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
6.8707    0            ! water gap
5.6007    16            ! aluminium disk
1.2700    0            ! water gap
14                ! steel disk

* Hole    6    Flood material model
PLATE
0    0    1
1
276.3618    0            ! Above flooded region
0                 ! Flooded region

* Hole    7    Support disk stack lower
PLATE
origin    0    0    21.5900    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
1.2700    0            ! water gap
14                ! steel disk

* Hole    8    Support disk stack upper
PLATE
origin    0    0    212.0138    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
1.2700    0            ! water gap
14                ! steel disk

end

*
* Unit 15 Source Strength - Fuel Gamma
*
* Class Yankee MPC - ce16y - CE16 (Rev 1) - Fuel Gamma - ce16y_36b37e08y
begin source strength
    component        1.1610E-05    ! 1/(volAssy) (1/8.6133E+04)
    component    r    11*1.0
    component    z
        6.0000E-01    7.0000E-01    8.0000E-01    9.0000E-01    1.0000E+00    1.1000E+00
        1.1500E+00        1.1000E+00    1.0250E+00    8.7500E-01    7.2500E-01
        5.7500E-01    4.2500E-01
    component    energy
        0.0000E+00    1.9491E+03    3.7701E+04    1.7759E+05    9.0547E+05    2.2566E+06
        6.2676E+08    5.1214E+09    1.0789E+11    9.9933E+10    1.6057E+12    2.3679E+13
        1.2298E+13    6.3503E+13    8.2332E+14    1.1897E+14    1.7831E+13    2.8386E+13
        1.0201E+14    1.3136E+14    3.0385E+14    2.0898E+14
end

*
* Unit 16 Simple Source Weights
*
*begin source weights
*
*end
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
*
* Unit 31 Tabular Output
*
begin tabular output
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRA - Surface - Response/
    response    interim
    number    some    1
    region    from    223    to    232
    output to file    also
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRAB - Inlet - Response/
    response
    number    some    1
    region    from    255    to    290
    output to file    also
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRB - 1ft - Response/
    response
    number    some    1
    region    from    329    to    340
    output to file    also
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRC - 1m - Response/
    response
    number    some    1
    region    from    342    to    353
    output to file    also
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRD - 2m - Response/
    response
    number    some    1
    region    from    355    to    374
    output to file    also
    /Case strStlDryRadFg_ce16y_36b37e08y - Det DRE - 4m - Response/
    response
    number    some    1
    region    from    376    to    395
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    gamma
normalise
nmixtures    4
weight    mixture    1
            u235    3.2615E-02
            u238    8.4888E-01
            o    1.1850E-01
atoms    mixture    2
            h    6.6667E-01
            o    3.3333E-01
weight    mixture    3
            al    5.8260E-01
            b10    4.5690E-02
            b11    2.7769E-01
            c    9.4020E-02
atoms    mixture    4
            c    2.8571E-01
            h    4.7619E-01
            o    2.3810E-01
*
* Materials List - Dry Conditions - v1.2 - Class Yankee MPC - ce16y - CE16 (Rev 1) Fuel
*
nmaterials    26
volume                              ! Homogenized fuel
material    1
    mixture    1    density    10.4120    prop    3.0283E-01    ! UO2 mixture at 3.7%
    void                prop    1.2812E-02    ! Gap
    zircalloy        density    6.5500    prop    1.2736E-01    ! Tube, clad
!    stainless 304l steel        density    7.9200    prop    0.0000E+00    ! Stainless steel hw
    zircalloy        density    6.5500    prop    3.4595E-03    ! Zircaloy hw
    void                prop    5.5354E-01    ! Interstitial, inside tubes
volume                              ! Fuel pin cladding
material    2
    zircalloy        density    6.5500    prop    1.0000
volume                              ! Water In Lattice and Tube
material    3
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                              ! Water In Fuel Rod Clad Gap
material    4
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                              ! Lower Nozzle Material
material    5
    stainless 304l steel        density    7.9200    prop    0.0965
    void                prop    0.9035
volume                              ! Lower Plenum Material
material    6
    stainless 304l steel        density    7.9200    prop    0.1094
    zircalloy        density    6.5500    prop    0.0373
    void                prop    0.8533
volume                              ! Upper Nozzle Material
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
material    7
    stainless 304l steel        density    7.9200    prop    0.0919
    void                prop    0.9081
volume                            ! Upper Plenum Material
material    8
    stainless 304l steel        density    7.9200    prop    0.0290
    void                prop    0.9710
volume                            ! Damaged Fuel Lower Nozzle
material    9
    stainless 304l steel        density    7.9200    prop    0.0965
    mixture    1    density    10.4120    prop    0.3318    ! UO2 mixture at 3.7%
    void                prop    0.5717
volume                            ! Damaged Fuel Upper Nozzle
material    10
    stainless 304l steel        density    7.9200    prop    0.0919
    mixture    1    density    10.4120    prop    0.2990    ! UO2 mixture at 3.7%
    void                prop    0.6091
*
* Materials List - Common Materials - v1.2
*
volume                            ! Tube wall and cover sheet
material    11
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! BORAL core
material    12
    mixture    3    density    2.6226    prop    0.9850    ! mixBORAL
    void                prop    0.0150
volume                            ! BORAL alumnimum clad
material    13
    aluminium                prop    1.0000
volume                            ! Structural Disk Material
material    14
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Weldment Material
material    15
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Heat Transfer Disk Material
material    16
    aluminium                prop    1.0000
volume                            ! Canister Material
material    17
    stainless 304l steel        density    7.9200    prop    1.0000
atoms                             ! Transfer steel
material    18        density    0            !  (SCALE carbonsteel 7.8212 g/cc)
        c            prop    3.9250E-03
        fe            prop    8.3498E-02
volume                            ! Lead
material    19
    pb        density    11.0400    prop    1.0000
atoms                             ! NS-4-FR
material    20        density    0            ! 0 means atom/b-cm
        b10            prop    8.5500E-05
        b11            prop    3.4200E-04
        al            prop    7.8000E-03
        h            prop    5.8500E-02
        o            prop    2.6100E-02
        c            prop    2.2600E-02
        n            prop    1.3900E-03
volume                            ! Stainless Steel 304
material    21
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Vent port middle cylinder
material    22
    stainless 304l steel        density    7.9200    prop    0.5000
    void                prop    0.5000
atoms                             ! SCALE Concrete
material    23        density    0            ! (density 2.2426 g/cc)
        h            prop    1.3401E-02
        o            prop    4.4931E-02
        na            prop    1.7036E-03
        al            prop    1.7018E-03
        si            prop    1.6205E-02
        ca            prop    1.4826E-03
        fe            prop    3.3857E-04
volume                            ! Heat fins for transport cask
material    24
    cu        density    8.9200    prop    0.4286
    stainless 304l steel        density    7.9200    prop    0.5714
volume                            ! Balsa
material    25
    mixture    4    density    0.1250    prop    1.0000
volume                            ! Redwood
material    26
    mixture    4    density    0.3870    prop    1.0000
end

*
* Unit 26 Angular Scoring
*
```

Figure 5.6.1.2-1 MCBEND Input File for Design Basis CE Fuel Gamma Source with Radial Biasing (Continued)

```
begin angular scoring
    score angular currents
    splitting mesh
    pole radial positive
    azimuth theta positive
    face    2
    block
    37    1    5
    37    1    65
    polar
    11    fill    -1.0
        p    0.0
    n    10    1.0
        cosine
    azimuthal
        dummy
    write currents to file
end
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing

```
columns 1 200
*
* Yankee-MPC VCC - ce16y_36b37e08y - Fuel Neutron - Radial
*   Shield Lid - Ports - With Covers
*   Structural Lid - No Weld Shield
*   Dry Conditions
*
*   Model Revision v1.6.0.0
*

*
* Parameters
*
@samps =    4000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit    1000m
    seeds    60706    21510
    chime every    [@samps/10]    samples
*    chime every    60m
    report interim results
    sbd    10s
    dump intervals    1
end

*
* Unit 3 Output Control
*
*begin output control
*    suppress inflows
*end

*
* Unit 4 Material Geometry
*
begin material geometry
* Fuel Assembly Type A - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    1    NEST
BOX    M5        0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6        0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1    S    0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8        0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7        0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* Fuel Assembly Type B - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    2    NEST
BOX    M5        0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6        0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1    S    0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8        0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7        0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* BORAL and Cover for Standard Opening v1.0
PART    3    NEST
BOX    BH1    0.0457    0.0000    0.3556    0.1905    18.2880    244.3480    ! BORAL Sheet - Axial offset from cover sheet bottom
BOX    M0    0.0457    0.0000    0.0000    0.1905    18.2880    248.9200    ! Space under cover sheet that allows sheet to shift
under cover
BOX    M11    0.0000    0.0000    0.0000    0.2362    18.2880    248.9200    ! SS cover sheet for BORAL
* Fuel Assembly in Tube (Type A) v1.0
PART    4
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.0
PART    5
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/Container/    H6    +4    -3    -2
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.0
PART    6    CLUSTER
BOX    P4    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type A with fuel assy
BOX    P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX    P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX    P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
        ZROT    90.0000
BOX    P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
        ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
*  Type B Disk Opening with Tube v1.0
PART    7    CLUSTER
BOX    P5    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type B with fuel assy
BOX    P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX    P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX    P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
        ZROT    90.0000
BOX    P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
        ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
* Basket v1.0
PART    8
BOX    1    -33.6702    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 1
BOX    2    -10.4826    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 2
BOX    3    12.7051    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 3
BOX    4    -56.6928    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 4
BOX    5    -33.6702    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 5
BOX    6    -10.4826    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 6
BOX    7    12.7051    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 7
BOX    8    35.7276    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 8
BOX    9    -79.5630    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 9
BOX    10    -56.6928    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 10
BOX    11    -33.6702    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 11
BOX    12    -10.4826    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 12
BOX    13    12.7051    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 13
BOX    14    35.7276    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 14
BOX    15    58.5978    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 15
BOX    16    -79.5630    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 16
BOX    17    -56.6928    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 17
BOX    18    -33.6702    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 18
BOX    19    -10.4826    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Middle Opening
BOX    20    12.7051    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 19
BOX    21    35.7276    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 20
BOX    22    58.5978    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 21
BOX    23    -79.5630    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 22
BOX    24    -56.6928    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 23
BOX    25    -33.6702    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 24
BOX    26    -10.4826    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 25
BOX    27    12.7051    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 26
BOX    28    35.7276    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 27
BOX    29    58.5978    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 28
BOX    30    -56.6928    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 29
BOX    31    -33.6702    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 30
BOX    32    -10.4826    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 31
BOX    33    12.7051    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 32
BOX    34    35.7276    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 33
BOX    35    -33.6702    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 34
BOX    36    -10.4826    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 35
BOX    37    12.7051    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 36
BOX    38    33.6703    -78.6004    270.5100    28.4480    21.9075    16.0020    ! Drain Baffle Box A
BOX    39    35.2578    -78.6004    270.5100    26.8605    20.3200    16.0020    ! Drain Baffle Box B
ZROD    40    46.2405    -61.3632    0.0000    2.6035    288.2900    ! Drain Baffle Hole
BOX    41    -62.1182    56.6929    270.5100    28.4480    21.9075    16.0020    ! Vent Baffle Box A
BOX    42    -62.1182    58.2804    270.5100    26.8605    20.3200    16.0020    ! Vent Baffle Box B
ZROD    43    -46.2405    61.3632    0.0000    2.6035    288.2900    ! Vent Baffle Hole
ZROD    44    0.0000    0.0000    0.0000    86.3346    288.2900    ! Baffle limiting radius
CONTAINER
ZROD    45    0.0000    0.0000    0.0000    87.4649    288.2900    ! Basket stack to cavity height
ZONES
/Opening01/    P6    +1
/Opening02/    P6    +2
/Opening03/    P6    +3
/Opening04/    P7    +4
/Opening05/    P6    +5
/Opening06/    P6    +6
/Opening07/    P6    +7
/Opening08/    P7    +8
/Opening09/    P6    +9
/Opening10/    P6    +10
/Opening11/    P6    +11
/Opening12/    P6    +12
/Opening13/    P6    +13
/Opening14/    P6    +14
/Opening15/    P6    +15
/Opening16/    P6    +16
/Opening17/    P6    +17
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/Opening18/    P6    +18
/Opening19/    P6    +20
/Opening20/    P6    +21
/Opening21/    P6    +22
/Opening22/    P6    +23
/Opening23/    P6    +24
/Opening24/    P6    +25
/Opening25/    P6    +26
/Opening26/    P6    +27
/Opening27/    P6    +28
/Opening28/    P6    +29
/Opening29/    P7    +30
/Opening30/    P6    +31
/Opening31/    P6    +32
/Opening32/    P6    +33
/Opening33/    P7    +34
/Opening34/    P6    +35
/Opening35/    P6    +36
/Opening36/    P6    +37
/Center/    H2    +19
/DrainBfl/    M17    +38    -39    +44
/DrainBflHole/    H6    +40
/DrainBflInner/    H2    +39    -40    +44
/VentBfl/    M17    +41    -42    +44
/VentBflHole/    H6    +43
/VentBflInner/    H2    +42    -43    +44
/Basket/    H2    +45    -1    -2    -3    -4    -5
        -6    -7    -8    -9    -10    -11
        -12    -13    -14    -15    -16    -17
        -18    -19    -20    -21    -22    -23
        -24    -25    -26    -27    -28    -29
        -30    -31    -32    -33    -34    -35
        -36    -37    -38    -40    -41    -43
/BasketDrain/    H2    +45    +38    -44
/BasketVent/    H2    +45    +41    -44

VOLUMES    UNITY
* Basket in Canister Cavity v1.0
PART    9    NEST
ZROD    P8    0.0000    0.0000    0.0000    87.4649    288.2900        ! Basket inserted - Includes gap to lid
        ZROT    0.0000
ZROD    H6    0.0000    0.0000    0.0000    88.1253    288.2900        ! Inserts flood matl to canister shell
* Canister - Structural Lid - No Weld Shield v1.0
PART    10
ZROD    1    0.0000    0.0000    0.0000    88.1253    288.2900        ! Canister cavity contents
ZROD    2    0.0000    0.0000    -2.5400    89.7128    2.5400        ! Canister Bottom Plate
ZROD    3    0.0000    0.0000    288.2900    88.1253    12.7000        ! Shield Lid
ZROD    4    0.0000    0.0000    300.9900    88.1253    7.6200        ! Structural Lid
ZROD    5    0.0000    0.0000    0.0000    88.1253    308.6100        ! Canister Shell Inner
ZROD    6    0.0000    0.0000    0.0000    89.7128    308.6100        ! Canister Shell Outer
ZROD    7    0.0000    0.0000    -2.5400    89.7128    311.1500        ! Inner Detector Surface
ZONES
/Cavity/    P9    +1
/BottomPlate/    M17    +2
/ShieldLid/    P11    +3
/StructLid/    M17    +4
/Shell/    M17    +6    -5
/Canister/    M0    +7    -6    -4    -2
VOLUMES    UNITY
* Shield Lid - With Ports v1.0
PART    11    CLUSTER
ZROD    P12    -46.2405    61.3632    0.0000    7.6200    12.7000        ! Vent port
ZROD    P12    46.2405    -61.3632    0.0000    7.6200    12.7000        ! Drain port
ZROD    M17    0.0000    0.0000    0.0000    88.1253    12.7000        ! Shield Lid
* Vent Port Model - With Covers v1.0
PART    12    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.3843    4.6228        ! Bottom Cylinder
ZROD    M17    0.0000    0.0000    4.6228    5.0800    6.6548        ! Middle Cyclinder
ZROD    M17    0.0000    0.0000    11.2776    7.6200    1.4224        ! Top Cylinder
ZROD    M17    0.0000    0.0000    0.0000    7.6200    12.7000        ! Shield lid material
* Storage Cask Air Inlet PIM Model
PART    13
YROD    1    5.0800    0.0000    22.8600    5.0800    30.4800        ! Pipe A Outer
YROD    2    5.0800    0.0000    22.8600    3.4646    30.4800        ! Pipe A Inner
YROD    3    25.4000    0.0000    10.1600    5.0800    30.4800        ! Pipe B Outer
YROD    4    25.4000    0.0000    10.1600    3.4646    30.4800        ! Pipe B Inner
YROD    5    45.7200    0.0000    22.8600    5.0800    30.4800        ! Pipe C Outer
YROD    6    45.7200    0.0000    22.8600    3.4646    30.4800        ! Pipe C Inner
YROD    7    66.0400    0.0000    10.1600    5.0800    30.4800        ! Pipe D Outer
YROD    8    66.0400    0.0000    10.1600    3.4646    30.4800        ! Pipe D Inner
BOX    9    0.0000    0.0000    0.0000    71.1200    30.4800    33.0200        ! Container
ZONES
/Pipe A Steel/    M18    +1    -2
/Pipe A Void/    M0    +2
/Pipe A Steel/    M18    +3    -4
/Pipe A Void/    M0    +4
/Pipe A Steel/    M18    +5    -6
/Pipe A Void/    M0    +6
/Pipe A Steel/    M18    +7    -8
/Pipe A Void/    M0    +8
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/Container/    M0    +9    -1    -3    -5    -7
VOLUMES UNITY
*Storage Cask Top Geometry v1.6.0.0
PART    14
ZROD    1    0.0000    0.0000    347.4720    116.9670    3.8100            ! VCC lid
ZROD    2    0.0000    0.0000    342.3920    124.3330    5.0800            ! Top flange outer
ZROD    3    0.0000    0.0000    342.3920    102.8700    5.0800            ! Top flange inner
ZROD    4    0.0000    0.0000    324.6120    100.3300    7.6200            ! Support ring outer
ZROD    5    0.0000    0.0000    324.6120    93.9800    7.6200            ! Support ring inner
ZROD    6    0.0000    0.0000    0.0000    109.2200    342.3920            ! VCC shell outer
ZROD    7    0.0000    0.0000    0.0000    100.3300    342.3920            ! VCC shell inner
ZROD    8    0.0000    0.0000    304.2920    109.2200    12.0650            ! VCC shell opening
ZROD    9    0.0000    0.0000    0.0000    162.5600    347.4720            ! Concrete
ZCONE    10    0.0000    0.0000    326.5170    92.0750    99.6950    7.6200        ! Shield plug cone
ZROD    11    0.0000    0.0000    334.1370    99.6950    1.9050            ! Shield plug cylinder
ZROD    12    0.0000    0.0000    336.0420    86.9950    3.4925            ! NS cover plate
ZROD    13    0.0000    0.0000    336.0420    86.0425    2.5400            ! NS
ZROD    14    0.0000    0.0000    304.2920    106.6800    12.0650            ! Air outlet inner radius
BOX    15    -54.2290    -162.5600    304.2920    108.4580    325.1200    33.1470        ! Air outlet A channel box
BOX    16    -53.2765    -162.5600    305.2445    106.5530    325.1200    31.2420        ! Air outlet A void box
BOX    17    -53.2765    -162.5600    304.2920    106.5530    325.1200    33.1470        ! Air outlet A wall box
BOX    18    -162.5600    -54.2290    304.2920    325.1200    108.4580    33.1470        ! Air outlet B channel box
BOX    19    -162.5600    -53.2765    305.2445    325.1200    106.5530    31.2420        ! Air outlet B void box
BOX    20    -162.5600    -53.2765    304.2920    325.1200    106.5530    33.1470        ! Air outlet B wall box
BOX    21    -162.5600    -162.5600    336.4865    325.1200    325.1200    0.9525        ! Box H8-H7 R5
BOX    22    -162.5600    -162.5600    326.3265    325.1200    325.1200    10.1600        ! Box H7-H6 R5
BOX    23    -162.5600    -162.5600    325.3740    325.1200    325.1200    0.9525        ! Box H6-H5 R5
BOX    24    -162.5600    -162.5600    304.2920    325.1200    325.1200    21.0820        ! Box H5-H1 R5
BOX    25    -128.0160    -128.0160    316.3570    256.0320    256.0320    21.0820        ! Box H8-H4 R2
BOX    26    -127.0635    -127.0635    316.3570    254.1270    254.1270    21.0820        ! Box H8-H4 R1
BOX    27    -143.2560    -143.2560    304.2920    286.5120    286.5120    21.0820        ! Box H5-H1 R4
BOX    28    -143.2560    -143.2560    304.2920    286.5120    286.5120    22.0345        ! Box H6-H1 R4
BOX    29    -128.0160    -128.0160    315.4045    256.0320    256.0320    0.9525        ! Box H4-H3 R2
BOX    30    -138.1760    -138.1760    305.2445    276.3520    276.3520    21.0820        ! Box H6-H2 R3
BOX    31    -128.0160    -128.0160    305.2445    256.0320    256.0320    10.1600        ! Box H3-H2 R2
BOX    32    -138.1760    -138.1760    304.2920    276.3520    276.3520    0.9525        ! Box H2-H1 R3
BOX    33    -138.1760    -138.1760    304.2920    276.3520    276.3520    22.0345        ! Box H6-H1 R3
BOX    34    -128.0160    -128.0160    305.2445    256.0320    256.0320    21.0820        ! Box H6-H2 R2
ZROD    35    0.0000    0.0000    0.0000    100.3300    342.3920            ! Cavity
ZROD    36    0.0000    0.0000    0.0000    162.5600    351.2820            ! Container
ZROD    37    0.0000    0.0000    0.0000    89.7128    311.1500            ! Canister
ZROD    38    0.0000    0.0000    311.1500    31.7271    1.0000            ! Canister Det 01
ZROD    39    0.0000    0.0000    311.1500    44.8689    1.0000            ! Canister Det 02
ZROD    40    0.0000    0.0000    311.1500    54.9530    1.0000            ! Canister Det 03
ZROD    41    0.0000    0.0000    311.1500    63.4543    1.0000            ! Canister Det 04
ZROD    42    0.0000    0.0000    311.1500    70.9440    1.0000            ! Canister Det 05
ZROD    43    0.0000    0.0000    311.1500    77.7153    1.0000            ! Canister Det 06
ZROD    44    0.0000    0.0000    311.1500    83.9421    1.0000            ! Canister Det 07
ZROD    45    0.0000    0.0000    311.1500    89.7379    1.0000            ! Canister Det 08
ZROD    46    0.0000    0.0000    311.1500    95.1814    1.0000            ! Canister Det 09
ZROD    47    0.0000    0.0000    311.1500    100.3300    1.0000            ! Canister Det 10
ZROD    48    0.0000    0.0000    312.1500    100.3300    1.0000            ! Can Azi Det Container
ZSEC    49    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 01
        345.0000    375.0000
ZSEC    50    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 02
        15.0000    45.0000
ZSEC    51    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 03
        45.0000    75.0000
ZSEC    52    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 04
        75.0000    105.0000
ZSEC    53    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 05
        105.0000    135.0000
ZSEC    54    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 06
        135.0000    165.0000
ZSEC    55    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 07
        165.0000    195.0000
ZSEC    56    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 08
        195.0000    225.0000
ZSEC    57    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 09
        225.0000    255.0000
ZSEC    58    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 10
        255.0000    285.0000
ZSEC    59    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 11
        285.0000    315.0000
ZSEC    60    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 12
        315.0000    345.0000
ZROD    61    0.0000    0.0000    339.5345    31.7271    1.0000            ! Shield Plug Det 01
ZROD    62    0.0000    0.0000    339.5345    44.8689    1.0000            ! Shield Plug Det 02
ZROD    63    0.0000    0.0000    339.5345    54.9530    1.0000            ! Shield Plug Det 03
ZROD    64    0.0000    0.0000    339.5345    63.4543    1.0000            ! Shield Plug Det 04
ZROD    65    0.0000    0.0000    339.5345    70.9440    1.0000            ! Shield Plug Det 05
ZROD    66    0.0000    0.0000    339.5345    77.7153    1.0000            ! Shield Plug Det 06
ZROD    67    0.0000    0.0000    339.5345    83.9421    1.0000            ! Shield Plug Det 07
ZROD    68    0.0000    0.0000    339.5345    89.7379    1.0000            ! Shield Plug Det 08
ZROD    69    0.0000    0.0000    339.5345    95.1814    1.0000            ! Shield Plug Det 09
ZROD    70    0.0000    0.0000    339.5345    100.3300    1.0000            ! Shield Plug Det 10
ZONES
/VCCLid/    M18    +1
/TopFlange/    M18    +2    -3
/SupportRing/    M18    +4    -5    -10
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/ShieldPlugCone/    M18    +10
/ShieldPlugCyl/    M18    +11
/NScover/    M18    +12    -13
/NS/    M20    +13
/VCC Shell1/    M18    +6    -7    -8                    ! Outside air outlet opening
/VCC Shell2/    M18    +8    -7    -15    -18              ! Outside air outlet channel
/Concrete1/    M23    +9    -6    -2    -15    -18          ! Non air outlet concrete
/Concrete2/    M23    +9    +24    -27    +15              ! Bot air outlet concrete
/Concrete3/    M23    +9    +24    -27    +18              ! Bot air outlet concrete
/Concrete4/    M23    +9    -6    +26    +15               ! Top air outlet concrete
/Concrete5/    M23    +9    -6    +26    +18               ! Top air outlet concrete
/AirOutTop1/    M18    +15    +21    -25    +9
/AirOutTop2/    M18    +18    +21    -25    +9
/AirOutMid1/    M18    +15    +23    -28    +9
/AirOutMid2/    M18    +18    +23    -28    +9
/AirOutBack1/    M18    +15    +25    -26
/AirOutBack2/    M18    +18    +25    -26
/AirOutBot1/    M18    +15    +32    -14
/AirOutBot2/    M18    +18    +32    -14
/AirOutBot3/    M18    +32    +15    +14    -7    -17
/AirOutBot4/    M18    +32    +18    +14    -7    -20
/AirOutShieldPlate1/    M18    +15    +28    -33
/AirOutShieldPlate2/    M18    +18    +28    -33
/AirOutTopThick1/    M18    +15    +29    -14
/AirOutTopThick2/    M18    +18    +29    -14
/AirOutTopThick3/    M18    +29    +15    +14    -7    -16
/AirOutTopThick4/    M18    +29    +18    +14    -7    -19
/AirOutTopVoid1/    M0    +16    +22    -25    +9
/AirOutTopVoid2/    M0    +19    +22    -25    +9
/AirOutMidVoid1/    M0    +16    +30    -34
/AirOutMidVoid2/    M0    +19    +30    -34
/AirOutBotVoid1/    M0    +16    +31    -14
/AirOutBotVoid2/    M0    +19    +31    -14
/AirOutWallTop1/    M18    +15    -16    +22    -25    +9
/AirOutWallTop2/    M18    +18    -19    +22    -25    +9
/AirOutWallMid1/    M18    +15    -16    +30    -34
/AirOutWallMid2/    M18    +18    -19    +30    -34
/AirOutWallBot1/    M18    +15    -16    +31    -7
/AirOutWallBot2/    M18    +18    -19    +31    -7
/ShellOpeningVoid1/    M0    +14    -7    +16    -29
/ShellOpeningVoid2/    M0    +14    -7    +19    -29
/ShellOpeningVoid3/    M0    +32    +14    -7    +17
/ShellOpeningVoid4/    M0    +32    +14    -7    +20
/ShellOpeningVoid5/    M0    +29    +14    -7    +16
/ShellOpeningVoid6/    M0    +29    +14    -7    +19
/FlangeVoid/    M0    +3    -12
/Cavity1/    M0    +35    -4    -10    -11    -12    -37        ! Outside support ring
        -47    -48    -70
/Cavity2/    M0    +35    +5    -10    -12                ! Inside support ring
/TSC/    P10    +37
/Container/    M0    +36    -9    -1
/TSCLid01/    M0    +38
/TSCLid02/    M0    +39    -38
/TSCLid03/    M0    +40    -39
/TSCLid04/    M0    +41    -40
/TSCLid05/    M0    +42    -41
/TSCLid06/    M0    +43    -42
/TSCLid07/    M0    +44    -43
/TSCLid08/    M0    +45    -44
/TSCLid09/    M0    +46    -45
/TSCLid10/    M0    +47    -46
/CanAziVoid/    M0    +48    -49    -50    -51    -52    -53
        -54    -55    -56    -57    -58    -59
        -60
/CanAziDet01/    M0    +49
/CanAziDet02/    M0    +50
/CanAziDet03/    M0    +51
/CanAziDet04/    M0    +52
/CanAziDet05/    M0    +53
/CanAziDet06/    M0    +54
/CanAziDet07/    M0    +55
/CanAziDet08/    M0    +56
/CanAziDet09/    M0    +57
/CanAziDet10/    M0    +58
/CanAziDet11/    M0    +59
/CanAziDet12/    M0    +60
/PlugTop01/    M0    +61
/PlugTop02/    M0    +62    -61
/PlugTop03/    M0    +63    -62
/PlugTop04/    M0    +64    -63
/PlugTop05/    M0    +65    -64
/PlugTop06/    M0    +66    -65
/PlugTop07/    M0    +67    -66
/PlugTop08/    M0    +68    -67
/PlugTop09/    M0    +69    -68
/PlugTop10/    M0    +70    -69
VOLUMES    53*1.0    10*3.1624E+03    1.0    12*2.6353E+02    10*3.1624E+03
*Storage Cask Bottom Geometry v1.6.0.0
PART    15
ZROD    1    0.0000    0.0000    53.5940    91.4400    5.0800    ! Base plate
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
ZCONE    2    0.0000    0.0000    2.5400    38.1000    29.2100    24.1300        ! Baffle weldment bot
ZCONE    3    0.0000    0.0000    2.5400    37.4543    28.5643    24.1300        ! Baffle weldment bot void
ZCONE    4    0.0000    0.0000    26.6700    29.2100    38.1000    24.1300        ! Baffle weldment top
ZCONE    5    0.0000    0.0000    26.6700    28.5643    37.4543    24.1300        ! Baffle weldment top void
ZROD    6    0.0000    0.0000    2.5400    63.5000    51.054            ! Stand outer
ZROD    7    0.0000    0.0000    2.5400    58.4200    51.054            ! Stand inner
ZP    8    33.0200                          ! Cut plane for stand
BOX    9    104.1710    -125.7236    0.0000    30.4800    325.1200    33.0200        ! Air inlet A void
       ZROT    -45.0000
BOX    10    103.4975    -126.3971    0.0000    32.3850    325.1200    35.5600        ! Air inlet A channel
       ZROT    -45.0000
BOX    11    -104.1710    -125.7236    0.0000    325.1200    30.4800    33.0200        ! Air inlet B void
       ZROT    -45.0000
BOX    12    -103.4975    -126.3971    0.0000    325.1200    32.3850    35.5600        ! Air inlet B channel
       ZROT    -45.0000
ZROD    13    0.0000    0.0000    0.0000    162.5600    2.5400            ! Bottom plate outer
ZROD    14    0.0000    0.0000    0.0000    63.5000    2.5400            ! Bottom plate inner
ZROD    15    0.0000    0.0000    2.5400    109.2200    56.1340            ! VCC shell outer
ZROD    16    0.0000    0.0000    2.5400    100.3300    56.1340            ! VCC shell inner
ZROD    17    0.0000    0.0000    2.5400    162.5600    56.1340            ! Concrete
ZROD    18    0.0000    0.0000    32.0675    99.6950    0.9525            ! Cover
BOX    19    -25.6540    -99.6950    33.0200    51.3080    199.3900    20.5740        ! Stand top cut box A
BOX    20    -99.6950    -25.6540    33.0200    199.3900    51.3080    20.5740        ! Stand top cut box B
ZROD    21    0.0000    0.0000    33.0200    99.6950    5.0800            ! Shield ring outer
ZROD    22    0.0000    0.0000    33.0200    90.1700    5.0800            ! Shield ring inner
BOX    23    35.2026    -56.7552    0.0000    71.1200    30.4800    33.0200        ! +x -y
       ZROT    45.0000
BOX    24    56.7552    35.2026    0.0000    71.1200    30.4800    33.0200        ! +x +y
       ZROT    -45.0000
BOX    25    -35.2026    56.7552    0.0000    71.1200    30.4800    33.0200        ! -x +y
       ZROT    -135.0000
BOX    26    -56.7552    -35.2026    0.0000    71.1200    30.4800    33.0200        ! -x -y
       ZROT    135.0000
ZROD    27    0.0000    0.0000    0.0000    162.5600    58.6740            ! Container
ZONES
/Container/    M0    +27    -17    -13
/BasePlate/    M18    +1
/BaffleTop/    M18    +4    -5
/BaffleTopVoid/    M0    +5
/BaffleBot/    M18    +2    -3
/BaffleBotVoid/    M0    +3
/InletAVoid/    M0    +9    -14    -7    +27    -23    -25        ! Outside of stand inner
/InletBVoid/    M0    +11    -14    -7    +27    -24    -26        ! Outside of stand inner
/PIM+x-y/    P13    +23                          ! PIM at +x - y
/PIM+x+y/    P13    +24                          ! PIM at +x + y
/PIM-x+y/    P13    +25                          ! PIM at -x + y
/PIM-x-y/    P13    +26                          ! PIM at -x - y
/InletAWalls/    M18    +10    -9    -6    +27    -14            ! Outside of stand outer
/InletBWalls/    M18    +12    -11    -6    +27    -14            ! Outside of stand outer
/VCCShell/    M18    +15    -16    -10    -12
/BotPlateInner/    M18    +14
/BotPlateOuter/    M18    +13    -14    -9    -11
/BaseVoid/    M0    +7    -2    -4                    ! Inside stand inner
/Concrete/    M23    +17    -15    -10    -12
/Cover/    M18    +18    -6    -10    -12
/StandBot/    M18    +6    -7    -8    -9    -11
/StandTop/    M18    +6    -7    +8    -19    -20
/ShieldRing/    M18    +21    -22    -10    -12
/StandTopVoid1/    M0    +6    +8    -7    +19
/StandTopVoid2/    M0    +6    +8    -7    +20
/ShieldRingVoid1/    M0    +22    -6    -10    -12            ! Inside the shield ring
/xyVoid/    M0    +16    -6    -10    -12    -8    -18
/OuterVoid/    M0    +16    -6    +8    -21    -1    -10    -12
VOLUMES UNITY
*Storage Cask Combined Geometry
PART    16
ZROD    1    0.0000    0.0000    -58.6740    162.5600    58.6740            ! Bottom
ZROD    2    0.0000    0.0000    0.0000    162.5600    351.2820            ! Top
ZROD    3    0.0000    0.0000    -158.6740    162.5600    100.0000            ! Concrete Pad
ZROD    4    0.0000    0.0000    -158.6740    162.5600    509.9560            ! Container
ZONES
/Bottom/    P15    +1
/Top/    P14    +2
/Concrete Pad/    M23    +3
/Container/    M0    +4    -3    -2    -1
VOLUMES UNITY
* Storage Cask Detector Description v1.6.0.0
PART    17
* Radial Detector DRA (Surface) Bodies
ZROD    1    0.0000    0.0000    -158.6740 162.5600  509.9560
ZROD    2    0.0000    0.0000    -58.6740  163.5600  40.9956
ZROD    3    0.0000    0.0000    -17.6784  163.5600  40.9956
ZROD    4    0.0000    0.0000    23.3172   163.5600  40.9956
ZROD    5    0.0000    0.0000    64.3128   163.5600  40.9956
ZROD    6    0.0000    0.0000    105.3084  163.5600  40.9956
ZROD    7    0.0000    0.0000    146.3040  163.5600  40.9956
ZROD    8    0.0000    0.0000    187.2996  163.5600  40.9956
ZROD    9    0.0000    0.0000    228.2952  163.5600  40.9956
ZROD    10   0.0000    0.0000    269.2908  163.5600  40.9956
ZROD    11   0.0000    0.0000    310.2864  163.5600  40.9956
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
* Radial Detector DRAA (Outlet) Bodies
ZROD      12                0.0000    0.0000    -159.6740 163.5600  511.9560
*   Band 1 Bodies
ZSEC      13                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   342.0000  360.0000
ZSEC      14                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   0.0000    18.0000
ZSEC      15                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   18.0000   36.0000
ZSEC      16                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   36.0000   54.0000
ZSEC      17                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   54.0000   72.0000
ZSEC      18                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   72.0000   90.0000
ZSEC      19                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   90.0000   108.0000
ZSEC      20                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   108.0000  126.0000
ZSEC      21                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   126.0000  144.0000
ZSEC      22                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   144.0000  162.0000
ZSEC      23                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   162.0000  180.0000
ZSEC      24                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   180.0000  198.0000
ZSEC      25                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   198.0000  216.0000
ZSEC      26                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   216.0000  234.0000
ZSEC      27                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   234.0000  252.0000
ZSEC      28                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   252.0000  270.0000
ZSEC      29                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   270.0000  288.0000
ZSEC      30                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   288.0000  306.0000
ZSEC      31                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   306.0000  324.0000
ZSEC      32                0.0000    0.0000    326.3265  163.5600  164.5600  10.1600   324.0000  342.0000
* Radial Detector DRAB (Inlet) Bodies
ZROD      33                0.0000    0.0000    -160.6740 164.5600  513.9560
*   Band 1 Bodies
ZSEC      34                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   40.0000   50.0000
ZSEC      35                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   50.0000   60.0000
ZSEC      36                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   60.0000   70.0000
ZSEC      37                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   70.0000   80.0000
ZSEC      38                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   80.0000   90.0000
ZSEC      39                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   90.0000   100.0000
ZSEC      40                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   100.0000  110.0000
ZSEC      41                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   110.0000  120.0000
ZSEC      42                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   120.0000  130.0000
ZSEC      43                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   130.0000  140.0000
ZSEC      44                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   140.0000  150.0000
ZSEC      45                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   150.0000  160.0000
ZSEC      46                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   160.0000  170.0000
ZSEC      47                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   170.0000  180.0000
ZSEC      48                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   180.0000  190.0000
ZSEC      49                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   190.0000  200.0000
ZSEC      50                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   200.0000  210.0000
ZSEC      51                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   210.0000  220.0000
ZSEC      52                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   220.0000  230.0000
ZSEC      53                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   230.0000  240.0000
ZSEC      54                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   240.0000  250.0000
ZSEC      55                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   250.0000  260.0000
ZSEC      56                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   260.0000  270.0000
ZSEC      57                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   270.0000  280.0000
ZSEC      58                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   280.0000  290.0000
ZSEC      59                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   290.0000  300.0000
ZSEC      60                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   300.0000  310.0000
ZSEC      61                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   310.0000  320.0000
ZSEC      62                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   320.0000  330.0000
ZSEC      63                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   330.0000  340.0000
ZSEC      64                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   340.0000  350.0000
ZSEC      65                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   350.0000  360.0000
ZSEC      66                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   360.0000  370.0000
ZSEC      67                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   10.0000   20.0000
ZSEC      68                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   20.0000   30.0000
ZSEC      69                0.0000    0.0000    -58.6740  164.5600  165.5600  33.0200   30.0000   40.0000
* Radial Detector DRAC (RadAzi) Bodies
ZROD      70                0.0000    0.0000    -161.6740 165.5600  515.9560
*   Band 1 Bodies
ZSEC      71                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   40.0000   50.0000
ZSEC      72                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   50.0000   60.0000
ZSEC      73                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   60.0000   70.0000
ZSEC      74                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   70.0000   80.0000
ZSEC      75                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   80.0000   90.0000
ZSEC      76                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   90.0000   100.0000
ZSEC      77                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   100.0000  110.0000
ZSEC      78                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   110.0000  120.0000
ZSEC      79                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   120.0000  130.0000
ZSEC      80                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   130.0000  140.0000
ZSEC      81                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   140.0000  150.0000
ZSEC      82                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   150.0000  160.0000
ZSEC      83                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   160.0000  170.0000
ZSEC      84                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   170.0000  180.0000
ZSEC      85                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   180.0000  190.0000
ZSEC      86                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   190.0000  200.0000
ZSEC      87                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   200.0000  210.0000
ZSEC      88                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   210.0000  220.0000
ZSEC      89                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   220.0000  230.0000
ZSEC      90                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   230.0000  240.0000
ZSEC      91                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   240.0000  250.0000
ZSEC      92                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   250.0000  260.0000
ZSEC      93                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   260.0000  270.0000
ZSEC      94                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   270.0000  280.0000
ZSEC      95                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   280.0000  290.0000
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
ZSEC      96                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   290.0000  300.0000
ZSEC      97                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   300.0000  310.0000
ZSEC      98                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   310.0000  320.0000
ZSEC      99                0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   320.0000  330.0000
ZSEC      100               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   330.0000  340.0000
ZSEC      101               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   340.0000  350.0000
ZSEC      102               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   350.0000  360.0000
ZSEC      103               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   360.0000  370.0000
ZSEC      104               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   10.0000   20.0000
ZSEC      105               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   20.0000   30.0000
ZSEC      106               0.0000    0.0000    134.4536  165.5600  166.5600  30.0000   30.0000   40.0000
* Radial Detector DRB (1ft) Bodies
ZROD      107               0.0000    0.0000    -162.6740 193.0400  544.4360
ZROD      108               0.0000    0.0000    -58.6740  194.0400  36.7030
ZROD      109               0.0000    0.0000    -21.9710  194.0400  36.7030
ZROD      110               0.0000    0.0000    14.7320   194.0400  36.7030
ZROD      111               0.0000    0.0000    51.4350   194.0400  36.7030
ZROD      112               0.0000    0.0000    88.1380   194.0400  36.7030
ZROD      113               0.0000    0.0000    124.8410  194.0400  36.7030
ZROD      114               0.0000    0.0000    161.5440  194.0400  36.7030
ZROD      115               0.0000    0.0000    198.2470  194.0400  36.7030
ZROD      116               0.0000    0.0000    234.9500  194.0400  36.7030
ZROD      117               0.0000    0.0000    271.6530  194.0400  36.7030
ZROD      118               0.0000    0.0000    308.3560  194.0400  36.7030
ZROD      119               0.0000    0.0000    345.0590  194.0400  36.7030
* Radial Detector DRC (1m) Bodies
ZROD      120               0.0000    0.0000    -163.6740 262.5600  614.9560
ZROD      121               0.0000    0.0000    -58.6740  263.5600  42.4963
ZROD      122               0.0000    0.0000    -16.1777  263.5600  42.4963
ZROD      123               0.0000    0.0000    26.3187   263.5600  42.4963
ZROD      124               0.0000    0.0000    68.8150   263.5600  42.4963
ZROD      125               0.0000    0.0000    111.3113  263.5600  42.4963
ZROD      126               0.0000    0.0000    153.8077  263.5600  42.4963
ZROD      127               0.0000    0.0000    196.3040  263.5600  42.4963
ZROD      128               0.0000    0.0000    238.8003  263.5600  42.4963
ZROD      129               0.0000    0.0000    281.2967  263.5600  42.4963
ZROD      130               0.0000    0.0000    323.7930  263.5600  42.4963
ZROD      131               0.0000    0.0000    366.2893  263.5600  42.4963
ZROD      132               0.0000    0.0000    408.7857  263.5600  42.4963
* Radial Detector DRD (2m) Bodies
ZROD      133               0.0000    0.0000    -164.6740 362.5600  715.9560
ZROD      134               0.0000    0.0000    -58.6740  363.5600  30.4978
ZROD      135               0.0000    0.0000    -28.1762  363.5600  30.4978
ZROD      136               0.0000    0.0000    2.3216    363.5600  30.4978
ZROD      137               0.0000    0.0000    32.8194   363.5600  30.4978
ZROD      138               0.0000    0.0000    63.3172   363.5600  30.4978
ZROD      139               0.0000    0.0000    93.8150   363.5600  30.4978
ZROD      140               0.0000    0.0000    124.3128  363.5600  30.4978
ZROD      141               0.0000    0.0000    154.8106  363.5600  30.4978
ZROD      142               0.0000    0.0000    185.3084  363.5600  30.4978
ZROD      143               0.0000    0.0000    215.8062  363.5600  30.4978
ZROD      144               0.0000    0.0000    246.3040  363.5600  30.4978
ZROD      145               0.0000    0.0000    276.8018  363.5600  30.4978
ZROD      146               0.0000    0.0000    307.2996  363.5600  30.4978
ZROD      147               0.0000    0.0000    337.7974  363.5600  30.4978
ZROD      148               0.0000    0.0000    368.2952  363.5600  30.4978
ZROD      149               0.0000    0.0000    398.7930  363.5600  30.4978
ZROD      150               0.0000    0.0000    429.2908  363.5600  30.4978
ZROD      151               0.0000    0.0000    459.7886  363.5600  30.4978
ZROD      152               0.0000    0.0000    490.2864  363.5600  30.4978
ZROD      153               0.0000    0.0000    520.7842  363.5600  30.4978
* Radial Detector DRE (4m) Bodies
ZROD      154               0.0000    0.0000    -165.6740 562.5600  916.9560
ZROD      155               0.0000    0.0000    -58.6740  563.5600  40.4978
ZROD      156               0.0000    0.0000    -18.1762  563.5600  40.4978
ZROD      157               0.0000    0.0000    22.3216   563.5600  40.4978
ZROD      158               0.0000    0.0000    62.8194   563.5600  40.4978
ZROD      159               0.0000    0.0000    103.3172  563.5600  40.4978
ZROD      160               0.0000    0.0000    143.8150  563.5600  40.4978
ZROD      161               0.0000    0.0000    184.3128  563.5600  40.4978
ZROD      162               0.0000    0.0000    224.8106  563.5600  40.4978
ZROD      163               0.0000    0.0000    265.3084  563.5600  40.4978
ZROD      164               0.0000    0.0000    305.8062  563.5600  40.4978
ZROD      165               0.0000    0.0000    346.3040  563.5600  40.4978
ZROD      166               0.0000    0.0000    386.8018  563.5600  40.4978
ZROD      167               0.0000    0.0000    427.2996  563.5600  40.4978
ZROD      168               0.0000    0.0000    467.7974  563.5600  40.4978
ZROD      169               0.0000    0.0000    508.2952  563.5600  40.4978
ZROD      170               0.0000    0.0000    548.7930  563.5600  40.4978
ZROD      171               0.0000    0.0000    589.2908  563.5600  40.4978
ZROD      172               0.0000    0.0000    629.7886  563.5600  40.4978
ZROD      173               0.0000    0.0000    670.2864  563.5600  40.4978
ZROD      174               0.0000    0.0000    710.7842  563.5600  40.4978
* World
ZROD      175               0.0000    0.0000    -215.6740 612.5600  1016.9560
* External Void
ZROD      176               0.0000    0.0000    -265.6740 662.5600  1116.9560

ZONES
/StorageCask/       P16       +1
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
* Detector DRA (Surface)
/DRA01/   M0        +2        -1
/DRA02/   M0        +3        -1
/DRA03/   M0        +4        -1
/DRA04/   M0        +5        -1
/DRA05/   M0        +6        -1
/DRA06/   M0        +7        -1
/DRA07/   M0        +8        -1
/DRA08/   M0        +9        -1
/DRA09/   M0        +10       -1
/DRA10/   M0        +11       -1
/Void/    M0        +12       -1
                    -2        -3        -4        -5        -6        -7
                    -8        -9        -10       -11
* Detector DRAA (Outlet)
/DRAA0101/          M0        +13
/DRAA0102/          M0        +14
/DRAA0103/          M0        +15
/DRAA0104/          M0        +16
/DRAA0105/          M0        +17
/DRAA0106/          M0        +18
/DRAA0107/          M0        +19
/DRAA0108/          M0        +20
/DRAA0109/          M0        +21
/DRAA0110/          M0        +22
/DRAA0111/          M0        +23
/DRAA0112/          M0        +24
/DRAA0113/          M0        +25
/DRAA0114/          M0        +26
/DRAA0115/          M0        +27
/DRAA0116/          M0        +28
/DRAA0117/          M0        +29
/DRAA0118/          M0        +30
/DRAA0119/          M0        +31
/DRAA0120/          M0        +32
/Void/    M0        +33       -12
                    -13       -14       -15       -16       -17       -18
                    -19       -20       -21       -22       -23       -24
                    -25       -26       -27       -28       -29       -30
                    -31       -32
* Detector DRAB (Inlet)
/DRAB0101/          M0        +34
/DRAB0102/          M0        +35
/DRAB0103/          M0        +36
/DRAB0104/          M0        +37
/DRAB0105/          M0        +38
/DRAB0106/          M0        +39
/DRAB0107/          M0        +40
/DRAB0108/          M0        +41
/DRAB0109/          M0        +42
/DRAB0110/          M0        +43
/DRAB0111/          M0        +44
/DRAB0112/          M0        +45
/DRAB0113/          M0        +46
/DRAB0114/          M0        +47
/DRAB0115/          M0        +48
/DRAB0116/          M0        +49
/DRAB0117/          M0        +50
/DRAB0118/          M0        +51
/DRAB0119/          M0        +52
/DRAB0120/          M0        +53
/DRAB0121/          M0        +54
/DRAB0122/          M0        +55
/DRAB0123/          M0        +56
/DRAB0124/          M0        +57
/DRAB0125/          M0        +58
/DRAB0126/          M0        +59
/DRAB0127/          M0        +60
/DRAB0128/          M0        +61
/DRAB0129/          M0        +62
/DRAB0130/          M0        +63
/DRAB0131/          M0        +64
/DRAB0132/          M0        +65
/DRAB0133/          M0        +66
/DRAB0134/          M0        +67
/DRAB0135/          M0        +68
/DRAB0136/          M0        +69
/Void/    M0        +70       -33
                    -34       -35       -36       -37       -38       -39
                    -40       -41       -42       -43       -44       -45
                    -46       -47       -48       -49       -50       -51
                    -52       -53       -54       -55       -56       -57
                    -58       -59       -60       -61       -62       -63
                    -64       -65       -66       -67       -68       -69
* Detector DRAC (RadAzi)
/DRAC0101/          M0        +71
/DRAC0102/          M0        +72
/DRAC0103/          M0        +73
/DRAC0104/          M0        +74
/DRAC0105/          M0        +75
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/DRAC0106/          M0        +76
/DRAC0107/          M0        +77
/DRAC0108/          M0        +78
/DRAC0109/          M0        +79
/DRAC0110/          M0        +80
/DRAC0111/          M0        +81
/DRAC0112/          M0        +82
/DRAC0113/          M0        +83
/DRAC0114/          M0        +84
/DRAC0115/          M0        +85
/DRAC0116/          M0        +86
/DRAC0117/          M0        +87
/DRAC0118/          M0        +88
/DRAC0119/          M0        +89
/DRAC0120/          M0        +90
/DRAC0121/          M0        +91
/DRAC0122/          M0        +92
/DRAC0123/          M0        +93
/DRAC0124/          M0        +94
/DRAC0125/          M0        +95
/DRAC0126/          M0        +96
/DRAC0127/          M0        +97
/DRAC0128/          M0        +98
/DRAC0129/          M0        +99
/DRAC0130/          M0        +100
/DRAC0131/          M0        +101
/DRAC0132/          M0        +102
/DRAC0133/          M0        +103
/DRAC0134/          M0        +104
/DRAC0135/          M0        +105
/DRAC0136/          M0        +106
/Void/    M0        +107      -70
                    -71       -72       -73       -74       -75       -76
                    -77       -78       -79       -80       -81       -82
                    -83       -84       -85       -86       -87       -88
                    -89       -90       -91       -92       -93       -94
                    -95       -96       -97       -98       -99       -100
                    -101      -102      -103      -104      -105      -106
* Detector DRB (1ft)
/DRB01/   M0        +108      -107
/DRB02/   M0        +109      -107
/DRB03/   M0        +110      -107
/DRB04/   M0        +111      -107
/DRB05/   M0        +112      -107
/DRB06/   M0        +113      -107
/DRB07/   M0        +114      -107
/DRB08/   M0        +115      -107
/DRB09/   M0        +116      -107
/DRB10/   M0        +117      -107
/DRB11/   M0        +118      -107
/DRB12/   M0        +119      -107
/Void/    M0        +120      -107
                    -108      -109      -110      -111      -112      -113
                    -114      -115      -116      -117      -118      -119
* Detector DRC (1m)
/DRC01/   M0        +121      -120
/DRC02/   M0        +122      -120
/DRC03/   M0        +123      -120
/DRC04/   M0        +124      -120
/DRC05/   M0        +125      -120
/DRC06/   M0        +126      -120
/DRC07/   M0        +127      -120
/DRC08/   M0        +128      -120
/DRC09/   M0        +129      -120
/DRC10/   M0        +130      -120
/DRC11/   M0        +131      -120
/DRC12/   M0        +132      -120
/Void/    M0        +133      -120
                    -121      -122      -123      -124      -125      -126
                    -127      -128      -129      -130      -131      -132
* Detector DRD (2m)
/DRD01/   M0        +134      -133
/DRD02/   M0        +135      -133
/DRD03/   M0        +136      -133
/DRD04/   M0        +137      -133
/DRD05/   M0        +138      -133
/DRD06/   M0        +139      -133
/DRD07/   M0        +140      -133
/DRD08/   M0        +141      -133
/DRD09/   M0        +142      -133
/DRD10/   M0        +143      -133
/DRD11/   M0        +144      -133
/DRD12/   M0        +145      -133
/DRD13/   M0        +146      -133
/DRD14/   M0        +147      -133
/DRD15/   M0        +148      -133
/DRD16/   M0        +149      -133
/DRD17/   M0        +150      -133
/DRD18/   M0        +151      -133
/DRD19/   M0        +152      -133
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
/DRD20/   M0        +153      -133
/Void/    M0        +154      -133
                    -134      -135      -136      -137      -138      -139
                    -140      -141      -142      -143      -144      -145
                    -146      -147      -148      -149      -150      -151
                    -152      -153
* Detector DRE (4m)
/DRE01/   M0        +155      -154
/DRE02/   M0        +156      -154
/DRE03/   M0        +157      -154
/DRE04/   M0        +158      -154
/DRE05/   M0        +159      -154
/DRE06/   M0        +160      -154
/DRE07/   M0        +161      -154
/DRE08/   M0        +162      -154
/DRE09/   M0        +163      -154
/DRE10/   M0        +164      -154
/DRE11/   M0        +165      -154
/DRE12/   M0        +166      -154
/DRE13/   M0        +167      -154
/DRE14/   M0        +168      -154
/DRE15/   M0        +169      -154
/DRE16/   M0        +170      -154
/DRE17/   M0        +171      -154
/DRE18/   M0        +172      -154
/DRE19/   M0        +173      -154
/DRE20/   M0        +174      -154
/Void/    M0        +175      -154
                    -155      -156      -157      -158      -159      -160
                    -161      -162      -163      -164      -165      -166
                    -167      -168      -169      -170      -171      -172
                    -173      -174
/ExtVoid/ M-2000    +176      -175
Volumes
                    1.0       10*4.2001E+04       1.0       20*5.2366E+02       1.0       36*9.5125E+02
                    1.0       36*8.6949E+02       1.0       12*4.4633E+04       1.0       12*7.0240E+04
                    1.0       20*6.9571E+04       1.0       20*1.4327E+05       1.0       1.0
end

*
* Unit 5 Splitting Geometry for Radial Detectors - Neutron
*
begin splitting geometry
    r    34    fill    0.0000
                    n    10    87.4649
                    n    2    100.3300
                    n    2    109.2200
                    n    18    162.5600
                    n    1    163.5600
                    n    1    168.5600

    z    45    fill    -158.6740
                    n    1    -68.6740
                    n    4    -58.6740
                    n    1    -56.1340
                    n    7    -5.0800
                    n    1    0.0000
                    n    1    2.5400
                    n    1    26.1620
                    n    13    257.3020
                    n    1    266.2174
                    n    1    286.4866
                    n    1    290.8300
                    n    2    303.5300
                    n    2    311.1500
                    n    1    326.5170
                    n    2    336.0420
                    n    2    338.5820
                    n    1    339.5345
                    n    1    347.4720
                    n    1    351.2820
                    n    1    352.2820

end
*
* Unit 6 - Source Geometry for Fuel Neutron
*
begin source geometry
    r    11    fill    0.0000    n    11    87.4649
    z    13
        26.1620    33.8667    41.5713    49.2760    56.9807    64.6853
        72.3900    187.9600    211.0740    220.3196    229.5652
        238.8108    248.0564    257.3020
end

*
* Unit 7
*
begin energy data
    neutron
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
    thermal treatment none
    importance    standard    28    groups
    scoring    as    importance
    simple    source    histogram    weighting    automatic
end

*
* Unit 8 Importance Map - Radial
*
begin importance map
    calculate
    targets    10
    part    17
    zones
        2    3    4    5    6
        7    8    9    10    11
    strengths
        1.0E+02    1.0E+01    1.0E+00    1.0E+00    1.0E+00
        1.0E+00    1.0E+00    1.0E+00    1.0E+01    1.0E+02
    defer mixing
    void density    0.10
    track
!    coupled source
!    write gamma importances to 32
!    write unformatted file to 31
!    use method d
end

*
* Unit 9 Scoring Data - Radial
*
begin scoring data
    flux
    part    17
    from    2    to    11    ! DRA
    from    13    to    32    ! DRAA
    from    34    to    69    ! DRAB
    from    71    to    106    ! DRAC
    from    108    to    119    ! DRB
    from    121    to    132    ! DRC
    from    134    to    153    ! DRD
    from    155    to    174    ! DRE
    responses    sos    ditto
    contributions to responses        ditto
    ! score distribution for response
    ! weight distribution    total
end

*
* Unit 10 Response Data
*
begin response data
* Scale to mrem/hr
/ncrp38 - ansi ans-6.1.1-1977 neutron flux-dose conversion factors - mcnp table h.1 - mrem/
function pairs
          2.0000E+01          2.2700E-01
          1.9299E+01          2.2502E-01
          1.8623E+01          2.2307E-01
          1.7970E+01          2.2112E-01
          1.7341E+01          2.1920E-01
          1.6733E+01          2.1729E-01
          1.6147E+01          2.1540E-01
          1.5581E+01          2.1353E-01
          1.5035E+01          2.1167E-01
          1.4508E+01          2.0983E-01
          1.4000E+01          2.0800E-01
          1.3537E+01          2.0090E-01
          1.3089E+01          1.9405E-01
          1.2656E+01          1.8743E-01
          1.2237E+01          1.8104E-01
          1.1832E+01          1.7486E-01
          1.1441E+01          1.6889E-01
          1.1062E+01          1.6313E-01
          1.0696E+01          1.5757E-01
          1.0342E+01          1.5219E-01
          1.0000E+01          1.4700E-01
          7.0000E+00          1.4700E-01
          6.7684E+00          1.4788E-01
          6.5444E+00          1.4876E-01
          6.3279E+00          1.4964E-01
          6.1185E+00          1.5054E-01
          5.9161E+00          1.5143E-01
          5.7203E+00          1.5234E-01
          5.5311E+00          1.5324E-01
          5.3481E+00          1.5416E-01
          5.1711E+00          1.5508E-01
          5.0000E+00          1.5600E-01
          4.6652E+00          1.5258E-01
          4.3528E+00          1.4924E-01
          4.0613E+00          1.4597E-01
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
3.7893E+00          1.4277E-01
3.5355E+00          1.3964E-01
3.2988E+00          1.3658E-01
3.0779E+00          1.3359E-01
2.8717E+00          1.3066E-01
2.6794E+00          1.2780E-01
2.5000E+00          1.2500E-01
2.2811E+00          1.2568E-01
2.0814E+00          1.2637E-01
1.8991E+00          1.2706E-01
1.7329E+00          1.2775E-01
1.5811E+00          1.2845E-01
1.4427E+00          1.2915E-01
1.3164E+00          1.2986E-01
1.2011E+00          1.3057E-01
1.0960E+00          1.3128E-01
1.0000E+00          1.3200E-01
9.3303E-01          1.2740E-01
8.7055E-01          1.2296E-01
8.1225E-01          1.1868E-01
7.5786E-01          1.1455E-01
7.0711E-01          1.1056E-01
6.5975E-01          1.0671E-01
6.1557E-01          1.0299E-01
5.7435E-01          9.9404E-02
5.3589E-01          9.5942E-02
5.0000E-01          9.2600E-02
4.2567E-01          8.0093E-02
3.6239E-01          6.9276E-02
3.0852E-01          5.9919E-02
2.6265E-01          5.1826E-02
2.2361E-01          4.4827E-02
1.9037E-01          3.8772E-02
1.6207E-01          3.3536E-02
1.3797E-01          2.9006E-02
1.1746E-01          2.5089E-02
1.0000E-01          2.1700E-02
7.9433E-02          1.8112E-02
6.3096E-02          1.5117E-02
5.0119E-02          1.2617E-02
3.9811E-02          1.0531E-02
3.1623E-02          8.7893E-03
2.5119E-02          7.3359E-03
1.9953E-02          6.1228E-03
1.5849E-02          5.1104E-03
1.2589E-02          4.2653E-03
1.0000E-02          3.5600E-03
7.9433E-03          3.5795E-03
6.3096E-03          3.5991E-03
5.0119E-03          3.6189E-03
3.9811E-03          3.6387E-03
3.1623E-03          3.6586E-03
2.5119E-03          3.6787E-03
1.9953E-03          3.6988E-03
1.5849E-03          3.7191E-03
1.2589E-03          3.7395E-03
1.0000E-03          3.7600E-03
7.9433E-04          3.8000E-03
6.3096E-04          3.8405E-03
5.0119E-04          3.8814E-03
3.9811E-04          3.9227E-03
3.1623E-04          3.9644E-03
2.5119E-04          4.0066E-03
1.9953E-04          4.0493E-03
1.5849E-04          4.0924E-03
1.2589E-04          4.1360E-03
1.0000E-04          4.1800E-03
7.9433E-05          4.2147E-03
6.3096E-05          4.2496E-03
5.0119E-05          4.2849E-03
3.9811E-05          4.3204E-03
3.1623E-05          4.3563E-03
2.5119E-05          4.3924E-03
1.9953E-05          4.4289E-03
1.5849E-05          4.4656E-03
1.2589E-05          4.5026E-03
1.0000E-05          4.5400E-03
7.9433E-06          4.5319E-03
6.3096E-06          4.5239E-03
5.0119E-06          4.5159E-03
3.9811E-06          4.5078E-03
3.1623E-06          4.4998E-03
2.5119E-06          4.4918E-03
1.9953E-06          4.4839E-03
1.5849E-06          4.4759E-03
1.2589E-06          4.4679E-03
1.0000E-06          4.4600E-03
7.9433E-07          4.3739E-03
6.3096E-07          4.2894E-03
5.0119E-07          4.2066E-03
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
          3.9811E-07          4.1254E-03
          3.1623E-07          4.0458E-03
          2.5119E-07          3.9677E-03
          1.9953E-07          3.8910E-03
          1.5849E-07          3.8159E-03
          1.2589E-07          3.7423E-03
          1.0000E-07          3.6700E-03
          2.5000E-08          3.6700E-03
end

*
* Unit 13 Hole Data
*
begin hole data
* Canister Hole Description v1.0
* Hole    1    BORAL Core
PLATE
1    0    0
2
0.1905    13
0.0000    12
13

* Hole    2    General Basket Structure
PLATE
0    0    1
7
286.5120    0            ! Top of Basket
258.0894    -3            ! Top of Highest Support Disk
212.0138    -8            ! Resume support disk only
55.1942    -5            ! Start of support+heat disk region
21.5900    -7            ! Bottom of Lowest Support Disk
0.0000    -4            ! Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole    3    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
86.3346
87.6046
5                ! number of axial intervals
258.0894                ! Top of diskstack
269.2400                ! Bottom of weldment
270.5100                ! Top of weldment plate
270.5100                ! Ullage
283.9720                ! Flange
286.5120                ! Void to top of basket
0    0            ! Material below weldment
15    15            ! Plate Material
0    15            ! Ullage
0    15            ! Flange
0    0            ! Void to top of basket
0                ! Outside material

* Hole    4    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ! number of radial points
87.6046
1                ! number of axial intervals
3.8100
5.0800                ! Coordinates inherited from PLATE Hole
15                ! Plate Material
0                ! Outside material

* Hole    5    Support disk and heat transfer disk stack
PLATE
origin    0    0    55.1942    ! Origin
0    0    1
4
CELL    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
6.8707    0            ! water gap
5.6007    16            ! aluminium disk
1.2700    0            ! water gap
14                ! steel disk

* Hole    6    Flood material model
PLATE
0    0    1
1
276.3618    0            ! Above flooded region
0                ! Flooded region

* Hole    7    Support disk stack lower
PLATE
origin    0    0    21.5900    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
11.2014    0            ! flood matl
1.2700    0            ! water gap
14                ! steel disk

* Hole    8    Support disk stack upper
PLATE
origin    0    0    212.0138    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
1.2700    0            ! water gap
14                ! steel disk

end

*
* Unit 15 Source Strength - Fuel Neutron
*
* Class Yankee MPC - ce16y - CE16 (Rev 1) - Fuel Neutron - ce16y_36b37e08y
begin source strength
    component        1.6667E+00    ! Subcritical multiplication factor
    component        1.1610E-05    ! 1/(volAssy) (1/8.6133E+04)
    component    r    11*1.0
    component    z
        1.2248E-01    2.3124E-01    4.0201E-01    6.5575E-01    1.0168E+00    1.5130E+00
        1.7986E+00        1.4923E+00    1.1492E+00    5.9896E-01    2.7775E-01
        1.0909E-01    3.3287E-02
    component    energy
        0.0000E+00    4.3750E+03    1.8230E+04    6.0560E+04    1.9000E+05    5.1000E+05
        8.8040E+05    2.9460E+06    5.0310E+06    6.9300E+06    1.6490E+07    2.5230E+07
        6.5350E+06    2.2680E+06    1.0820E+02    0.0000E+00    0.0000E+00    0.0000E+00
        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
end

*
* Unit 16 Simple Source Weights
*
*begin source weights
*
*end

*
* Unit 31 Tabular Output
*
begin tabular output
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRA - Surface - Response/
    response    interim
    number    some    1
    region    from    223    to    232
    output to file    also
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRAB - Inlet - Response/
    response
    number    some    1
    region    from    255    to    290
    output to file    also
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRB - 1ft - Response/
    response
    number    some    1
    region    from    329    to    340
    output to file    also
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRC - 1m - Response/
    response
    number    some    1
    region    from    342    to    353
    output to file    also
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRD - 2m - Response/
    response
    number    some    1
    region    from    355    to    374
    output to file    also
    /Case strStlDryRadFn_ce16y_36b37e08y - Det DRE - 4m - Response/
    response
    number    some    1
    region    from    376    to    395
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    dice
normalise
nmixtures    4
weight    mixture    1
            u235    3.2615E-02
            u238    8.4888E-01
            o    1.1850E-01
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
atoms    mixture    2
           h    6.6667E-01
           o    3.3333E-01
weight    mixture    3
           al    5.8260E-01
           b10    4.5690E-02
           b11    2.7769E-01
           c    9.4020E-02
atoms    mixture    4
           c    2.8571E-01
           h    4.7619E-01
           o    2.3810E-01
*
* Materials List - Dry Conditions - v1.2 - Class Yankee MPC - ce16y - CE16 (Rev 1) Fuel
*
nmaterials    26
volume                          ! Homogenized fuel
material    1
    mixture    1    density    10.4120    prop    3.0283E-01    ! UO2 mixture at 3.7%
    void                prop    1.2812E-02    ! Gap
    zircalloy        density    6.5500    prop    1.2736E-01    ! Tube, clad
!    stainless 304l steel        density    7.9200    prop    0.0000E+00    ! Stainless steel hw
    zircalloy        density    6.5500    prop    3.4595E-03    ! Zircaloy hw
    void                prop    5.5354E-01    ! Interstitial, inside tubes
volume                          ! Fuel pin cladding
material    2
    zircalloy        density    6.5500    prop    1.0000
volume                          ! Water In Lattice and Tube
material    3
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                          ! Water In Fuel Rod Clad Gap
material    4
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                          ! Lower Nozzle Material
material    5
    stainless 304l steel        density    7.9200    prop    0.0965
    void                prop    0.9035
volume                          ! Lower Plenum Material
material    6
    stainless 304l steel        density    7.9200    prop    0.1094
    zircalloy        density    6.5500    prop    0.0373
    void                prop    0.8533
volume                          ! Upper Nozzle Material
material    7
    stainless 304l steel        density    7.9200    prop    0.0919
    void                prop    0.9081
volume                          ! Upper Plenum Material
material    8
    stainless 304l steel        density    7.9200    prop    0.0290
    void                prop    0.9710
volume                          ! Damaged Fuel Lower Nozzle
material    9
    stainless 304l steel        density    7.9200    prop    0.0965
    mixture    1    density    10.4120    prop    0.3318    ! UO2 mixture at 3.7%
    void                prop    0.5717
volume                          ! Damaged Fuel Upper Nozzle
material    10
    stainless 304l steel        density    7.9200    prop    0.0919
    mixture    1    density    10.4120    prop    0.2990    ! UO2 mixture at 3.7%
    void                prop    0.6091
*
* Materials List - Common Materials - v1.2
*
volume                          ! Tube wall and cover sheet
material    11
    stainless 304l steel        density    7.9200    prop    1.0000
volume                          ! BORAL core
material    12
    mixture    3    density    2.6226    prop    0.9850    ! mixBORAL
    void                prop    0.0150
volume                          ! BORAL alumnimum clad
material    13
    aluminium                prop    1.0000
volume                          ! Structural Disk Material
material    14
    stainless 304l steel        density    7.9200    prop    1.0000
volume                          ! Weldment Material
material    15
    stainless 304l steel        density    7.9200    prop    1.0000
volume                          ! Heat Transfer Disk Material
material    16
    aluminium                prop    1.0000
volume                          ! Canister Material
material    17
    stainless 304l steel        density    7.9200    prop    1.0000
atoms                           ! Transfer steel
material    18        density    0            !  (SCALE carbonsteel 7.8212 g/cc)
        c            prop    3.9250E-03
        fe            prop    8.3498E-02
volume                          ! Lead
```

Figure 5.6.1.2-2 MCBEND Input File for Design Basis CE Fuel Neutron Source with Radial Biasing (Continued)

```
material    19
    pb        density    11.0400    prop    1.0000
atoms                                  ! NS-4-FR
material    20        density    0              ! 0 means atom/b-cm
        b10            prop    8.5500E-05
        b11            prop    3.4200E-04
        al            prop    7.8000E-03
        h            prop    5.8500E-02
        o            prop    2.6100E-02
        c            prop    2.2600E-02
        n            prop    1.3900E-03
volume                                 ! Stainless Steel 304
material    21
    stainless 304l steel        density    7.9200    prop    1.0000
volume                                   ! Vent port middle cylinder
material    22
    stainless 304l steel        density    7.9200    prop    0.5000
    void                prop    0.5000
atoms                                   ! SCALE Concrete
material    23        density    0              ! (density 2.2426 g/cc)
        h            prop    1.3401E-02
        o            prop    4.4931E-02
        na            prop    1.7036E-03
        al            prop    1.7018E-03
        si            prop    1.6205E-02
        ca            prop    1.4826E-03
        fe            prop    3.3857E-04
volume                                 ! Heat fins for transport cask
material    24
    cu        density    8.9200    prop    0.4286
    stainless 304l steel        density    7.9200    prop    0.5714
volume                                   ! Balsa
material    25
    mixture    4    density    0.1250    prop    1.0000
volume                                 ! Redwood
material    26
    mixture    4    density    0.3870    prop    1.0000
end

*
* Unit 26 Angular Scoring
*
begin angular scoring
    score angular currents
    splitting mesh
    pole radial positive
    azimuth theta positive
    face    2
    block
    32    1    5
    32    1    44
    polar
    11    fill    -1.0
        p    0.0
    n    10    1.0
        cosine
    azimuthal
        dummy
    write currents to file
end
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing

```
columns 1 200
*
* Yankee-MPC VCC - ce16y_36b37e08y - Lower Nozzle - Inlet
*   Shield Lid - Ports - With Covers
*   Structural Lid - No Weld Shield
*   Dry Conditions
*
*   Model Revision v1.6.0.0
*

*
* Parameters
*
@samps =    20000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit    1000m
    seeds    19075    61671
    chime every    [@samps/10]    samples
*    chime every    60m
    report interim results
    sbd    10s
    dump intervals    1
end

*
* Unit 3 Output Control
*
*begin output control
*    suppress inflows
*end

*
* Unit 4 Material Geometry
*
begin material geometry
* Fuel Assembly Type A - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    1    NEST
BOX    M5    S    0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6         0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1         0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8         0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7         0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* Fuel Assembly Type B - Class Yankee MPC - ce16y - CE16 (Rev 1)
PART    2    NEST
BOX    M5    S    0.0000    0.0000    0.0000    19.3040    19.3040    18.2626    ! lower nozzle
BOX    M6         0.0000    0.0000    0.0000    19.3040    19.3040    23.6220    ! Lower plenum
BOX    M1         0.0000    0.0000    0.0000    19.3040    19.3040    254.7620    ! fuel
BOX    M8         0.0000    0.0000    0.0000    19.3040    19.3040    263.6774    ! top plenum
BOX    M7         0.0000    0.0000    0.0000    19.3040    19.3040    283.9466    ! upper nozzle
* BORAL and Cover for Standard Opening v1.0
PART    3    NEST
BOX    BH1    0.0457    0.0000    0.3556    0.1905    18.2880    244.3480    ! BORAL Sheet - Axial offset from cover sheet bottom
BOX    M0    0.0457    0.0000    0.0000    0.1905    18.2880    248.9200    ! Space under cover sheet that allows sheet to shift
under cover
BOX    M11    0.0000    0.0000    0.0000    0.2362    18.2880    248.9200    ! SS cover sheet for BORAL
* Fuel Assembly in Tube (Type A) v1.0
PART    4
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.0
PART    5
BOX    1    0.3759    0.3759    0.0000    19.3040    19.3040    283.9466    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    19.8120    19.8120    288.2900    ! Space inside tube from can lid to bottom
BOX    3    0.0000    0.0000    5.0800    20.0558    20.0558    262.8900    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    20.0558    20.0558    288.2900    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M11    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.0
PART    6    CLUSTER
BOX    P4    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type A with fuel assy
BOX    P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX    P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX    P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
        ZROT    90.0000
BOX    P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
        ZROT    270.0000
BOX     H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
*  Type B Disk Opening with Tube v1.0
PART    7     CLUSTER
BOX     P5    0.4546    0.4546    0.0000    20.0558    20.0558    288.2900    ! Fuel tube type B with fuel assy
BOX     P3    0.2184    1.3386    16.5100    0.2362    18.2880    248.9200
BOX     P3    20.7467    19.6266    16.5100    0.2362    18.2880    248.9200
        ZROT    180.0000
BOX     P3    1.3386    20.7467    16.5100    0.2362    18.2880    248.9200
        ZROT    90.0000
BOX     P3    19.6266    0.2184    16.5100    0.2362    18.2880    248.9200
        ZROT    270.0000
BOX     H6    0.0000    0.0000    0.0000    20.9652    20.9652    288.2900    ! Support disk opening width
* Basket v1.0
PART    8
BOX     1    -33.6702    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 1
BOX     2    -10.4826    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 2
BOX     3    12.7051    58.5978    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 3
BOX     4    -56.6928    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 4
BOX     5    -33.6702    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 5
BOX     6    -10.4826    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 6
BOX     7    12.7051    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 7
BOX     8    35.7276    35.7276    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 8
BOX     9    -79.5630    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 9
BOX     10    -56.6928    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 10
BOX     11    -33.6702    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 11
BOX     12    -10.4826    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 12
BOX     13    12.7051    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 13
BOX     14    35.7276    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 14
BOX     15    58.5978    12.7051    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 15
BOX     16    -79.5630    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 16
BOX     17    -56.6928    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 17
BOX     18    -33.6702    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 18
BOX     19    -10.4826    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Middle Opening
BOX     20    12.7051    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 19
BOX     21    35.7276    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 20
BOX     22    58.5978    -10.4826    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 21
BOX     23    -79.5630    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 22
BOX     24    -56.6928    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 23
BOX     25    -33.6702    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 24
BOX     26    -10.4826    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 25
BOX     27    12.7051    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 26
BOX     28    35.7276    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 27
BOX     29    58.5978    -33.6702    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 28
BOX     30    -56.6928    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 29
BOX     31    -33.6702    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 30
BOX     32    -10.4826    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 31
BOX     33    12.7051    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 32
BOX     34    35.7276    -56.6928    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 33
BOX     35    -33.6702    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 34
BOX     36    -10.4826    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 35
BOX     37    12.7051    -79.5630    0.0000    20.9652    20.9652    288.2900    ! Basket Opening 36
BOX     38    33.6703    -78.6004    270.5100    28.4480    21.9075    16.0020    ! Drain Baffle Box A
BOX     39    35.2578    -78.6004    270.5100    26.8605    20.3200    16.0020    ! Drain Baffle Box B
ZROD    40    46.2405    -61.3632    0.0000    2.6035    288.2900    ! Drain Baffle Hole
BOX     41    -62.1182    56.6929    270.5100    28.4480    21.9075    16.0020    ! Vent Baffle Box A
BOX     42    -62.1182    58.2804    270.5100    26.8605    20.3200    16.0020    ! Vent Baffle Box B
ZROD    43    -46.2405    61.3632    0.0000    2.6035    288.2900    ! Vent Baffle Hole
ZROD    44    0.0000    0.0000    0.0000    86.3346    288.2900    ! Baffle limiting radius
CONTAINER
ZROD    45    0.0000    0.0000    0.0000    87.4649    288.2900    ! Basket stack to cavity height
ZONES
/Opening01/    P6    +1
/Opening02/    P6    +2
/Opening03/    P6    +3
/Opening04/    P7    +4
/Opening05/    P6    +5
/Opening06/    P6    +6
/Opening07/    P6    +7
/Opening08/    P7    +8
/Opening09/    P6    +9
/Opening10/    P6    +10
/Opening11/    P6    +11
/Opening12/    P6    +12
/Opening13/    P6    +13
/Opening14/    P6    +14
/Opening15/    P6    +15
/Opening16/    P6    +16
/Opening17/    P6    +17
/Opening18/    P6    +18
/Opening19/    P6    +20
/Opening20/    P6    +21
/Opening21/    P6    +22
/Opening22/    P6    +23
/Opening23/    P6    +24
/Opening24/    P6    +25
/Opening25/    P6    +26
/Opening26/    P6    +27
/Opening27/    P6    +28
/Opening28/    P6    +29
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
/Opening29/    P7    +30
/Opening30/    P6    +31
/Opening31/    P6    +32
/Opening32/    P6    +33
/Opening33/    P7    +34
/Opening34/    P6    +35
/Opening35/    P6    +36
/Opening36/    P6    +37
/Center/    H2    +19
/DrainBfl/    M17    +38    -39    +44
/DrainBflHole/    H6    +40
/DrainBflInner/    H2    +39    -40    +44
/VentBfl/    M17    +41    -42    +44
/VentBflHole/    H6    +43
/VentBflInner/    H2    +42    -43    +44
/Basket/    H2    +45    -1    -2    -3    -4    -5
        -6    -7    -8    -9    -10    -11
        -12    -13    -14    -15    -16    -17
        -18    -19    -20    -21    -22    -23
        -24    -25    -26    -27    -28    -29
        -30    -31    -32    -33    -34    -35
        -36    -37    -38    -40    -41    -43
/BasketDrain/    H2    +45    +38    -44
/BasketVent/    H2    +45    +41    -44

VOLUMES    UNITY
* Basket in Canister Cavity v1.0
PART    9    NEST
ZROD    P8    0.0000    0.0000    0.0000    87.4649    288.2900        ! Basket inserted - Includes gap to lid
        ZROT    0.0000
ZROD    H6    0.0000    0.0000    0.0000    88.1253    288.2900        ! Inserts flood matl to canister shell
* Canister - Structural Lid - No Weld Shield v1.0
PART    10
ZROD    1    0.0000    0.0000    0.0000    88.1253    288.2900        ! Canister cavity contents
ZROD    2    0.0000    0.0000    -2.5400    89.7128    2.5400        ! Canister Bottom Plate
ZROD    3    0.0000    0.0000    288.2900    88.1253    12.7000        ! Shield Lid
ZROD    4    0.0000    0.0000    300.9900    88.1253    7.6200        ! Structural Lid
ZROD    5    0.0000    0.0000    0.0000    88.1253    308.6100        ! Canister Shell Inner
ZROD    6    0.0000    0.0000    0.0000    89.7128    308.6100        ! Canister Shell Outer
ZROD    7    0.0000    0.0000    -2.5400    89.7128    311.1500        ! Inner Detector Surface
ZONES
/Cavity/    P9    +1
/BottomPlate/    M17    +2
/ShieldLid/    P11    +3
/StructLid/    M17    +4
/Shell/    M17    +6    -5
/Canister/    M0    +7    -6    -4    -2
VOLUMES    UNITY
* Shield Lid - With Ports v1.0
PART    11    CLUSTER
ZROD    P12    -46.2405    61.3632    0.0000    7.6200    12.7000        ! Vent port
ZROD    P12    46.2405    -61.3632    0.0000    7.6200    12.7000        ! Drain port
ZROD    M17    0.0000    0.0000    0.0000    88.1253    12.7000        ! Shield Lid
* Vent Port Model - With Covers v1.0
PART    12    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.3843    4.6228        ! Bottom Cylinder
ZROD    M17    0.0000    0.0000    4.6228    5.0800    6.6548        ! Middle Cyclinder
ZROD    M17    0.0000    0.0000    11.2776    7.6200    1.4224        ! Top Cylinder
ZROD    M17    0.0000    0.0000    0.0000    7.6200    12.7000        ! Shield lid material
* Storage Cask Air Inlet PIM Model
PART    13
YROD    1    5.0800    0.0000    22.8600    5.0800    30.4800        ! Pipe A Outer
YROD    2    5.0800    0.0000    22.8600    3.4646    30.4800        ! Pipe A Inner
YROD    3    25.4000    0.0000    10.1600    5.0800    30.4800        ! Pipe B Outer
YROD    4    25.4000    0.0000    10.1600    3.4646    30.4800        ! Pipe B Inner
YROD    5    45.7200    0.0000    22.8600    5.0800    30.4800        ! Pipe C Outer
YROD    6    45.7200    0.0000    22.8600    3.4646    30.4800        ! Pipe C Inner
YROD    7    66.0400    0.0000    10.1600    5.0800    30.4800        ! Pipe D Outer
YROD    8    66.0400    0.0000    10.1600    3.4646    30.4800        ! Pipe D Inner
BOX    9    0.0000    0.0000    0.0000    71.1200    30.4800    33.0200        ! Container
ZONES
/Pipe A Steel/    M18    +1    -2
/Pipe A Void/    M0    +2
/Pipe A Steel/    M18    +3    -4
/Pipe A Void/    M0    +4
/Pipe A Steel/    M18    +5    -6
/Pipe A Void/    M0    +6
/Pipe A Steel/    M18    +7    -8
/Pipe A Void/    M0    +8
/Container/    M0    +9    -1    -3    -5    -7
VOLUMES UNITY
*Storage Cask Top Geometry v1.6.0.0
PART    14
ZROD    1    0.0000    0.0000    347.4720    116.9670    3.8100        ! VCC lid
ZROD    2    0.0000    0.0000    342.3920    124.3330    5.0800        ! Top flange outer
ZROD    3    0.0000    0.0000    342.3920    102.8700    5.0800        ! Top flange inner
ZROD    4    0.0000    0.0000    324.6120    100.3300    7.6200        ! Support ring outer
ZROD    5    0.0000    0.0000    324.6120    93.9800    7.6200        ! Support ring inner
ZROD    6    0.0000    0.0000    0.0000    109.2200    342.3920        ! VCC shell outer
ZROD    7    0.0000    0.0000    0.0000    100.3300    342.3920        ! VCC shell inner
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
ZROD    8    0.0000    0.0000    304.2920    109.2200    12.0650            ! VCC shell opening
ZROD    9    0.0000    0.0000    0.0000    162.5600    347.4720            ! Concrete
ZCONE   10    0.0000    0.0000    326.5170    92.0750    99.6950    7.6200        ! Shield plug cone
ZROD    11    0.0000    0.0000    334.1370    99.6950    1.9050            ! Shield plug cylinder
ZROD    12    0.0000    0.0000    336.0420    86.9950    3.4925            ! NS cover plate
ZROD    13    0.0000    0.0000    336.0420    86.0425    2.5400            ! NS
ZROD    14    0.0000    0.0000    304.2920    106.6800    12.0650            ! Air outlet inner radius
BOX    15    -54.2290    -162.5600    304.2920    108.4580    325.1200    33.1470        ! Air outlet A channel box
BOX    16    -53.2765    -162.5600    305.2445    106.5530    325.1200    31.2420        ! Air outlet A void box
BOX    17    -53.2765    -162.5600    304.2920    106.5530    325.1200    33.1470        ! Air outlet A wall box
BOX    18    -162.5600    -54.2290    304.2920    325.1200    108.4580    33.1470        ! Air outlet B channel box
BOX    19    -162.5600    -53.2765    305.2445    325.1200    106.5530    31.2420        ! Air outlet B void box
BOX    20    -162.5600    -53.2765    304.2920    325.1200    106.5530    33.1470        ! Air outlet B wall box
BOX    21    -162.5600    -162.5600    336.4865    325.1200    325.1200    0.9525        ! Box H8-H7 R5
BOX    22    -162.5600    -162.5600    326.3265    325.1200    325.1200    10.1600        ! Box H7-H6 R5
BOX    23    -162.5600    -162.5600    325.3740    325.1200    325.1200    0.9525        ! Box H6-H5 R5
BOX    24    -162.5600    -162.5600    304.2920    325.1200    325.1200    21.0820        ! Box H5-H1 R5
BOX    25    -128.0160    -128.0160    316.3570    256.0320    256.0320    21.0820        ! Box H8-H4 R2
BOX    26    -127.0635    -127.0635    316.3570    254.1270    254.1270    21.0820        ! Box H8-H4 R1
BOX    27    -143.2560    -143.2560    304.2920    286.5120    286.5120    21.0820        ! Box H5-H1 R4
BOX    28    -143.2560    -143.2560    304.2920    286.5120    286.5120    22.0345        ! Box H6-H1 R4
BOX    29    -128.0160    -128.0160    315.4045    256.0320    256.0320    0.9525        ! Box H4-H3 R2
BOX    30    -138.1760    -138.1760    305.2445    276.3520    276.3520    21.0820        ! Box H6-H2 R3
BOX    31    -128.0160    -128.0160    305.2445    256.0320    256.0320    10.1600        ! Box H3-H2 R2
BOX    32    -138.1760    -138.1760    304.2920    276.3520    276.3520    0.9525        ! Box H2-H1 R3
BOX    33    -138.1760    -138.1760    304.2920    276.3520    276.3520    22.0345        ! Box H6-H1 R3
BOX    34    -128.0160    -128.0160    305.2445    256.0320    256.0320    21.0820        ! Box H6-H2 R2
ZROD    35    0.0000    0.0000    0.0000    100.3300    342.3920            ! Cavity
ZROD    36    0.0000    0.0000    0.0000    162.5600    351.2820            ! Container
ZROD    37    0.0000    0.0000    0.0000    89.7128    311.1500            ! Canister
ZROD    38    0.0000    0.0000    311.1500    31.7271    1.0000            ! Canister Det 01
ZROD    39    0.0000    0.0000    311.1500    44.8689    1.0000            ! Canister Det 02
ZROD    40    0.0000    0.0000    311.1500    54.9530    1.0000            ! Canister Det 03
ZROD    41    0.0000    0.0000    311.1500    63.4543    1.0000            ! Canister Det 04
ZROD    42    0.0000    0.0000    311.1500    70.9440    1.0000            ! Canister Det 05
ZROD    43    0.0000    0.0000    311.1500    77.7153    1.0000            ! Canister Det 06
ZROD    44    0.0000    0.0000    311.1500    83.9421    1.0000            ! Canister Det 07
ZROD    45    0.0000    0.0000    311.1500    89.7379    1.0000            ! Canister Det 08
ZROD    46    0.0000    0.0000    311.1500    95.1814    1.0000            ! Canister Det 09
ZROD    47    0.0000    0.0000    311.1500    100.3300    1.0000            ! Canister Det 10
ZROD    48    0.0000    0.0000    312.1500    100.3300    1.0000            ! Can Azi Det Container
ZSEC    49    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 01
        345.0000    375.0000
ZSEC    50    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 02
        15.0000    45.0000
ZSEC    51    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 03
        45.0000    75.0000
ZSEC    52    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 04
        75.0000    105.0000
ZSEC    53    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 05
        105.0000    135.0000
ZSEC    54    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 06
        135.0000    165.0000
ZSEC    55    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 07
        165.0000    195.0000
ZSEC    56    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 08
        195.0000    225.0000
ZSEC    57    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 09
        225.0000    255.0000
ZSEC    58    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 10
        255.0000    285.0000
ZSEC    59    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 11
        285.0000    315.0000
ZSEC    60    0.0000    0.0000    312.1500    95.1814    100.3300    1.0000        ! Can Azi Det 12
        315.0000    345.0000
ZROD    61    0.0000    0.0000    339.5345    31.7271    1.0000            ! Shield Plug Det 01
ZROD    62    0.0000    0.0000    339.5345    44.8689    1.0000            ! Shield Plug Det 02
ZROD    63    0.0000    0.0000    339.5345    54.9530    1.0000            ! Shield Plug Det 03
ZROD    64    0.0000    0.0000    339.5345    63.4543    1.0000            ! Shield Plug Det 04
ZROD    65    0.0000    0.0000    339.5345    70.9440    1.0000            ! Shield Plug Det 05
ZROD    66    0.0000    0.0000    339.5345    77.7153    1.0000            ! Shield Plug Det 06
ZROD    67    0.0000    0.0000    339.5345    83.9421    1.0000            ! Shield Plug Det 07
ZROD    68    0.0000    0.0000    339.5345    89.7379    1.0000            ! Shield Plug Det 08
ZROD    69    0.0000    0.0000    339.5345    95.1814    1.0000            ! Shield Plug Det_09
ZROD    70    0.0000    0.0000    339.5345    100.3300    1.0000            ! Shield Plug Det 10
ZONES
/VCCLid/    M18    +1
/TopFlange/    M18    +2    -3
/SupportRing/    M18    +4    -5    -10
/ShieldPlugCone/    M18    +10
/ShieldPlugCyl/    M18    +11
/NScover/    M18    +12    -13
/NS/    M20    +13
/VCC Shell1/    M18    +6    -7    -8                    ! Outside air outlet opening
/VCC Shell2/    M18    +8    -7    -15    -18                ! Outside air outlet channel
/Concrete1/    M23    +9    -6    -2    -15    -18            ! Non air outlet concrete
/Concrete2/    M23    +9    +24    -27    +15                ! Bot air outlet concrete
/Concrete3/    M23    +9    +24    -27    +18                ! Bot air outlet concrete
/Concrete4/    M23    +9    -6    +26    +15                ! Top air outlet concrete
/Concrete5/    M23    +9    -6    +26    +18                ! Top air outlet concrete
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
/AirOutTop1/    M18    +15    +21    -25    +9
/AirOutTop2/    M18    +18    +21    -25    +9
/AirOutMid1/    M18    +15    +23    -28    +9
/AirOutMid2/    M18    +18    +23    -28    +9
/AirOutBack1/    M18    +15    +25    -26
/AirOutBack2/    M18    +18    +25    -26
/AirOutBot1/    M18    +15    +32    -14
/AirOutBot2/    M18    +18    +32    -14
/AirOutBot3/    M18    +32    +15    +14    -7    -17
/AirOutBot4/    M18    +32    +18    +14    -7    -20
/AirOutShieldPlate1/    M18    +15    +28    -33
/AirOutShieldPlate2/    M18    +18    +28    -33
/AirOutTopThick1/    M18    +15    +29    -14
/AirOutTopThick2/    M18    +18    +29    -14
/AirOutTopThick3/    M18    +29    +15    +14    -7    -16
/AirOutTopThick4/    M18    +29    +18    +14    -7    -19
/AirOutTopVoid1/    M0    +16    +22    -25    +9
/AirOutTopVoid2/    M0    +19    +22    -25    +9
/AirOutMidVoid1/    M0    +16    +30    -34
/AirOutMidVoid2/    M0    +19    +30    -34
/AirOutBotVoid1/    M0    +16    +31    -14
/AirOutBotVoid2/    M0    +19    +31    -14
/AirOutWallTop1/    M18    +15    -16    +22    -25    +9
/AirOutWallTop2/    M18    +18    -19    +22    -25    +9
/AirOutWallMid1/    M18    +15    -16    +30    -34
/AirOutWallMid2/    M18    +18    -19    +30    -34
/AirOutWallBot1/    M18    +15    -16    +31    -7
/AirOutWallBot2/    M18    +18    -19    +31    -7
/ShellOpeningVoid1/    M0    +14    -7    +16    -29
/ShellOpeningVoid2/    M0    +14    -7    +19    -29
/ShellOpeningVoid3/    M0    +32    +14    -7    +17
/ShellOpeningVoid4/    M0    +32    +14    -7    +20
/ShellOpeningVoid5/    M0    +29    +14    -7    +16
/ShellOpeningVoid6/    M0    +29    +14    -7    +19
/FlangeVoid/    M0    +3    -12
/Cavity1/    M0    +35    -4    -10    -11    -12    -37        ! Outside support ring
        -47    -48    -70
/Cavity2/    M0    +35    +5    -10    -12                ! Inside support ring
/TSC/    P10    +37
/Container/    M0    +36    -9    -1
/TSCLid01/    M0    +38
/TSCLid02/    M0    +39    -38
/TSCLid03/    M0    +40    -39
/TSCLid04/    M0    +41    -40
/TSCLid05/    M0    +42    -41
/TSCLid06/    M0    +43    -42
/TSCLid07/    M0    +44    -43
/TSCLid08/    M0    +45    -44
/TSCLid09/    M0    +46    -45
/TSCLid10/    M0    +47    -46
/CanAziVoid/    M0    +48    -49    -50    -51    -52    -53
        -54    -55    -56    -57    -58    -59
        -60
/CanAziDet01/    M0    +49
/CanAziDet02/    M0    +50
/CanAziDet03/    M0    +51
/CanAziDet04/    M0    +52
/CanAziDet05/    M0    +53
/CanAziDet06/    M0    +54
/CanAziDet07/    M0    +55
/CanAziDet08/    M0    +56
/CanAziDet09/    M0    +57
/CanAziDet10/    M0    +58
/CanAziDet11/    M0    +59
/CanAziDet12/    M0    +60
/PlugTop01/    M0    +61
/PlugTop02/    M0    +62    -61
/PlugTop03/    M0    +63    -62
/PlugTop04/    M0    +64    -63
/PlugTop05/    M0    +65    -64
/PlugTop06/    M0    +66    -65
/PlugTop07/    M0    +67    -66
/PlugTop08/    M0    +68    -67
/PlugTop09/    M0    +69    -68
/PlugTop10/    M0    +70    -69
VOLUMES    53*1.0        10*3.1624E+03        1.0    12*2.6353E+02        10*3.1624E+03
*Storage Cask Bottom Geometry v1.6.0.0
PART    15
ZROD    1    0.0000    0.0000    53.5940    91.4400    5.0800            ! Base plate
ZCONE    2    0.0000    0.0000    2.5400    38.1000    29.2100    24.1300        ! Baffle weldment bot
ZCONE    3    0.0000    0.0000    2.5400    37.4543    28.5643    24.1300        ! Baffle weldment bot void
ZCONE    4    0.0000    0.0000    26.6700    29.2100    38.1000    24.1300        ! Baffle weldment top
ZCONE    5    0.0000    0.0000    26.6700    28.5643    37.4543    24.1300        ! Baffle weldment top void
ZROD    6    0.0000    0.0000    2.5400    63.5000    51.054            ! Stand outer
ZROD    7    0.0000    0.0000    2.5400    58.4200    51.054            ! Stand inner
ZP    8    33.0200                        ! Cut plane for stand
BOX    9    104.1710    -125.7236    0.0000    30.4800    325.1200    33.0200        ! Air inlet A void
        ZROT    -45.0000
BOX    10    103.4975    -126.3971    0.0000    32.3850    325.1200    35.5600        ! Air inlet A channel
        ZROT    -45.0000
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
BOX    11    -104.1710    -125.7236    0.0000    325.1200    30.4800    33.0200        ! Air inlet B void
        ZROT    -45.0000
BOX    12    -103.4975    -126.3971    0.0000    325.1200    32.3850    35.5600        ! Air inlet B channel
        ZROT    -45.0000
ZROD    13    0.0000    0.0000    0.0000    162.5600    2.5400            ! Bottom plate outer
ZROD    14    0.0000    0.0000    0.0000    63.5000    2.5400            ! Bottom plate inner
ZROD    15    0.0000    0.0000    2.5400    109.2200    56.1340            ! VCC shell outer
ZROD    16    0.0000    0.0000    2.5400    100.3300    56.1340            ! VCC shell inner
ZROD    17    0.0000    0.0000    2.5400    162.5600    56.1340            ! Concrete
ZROD    18    0.0000    0.0000    32.0675    99.6950    0.9525            ! Cover
BOX    19    -25.6540    -99.6950    33.0200    51.3080    199.3900    20.5740        ! Stand top cut box A
BOX    20    -99.6950    -25.6540    33.0200    199.3900    51.3080    20.5740        ! Stand top cut box B
ZROD    21    0.0000    0.0000    33.0200    99.6950    5.0800            ! Shield ring outer
ZROD    22    0.0000    0.0000    33.0200    90.1700    5.0800            ! Shield ring inner
BOX    23    35.2026    -56.7552    0.0000    71.1200    30.4800    33.0200        ! +x -y
        ZROT    45.0000
BOX    24    56.7552    35.2026    0.0000    71.1200    30.4800    33.0200        ! +x +y
        ZROT    -45.0000
BOX    25    -35.2026    56.7552    0.0000    71.1200    30.4800    33.0200        ! -x +y
        ZROT    -135.0000
BOX    26    -56.7552    -35.2026    0.0000    71.1200    30.4800    33.0200        ! -x -y
        ZROT    135.0000
ZROD    27    0.0000    0.0000    0.0000    162.5600    58.6740            ! Container
ZONES
/Container/    M0    +27    -17    -13
/BasePlate/    M18    +1
/BaffleTop/    M18    +4    -5
/BaffleTopVoid/    M0    +5
/BaffleBot/    M18    +2    -3
/BaffleBotVoid/    M0    +3
/InletAVoid/    M0    +9    -14    -7    +27    -23    -25        ! Outside of stand inner
/InletBVoid/    M0    +11    -14    -7    +27    -24    -26        ! Outside of stand inner
/PIM+x-y/    P13    +23                    ! PIM at +x - y
/PIM+x+y/    P13    +24                    ! PIM at +x + y
/PIM-x+y/    P13    +25                    ! PIM at -x + y
/PIM-x-y/    P13    +26                    ! PIM at -x - y
/InletAWalls/    M18    +10    -9    -6    +27    -14            ! Outside of stand outer
/InletBWalls/    M18    +12    -11    -6    +27    -14            ! Outside of stand outer
/VCCShell/    M18    +15    -16    -10    -12
/BotPlateInner/    M18    +14
/BotPlateOuter/    M18    +13    -14    -9    -11
/BaseVoid/    M0    +7    -2    -4                    ! Inside stand inner
/Concrete/    M23    +17    -15    -10    -12
/Cover/    M18    +18    -6    -10    -12
/StandBot/    M18    +6    -7    -8    -9    -11
/StandTop/    M18    +6    -7    +8    -19    -20
/ShieldRing/    M18    +21    -22    -10    -12
/StandTopVoid1/    M0    +6    +8    -7    +19
/StandTopVoid2/    M0    +6    +8    -7    +20
/ShieldRingVoid1/    M0    +22    -6    -10    -12                ! Inside the shield ring
/xyVoid/    M0    +16    -6    -10    -12    -8    -18
/OuterVoid/    M0    +16    -6    +8    -21    -1    -10    -12
VOLUMES UNITY
*Storage Cask Combined Geometry
PART    16
ZROD    1    0.0000    0.0000    -58.6740    162.5600    58.6740            ! Bottom
ZROD    2    0.0000    0.0000    0.0000    162.5600    351.2820            ! Top
ZROD    3    0.0000    0.0000    -158.6740    162.5600    100.0000            ! Concrete Pad
ZROD    4    0.0000    0.0000    -158.6740    162.5600    509.9560            ! Container
ZONES
/Bottom/    P15    +1
/Top/    P14    +2
/Concrete Pad/    M23    +3
/Container/    M0    +4    -3    -2    -1
VOLUMES UNITY
* Storage Cask Detector Description v1.6.0.0
PART    17
* Inlet Detector DIA (Surface) Bodies
ZROD    1                    0.0000    0.0000    -158.6740 162.5600  509.9560
ZROD    2                    0.0000    0.0000    -58.6740  163.5600  40.9956
ZROD    3                    0.0000    0.0000    -17.6784  163.5600  40.9956
ZROD    4                    0.0000    0.0000    23.3172   163.5600  40.9956
ZROD    5                    0.0000    0.0000    64.3128   163.5600  40.9956
ZROD    6                    0.0000    0.0000    105.3084  163.5600  40.9956
ZROD    7                    0.0000    0.0000    146.3040  163.5600  40.9956
ZROD    8                    0.0000    0.0000    187.2996  163.5600  40.9956
ZROD    9                    0.0000    0.0000    228.2952  163.5600  40.9956
ZROD    10                   0.0000    0.0000    269.2908  163.5600  40.9956
ZROD    11                   0.0000    0.0000    310.2864  163.5600  40.9956
* Inlet Detector DIAA (InletSurf) Bodies
ZROD    12                   0.0000    0.0000    -159.6740 163.5600  511.9560
*   Band 1 Bodies
ZSEC    13                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   40.0000   50.0000
ZSEC    14                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   50.0000   60.0000
ZSEC    15                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   60.0000   70.0000
ZSEC    16                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   70.0000   80.0000
ZSEC    17                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   80.0000   90.0000
ZSEC    18                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   90.0000   100.0000
ZSEC    19                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   100.0000  110.0000
ZSEC    20                   0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   110.0000  120.0000
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
ZSEC      21                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   120.0000  130.0000
ZSEC      22                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   130.0000  140.0000
ZSEC      23                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   140.0000  150.0000
ZSEC      24                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   150.0000  160.0000
ZSEC      25                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   160.0000  170.0000
ZSEC      26                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   170.0000  180.0000
ZSEC      27                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   180.0000  190.0000
ZSEC      28                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   190.0000  200.0000
ZSEC      29                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   200.0000  210.0000
ZSEC      30                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   210.0000  220.0000
ZSEC      31                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   220.0000  230.0000
ZSEC      32                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   230.0000  240.0000
ZSEC      33                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   240.0000  250.0000
ZSEC      34                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   250.0000  260.0000
ZSEC      35                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   260.0000  270.0000
ZSEC      36                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   270.0000  280.0000
ZSEC      37                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   280.0000  290.0000
ZSEC      38                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   290.0000  300.0000
ZSEC      39                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   300.0000  310.0000
ZSEC      40                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   310.0000  320.0000
ZSEC      41                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   320.0000  330.0000
ZSEC      42                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   330.0000  340.0000
ZSEC      43                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   340.0000  350.0000
ZSEC      44                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   350.0000  360.0000
ZSEC      45                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   360.0000  370.0000
ZSEC      46                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   10.0000   20.0000
ZSEC      47                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   20.0000   30.0000
ZSEC      48                  0.0000    0.0000    -58.6740  163.5600  164.5600  33.0200   30.0000   40.0000
* Inlet Detector DIB (1ft) Bodies
ZROD      49                  0.0000    0.0000    -160.6740 193.0400  542.4360
ZROD      50                  0.0000    0.0000    -58.6740  194.0400  36.7030
ZROD      51                  0.0000    0.0000    -21.9710  194.0400  36.7030
ZROD      52                  0.0000    0.0000    14.7320   194.0400  36.7030
ZROD      53                  0.0000    0.0000    51.4350   194.0400  36.7030
ZROD      54                  0.0000    0.0000    88.1380   194.0400  36.7030
ZROD      55                  0.0000    0.0000    124.8410  194.0400  36.7030
ZROD      56                  0.0000    0.0000    161.5440  194.0400  36.7030
ZROD      57                  0.0000    0.0000    198.2470  194.0400  36.7030
ZROD      58                  0.0000    0.0000    234.9500  194.0400  36.7030
ZROD      59                  0.0000    0.0000    271.6530  194.0400  36.7030
ZROD      60                  0.0000    0.0000    308.3560  194.0400  36.7030
ZROD      61                  0.0000    0.0000    345.0590  194.0400  36.7030
* Inlet Detector DIBA (Inlet+1ft) Bodies
ZROD      62                  0.0000    0.0000    -161.6740 194.0400  544.4360
*   Band 1 Bodies
ZSEC      63                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   40.0000   50.0000
ZSEC      64                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   50.0000   60.0000
ZSEC      65                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   60.0000   70.0000
ZSEC      66                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   70.0000   80.0000
ZSEC      67                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   80.0000   90.0000
ZSEC      68                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   90.0000   100.0000
ZSEC      69                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   100.0000  110.0000
ZSEC      70                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   110.0000  120.0000
ZSEC      71                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   120.0000  130.0000
ZSEC      72                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   130.0000  140.0000
ZSEC      73                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   140.0000  150.0000
ZSEC      74                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   150.0000  160.0000
ZSEC      75                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   160.0000  170.0000
ZSEC      76                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   170.0000  180.0000
ZSEC      77                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   180.0000  190.0000
ZSEC      78                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   190.0000  200.0000
ZSEC      79                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   200.0000  210.0000
ZSEC      80                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   210.0000  220.0000
ZSEC      81                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   220.0000  230.0000
ZSEC      82                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   230.0000  240.0000
ZSEC      83                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   240.0000  250.0000
ZSEC      84                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   250.0000  260.0000
ZSEC      85                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   260.0000  270.0000
ZSEC      86                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   270.0000  280.0000
ZSEC      87                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   280.0000  290.0000
ZSEC      88                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   290.0000  300.0000
ZSEC      89                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   300.0000  310.0000
ZSEC      90                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   310.0000  320.0000
ZSEC      91                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   320.0000  330.0000
ZSEC      92                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   330.0000  340.0000
ZSEC      93                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   340.0000  350.0000
ZSEC      94                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   350.0000  360.0000
ZSEC      95                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   360.0000  370.0000
ZSEC      96                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   10.0000   20.0000
ZSEC      97                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   20.0000   30.0000
ZSEC      98                  0.0000    0.0000    -58.6740  194.0400  195.0400  33.0200   30.0000   40.0000
* Inlet Detector DIC (1m) Bodies
ZROD      99                  0.0000    0.0000    -162.6740 262.5600  613.9560
ZROD      100                 0.0000    0.0000    -58.6740  263.5600  42.4963
ZROD      101                 0.0000    0.0000    -16.1777  263.5600  42.4963
ZROD      102                 0.0000    0.0000    26.3187   263.5600  42.4963
ZROD      103                 0.0000    0.0000    68.8150   263.5600  42.4963
ZROD      104                 0.0000    0.0000    111.3113  263.5600  42.4963
ZROD      105                 0.0000    0.0000    153.8077  263.5600  42.4963
ZROD      106                 0.0000    0.0000    196.3040  263.5600  42.4963
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
ZROD      107                 0.0000    0.0000    238.8003  263.5600  42.4963
ZROD      108                 0.0000    0.0000    281.2967  263.5600  42.4963
ZROD      109                 0.0000    0.0000    323.7930  263.5600  42.4963
ZROD      110                 0.0000    0.0000    366.2893  263.5600  42.4963
ZROD      111                 0.0000    0.0000    408.7857  263.5600  42.4963
* Inlet Detector DICA (Inlet+1m) Bodies
ZROD      112                 0.0000    0.0000    -163.6740 263.5600  615.9560
*   Band 1 Bodies
ZSEC      113                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   40.0000   50.0000
ZSEC      114                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   50.0000   60.0000
ZSEC      115                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   60.0000   70.0000
ZSEC      116                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   70.0000   80.0000
ZSEC      117                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   80.0000   90.0000
ZSEC      118                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   90.0000   100.0000
ZSEC      119                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   100.0000  110.0000
ZSEC      120                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   110.0000  120.0000
ZSEC      121                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   120.0000  130.0000
ZSEC      122                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   130.0000  140.0000
ZSEC      123                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   140.0000  150.0000
ZSEC      124                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   150.0000  160.0000
ZSEC      125                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   160.0000  170.0000
ZSEC      126                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   170.0000  180.0000
ZSEC      127                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   180.0000  190.0000
ZSEC      128                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   190.0000  200.0000
ZSEC      129                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   200.0000  210.0000
ZSEC      130                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   210.0000  220.0000
ZSEC      131                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   220.0000  230.0000
ZSEC      132                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   230.0000  240.0000
ZSEC      133                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   240.0000  250.0000
ZSEC      134                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   250.0000  260.0000
ZSEC      135                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   260.0000  270.0000
ZSEC      136                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   270.0000  280.0000
ZSEC      137                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   280.0000  290.0000
ZSEC      138                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   290.0000  300.0000
ZSEC      139                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   300.0000  310.0000
ZSEC      140                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   310.0000  320.0000
ZSEC      141                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   320.0000  330.0000
ZSEC      142                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   330.0000  340.0000
ZSEC      143                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   340.0000  350.0000
ZSEC      144                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   350.0000  360.0000
ZSEC      145                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   360.0000  370.0000
ZSEC      146                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   10.0000   20.0000
ZSEC      147                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   20.0000   30.0000
ZSEC      148                 0.0000    0.0000    -58.6740  263.5600  264.5600  33.0200   30.0000   40.0000
* World
ZROD      149                 0.0000    0.0000    -213.6740 313.5600  715.9560
* External Void
ZROD      150                 0.0000    0.0000    -263.6740 363.5600  815.9560

ZONES
/StorageCask/       P16       +1
* Detector DIA (Surface)
/DIA01/   M0        +2        -1
/DIA02/   M0        +3        -1
/DIA03/   M0        +4        -1
/DIA04/   M0        +5        -1
/DIA05/   M0        +6        -1
/DIA06/   M0        +7        -1
/DIA07/   M0        +8        -1
/DIA08/   M0        +9        -1
/DIA09/   M0        +10       -1
/DIA10/   M0        +11       -1
/Void/    M0        +12       -1
                    -2        -3        -4        -5        -6        -7
                    -8        -9        -10       -11
* Detector DIAA (InletSurf)
/DIAA0101/          M0        +13
/DIAA0102/          M0        +14
/DIAA0103/          M0        +15
/DIAA0104/          M0        +16
/DIAA0105/          M0        +17
/DIAA0106/          M0        +18
/DIAA0107/          M0        +19
/DIAA0108/          M0        +20
/DIAA0109/          M0        +21
/DIAA0110/          M0        +22
/DIAA0111/          M0        +23
/DIAA0112/          M0        +24
/DIAA0113/          M0        +25
/DIAA0114/          M0        +26
/DIAA0115/          M0        +27
/DIAA0116/          M0        +28
/DIAA0117/          M0        +29
/DIAA0118/          M0        +30
/DIAA0119/          M0        +31
/DIAA0120/          M0        +32
/DIAA0121/          M0        +33
/DIAA0122/          M0        +34
/DIAA0123/          M0        +35
/DIAA0124/          M0        +36
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
/DIAA0125/          M0        +37
/DIAA0126/          M0        +38
/DIAA0127/          M0        +39
/DIAA0128/          M0        +40
/DIAA0129/          M0        +41
/DIAA0130/          M0        +42
/DIAA0131/          M0        +43
/DIAA0132/          M0        +44
/DIAA0133/          M0        +45
/DIAA0134/          M0        +46
/DIAA0135/          M0        +47
/DIAA0136/          M0        +48
/Void/    M0        +49       -12
                    -13       -14       -15       -16       -17       -18
                    -19       -20       -21       -22       -23       -24
                    -25       -26       -27       -28       -29       -30
                    -31       -32       -33       -34       -35       -36
                    -37       -38       -39       -40       -41       -42
                    -43       -44       -45       -46       -47       -48
* Detector DIB (1ft)
/DIB01/   M0        +50       -49
/DIB02/   M0        +51       -49
/DIB03/   M0        +52       -49
/DIB04/   M0        +53       -49
/DIB05/   M0        +54       -49
/DIB06/   M0        +55       -49
/DIB07/   M0        +56       -49
/DIB08/   M0        +57       -49
/DIB09/   M0        +58       -49
/DIB10/   M0        +59       -49
/DIB11/   M0        +60       -49
/DIB12/   M0        +61       -49
/Void/    M0        +62       -49
                    -50       -51       -52       -53       -54       -55
                    -56       -57       -58       -59       -60       -61
* Detector DIBA (Inlet+1ft)
/DIBA0101/          M0        +63
/DIBA0102/          M0        +64
/DIBA0103/          M0        +65
/DIBA0104/          M0        +66
/DIBA0105/          M0        +67
/DIBA0106/          M0        +68
/DIBA0107/          M0        +69
/DIBA0108/          M0        +70
/DIBA0109/          M0        +71
/DIBA0110/          M0        +72
/DIBA0111/          M0        +73
/DIBA0112/          M0        +74
/DIBA0113/          M0        +75
/DIBA0114/          M0        +76
/DIBA0115/          M0        +77
/DIBA0116/          M0        +78
/DIBA0117/          M0        +79
/DIBA0118/          M0        +80
/DIBA0119/          M0        +81
/DIBA0120/          M0        +82
/DIBA0121/          M0        +83
/DIBA0122/          M0        +84
/DIBA0123/          M0        +85
/DIBA0124/          M0        +86
/DIBA0125/          M0        +87
/DIBA0126/          M0        +88
/DIBA0127/          M0        +89
/DIBA0128/          M0        +90
/DIBA0129/          M0        +91
/DIBA0130/          M0        +92
/DIBA0131/          M0        +93
/DIBA0132/          M0        +94
/DIBA0133/          M0        +95
/DIBA0134/          M0        +96
/DIBA0135/          M0        +97
/DIBA0136/          M0        +98
/Void/    M0        +99       -62
                    -63       -64       -65       -66       -67       -68
                    -69       -70       -71       -72       -73       -74
                    -75       -76       -77       -78       -79       -80
                    -81       -82       -83       -84       -85       -86
                    -87       -88       -89       -90       -91       -92
                    -93       -94       -95       -96       -97       -98
* Detector DIC (1m)
/DIC01/   M0        +100      -99
/DIC02/   M0        +101      -99
/DIC03/   M0        +102      -99
/DIC04/   M0        +103      -99
/DIC05/   M0        +104      -99
/DIC06/   M0        +105      -99
/DIC07/   M0        +106      -99
/DIC08/   M0        +107      -99
/DIC09/   M0        +108      -99
/DIC10/   M0        +109      -99
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
/DIC11/   M0        +110      -99
/DIC12/   M0        +111      -99
/Void/    M0        +112      -99
                    -100      -101      -102      -103      -104      -105
                    -106      -107      -108      -109      -110      -111
* Detector DICA (Inlet+1m)
/DICA0101/          M0        +113
/DICA0102/          M0        +114
/DICA0103/          M0        +115
/DICA0104/          M0        +116
/DICA0105/          M0        +117
/DICA0106/          M0        +118
/DICA0107/          M0        +119
/DICA0108/          M0        +120
/DICA0109/          M0        +121
/DICA0110/          M0        +122
/DICA0111/          M0        +123
/DICA0112/          M0        +124
/DICA0113/          M0        +125
/DICA0114/          M0        +126
/DICA0115/          M0        +127
/DICA0116/          M0        +128
/DICA0117/          M0        +129
/DICA0118/          M0        +130
/DICA0119/          M0        +131
/DICA0120/          M0        +132
/DICA0121/          M0        +133
/DICA0122/          M0        +134
/DICA0123/          M0        +135
/DICA0124/          M0        +136
/DICA0125/          M0        +137
/DICA0126/          M0        +138
/DICA0127/          M0        +139
/DICA0128/          M0        +140
/DICA0129/          M0        +141
/DICA0130/          M0        +142
/DICA0131/          M0        +143
/DICA0132/          M0        +144
/DICA0133/          M0        +145
/DICA0134/          M0        +146
/DICA0135/          M0        +147
/DICA0136/          M0        +148
/Void/    M0        +149      -112
                    -113      -114      -115      -116      -117      -118
                    -119      -120      -121      -122      -123      -124
                    -125      -126      -127      -128      -129      -130
                    -131      -132      -133      -134      -135      -136
                    -137      -138      -139      -140      -141      -142
                    -143      -144      -145      -146      -147      -148
/ExtVoid/ M-2000    +150      -149
Volumes
                    1.0       10*4.2001E+04       1.0       36*9.4549E+02       1.0       12*4.4633E+04
                    1.0       36*1.1211E+03       1.0       12*7.0240E+04       1.0       36*1.5218E+03
                    1.0       1.0
end

*
* Unit 5 Splitting Geometry for Inlet Detectors - Gamma
*
begin splitting geometry
    r    39    fill    0.0000
                  n    10    87.4649
                  n    2    100.3300
                  n    7    109.2200
                  n    18    162.5600
                  n    1    163.5600
                  n    1    168.5600

    theta    8    fill    40.0000
                  n    1    50.0000
                  n    1    130.0000
                  n    1    140.0000
                  n    1    220.0000
                  n    1    230.0000
                  n    1    310.0000
                  n    1    320.0000
                  n    1    40.0000
              degrees

    z    45    fill    -158.6740
                  n    1    -68.6740
                  n    4    -58.6740
                  n    2    -56.1340
                  n    4    -5.0800
                  n    4    0.0000
                  n    2    2.5400
                  n    2    26.1620
                  n    13    257.3020
                  n    1    266.2174
                  n    2    286.4866
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
                    n    1    290.8300
                    n    1    303.5300
                    n    1    311.1500
                    n    1    326.5170
                    n    1    336.0420
                    n    1    338.5820
                    n    1    339.5345
                    n    1    347.4720
                    n    1    351.2820
                    n    1    352.2820

end
*
* Unit 6 - Source Geometry for Lower Nozzle
*
begin source geometry
    r    11    fill    0.0000    n    11    87.4649
    z    1    fill    2.5400    n    1    20.8026
end

*
* Unit 7
*
begin energy data
    gamma    dice
    importance    standard    22    groups
    scoring    as    importance
    simple    source    histogram    weighting    automatic
end

*
* Unit 8 Importance Map - Air Inlet
*
begin importance map
    calculate
    targets    10
    part    17
    zones    2    3    4    5    6
        7    8    9    10    11
    strengths    1.0E+02    1.0E+01    1.0E+00    1.0E+00    1.0E+00
        1.0E+00    1.0E+00    1.0E+00    1.0E+00    1.0E+00
    defer mixing
    void density    0.10
    track
!    coupled source
!    write gamma importances to 32
!    write unformatted file to 31
!    use method d
end

*
* Unit 9 Scoring Data - Inlet
*
begin scoring data
    flux
    part    17
    from    2    to    11    ! DIA
    from    13    to    48    ! DIAA
    from    50    to    61    ! DIB
    from    63    to    98    ! DIBA
    from    100    to    111    ! DIC
    from    113    to    148    ! DICA
    responses    sos    ditto
    contributions to responses        ditto
    ! score distribution for response
    ! weight distribution    total
end

*
* Unit 10 Response Data
*
begin response data
* Scaled to mrem/hr
/ansi ans-6.1.1-1977 photon flux-dose conversion factors - mcnp table h.2 - mrem/
          function pairs
          1.5000E+01          1.3300E-02
          1.4787E+01          1.3142E-02
          1.4577E+01          1.2985E-02
          1.4370E+01          1.2831E-02
          1.4166E+01          1.2678E-02
          1.3964E+01          1.2528E-02
          1.3766E+01          1.2379E-02
          1.3570E+01          1.2231E-02
          1.3377E+01          1.2086E-02
          1.3187E+01          1.1942E-02
          1.3000E+01          1.1800E-02
          1.2785E+01          1.1641E-02
          1.2573E+01          1.1483E-02
          1.2365E+01          1.1328E-02
          1.2160E+01          1.1175E-02
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
1.1958E+01          1.1025E-02
1.1760E+01          1.0876E-02
1.1565E+01          1.0729E-02
1.1374E+01          1.0584E-02
1.1185E+01          1.0441E-02
1.1000E+01          1.0300E-02
1.0781E+01          1.0136E-02
1.0567E+01          9.9740E-03
1.0357E+01          9.8149E-03
1.0152E+01          9.6583E-03
9.9499E+00          9.5043E-03
9.7522E+00          9.3526E-03
9.5585E+00          9.2035E-03
9.3686E+00          9.0566E-03
9.1824E+00          8.9122E-03
9.0000E+00          8.7700E-03
8.8374E+00          8.6521E-03
8.6777E+00          8.5358E-03
8.5210E+00          8.4211E-03
8.3670E+00          8.3079E-03
8.2158E+00          8.1962E-03
8.0674E+00          8.0861E-03
7.9216E+00          7.9774E-03
7.7785E+00          7.8701E-03
7.6380E+00          7.7644E-03
7.5000E+00          7.6600E-03
7.4214E+00          7.6031E-03
7.3436E+00          7.5467E-03
7.2666E+00          7.4907E-03
7.1905E+00          7.4351E-03
7.1151E+00          7.3799E-03
7.0406E+00          7.3251E-03
6.9668E+00          7.2707E-03
6.8937E+00          7.2167E-03
6.8215E+00          7.1632E-03
6.7500E+00          7.1100E-03
6.6983E+00          7.0721E-03
6.6469E+00          7.0344E-03
6.5959E+00          6.9969E-03
6.5454E+00          6.9596E-03
6.4952E+00          6.9225E-03
6.4454E+00          6.8856E-03
6.3960E+00          6.8489E-03
6.3469E+00          6.8124E-03
6.2983E+00          6.7761E-03
6.2500E+00          6.7400E-03
6.1981E+00          6.7021E-03
6.1466E+00          6.6643E-03
6.0956E+00          6.6268E-03
6.0450E+00          6.5895E-03
5.9948E+00          6.5524E-03
5.9450E+00          6.5155E-03
5.8956E+00          6.4788E-03
5.8467E+00          6.4423E-03
5.7981E+00          6.4061E-03
5.7500E+00          6.3700E-03
5.6979E+00          6.3331E-03
5.6463E+00          6.2963E-03
5.5952E+00          6.2598E-03
5.5445E+00          6.2235E-03
5.4943E+00          6.1874E-03
5.4446E+00          6.1515E-03
5.3953E+00          6.1158E-03
5.3464E+00          6.0803E-03
5.2980E+00          6.0451E-03
5.2500E+00          6.0100E-03
5.2244E+00          5.9887E-03
5.1990E+00          5.9674E-03
5.1737E+00          5.9462E-03
5.1485E+00          5.9251E-03
5.1235E+00          5.9041E-03
5.0985E+00          5.8831E-03
5.0737E+00          5.8622E-03
5.0490E+00          5.8414E-03
5.0245E+00          5.8207E-03
5.0000E+00          5.8000E-03
4.9744E+00          5.7797E-03
4.9490E+00          5.7594E-03
4.9236E+00          5.7393E-03
4.8985E+00          5.7192E-03
4.8734E+00          5.6991E-03
4.8485E+00          5.6792E-03
4.8237E+00          5.6593E-03
4.7990E+00          5.6394E-03
4.7744E+00          5.6197E-03
4.7500E+00          5.6000E-03
4.6975E+00          5.5619E-03
4.6455E+00          5.5240E-03
4.5941E+00          5.4863E-03
4.5433E+00          5.4490E-03
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
4.4931E+00          5.4118E-03
4.4434E+00          5.3750E-03
4.3942E+00          5.3384E-03
4.3456E+00          5.3020E-03
4.2975E+00          5.2659E-03
4.2500E+00          5.2300E-03
4.1971E+00          5.1886E-03
4.1449E+00          5.1474E-03
4.0934E+00          5.1066E-03
4.0425E+00          5.0662E-03
3.9922E+00          5.0260E-03
3.9425E+00          4.9862E-03
3.8935E+00          4.9467E-03
3.8451E+00          4.9075E-03
3.7972E+00          4.8686E-03
3.7500E+00          4.8300E-03
3.6967E+00          4.7863E-03
3.6442E+00          4.7429E-03
3.5924E+00          4.7000E-03
3.5414E+00          4.6574E-03
3.4911E+00          4.6152E-03
3.4415E+00          4.5734E-03
3.3926E+00          4.5320E-03
3.3444E+00          4.4910E-03
3.2968E+00          4.4503E-03
3.2500E+00          4.4100E-03
3.2019E+00          4.3683E-03
3.1546E+00          4.3269E-03
3.1079E+00          4.2860E-03
3.0619E+00          4.2454E-03
3.0166E+00          4.2052E-03
2.9720E+00          4.1655E-03
2.9280E+00          4.1260E-03
2.8847E+00          4.0870E-03
2.8420E+00          4.0483E-03
2.8000E+00          4.0100E-03
2.7793E+00          3.9906E-03
2.7588E+00          3.9713E-03
2.7384E+00          3.9520E-03
2.7182E+00          3.9329E-03
2.6981E+00          3.9138E-03
2.6782E+00          3.8949E-03
2.6585E+00          3.8760E-03
2.6388E+00          3.8573E-03
2.6193E+00          3.8386E-03
2.6000E+00          3.8200E-03
2.5569E+00          3.7780E-03
2.5146E+00          3.7364E-03
2.4729E+00          3.6953E-03
2.4319E+00          3.6547E-03
2.3917E+00          3.6145E-03
2.3520E+00          3.5747E-03
2.3131E+00          3.5354E-03
2.2747E+00          3.4965E-03
2.2371E+00          3.4580E-03
2.2000E+00          3.4200E-03
2.1563E+00          3.3744E-03
2.1135E+00          3.3293E-03
2.0715E+00          3.2849E-03
2.0303E+00          3.2410E-03
1.9900E+00          3.1978E-03
1.9504E+00          3.1551E-03
1.9117E+00          3.1130E-03
1.8737E+00          3.0714E-03
1.8365E+00          3.0304E-03
1.8000E+00          2.9900E-03
1.7553E+00          2.9381E-03
1.7118E+00          2.8872E-03
1.6693E+00          2.8371E-03
1.6279E+00          2.7879E-03
1.5875E+00          2.7395E-03
1.5481E+00          2.6920E-03
1.5096E+00          2.6453E-03
1.4722E+00          2.5994E-03
1.4356E+00          2.5543E-03
1.4000E+00          2.5100E-03
1.3537E+00          2.4512E-03
1.3089E+00          2.3937E-03
1.2656E+00          2.3376E-03
1.2237E+00          2.2828E-03
1.1832E+00          2.2293E-03
1.1441E+00          2.1771E-03
1.1062E+00          2.1260E-03
1.0696E+00          2.0762E-03
1.0342E+00          2.0275E-03
1.0000E+00          1.9800E-03
9.7793E-01          1.9477E-03
9.5635E-01          1.9160E-03
9.3525E-01          1.8848E-03
9.1461E-01          1.8541E-03
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
8.9443E-01          1.8238E-03
8.7469E-01          1.7941E-03
8.5539E-01          1.7649E-03
8.3651E-01          1.7361E-03
8.1805E-01          1.7078E-03
8.0000E-01          1.6800E-03
7.8939E-01          1.6633E-03
7.7892E-01          1.6467E-03
7.6859E-01          1.6303E-03
7.5839E-01          1.6141E-03
7.4833E-01          1.5980E-03
7.3841E-01          1.5821E-03
7.2861E-01          1.5663E-03
7.1895E-01          1.5507E-03
7.0941E-01          1.5353E-03
7.0000E-01          1.5200E-03
6.9483E-01          1.5118E-03
6.8970E-01          1.5037E-03
6.8461E-01          1.4955E-03
6.7955E-01          1.4875E-03
6.7454E-01          1.4795E-03
6.6956E-01          1.4715E-03
6.6461E-01          1.4635E-03
6.5971E-01          1.4557E-03
6.5483E-01          1.4478E-03
6.5000E-01          1.4400E-03
6.4482E-01          1.4318E-03
6.3968E-01          1.4236E-03
6.3458E-01          1.4155E-03
6.2952E-01          1.4075E-03
6.2450E-01          1.3994E-03
6.1952E-01          1.3915E-03
6.1458E-01          1.3835E-03
6.0968E-01          1.3756E-03
6.0482E-01          1.3678E-03
6.0000E-01          1.3600E-03
5.9480E-01          1.3507E-03
5.8965E-01          1.3415E-03
5.8454E-01          1.3324E-03
5.7948E-01          1.3233E-03
5.7446E-01          1.3142E-03
5.6948E-01          1.3053E-03
5.6455E-01          1.2964E-03
5.5966E-01          1.2875E-03
5.5481E-01          1.2787E-03
5.5000E-01          1.2700E-03
5.4478E-01          1.2596E-03
5.3962E-01          1.2493E-03
5.3450E-01          1.2391E-03
5.2943E-01          1.2290E-03
5.2440E-01          1.2190E-03
5.1943E-01          1.2090E-03
5.1450E-01          1.1991E-03
5.0962E-01          1.1893E-03
5.0479E-01          1.1796E-03
5.0000E-01          1.1700E-03
4.9476E-01          1.1607E-03
4.8957E-01          1.1514E-03
4.8444E-01          1.1422E-03
4.7937E-01          1.1331E-03
4.7434E-01          1.1241E-03
4.6937E-01          1.1151E-03
4.6445E-01          1.1062E-03
4.5958E-01          1.0974E-03
4.5477E-01          1.0887E-03
4.5000E-01          1.0800E-03
4.4473E-01          1.0701E-03
4.3952E-01          1.0603E-03
4.3438E-01          1.0506E-03
4.2929E-01          1.0409E-03
4.2426E-01          1.0314E-03
4.1930E-01          1.0220E-03
4.1439E-01          1.0126E-03
4.0953E-01          1.0033E-03
4.0474E-01          9.9411E-04
4.0000E-01          9.8500E-04
3.9469E-01          9.7374E-04
3.8946E-01          9.6260E-04
3.8429E-01          9.5160E-04
3.7920E-01          9.4072E-04
3.7417E-01          9.2996E-04
3.6920E-01          9.1933E-04
3.6431E-01          9.0882E-04
3.5947E-01          8.9843E-04
3.5470E-01          8.8815E-04
3.5000E-01          8.7800E-04
3.4465E-01          8.6531E-04
3.3937E-01          8.5279E-04
3.3418E-01          8.4046E-04
3.2907E-01          8.2831E-04
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
        3.2404E-01          8.1633E-04
        3.1908E-01          8.0453E-04
        3.1420E-01          7.9290E-04
        3.0939E-01          7.8143E-04
        3.0466E-01          7.7014E-04
        3.0000E-01          7.5900E-04
        2.9458E-01          7.4511E-04
        2.8926E-01          7.3147E-04
        2.8403E-01          7.1809E-04
        2.7890E-01          7.0495E-04
        2.7386E-01          6.9205E-04
        2.6891E-01          6.7938E-04
        2.6405E-01          6.6695E-04
        2.5928E-01          6.5474E-04
        2.5460E-01          6.4276E-04
        2.5000E-01          6.3100E-04
        2.4448E-01          6.1661E-04
        2.3909E-01          6.0255E-04
        2.3381E-01          5.8881E-04
        2.2865E-01          5.7538E-04
        2.2361E-01          5.6226E-04
        2.1867E-01          5.4943E-04
        2.1385E-01          5.3690E-04
        2.0913E-01          5.2466E-04
        2.0451E-01          5.1269E-04
        2.0000E-01          5.0100E-04
        1.9433E-01          4.8721E-04
        1.8882E-01          4.7380E-04
        1.8346E-01          4.6076E-04
        1.7826E-01          4.4808E-04
        1.7321E-01          4.3575E-04
        1.6829E-01          4.2376E-04
        1.6352E-01          4.1210E-04
        1.5888E-01          4.0075E-04
        1.5438E-01          3.8973E-04
        1.5000E-01          3.7900E-04
        1.4404E-01          3.6809E-04
        1.3832E-01          3.5749E-04
        1.3282E-01          3.4720E-04
        1.2754E-01          3.3721E-04
        1.2247E-01          3.2750E-04
        1.1761E-01          3.1807E-04
        1.1293E-01          3.0892E-04
        1.0845E-01          3.0002E-04
        1.0414E-01          2.9139E-04
        1.0000E-01          2.8300E-04
        9.6496E-02          2.8039E-04
        9.3115E-02          2.7781E-04
        8.9852E-02          2.7526E-04
        8.6704E-02          2.7272E-04
        8.3666E-02          2.7021E-04
        8.0734E-02          2.6772E-04
        7.7906E-02          2.6526E-04
        7.5176E-02          2.6282E-04
        7.2542E-02          2.6040E-04
        7.0000E-02          2.5800E-04
        6.7684E-02          2.6103E-04
        6.5444E-02          2.6410E-04
        6.3279E-02          2.6721E-04
        6.1185E-02          2.7035E-04
        5.9161E-02          2.7353E-04
        5.7203E-02          2.7675E-04
        5.5311E-02          2.8000E-04
        5.3481E-02          2.8330E-04
        5.1711E-02          2.8663E-04
        5.0000E-02          2.9000E-04
        4.7510E-02          3.1092E-04
        4.5144E-02          3.3335E-04
        4.2896E-02          3.5740E-04
        4.0760E-02          3.8318E-04
        3.8730E-02          4.1083E-04
        3.6801E-02          4.4047E-04
        3.4968E-02          4.7224E-04
        3.3227E-02          5.0631E-04
        3.1572E-02          5.4284E-04
        3.0000E-02          5.8200E-04
        2.6879E-02          7.0502E-04
        2.4082E-02          8.5404E-04
        2.1577E-02          1.0346E-03
        1.9332E-02          1.2532E-03
        1.7321E-02          1.5181E-03
        1.5518E-02          1.8390E-03
        1.3904E-02          2.2277E-03
        1.2457E-02          2.6986E-03
        1.1161E-02          3.2690E-03
        1.0000E-02          3.9600E-03
end
*
* Unit 13 Hole Data
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
*
begin hole data
* Canister Hole Description v1.0
* Hole     1    BORAL Core
PLATE
1    0    0
2
0.1905    13
0.0000    12
13

* Hole     2    General Basket Structure
PLATE
0    0    1
7
286.5120    0            ! Top of Basket
258.0894    -3            ! Top of Highest Support Disk
212.0138    -8            ! Resume support disk only
55.1942    -5            ! Start of support+heat disk region
21.5900    -7            ! Bottom of Lowest Support Disk
0.0000    -4            ! Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole     3    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
86.3346
87.6046
5                ! number of axial intervals
258.0894                ! Top of diskstack
269.2400                ! Bottom of weldment
270.5100                ! Top of weldment plate
270.5100                ! Ullage
283.9720                ! Flange
286.5120                ! Void to top of basket
0    0            ! Material below weldment
15    15            ! Plate Material
0    15            ! Ullage
0    15            ! Flange
0    0            ! Void to top of basket
0                ! Outside material

* Hole     4    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ! number of radial points
87.6046
1                ! number of axial intervals
3.8100
5.0800                ! Coordinates inherited from PLATE Hole
15                ! Plate Material
0                ! Outside material

* Hole     5    Support disk and heat transfer disk stack
PLATE
origin    0    0    55.1942    ! Origin
0    0    1
4
CELL    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
6.8707    0            ! water gap
5.6007    16            ! aluminium disk
1.2700    0            ! water gap
14                ! steel disk

* Hole     6    Flood material model
PLATE
0    0    1
1
276.3618    0            ! Above flooded region
0                ! Flooded region

* Hole     7    Support disk stack lower
PLATE
origin    0    0    21.5900    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
1.2700    0            ! water gap
14                ! steel disk

* Hole     8    Support disk stack upper
PLATE
origin    0    0    212.0138    ! Origin
0    0    1
2
cell    11.2014            ! Sets up a repeating lattice of cells
11.2014    0            ! flood matl
1.2700    0            ! water gap
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
14                  ! steel disk

end

*
* Unit 15 Source Strength - Non-Fuel Source Region
*
* Class Yankee MPC - ce16y - CE16 (Rev 1) - Lower Nozzle - ce16y_36b37e08y
begin source strength
    component        5.2000E-01     ! Effective Mass (Mass*FluxRatio*MassRatio)
    component        1.4694E-04     ! 1/(volLef) (1/6.8055E+03)
    component    r    11*1.0
    component    z    1*1.0
    component    energy
        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
        1.0141E-15    3.3511E+04    2.1611E+07    9.5163E-03    5.7445E+00    2.0473E+12
        2.1580E+12    4.3841E+09    3.8100E+06    1.0971E+07    1.7359E+08    1.3230E+08
        2.6645E+09    1.1044E+10    3.1609E+10    3.7591E+10
end

*
* Unit 16 Simple Source Weights
*
*begin source weights
*
*end

*
* Unit 28 Forced Flight Data
*
begin forced flight
    interfaces    4
    ! Inlet at angle    45
    rectangle    114.9473    114.9473    -42.1640
        16.5100    16.1925
        0.0000    0.0000    1.0000
        -0.7071    -0.7071    0.0000
        materials    all
    ! Inlet at angle    135
    rectangle    -114.9473    114.9473    -42.1640
        16.5100    16.1925
        0.0000    0.0000    1.0000
        0.7071    -0.7071    0.0000
        materials    all
    ! Inlet at angle    225
    rectangle    -114.9473    -114.9473    -42.1640
        16.5100    16.1925
        0.0000    0.0000    1.0000
        0.7071    0.7071    0.0000
        materials    all
    ! Inlet at angle    315
    rectangle    114.9473    -114.9473    -42.1640
        16.5100    16.1925
        0.0000    0.0000    1.0000
        -0.7071    0.7071    0.0000
        materials    all
    ff    splitting
end

*
* Unit 31 Tabular Output
*
begin tabular output
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DIA - Surface - Response/
    response    interim
    number    some    1
    region    from    223    to    232
    output to file    also
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DIAA - InletSurf - Response/
    response    interim
    number    some    1
    region    some    234    243    252    261
    output to file    also
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DIB - 1ft - Response/
    response
    number    some    1
    region    from    271    to    282
    output to file    also
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DIBA - Inlet+1ft - Response/
    response
    number    some    1
    region    some    284    293    302    311
    output to file    also
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DIC - 1m - Response/
    response
    number    some    1
    region    from    321    to    332
    output to file    also
    /Case strStlDryInlLf_ce16y_36b37e08y - Det DICA - Inlet+1m - Response/
    response
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
    number    some    1
    region    some    334    343    352    361
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    gamma
normalise
nmixtures    4
weight    mixture    1
            u235    3.2615E-02
            u238    8.4888E-01
            o    1.1850E-01
atoms    mixture    2
            h    6.6667E-01
            o    3.3333E-01
weight    mixture    3
            al    5.8260E-01
            b10    4.5690E-02
            b11    2.7769E-01
            c    9.4020E-02
atoms    mixture    4
            c    2.8571E-01
            h    4.7619E-01
            o    2.3810E-01
*
* Materials List - Dry Conditions - v1.2 - Class Yankee MPC - ce16y - CE16 (Rev 1) Fuel
*
nmaterials    26
volume                              ! Homogenized fuel
material    1
    mixture    1    density    10.4120    prop    3.0283E-01    ! UO2 mixture at 3.7%
    void                prop    1.2812E-02    ! Gap
    zircalloy        density    6.5500    prop    1.2736E-01    ! Tube, clad
!    stainless 3041 steel        density    7.9200    prop    0.0000E+00    ! Stainless steel hw
    zircalloy        density    6.5500    prop    3.4595E-03    ! Zircaloy hw
    void                prop    5.5354E-01    ! Interstitial, inside tubes
volume                              ! Fuel pin cladding
material    2
    zircalloy        density    6.5500    prop    1.0000
volume                              ! Water In Lattice and Tube
material    3
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                              ! Water In Fuel Rod Clad Gap
material    4
    mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                              ! Lower Nozzle Material
material    5
    stainless 3041 steel        density    7.9200    prop    0.0965
    void                prop    0.9035
volume                              ! Lower Plenum Material
material    6
    stainless 3041 steel        density    7.9200    prop    0.1094
    zircalloy        density    6.5500    prop    0.0373
    void                prop    0.8533
volume                              ! Upper Nozzle Material
material    7
    stainless 3041 steel        density    7.9200    prop    0.0919
    void                prop    0.9081
volume                              ! Upper Plenum Material
material    8
    stainless 3041 steel        density    7.9200    prop    0.0290
    void                prop    0.9710
volume                              ! Damaged Fuel Lower Nozzle
material    9
    stainless 3041 steel        density    7.9200    prop    0.0965
    mixture    1    density    10.4120    prop    0.3318    ! UO2 mixture at 3.7%
    void                prop    0.5717
volume                              ! Damaged Fuel Upper Nozzle
material    10
    stainless 3041 steel        density    7.9200    prop    0.0919
    mixture    1    density    10.4120    prop    0.2990    ! UO2 mixture at 3.7%
    void                prop    0.6091
*
* Materials List - Common Materials - v1.2
*
volume                              ! Tube wall and cover sheet
material    11
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                              ! BORAL core
material    12
    mixture    3    density    2.6226    prop    0.9850    ! mixBORAL
    void                prop    0.0150
volume                              ! BORAL alumnimum clad
material    13
    aluminium                prop    1.0000
volume                              ! Structural Disk Material
```

Figure 5.6.1.2-3 MCBEND Input File for Design Basis CE Lower End Fitting Source with Air Inlet Biasing (Continued)

```
material    14
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Weldment Material
material    15
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Heat Transfer Disk Material
material    16
    aluminium                prop    1.0000
volume                            ! Canister Material
material    17
    stainless 304l steel        density    7.9200    prop    1.0000
atoms                             ! Transfer steel
material    18        density    0            !  (SCALE carbonsteel 7.8212 g/cc)
        c            prop    3.9250E-03
        fe            prop    8.3498E-02
volume                            ! Lead
material    19
    pb        density    11.0400    prop    1.0000
atoms                             ! NS-4-FR
material    20        density    0            ! 0 means atom/b-cm
        b10            prop    8.5500E-05
        b11            prop    3.4200E-04
        al            prop    7.8000E-03
        h            prop    5.8500E-02
        o            prop    2.6100E-02
        c            prop    2.2600E-02
        n            prop    1.3900E-03
volume                            ! Stainless Steel 304
material    21
    stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Vent port middle cylinder
material    22
    stainless 304l steel        density    7.9200    prop    0.5000
    void                prop    0.5000
atoms                             ! SCALE Concrete
material    23        density    0            ! (density 2.2426 g/cc)
        h            prop    1.3401E-02
        o            prop    4.4931E-02
        na            prop    1.7036E-03
        al            prop    1.7018E-03
        si            prop    1.6205E-02
        ca            prop    1.4826E-03
        fe            prop    3.3857E-04
volume                            ! Heat fins for transport cask
material    24
    cu        density    8.9200    prop    0.4286
    stainless 304l steel        density    7.9200    prop    0.5714
volume                            ! Balsa
material    25
    mixture    4    density    0.1250    prop    1.0000
volume                            ! Redwood
material    26
    mixture    4    density    0.3870    prop    1.0000
end
```

5.6.1.3 SAS4 Sample Input Files

Sample SAS4 transfer cask input files are shown in Figure 5.6.1.3-1 and Figure 5.6.1.3-2. The modeled geometry for the top model includes the damaged fuel shield lid and a wet canister. The modeled geometry for the bottom model includes the lower end fitting damaged fuel material description in the four corner basket positions.

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source

```
=SAS4A     PARM='SIZE=10000000'
Top Half of Yankee-MPC Transfer Cask - Top Axial - Upper Nozzle
27N-18COUPLE    INPHOMMEDIUM
'
' Material 1 is fuel/basket
'
UO2        1  0.2077  293.0 END
ZIRCALLOY  1  0.0964  293.0 END
SS304      1  0.0416  293.0 END
AL         1  0.0349  293.0 END
B4C        1  0.0040  293.0 END
H2O        1  0.6061  293.0 END
'
' Material 2 is lower plenum/basket
'
ZIRCALLOY  2  0.0934  293.0 END
SS304      2  0.1329  293.0 END
H2O        2  0.5457  293.0 END
'
' Material 3 is lower endfitting/basket
'
SS304      3  0.1220  293.0 END
H2O        3  0.8780  293.0 END
'
' Material 4 is upper plenum/basket
'
ZIRCALLOY  4  0.0872  293.0 END
SS304      4  0.0609  293.0 END
H2O        4  0.7032  293.0 END
'
' Material 5 is upper endfitting/basket
'
SS304      5  0.0852  293.0 END
'
' Common transfer cask materials
SS304         6  1.0 END
AL            7  1.0 END
CARBONSTEEL   8  1.0 END
PB            9  1.0 END
H            10  DEN=1.6291  0.060  293.0 END
O            10  DEN=1.6291  0.425  293.0 END
C            10  DEN=1.6291  0.277  293.0 END
N            10  DEN=1.6291  0.020  293.0 END
AL           10  DEN=1.6291  0.214  293.0 END
B-10         10  DEN=1.6291  0.001  293.0 END
B-11         10  DEN=1.6291  0.004  293.0 END
H2O          11  DEN=0.0001  293.0  END
H2O          12  DEN=0.0001  293.0  END
H2O          13  DEN=0.0001  293.0  END
SS304        14  0.5  293.0 END
H2O          15  1.0  293.0  END
END COMP
' Top Axial Biasing - Shield Lid w/Weld Shield - Upper Nozzle
IDR=1  ITY=2  IZM=5  FRD=87.82  END
  115.57  124.49  144.75  149.10  173.99  END
  1  4  5  0  6  END
XEND
' Monte Carlo Input - Upper Nozzle
TIM=9999  NST=8000  NIT=25000  ISO=1  IGO=4  RAN=3BEC307  SFA=1.6670E+14
ICS=13  NOD=0  IPF=0  END
' Upper Nozzle Source Spectrum & Geometry
SOE  27Z  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  1.0141E-15
3.3511E+04  2.1611E+07  9.5163E-03  9.1066E+11  3.2247E+12  4.3841E+09
3.8100E+06  1.0971E+07  1.7359E+08  1.3230E+08  2.6645E+09  1.1044E+10
5.5673E+10  END
SXY 5  -88.13  88.13  -88.13  88.13  124.49  144.75
  88.13  144.75  1.0  1.0  END
' Top Axial Detector Description - Shield Lid w/Weld Shield
CSF  161.29  161.29
  168.91
  173.99  173.99  173.99  173.99
  204.47  204.47  204.47
  273.99
  373.99
  473.99        END
CSL  71.74  82.00  83.05  88.13
  89.71  90.81
  0.00  63.00  63.00  71.74  71.74  82.00  82.00  88.13
  0.00  71.74  71.74  82.00  82.00  88.13
  0.00  88.13
  0.00  100.00
  0.00  131.691  END
CSD  1  38  1  10
  1  10
  20  20  10  10  1  38  10  10
  20  20  1  38  10  10
  20  20
  20  20
  30  30  END
GEND
 Top Model -------- Yankee-MPC Transfer Cask - Shield Lid w/Weld  v1.1.2
```

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source (Continued)

```
 0 0 1 50
'
' FUEL Bodies
RPP  1  -10.48  10.48  -10.48  10.48  -124.49  124.49
RPP  2  -10.48  10.48  -10.48  10.48  -144.75  144.75
RPP  3  -79.56  79.56  -33.67  33.67  -115.57  115.57
RPP  4  -56.69  56.69  -56.69  56.69  -115.57  115.57
RPP  5  -33.67  33.67  -79.56  79.56  -115.57  115.57
RPP  6  -79.56  79.56  -33.67  33.67  -124.49  124.49
RPP  7  -56.69  56.69  -56.69  56.69  -124.49  124.49
RPP  8  -33.67  33.67  -79.56  79.56  -124.49  124.49
RPP  9  -79.56  79.56  -33.67  33.67  -144.75  144.75
RPP  10  -56.69  56.69  -56.69  56.69  -144.75  144.75
RPP  11  -33.67  33.67  -79.56  79.56  -144.75  144.75
'
' DISK Bodies
RCC  12  2*0.0  0.635  2*0.0  -1.27  87.06
RCC  13  2*0.0  7.03  2*0.0  -1.27  87.60
RCC  14  2*0.0  -7.03  2*0.0  1.27  87.60
RCC  15  2*0.0  12.62  2*0.0  -1.27  87.06
RCC  16  2*0.0  -12.62  2*0.0  1.27  87.06
RCC  17  2*0.0  18.21  2*0.0  -1.27  87.60
RCC  18  2*0.0  -18.21  2*0.0  1.27  87.60
RCC  19  2*0.0  23.8  2*0.0  -1.27  87.06
RCC  20  2*0.0  -23.8  2*0.0  1.27  87.06
RCC  21  2*0.0  29.39  2*0.0  -1.27  87.60
RCC  22  2*0.0  -29.39  2*0.0  1.27  87.60
RCC  23  2*0.0  34.97  2*0.0  -1.27  87.06
RCC  24  2*0.0  -34.97  2*0.0  1.27  87.06
RCC  25  2*0.0  40.56  2*0.0  -1.27  87.60
RCC  26  2*0.0  -40.56  2*0.0  1.27  87.60
RCC  27  2*0.0  46.15  2*0.0  -1.27  87.06
RCC  28  2*0.0  -46.15  2*0.0  1.27  87.06
RCC  29  2*0.0  51.74  2*0.0  -1.27  87.60
RCC  30  2*0.0  -51.74  2*0.0  1.27  87.60
RCC  31  2*0.0  57.33  2*0.0  -1.27  87.06
RCC  32  2*0.0  -57.33  2*0.0  1.27  87.06
RCC  33  2*0.0  62.91  2*0.0  -1.27  87.60
RCC  34  2*0.0  -62.91  2*0.0  1.27  87.60
RCC  35  2*0.0  68.5  2*0.0  -1.27  87.06
RCC  36  2*0.0  -68.5  2*0.0  1.27  87.06
RCC  37  2*0.0  74.09  2*0.0  -1.27  87.60
RCC  38  2*0.0  -74.09  2*0.0  1.27  87.60
RCC  39  2*0.0  85.27  2*0.0  -1.27  87.60
RCC  40  2*0.0  -85.27  2*0.0  1.27  87.60
RCC  41  2*0.0  96.44  2*0.0  -1.27  87.60
RCC  42  2*0.0  -96.44  2*0.0  1.27  87.60
RCC  43  2*0.0  107.62  2*0.0  -1.27  87.60
RCC  44  2*0.0  -107.62  2*0.0  1.27  87.60
RCC  45  2*0.0  118.79  2*0.0  -1.27  87.60
RCC  46  2*0.0  -118.79  2*0.0  1.27  87.60
RCC  47  2*0.0  129.97  2*0.0  -1.27  87.60
RCC  48  2*0.0  -129.97  2*0.0  1.27  87.60
'
' TSC SHELL Bodies
RCC  49  2*0.0  -124.49  2*0.0  248.98  88.13
RCC  50  2*0.0  -148.59  2*0.0  297.18  88.13
RCC  51  2*0.0  -168.91  2*0.0  337.82  89.71
RCC  52  2*0.0  161.29  2*0.0  15.00  88.13
RCC  53  2*0.0  -161.29  2*0.0  -15.00  88.13
'
' TEMP. SHIELD Bodies
TRC  54  2*0.0  161.29  2*0.0  13.70  83.05  71.89
TRC  55  2*0.0  -161.29  2*0.0  -13.70  83.05  71.89
RCC  56  46.24  61.36  161.29  2*0.0  13.70  10.16
RCC  57  -46.24  -61.36  161.29  2*0.0  13.70  10.16
RCC  58  46.24  61.36  -161.29  2*0.0  -13.70  10.16
RCC  59  -46.24  -61.36  -161.29  2*0.0  -13.70  10.16
'
' PIPE Bodies
RCC  60  46.24  61.36  129.87  2*0.0  28.98  1.18
RCC  61  -46.24  -61.36  145.95  2*0.0  12.90  1.18
RCC  62  46.24  61.36  -129.87  2*0.0  -28.98  1.18
RCC  63  -46.24  -61.36  -145.95  2*0.0  -12.90  1.18
RCC  64  46.24  61.36  129.87  2*0.0  28.98  1.27
RCC  65  -46.24  -61.36  145.95  2*0.0  12.90  1.27
RCC  66  46.24  61.36  -129.87  2*0.0  -28.98  1.27
RCC  67  -46.24  -61.36  -145.95  2*0.0  -12.90  1.27
'
' PORT COVER Bodies
RCC  68  46.24  61.36  159.87  2*0.0  3.00  7.62
RCC  69  -46.24  -61.36  159.87  2*0.0  3.00  7.62
RCC  70  46.24  61.36  -159.87  2*0.0  -3.00  7.62
RCC  71  -46.24  -61.36  -159.87  2*0.0  -3.00  7.62
RCC  72  46.24  61.36  153.21  2*0.0  9.00  5.08
RCC  73  -46.24  -61.36  153.21  2*0.0  9.00  5.08
RCC  74  46.24  61.36  -153.21  2*0.0  -9.00  5.08
RCC  75  -46.24  -61.36  -153.21  2*0.0  -9.00  5.08
'
' VALVE Bodies
```

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source (Continued)

```
RCC  76  46.24  61.36  153.21  2*0.0  3.302  2.50
RCC  77  -46.24  -61.36  153.21  2*0.0  3.302  2.50
RCC  78  46.24  61.36  -153.21  2*0.0  -3.302  2.50
RCC  79  -46.24  -61.36  -153.21  2*0.0  -3.302  2.50
'
' Baffle Bodies
RPP  80  33.67  35.26  56.69  79.56  129.97  145.97
RPP  81  35.26  56.69  56.69  58.28  129.97  145.97
RPP  82  -35.26  -33.67  -79.56  -56.69  129.97  145.97
RPP  83  -56.69  -35.26  -58.28  -56.69  129.97  145.97
RPP  84  33.67  35.26  56.69  79.56  -145.97  -129.97
RPP  85  35.26  56.69  56.69  58.28  -145.97  -129.97
RPP  86  -35.26  -33.67  -79.56  -56.69  -145.97  -129.97
RPP  87  -56.69  -35.26  -58.28  -56.69  -145.97  -129.97
'
' TFR SHELL Bodies
RCC  88  2*0.0  -180.00  2*0.0  360.00  90.81
RCC  89  2*0.0  -180.00  2*0.0  360.00  92.71
RCC  90  2*0.0  -158.75  2*0.0  317.50  101.60
RCC  91  2*0.0  -168.91  2*0.0  337.82  106.68
RCC  92  2*0.0  -180.00  2*0.0  360.00  109.86
'
' TOP CUT PLANES
RCC  93  2*0.0  173.99  2*0.0  10.0  109.86
RCC  94  2*0.0  -173.99  2*0.0  -10.0  109.86
'
' TFR TRUNNION Bodies
RCC  95  0.00  90.81  135.89  0.00  20.00  0.00  12.70
RCC  96  0.00  -90.81  135.89  0.00  -20.00  0.00  12.70
RCC  97  0.00  90.81  -135.89  0.00  20.00  0.00  12.70
RCC  98  0.00  -90.81  -135.89  0.00  -20.00  0.00  12.70
'
' DETECTOR SURFACES
RCC  99  2*0.0  -204.47  2*0.0  408.94  140.34
RCC  100  2*0.0  -273.99  2*0.0  547.98  209.86
RCC  101  2*0.0  -373.99  2*0.0  747.98  309.86
RCC  102  2*0.0  -473.99  2*0.0  947.98  409.86
RCC  103  2*0.0  -673.99  2*0.0  1347.98  609.86
RCC  104  2*0.0  -900.00  2*0.0  1800.00  900.00
'
' Top Weldment Flange Bodies
RCC  105  2*0.0  129.97  2*0.0  14.732  86.33
RCC  106  2*0.0  129.97  2*0.0  14.732  87.60
RCC  107  2*0.0  -129.97  2*0.0  -14.732  86.33
RCC  108  2*0.0  -129.97  2*0.0  -14.732  87.60
'
' Shield Lid Cutouts
RPP  109  -58.01  -34.39  34.39  58.01  -152.17  152.17
RPP  110  -58.01  -34.39  -58.01  -34.39  -152.17  152.17
RPP  111  34.39  58.01  34.39  58.01  -152.17  152.17
RPP  112  34.39  58.01  -58.01  -34.39  -152.17  152.17
'
' Additional Port Shielding
RCC  113  2*0.0  -163.83  2*0.0  327.66  88.13
'
' DFC Lid Structure
RPP  114  -56.20  -36.21  36.21  56.20  -147.07  147.07
RPP  115  -56.20  -36.21  -56.20  -36.21  -147.07  147.07
RPP  116  36.21  56.20  36.21  56.20  -147.07  147.07
RPP  117  36.21  56.20  -56.20  -36.21  -147.07  147.07
RPP  118  -56.20  -36.21  36.21  56.20  -148.34  148.34
RPP  119  -56.20  -36.21  -56.20  -36.21  -148.34  148.34
RPP  120  36.21  56.20  36.21  56.20  -148.34  148.34
RPP  121  36.21  56.20  -56.20  -36.21  -148.34  148.34
 END
'
' FUEL ZONES
CEN  +1
UCN  +2  -1
FUE  OR  +3  -2
  OR  +4  -2
  OR  +5  -2
UPL  OR  +6  -2  -3  -4  -5
  OR  +7  -2  -3  -4  -5
  OR  +8  -2  -3  -4  -5
UEF  OR  +9  -2  -6  -7  -8
  OR  +10  -2  -6  -7  -8
  OR  +11  -2  -6  -7  -8
'
' TSC CAVITY ZONES
CAV  +49  -1  -3  -4  -5  -6  -7  -8
  -12  -13  -14  -15  -16  -17  -18  -19  -20  -21
  -22  -23  -24  -25  -26  -27  -28  -29  -30  -31
  -32  -33  -34  -35  -36  -37  -38  -39  -40  -41
  -42  -43  -44  -45  -46
UCV  +50  -2  -9  -10  -11
  -47  -48  -49  -64  -66
  -80  -81  -82  -83  -84  -85  -86  -87
  -106  -108  -118  -119  -120  -121
'
' DFC Lids & Voids
```

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source (Continued)

```
FCL  OR  +118  -114
  OR  +119  -115
  OR  +120  -116
  OR  +121  -117
FCV  OR  +114  -9  -10  -11  -47  -48  -49
    -80  -81  -82  -83  -84  -85  -86  -87
    -106  -108
  OR  +115  -9  -10  -11  -47  -48  -49
    -80  -81  -82  -83  -84  -85  -86  -87
    -106  -108
  OR  +116  -9  -10  -11  -47  -48  -49
    -80  -81  -82  -83  -84  -85  -86  -87
    -106  -108
  OR  +117  -9  -10  -11  -47  -48  -49
    -80  -81  -82  -83  -84  -85  -86  -87
    -106  -108
'
' DISK ZONES
A01  +12  -9  -10  -11
S01  +13  -9  -10  -11
S02  +14  -9  -10  -11
A02  +15  -9  -10  -11
A03  +16  -9  -10  -11
S03  +17  -9  -10  -11
S04  +18  -9  -10  -11
A04  +19  -9  -10  -11
A05  +20  -9  -10  -11
S05  +21  -9  -10  -11
S06  +22  -9  -10  -11
A06  +23  -9  -10  -11
A07  +24  -9  -10  -11
S07  +25  -9  -10  -11
S08  +26  -9  -10  -11
A08  +27  -9  -10  -11
A09  +28  -9  -10  -11
S09  +29  -9  -10  -11
S10  +30  -9  -10  -11
A10  +31  -9  -10  -11
A11  +32  -9  -10  -11
S11  +33  -9  -10  -11
S12  +34  -9  -10  -11
A12  +35  -9  -10  -11
A13  +36  -9  -10  -11
S13  +37  -9  -10  -11
S14  +38  -9  -10  -11
S15  +39  -9  -10  -11
S16  +40  -9  -10  -11
S17  +41  -9  -10  -11
S18  +42  -9  -10  -11
S19  +43  -9  -10  -11
S20  +44  -9  -10  -11
S21  +45  -9  -10  -11
S22  +46  -9  -10  -11
TW1  +47  -9  -10  -11
TW2  +48  -9  -10  -11
'
' Top Weldment Flange Zones
RVT  +105  -9  -10  -11
  -64  -65  -66  -67
  -60  -61  -62  -63  -64  -65  -66  -67
  -80  -81  -82  -83  -84  -85  -86  -87
SRT  +106  -105
RVB  +107  -9  -10  -11
  -64  -65  -66  -67
  -60  -61  -62  -63  -64  -65  -66  -67
  -80  -81  -82  -83  -84  -85  -86  -87
SRB  +108  -107
'
' Shield Lid Cutouts
SHC  OR  +109  -50
  OR  +110  -50
  OR  +111  -50
  OR  +112  -50
'
' TSC SHELL ZONE
SHL  +51  -49  -50  -52  -53  -54  -55
  -64  -65  -66  -67  -68  -69  -70  -71
  -72  -73  -74  -75
  -109  -110  -111  -112
'
' Baffle Zones
PT1  OR  +80
  OR  +81
  OR  +82
  OR  +83
PT2  OR  +84
  OR  +85
  OR  +86
  OR  +87
'
' PORT COVER ZONES
```

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source (Continued)

```
PC1  OR  +68  -56
  OR  +69  -57
  OR  +70  -58
  OR  +71  -59
  OR  +72  -60  -64  -68  -76
  OR  +73  -61  -65  -69  -77
  OR  +74  -62  -66  -70  -78
  OR  +75  -63  -67  -71  -79
'
' PIPE ZONES
PP1  OR  +60  -47
  OR  +61  -50
  OR  +62  -48
  OR  +63  -50
PP2  OR  +64  -47  -60
  OR  +65  -50  -61
  OR  +66  -48  -62
  OR  +67  -50  -63
HEX  OR  +76  -64
  OR  +77  -65
  OR  +78  -66
  OR  +79  -67
'
' TEMP. SHIELD ZONES
PC2  OR  +56  +54  -93  -113
  OR  +57  +54  -93  -113
  OR  +58  +55  -94  -113
  OR  +59  +55  -94  -113
PPB  OR  +56  +54  -93  +113
  OR  +57  +54  -93  +113
  OR  +58  +55  -94  +113
  OR  +59  +55  -94  +113
TMP  OR  +54  -56  -57  -93
  OR  +55  -58  -59  -94
LID  OR  +52  -54  -93
  OR  +53  -55  -94
'
' TFR SHELL ZONES
TFV  +88  -51  -52  -53  -93  -94
INS  +89  -88  -93  -94
PBS  +90  -89  -95  -96  -97  -98
NS4  +91  -90  -89  -95  -96  -97  -98
OTS  +92  -89  -91  -93  -94  -95  -96  -97  -98
'
' TRUNNION ZONES
TR1  OR  +95  -89  +92
  OR  +96  -89  +92
TR2  OR  +97  -89  +92
  OR  +98  -89  +92
'
' TOP AND BOTTOM CUT ZONES
TOP  OR  +93
  OR  +94
'
' DETECTOR SURFACES
SR1  +99  -92  -93  -94
SR2  +100  -99
SR3  +101  -100
SR4  +102  -101
INV  +103  -102
EXV  +104  -103
 END
70R1  2  1  2  1  2  1
76R0
'
' CENTRAL VOID
15  1000
'
' FUEL
1  4  5
'
' TSC CAVITY
15  1000
' DFC Lids & Voids
6  1000
'
' TSC DISKS
7  6  6  7  7  6  6  7  7
  6  6  7  7  6  6  7  7
  6  6  7  7  6  6  7  7
  6  6  6  6  6  6  6  6
  6  6  6  6
' Top Weldment Flange
1000  6  1000  6
'
' TSC SHELL
1000  6
'
' Baffle Plates
6  6
'
```

Figure 5.6.1.3-1 SAS4 Input File for Transfer Cask Damaged Fuel Top Model with Upper End Fitting Source (Continued)

```
' Port Covers
14
'
' VENT/DRAIN PIPE
1000  6  6
'
' TEMP SHIELD (MAT 12&13 ARE LOW DENSITY H20)
12  9  8  13
'
' TFR SHELLS
1000  8  9  10  8
'
' TRUNNIONS
8  8
'
' DETECTOR SURFACES
1000  1000  1000  1000  1000  1000  0
0 0
0
END
```

Figure 5.6.1.3-2 SAS4 Input File for Transfer Cask Damaged Fuel Bottom Model with Damaged Fuel Gamma Source

```
=SAS4A     PARM='SIZE=10000000'
Bottom Half of Yankee-MPC Transfer Cask - Radial - Damaged Fuel Gamma
27N-18COUPLE    INFHOMMEDIUM
'
' Material 1 is fuel/basket
'
UO2         1  0.2077  293.0 END
ZIRCALLOY   1  0.0964  293.0 END
SS304       1  0.0416  293.0 END
AL          1  0.0349  293.0 END
B4C         1  0.0040  293.0 END
'
' Material 2 is lower plenum/basket
'
ZIRCALLOY   2  0.0934  293.0 END
SS304       2  0.1329  293.0 END
'
' Material 3 is lower endfitting/basket
'
SS304       3  0.1220  293.0 END
'
' Material 4 is upper plenum/basket
'
ZIRCALLOY   4  0.0872  293.0 END
SS304       4  0.0609  293.0 END
'
' Material 5 is upper endfitting/basket
'
SS304       5  0.0852  293.0 END
'
' Common transfer cask materials
SS304          6  1.0 END
AL             7  1.0 END
CARBONSTEEL    8  1.0 END
PB             9  1.0 END
H             10  DEN=1.6291  0.060  293.0 END
O             10  DEN=1.6291  0.425  293.0 END
C             10  DEN=1.6291  0.277  293.0 END
N             10  DEN=1.6291  0.020  293.0 END
AL            10  DEN=1.6291  0.214  293.0 END
B-10          10  DEN=1.6291  0.001  293.0 END
B-11          10  DEN=1.6291  0.004  293.0 END
H2O           11  DEN=0.0001  293.0  END
' Material 12 is lower endfitting/basket & UO2
SS304        12  DEN=0.9664  1.0 END
UO2          12  DEN=2.4952  1.0 END
H2O           13  DEN=0.0001  293.0  END
SS304         14  0.5  293.0 END
END COMP
' Radial Biasing - Damaged Fuel Gamma
IDR=0  ITY=2  IZM=8  FRD=87.82  END
  87.820  88.125  89.713  90.805  92.710  101.600
  106.680  109.855  END
  3  0  6  0  8  9
  10  8  END
XEND
' Monte Carlo Input - Damaged Fuel Gamma
TIM=9999  NST=8000  NIT=1000  ISO=1  IGO=4  RAN=3A1313F  SFA=1.2355E+15
ICS=6  NOD=0  IPF=0  END
' Lower Nozzle Gamma Source Spectrum - Damaged Condition
SOE  27Z  3.7701E+04  1.7759E+05  9.0547E+05  2.2566E+06  6.2676E+08
5.1211E+09  1.0789E+11  9.9933E+10  4.8070E+12  3.4718E+13  6.3503E+13
8.2333E+14  1.1897E+14  1.7831E+13  2.8386E+13  1.0201E+14  1.3136E+14
4.5899E+14  END
SXY 12  -88.13  88.13  -88.13  88.13  120.93  139.19
```

Figure 5.6.1.3-2 SAS4 Input File for Transfer Cask Damaged Fuel Bottom Model with Damaged Fuel Gamma Source (Continued)

```
  88.13  139.19  1.0  1.0  END
' Bottom Radial Detector Description
CSF  109.855  140.335  209.855  309.855  409.855  509.855  END
CSL  0.000  165.860
  0.000  196.340
  0.000  265.860
  0.000  365.860
  0.000  465.860
  0.000  565.860  END
CSD  16  1
  10  1
  10  1
  10  1
  10  1
  10  1  END
GEND
 Bottom Model - Yankee-MPC Transfer Cask v1.1.8.1
 0 0 1 50
'
' Fuel Bodies
RPP  1  -10.48  10.48  -10.48  10.48  -139.19  139.19
RPP  2  -79.56  79.56  -33.67  33.67  -115.57  115.57
RPP  3  -56.69  56.69  -56.69  56.69  -115.57  115.57
RPP  4  -33.67  33.67  -79.56  79.56  -115.57  115.57
RPP  5  -79.56  79.56  -33.67  33.67  -120.93  120.93
RPP  6  -56.69  56.69  -56.69  56.69  -120.93  120.93
RPP  7  -33.67  33.67  -79.56  79.56  -120.93  120.93
RPP  8  -79.56  79.56  -33.67  33.67  -139.19  139.19
RPP  9  -56.69  56.69  -56.69  56.69  -139.19  139.19
RPP  10  -33.67  33.67  -79.56  79.56  -139.19  139.19
RPP  11  33.67  56.69  33.67  56.69  -139.19  139.19
RPP  12  33.67  56.69  -56.69  -33.67  -139.19  139.19
RPP  13  -56.69  -33.67  33.67  56.69  -139.19  139.19
RPP  14  -56.69  -33.67  -56.69  -33.67  -139.19  139.19
'
' Disk Bodies
RCC  15  2*0.0  134.11  2*0.0  1.27  87.60
RCC  16  2*0.0  -134.11  2*0.0  -1.27  87.60
RCC  17  2*0.0  116.33  2*0.0  1.27  87.82
RCC  18  2*0.0  -116.33  2*0.0  -1.27  87.82
RCC  19  2*0.0  105.13  2*0.0  1.27  87.82
RCC  20  2*0.0  -105.13  2*0.0  -1.27  87.82
RCC  21  2*0.0  93.93  2*0.0  1.27  87.82
RCC  22  2*0.0  -93.93  2*0.0  -1.27  87.82
RCC  23  2*0.0  82.73  2*0.0  1.27  87.82
RCC  24  2*0.0  -82.73  2*0.0  -1.27  87.82
RCC  25  2*0.0  77.13  2*0.0  1.27  87.46
RCC  26  2*0.0  -77.13  2*0.0  -1.27  87.46
RCC  27  2*0.0  71.52  2*0.0  1.27  87.82
RCC  28  2*0.0  -71.52  2*0.0  -1.27  87.82
RCC  29  2*0.0  65.92  2*0.0  1.27  87.46
RCC  30  2*0.0  -65.92  2*0.0  -1.27  87.46
RCC  31  2*0.0  60.32  2*0.0  1.27  87.82
RCC  32  2*0.0  -60.32  2*0.0  -1.27  87.82
RCC  33  2*0.0  54.72  2*0.0  1.27  87.46
RCC  34  2*0.0  -54.72  2*0.0  -1.27  87.46
RCC  35  2*0.0  49.12  2*0.0  1.27  87.82
RCC  36  2*0.0  -49.12  2*0.0  -1.27  87.82
RCC  37  2*0.0  43.52  2*0.0  1.27  87.46
RCC  38  2*0.0  -43.52  2*0.0  -1.27  87.46
RCC  39  2*0.0  37.92  2*0.0  1.27  87.82
RCC  40  2*0.0  -37.92  2*0.0  -1.27  87.82
RCC  41  2*0.0  32.32  2*0.0  1.27  87.46
RCC  42  2*0.0  -32.32  2*0.0  -1.27  87.46
RCC  43  2*0.0  26.72  2*0.0  1.27  87.82
RCC  44  2*0.0  -26.72  2*0.0  -1.27  87.82
RCC  45  2*0.0  21.12  2*0.0  1.27  87.46
RCC  46  2*0.0  -21.12  2*0.0  -1.27  87.46
RCC  47  2*0.0  15.52  2*0.0  1.27  87.82
RCC  48  2*0.0  -15.52  2*0.0  -1.27  87.82
RCC  49  2*0.0  9.92  2*0.0  1.27  87.46
RCC  50  2*0.0  -9.92  2*0.0  -1.27  87.46
RCC  51  2*0.0  4.32  2*0.0  1.27  87.82
```

Figure 5.6.1.3-2 SAS4 Input File for Transfer Cask Damaged Fuel Bottom Model with Damaged Fuel Gamma Source (Continued)

```
RCC  52  2*0.0  -4.32  2*0.0  -1.27  87.82
RCC  53  2*0.0  -0.64  2*0.0  1.27  87.46
'
' TSC Shell Bodies
RCC  54  2*0.0  -139.19  2*0.0  278.38  88.13
RCC  55  2*0.0  -141.73  2*0.0  283.46  89.71
'
' Transfer shell bodies
RCC  56  2*0.0  -165.86  2*0.0  331.72  109.86
RCC  57  2*0.0  -141.73  2*0.0  283.46  109.86
RCC  58  2*0.0  -139.19  2*0.0  278.38  109.86
RCC  59  2*0.0  -141.73  2*0.0  283.46  90.805
RCC  60  2*0.0  -141.73  2*0.0  283.46  92.71
RCC  61  2*0.0  -141.73  2*0.0  283.46  101.60
RCC  62  2*0.0  -141.73  2*0.0  283.46  106.68
RCC  63  2*0.0  -141.73  2*0.0  283.46  109.86
'
' DETECTOR SURFACES
RCC  64  2*0.0  -196.34  2*0.0  392.68  140.335
RCC  65  2*0.0  -265.86  2*0.0  531.72  209.86
RCC  66  2*0.0  -365.86  2*0.0  731.72  309.86
RCC  67  2*0.0  -465.86  2*0.0  931.72  409.86
RCC  68  2*0.0  -565.86  2*0.0  1131.72  509.86
RCC  69  2*0.0  -665.86  2*0.0  1331.72  609.86
RCC  70  2*0.0  -900.00  2*0.0  1800.00  900.00
 END
'
' FUEL ZONES
CEN  +1
FUE  OR  +2  -1
  OR  +3  -1
  OR  +4  -1
LPL  OR  +5  -1  -2  -3  -4
  OR  +6  -1  -2  -3  -4
  OR  +7  -1  -2  -3  -4
LFA  OR  +8  -1  -5  -6  -7  -11  -12  -13  -14
  OR  +9  -1  -5  -6  -7  -11  -12  -13  -14
  OR  +10  -1  -5  -6  -7  -11  -12  -13  -14
LFB  OR  +11  -1  -5  -6  -7
  OR  +12  -1  -5  -6  -7
  OR  +13  -1  -5  -6  -7
  OR  +14  -1  -5  -6  -7
'
' TSC CAVITY ZONES
CAV  +54  -1  -2  -3  -4  -5  -6  -7  -8  -9
  -10  -11  -12  -13  -14
  -15  -16  -17  -18  -19  -20  -21  -22  -23  -24
  -25  -26  -27  -28  -29  -30  -31  -32  -33  -34
  -35  -36  -37  -38  -39  -40  -41  -42  -43  -44
  -45  -46  -47  -48  -49  -50  -51  -52  -53
'
' DISK ZONES
BW1  +15  -8  -9  -10  -1
BW2  +16  -8  -9  -10  -1
S01  +17  -8  -9  -10  -1
T01  +18  -8  -9  -10  -1
S02  +19  -8  -9  -10  -1
T02  +20  -8  -9  -10  -1
S03  +21  -8  -9  -10  -1
T03  +22  -8  -9  -10  -1
S04  +23  -8  -9  -10  -1
T04  +24  -8  -9  -10  -1
A01  +25  -8  -9  -10  -1
B01  +26  -8  -9  -10  -1
S05  +27  -8  -9  -10  -1
T05  +28  -8  -9  -10  -1
A02  +29  -8  -9  -10  -1
B02  +30  -8  -9  -10  -1
S06  +31  -8  -9  -10  -1
T06  +32  -8  -9  -10  -1
A03  +33  -8  -9  -10  -1
B03  +34  -8  -9  -10  -1
S07  +35  -8  -9  -10  -1
```

Figure 5.6.1.3-2 SAS4 Input File for Transfer Cask Damaged Fuel Bottom Model with Damaged Fuel Gamma Source (Continued)

```
T07  +36  -8  -9  -10  -1
A04  +37  -8  -9  -10  -1
B04  +38  -8  -9  -10  -1
S08  +39  -8  -9  -10  -1
T08  +40  -8  -9  -10  -1
A05  +41  -8  -9  -10  -1
B05  +42  -8  -9  -10  -1
S09  +43  -8  -9  -10  -1
T09  +44  -8  -9  -10  -1
A06  +45  -8  -9  -10  -1
B06  +46  -8  -9  -10  -1
S10  +47  -8  -9  -10  -1
T10  +48  -8  -9  -10  -1
A07  +49  -8  -9  -10  -1
B07  +50  -8  -9  -10  -1
S11  +51  -8  -9  -10  -1
T11  +52  -8  -9  -10  -1
A08  +53  -8  -9  -10  -1
'
' TSC Shell Zones
SHL  +55  -54
'
' TFR Shell Zones
TFV  +59  +57  -55
INS  +60  +58  -59
PBS  +61  +58  -60
NS4  +62  +58  -61
OTS  +63  +58  -62
BPL  +57  -58  -59
DRS  +56  -57  -59  -55
'
' DETECTOR SURFACES
SR1  +64  -56
SR2  +65  -64
SR3  +66  -65
SR4  +67  -66
SR5  +68  -67
INV  +69  -68
EXV  +70  -69
 END
53R1  2  1  2  1  2  1  2
60R0
' CENTRAL VOID
1000
' FUEL
1  2  3  12
' TSC CAVITY
1000
' TSC DISKS
6  6  6  6  6  6  6  6
6  6  7  7  6  6  7  7
6  6  7  7  6  6  7  7
6  6  7  7  6  6  7  7
6  6  7  7  6  6  7
' TSC SHELL
  6
' TFR SHELLS
1000  8  9  10  8  8  8
' DETECTOR SURFACES
1000  1000  1000  1000  1000  1000  0
0 0
0
END
```

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5.6.2 Connecticut Yankee Sample Input Files

Sample MCBEND input files are included here. Figure 5.6.2–1 shows the input file for the storage cask radial analysis for the fuel gamma source from stainless steel clad fuel input case. Figure 5.6.2–2 shows the MCBEND input file for the transfer cask structural lid with weld shield model (Stw) for a top axial analysis of the Zircaloy clad fuel neutron source

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source

```
columns 1 200
*
* CY Storage Cask - SS_38b_05y - Fuel Gamma - Radial
*   Shield Lid - Ports - With Covers
*   Structural Lid - No Weld Shield
*   Dry Conditions
*
*   Model Revision v3.2.0
*

*
* Parameters
*
@samps =    20000000

*
* Unit 1 Control Data
*
begin control data
run
sample limit     @samps
time limit     1000m
seeds    30354    47154
chime every    [@samps/10]    samples
report interim results
sbd    10s
dump intervals    1
end

*
* Unit 3 Output Control
*
*begin output control
*    suppress inflows
*end

*
* Unit 4 Material Geometry
*
begin material geometry
* Fuel Assembly Type A - Stainless Steel Clad - v2.1
PART    1    NEST
BOX    M7        0.0000    0.0000    0.0000    21.4605    21.4605    8.0975    ! lower nozzle
BOX    M5        0.0000    0.0000    0.0000    21.4605    21.4605    9.8374    ! bottom end plug
BOX    M1    S    0.0000    0.0000    0.0000    21.4605    21.4605    319.2094    ! fuel
BOX    M9        0.0000    0.0000    0.0000    21.4605    21.4605    328.2256    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    21.4605    21.4605    329.9655    ! top end plug
BOX    M0        0.0000    0.0000    0.0000    21.4605    21.4605    330.8858    ! gap to top nozzle
BOX    M8        0.0000    0.0000    0.0000    21.4605    21.4605    348.1324    ! upper nozzle
* Fuel Assembly Type B - Stainless Steel Clad - v2.1
PART    2    NEST
BOX    M7        0.0000    0.0000    0.0000    21.4605    21.4605    8.0975    ! lower nozzle
BOX    M5        0.0000    0.0000    0.0000    21.4605    21.4605    9.8374    ! bottom end plug
BOX    M1    S    0.0000    0.0000    0.0000    21.4605    21.4605    319.2094    ! fuel
BOX    M9        0.0000    0.0000    0.0000    21.4605    21.4605    328.2256    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    21.4605    21.4605    329.9655    ! top end plug
BOX    M0        0.0000    0.0000    0.0000    21.4605    21.4605    330.8858    ! gap to top nozzle
BOX    M8        0.0000    0.0000    0.0000    21.4605    21.4605    348.1324    ! upper nozzle
* BORAL and Cover for Standard Opening v2.0
PART    3    NEST
BOX    BH1    0.0457    0.0000    0.3556    0.1905    20.9042    326.3900    ! BORAL Sheet - Axial
offset from cover sheet bottom
BOX    M0    0.0457    0.0000    0.0000    0.1905    20.9042    328.4220    ! Space under cover sheet
that allows sheet to shift under cover
BOX    M10    0.0000    0.0000    0.0000    0.2362    20.9042    328.4220    ! SS cover sheet for
BORAL
* Fuel Assembly in Tube (Type A) v2.0
PART    4
BOX    1    0.4661    0.4661    0.0000    21.4605    21.4605    348.1324    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.1488    22.1488    360.6800    ! Space inside tube from
can lid to bottom
BOX    3    0.0000    0.0000    5.0800    22.3926    22.3926    335.7880    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.3926    22.3926    360.6800    ! Container body - extent
of basket cavity
ZONES
/Fuel Assembly/    P1    +1
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M10    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v2.0
PART    5
BOX    1    0.4661    0.4661    0.0000    21.4605    21.4605    348.1324    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.1488    22.1488    360.6800    ! Space inside tube from
can lid to bottom
BOX    3    0.0000    0.0000    5.0800    22.3926    22.3926    335.7880    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.3926    22.3926    360.6800    ! Container body - extent
of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M10    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
*  Type A Disk Opening with Tube v2.2
PART    6    CLUSTER
BOX    P4    0.4496    0.4496    0.0000    22.3926    22.3926    360.6800    ! Fuel tube type A with
fuel assy
BOX    P3    0.2134    1.1938    7.1120    0.2362    20.9042    328.4220
BOX    P3    23.0785    22.0980    7.1120    0.2362    20.9042    328.4220
ZROT    180.0000
BOX    P3    1.1938    23.0785    7.1120    0.2362    20.9042    328.4220
ZROT    90.0000
BOX    P3    22.0980    0.2134    7.1120    0.2362    20.9042    328.4220
ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    23.2918    23.2918    360.6800    ! Support disk opening
width
*  Type B Disk Opening with Tube v2.2
PART    7    CLUSTER
BOX    P5    0.4496    0.4496    0.0000    22.3926    22.3926    360.6800    ! Fuel tube type B with
fuel assy
BOX    P3    0.2134    1.1938    7.1120    0.2362    20.9042    328.4220
BOX    P3    23.0785    22.0980    7.1120    0.2362    20.9042    328.4220
ZROT    180.0000
BOX    P3    1.1938    23.0785    7.1120    0.2362    20.9042    328.4220
ZROT    90.0000
BOX    P3    22.0980    0.2134    7.1120    0.2362    20.9042    328.4220
ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    23.2918    23.2918    360.6800    ! Support disk opening
width
* Canister Cavity v2.2
PART    8
BOX    1    -51.2826    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 1
BOX    2    -25.1968    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 2
BOX    3    1.9050    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 3
BOX    4    27.9908    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 4
BOX    5    -77.1144    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 5
BOX    6    -51.2826    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 6
BOX    7    -25.1968    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 7
BOX    8    1.9050    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 8
BOX    9    27.9908    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 9
BOX    10    53.8226    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 10
BOX    11    -77.1144    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 11
BOX    12    -51.2826    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 12
BOX    13    -25.1968    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 13
BOX    14    1.9050    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 14
BOX    15    27.9908    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 15
BOX    16    53.8226    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 16
BOX    17    -77.1144    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 17
BOX    18    -51.2826    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 18
BOX    19    -25.1968    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 19
BOX    20    1.9050    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 20
BOX    21    27.9908    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 21
BOX    22    53.8226    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 22
BOX    23    -51.2826    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 23
BOX    24    -25.1968    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 24
BOX    25    1.9050    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 25
BOX    26    27.9908    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 26
BOX    27    53.8226    -67.9577    327.9394    22.0980    27.9400    16.0020    ! Drain Baffle Box A
BOX    28    57.6326    -67.9577    327.9394    18.2880    24.1300    10.9220    ! Drain Baffle Box B
ZROD    29    60.5468    -47.3043    338.8614    2.5400    5.0800    ! Drain Baffle Hole
BOX    30    -77.1144    40.0177    327.9394    22.0980    27.9400    16.0020    ! Vent Baffle Box A
BOX    31    -77.1144    43.8277    327.9394    18.2880    24.1300    10.9220    ! Vent Baffle Box B
ZROD    32    -60.5468    47.3043    338.8614    2.5400    5.0800    ! Vent Baffle Hole
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
ZROD    33    0.0000    0.0000    -15.4686    86.3346    360.6800        ! Baffle limiting radius
CONTAINER
ZROD    34    0.0000    0.0000    -15.4686    87.5284    360.6800        ! Basket stack to cavity
height
ZONES
/Opening01/    P7    +1
/Opening02/    P6    +2
/Opening03/    P6    +3
/Opening04/    P7    +4
/Opening05/    P6    +5
/Opening06/    P6    +6
/Opening07/    P6    +7
/Opening08/    P6    +8
/Opening09/    P6    +9
/Opening10/    P6    +10
/Opening11/    P6    +11
/Opening12/    P6    +12
/Opening13/    P6    +13
/Opening14/    P6    +14
/Opening15/    P6    +15
/Opening16/    P6    +16
/Opening17/    P6    +17
/Opening18/    P6    +18
/Opening19/    P6    +19
/Opening20/    P6    +20
/Opening21/    P6    +21
/Opening22/    P6    +22
/Opening23/    P7    +23
/Opening24/    P6    +24
/Opening25/    P6    +25
/Opening26/    P7    +26
/DrainBfl/    M16    +27    +33    -28    -29
/DrainBflHole/    H2    +29
/DrainBflInner/    H2    +28    +33
/VentBfl/    M16    +30    +33    -31    -32
/VentBflHole/    H2    +32
/VentBflInner/    H2    +31    +33
/Basket/    H2    +34    -1    -2    -3    -4    -5
-6    -7    -8    -9    -10    -11
-12    -13    -14    -15    -16    -17
-18    -19    -20    -21    -22    -23
-24    -25    -26    -27    -30
/BasketDrain/    H2    +34    +27    -33
/BasketVent/    H2    +34    +30    -33

VOLUMES    UNITY
* Basket in Cask Cavity v2.2
PART    9    NEST
ZROD    P8    0.0000    0.0000    0.0000    87.5284    360.6800        ! Basket inserted - Includes
gap to lid
ZROD    H6    0.0000    0.0000    0.0000    88.1253    360.6800        ! Inserts flood matl to
canister shell
* Canister - Structural Lid - No Weld Shield v2.2
PART    10
ZROD    1    0.0000    0.0000    0.0000    88.1253    360.6800        ! Canister cavity contents
ZROD    2    0.0000    0.0000    -4.4450    89.7128    4.4450        ! Canister Bottom Plate
ZROD    3    0.0000    0.0000    360.6800    88.1253    12.7000        ! Shield Lid
ZROD    4    0.0000    0.0000    373.3800    88.1253    7.6200        ! Structural Lid
ZROD    5    0.0000    0.0000    0.0000    88.1253    381.0000        ! Canister Shell Inner
ZROD    6    0.0000    0.0000    0.0000    89.7128    381.0000        ! Canister Shell Outer
ZROD    7    0.0000    0.0000    -4.4450    89.7128    385.4450        ! Inner Detector Surface
ZONES
/Cavity/    P9    +1
/BottomPlate/    M16    +2
/ShieldLid/    P11    +3
/StructLid/    M16    +4
/Shell/    M16    +6    -5
/Canister/    M0    +7    -6    -4    -2
VOLUMES    UNITY
* Shield Lid - With Ports v2.2
PART    11    CLUSTER
ZROD    P12    -60.5468    47.3043    0.0000    7.6200    12.7000        ! Vent port
ZROD    P12    60.5468    -47.3043    0.0000    7.6200    12.7000        ! Drain port
ZROD    M16    0.0000    0.0000    0.0000    88.1253    12.7000        ! Shield Lid
* Vent Port Model - With Covers v2.2
PART    12    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.3843    4.6228        ! Bottom Cylinder
ZROD    M16    0.0000    0.0000    4.6228    5.0800    6.6548        ! Middle Cyclinder
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
ZROD    M16    0.0000    0.0000    11.2776    7.6200    1.4224        ! Top Cylinder
ZROD    M16    0.0000    0.0000    0.0000    7.6200    12.7000        ! Shield lid material
*Storage Cask Top Geometry v3.2.0
PART    13
ZROD    1    0.0000    0.0000    424.4975    116.9670    3.8100            ! VCC lid
ZROD    2    0.0000    0.0000    419.4175    124.3330    5.0800            ! Top flange outer
ZROD    3    0.0000    0.0000    419.4175    102.8700    5.0800            ! Top flange inner
ZROD    4    0.0000    0.0000    397.8275    100.3300    7.6200            ! Support ring outer
ZROD    5    0.0000    0.0000    397.8275    93.9800    7.6200            ! Support ring inner
ZCONE    6    0.0000    0.0000    401.6375    93.9800    97.1550    3.8100          ! Support ring cut
cone
ZROD    7    0.0000    0.0000    0.0000    109.2200    419.4175            ! VCC shell outer
ZROD    8    0.0000    0.0000    0.0000    100.3300    419.4175            ! VCC shell inner
ZROD    9    0.0000    0.0000    377.5075    109.2200    15.8877            ! VCC shell opening
ZROD    10    0.0000    0.0000    0.0000    162.5600    424.4975            ! Concrete
ZCONE    11    0.0000    0.0000    399.7325    92.0750    99.6950    7.6200          ! Shield plug cone
ZROD    12    0.0000    0.0000    407.3525    99.6950    1.9050            ! Shield plug cylinder
ZROD    13    0.0000    0.0000    421.0050    101.9810    3.4925            ! NS cover plate
ZROD    14    0.0000    0.0000    421.9575    101.0285    2.5400            ! NS
ZROD    15    0.0000    0.0000    377.5075    101.6000    15.8877            ! Air outlet inner radius
BOX    16    -54.2925    -162.5600    377.5075    108.5850    325.1200    32.6390          ! Air outlet
A channel box
BOX    17    -53.3400    -162.5600    378.4600    106.6800    325.1200    30.7340          ! Air outlet
A void box
BOX    18    -53.3400    -162.5600    377.5075    106.6800    325.1200    32.6390          ! Air outlet
A wall box
BOX    19    -162.5600    -54.2925    377.5075    325.1200    108.5850    32.6390          ! Air outlet
B channel box
BOX    20    -162.5600    -53.3400    378.4600    325.1200    106.6800    30.7340          ! Air outlet
B void box
BOX    21    -162.5600    -53.3400    377.5075    325.1200    106.6800    32.6390          ! Air outlet
B wall box
BOX    22    -162.5600    -162.5600    409.1940    325.1200    325.1200    0.9525          ! Box H8-H7
R5
BOX    23    -162.5600    -162.5600    399.3388    325.1200    325.1200    9.8552          ! Box H7-H6
R5
BOX    24    -162.5600    -162.5600    398.3863    325.1200    325.1200    0.9525          ! Box H6-H5
R5
BOX    25    -162.5600    -162.5600    377.5075    325.1200    325.1200    20.8788          ! Box H5-H1
R5
BOX    26    -162.5600    -162.5600    377.5075    325.1200    325.1200    32.6390          ! Box H8-H1
R5
BOX    27    -128.4478    -128.4478    393.3952    256.8956    256.8956    16.7513          ! Box H8-H4
R2
BOX    28    -127.4953    -127.4953    393.3952    254.9906    254.9906    16.7513          ! Box H8-H4
R1
BOX    29    -143.3830    -143.3830    377.5075    286.7660    286.7660    20.8788          ! Box H5-H1
R4
BOX    30    -143.3830    -143.3830    377.5075    286.7660    286.7660    21.8313          ! Box H6-H1
R4
BOX    31    -128.4478    -128.4478    388.3152    256.8956    256.8956    5.0800          ! Box H4-H3
R2
BOX    32    -138.3030    -138.3030    378.4600    276.6060    276.6060    20.8788          ! Box H6-H2
R3
BOX    33    -128.4478    -128.4478    378.4600    256.8956    256.8956    9.8552          ! Box H3-H2
R2
BOX    34    -138.3030    -138.3030    377.5075    276.6060    276.6060    0.9525          ! Box H2-H1
R3
BOX    35    -138.3030    -138.3030    377.5075    276.6060    276.6060    21.8313          ! Box H6-H1
R3
BOX    36    -128.4478    -128.4478    378.4600    256.8956    256.8956    20.8788          ! Box H6-H2
R2
ZROD    37    0.0000    0.0000    0.0000    100.3300    419.4175            ! Cavity
ZROD    38    0.0000    0.0000    0.0000    162.5600    428.3075            ! Container
ZROD    39    0.0000    0.0000    0.0000    89.7128    385.4450            ! Canister
ZONES
/VCCLid/    M17    +1
/TopFlange/    M17    +2    -3
/SupportRing/    M17    +4    -5    -6
/ShieldPlugCone/    M17    +11
/ShieldPlugCyl/    M17    +12
/NScover/    M17    +13    -14
/NS/    M19    +14
/VCC Shell1/    M17    +7    -8    -9                    ! Outside air outlet opening
/VCC Shell2/    M17    +9    -8    -16    -19                ! Outside air outlet channel
/Concrete1/    M22    +10    -7    -2    -16    -19            ! Non air outlet concrete
/Concrete2/    M22    +10    +25    -29    +16                ! Bot air outlet concrete
/Concrete3/    M22    +10    +25    -29    +19                ! Bot air outlet concrete
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
/Concrete4/    M22    +10    -7    +28    +16                    ! Top air outlet concrete
/Concrete5/    M22    +10    -7    +28    +19                    ! Top air outlet concrete
/AirOutTop1/    M17    +16    +22    -27    +10
/AirOutTop2/    M17    +19    +22    -27    +10
/AirOutMid1/    M17    +16    +24    -30    +10
/AirOutMid2/    M17    +19    +24    -30    +10
/AirOutBack1/    M17    +16    +27    -28
/AirOutBack2/    M17    +19    +27    -28
/AirOutBot1/    M17    +16    +34    -15
/AirOutBot2/    M17    +19    +34    -15
/AirOutBot3/    M17    +34    +16    +15    -8    -18
/AirOutBot4/    M17    +34    +19    +15    -8    -21
/AirOutShieldPlate1/    M17    +16    +30    -35
/AirOutShieldPlate2/    M17    +19    +30    -35
/AirOutTopThick1/    M17    +16    +31    -15
/AirOutTopThick2/    M17    +19    +31    -15
/AirOutTopThick3/    M17    +31    +16    +15    -8    -17
/AirOutTopThick4/    M17    +31    +19    +15    -8    -20
/AirOutTopVoid1/    M0    +17    +23    -27    +10
/AirOutTopVoid2/    M0    +20    +23    -27    +10
/AirOutMidVoid1/    M0    +17    +32    -36
/AirOutMidVoid2/    M0    +20    +32    -36
/AirOutBotVoid1/    M0    +17    +33    -15
/AirOutBotVoid2/    M0    +20    +33    -15
/AirOutWallTop1/    M17    +16    -17    +23    -27    +10
/AirOutWallTop2/    M17    +19    -20    +23    -27    +10
/AirOutWallMid1/    M17    +16    -17    +32    -36
/AirOutWallMid2/    M17    +19    -20    +32    -36
/AirOutWallBot1/    M17    +16    -17    +33    -8
/AirOutWallBot2/    M17    +19    -20    +33    -8
/ShellOpeningVoid1/    M0    +15    -8    +17
/ShellOpeningVoid2/    M0    +15    -8    +20
/ShellOpeningVoid3/    M0    +34    +15    -8    +18
/ShellOpeningVoid4/    M0    +34    +15    -8    +21
/ShellOpeningVoid5/    M0    +31    +15    -8    +17
/ShellOpeningVoid6/    M0    +31    +15    -8    +20
/FlangeVoid/    M0    +3    -13
/Cavity1/    M0    +37    -4    -11    -12    -39
/Cavity2/    M0    +37    +5    -11
/TSC/    P10    +39
/Container/    M0    +38    -10    -1
VOLUMES UNITY
*Storage Cask Bottom Geometry v3.2.0
PART    14
ZROD    1    0.0000    0.0000    48.5140    91.4400    10.1600    ! Base plate
ZCONE    2    0.0000    0.0000    2.5400    38.1000    29.2100    21.5900    ! Baffle weldment bot
ZCONE    3    0.0000    0.0000    2.5400    37.4517    28.5617    21.5900    ! Baffle weldment bot
void
ZCONE    4    0.0000    0.0000    24.1300    29.2100    38.1000    21.5900    ! Baffle weldment
top
ZCONE    5    0.0000    0.0000    24.1300    28.5617    37.4517    21.5900    ! Baffle weldment
top void
ZROD    6    0.0000    0.0000    2.5400    63.5000    45.974    ! Stand outer
ZROD    7    0.0000    0.0000    2.5400    58.4200    45.974    ! Stand inner
ZP    8    27.9400    ! Cut plane for stand
BOX    9    104.1710    -125.7236    0.0000    30.4800    325.1200    27.9400    ! Air inlet A
void
ZROT    -45.0000
BOX    10    103.4975    -126.3971    0.0000    32.3850    325.1200    33.6550    ! Air inlet A
channel
ZROT    -45.0000
BOX    11    -104.1710    -125.7236    0.0000    325.1200    30.4800    27.9400    ! Air inlet B
void
ZROT    -45.0000
BOX    12    -103.4975    -126.3971    0.0000    325.1200    32.3850    33.6550    ! Air inlet B
channel
ZROT    -45.0000
ZROD    13    0.0000    0.0000    0.0000    162.5600    2.5400    ! Bottom plate outer
ZROD    14    0.0000    0.0000    0.0000    63.5000    2.5400    ! Bottom plate inner
ZROD    15    0.0000    0.0000    2.5400    109.2200    57.0865    ! VCC shell outer
ZROD    16    0.0000    0.0000    2.5400    100.3300    57.0865    ! VCC shell inner
ZROD    17    0.0000    0.0000    2.5400    162.5600    57.0865    ! Concrete
ZROD    18    0.0000    0.0000    26.9875    99.6950    0.9525    ! Cover
BOX    19    -25.6540    -99.6950    27.9400    51.3080    199.3900    20.5740    ! Stand top cut
box A
BOX    20    -99.6950    -25.6540    27.9400    199.3900    51.3080    20.5740    ! Stand top cut
box B
ZROD    21    0.0000    0.0000    27.9400    99.6950    5.0800    ! Shield ring outer
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
ZROD    22    0.0000    0.0000    27.9400    90.1700    5.0800            ! Shield ring inner
ZROD    23    0.0000    0.0000    0.0000    162.5600    59.6265           ! Container
ZROD    24    0.0000    0.0000    58.6740    91.4400    0.9525            ! Base plate cover
ZONES
/Container/    M0    +23    -17    -13
/BasePlate/    M17    +1
/BasePlateCover/    M20    +24
/BaffleTop/    M17    +4    -5
/BaffleTopVoid/    M0    +5
/BaffleBot/    M17    +2    -3
/BaffleBotVoid/    M0    +3
/InletAVoid1/    M0    +9    -14    -7    +23                ! Outside of stand inner
/InletBVoid1/    M0    +11    -14    -7    +23                ! Outside of stand inner
/InletAWalls/    M17    +10    -9    -6    +23                ! Outside of stand outer
/InletBWalls/    M17    +12    -11    -6    +23                ! Outside of stand outer
/VCCShell/    M17    +15    -16    -10    -12
/BotPlateInner/    M17    +14
/BotPlateOuter/    M17    +13    -14    -9    -11
/BaseVoid/    M0    +7    -2    -4                    ! Inside stand inner
/Concrete/    M22    +17    -15    -10    -12
/Cover/    M17    +18    -6    -10    -12
/StandBot/    M17    +6    -7    -8    -9    -11
/StandTop/    M17    +6    -7    +8    -19    -20
/ShieldRing/    M17    +21    -22    -10    -12
/StandTopVoid1/    M0    +6    +8    -7    +19
/StandTopVoid2/    M0    +6    +8    -7    +20
/ShieldRingVoid1/    M0    +22    -6    -10    -12                ! Inside the shield ring
/xyVoid/    M0    +16    -6    -10    -12    -8    -18
/OuterVoid/    M0    +16    -6    +8    -21    -1    -10    -12
-24
VOLUMES UNITY
*Storage Cask Combined Geometry
PART    15
ZROD    1    0.0000    0.0000    -59.6265    162.5600    59.6265            ! Bottom
ZROD    2    0.0000    0.0000    0.0000    162.5600    428.3075            ! Top
ZROD    3    0.0000    0.0000    -159.6265    162.5600    100.0000            ! Concrete Pad
ZROD    4    0.0000    0.0000    -159.6265    162.5600    587.9340            ! Container
ZONES
/Bottom/    P14    +1
/Top/    P13    +2
/Concrete Pad/    M22    +3
/Container/    M0    +4    -3    -2    -1
VOLUMES UNITY
* Storage Cask Detector Description v3.2.0
PART    16
* Radial Detector DRA (Surface) Bodies
ZROD    1    0.0000    0.0000    -159.6265    162.5600 587.9340
ZROD    2    0.0000    0.0000    -59.6265 163.5600 40.6612
ZROD    3    0.0000    0.0000    -18.9653 163.5600 40.6612
ZROD    4    0.0000    0.0000    21.6958  163.5600 40.6612
ZROD    5    0.0000    0.0000    62.3570  163.5600 40.6612
ZROD    6    0.0000    0.0000    103.0182 163.5600 40.6612
ZROD    7    0.0000    0.0000    143.6793 163.5600 40.6612
ZROD    8    0.0000    0.0000    184.3405 163.5600 40.6612
ZROD    9    0.0000    0.0000    225.0017 163.5600 40.6612
ZROD    10    0.0000    0.0000    265.6628 163.5600 40.6612
ZROD    11    0.0000    0.0000    306.3240 163.5600 40.6612
ZROD    12    0.0000    0.0000    346.9852 163.5600 40.6612
ZROD    13    0.0000    0.0000    387.6463 163.5600 40.6612
* Radial Detector DRAA (TopVent) Bodies
ZROD    14    0.0000    0.0000    -160.6265    163.5600 589.9340
*   Band 1 Bodies
ZSEC    15    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    342.0000 360.0000
ZSEC    16    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    0.0000    18.0000
ZSEC    17    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    18.0000    36.0000
ZSEC    18    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    36.0000    54.0000
ZSEC    19    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    54.0000    72.0000
ZSEC    20    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    72.0000    90.0000
ZSEC    21    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    90.0000    108.0000
ZSEC    22    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    108.0000 126.0000
ZSEC    23    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    126.0000 144.0000
ZSEC    24    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    144.0000 162.0000
ZSEC    25    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    162.0000 180.0000
ZSEC    26    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    180.0000 198.0000
ZSEC    27    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    198.0000 216.0000
ZSEC    28    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    216.0000 234.0000
ZSEC    29    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    234.0000 252.0000
ZSEC    30    0.0000    0.0000    399.3388 163.5600 164.5600 9.8552    252.0000 270.0000
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
ZSEC    31              0.0000   0.0000   399.3388 163.5600 164.5600 9.8552   270.0000 288.0000
ZSEC    32              0.0000   0.0000   399.3388 163.5600 164.5600 9.8552   288.0000 306.0000
ZSEC    33              0.0000   0.0000   399.3388 163.5600 164.5600 9.8552   306.0000 324.0000
ZSEC    34              0.0000   0.0000   399.3388 163.5600 164.5600 9.8552   324.0000 342.0000
* Radial Detector DRAB (BotVent) Bodies
ZROD    35              0.0000   0.0000   -161.6265         164.5600 591.9340
*   Band 1 Bodies
ZSEC    36              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  40.0000  50.0000
ZSEC    37              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  50.0000  60.0000
ZSEC    38              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  60.0000  70.0000
ZSEC    39              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  70.0000  80.0000
ZSEC    40              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  80.0000  90.0000
ZSEC    41              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  90.0000  100.0000
ZSEC    42              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  100.0000 110.0000
ZSEC    43              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  110.0000 120.0000
ZSEC    44              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  120.0000 130.0000
ZSEC    45              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  130.0000 140.0000
ZSEC    46              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  140.0000 150.0000
ZSEC    47              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  150.0000 160.0000
ZSEC    48              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  160.0000 170.0000
ZSEC    49              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  170.0000 180.0000
ZSEC    50              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  180.0000 190.0000
ZSEC    51              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  190.0000 200.0000
ZSEC    52              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  200.0000 210.0000
ZSEC    53              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  210.0000 220.0000
ZSEC    54              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  220.0000 230.0000
ZSEC    55              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  230.0000 240.0000
ZSEC    56              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  240.0000 250.0000
ZSEC    57              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  250.0000 260.0000
ZSEC    58              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  260.0000 270.0000
ZSEC    59              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  270.0000 280.0000
ZSEC    60              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  280.0000 290.0000
ZSEC    61              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  290.0000 300.0000
ZSEC    62              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  300.0000 310.0000
ZSEC    63              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  310.0000 320.0000
ZSEC    64              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  320.0000 330.0000
ZSEC    65              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  330.0000 340.0000
ZSEC    66              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  340.0000 350.0000
ZSEC    67              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  350.0000 360.0000
ZSEC    68              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  360.0000 370.0000
ZSEC    69              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  10.0000  20.0000
ZSEC    70              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  20.0000  30.0000
ZSEC    71              0.0000   0.0000   -59.6265 164.5600 165.5600 27.9400  30.0000  40.0000
* Radial Detector DRB (1ft) Bodies
ZROD    72              0.0000   0.0000   -162.6265         193.0400 621.4140
ZROD    73              0.0000   0.0000   -59.6265 194.0400 43.2012
ZROD    74              0.0000   0.0000   -16.4253 194.0400 43.2012
ZROD    75              0.0000   0.0000   26.7758  194.0400 43.2012
ZROD    76              0.0000   0.0000   69.9770  194.0400 43.2012
ZROD    77              0.0000   0.0000   113.1782 194.0400 43.2012
ZROD    78              0.0000   0.0000   156.3793 194.0400 43.2012
ZROD    79              0.0000   0.0000   199.5805 194.0400 43.2012
ZROD    80              0.0000   0.0000   242.7817 194.0400 43.2012
ZROD    81              0.0000   0.0000   285.9828 194.0400 43.2012
ZROD    82              0.0000   0.0000   329.1840 194.0400 43.2012
ZROD    83              0.0000   0.0000   372.3852 194.0400 43.2012
ZROD    84              0.0000   0.0000   415.5863 194.0400 43.2012
* Radial Detector DRC (1m) Bodies
ZROD    85              0.0000   0.0000   -163.6265         262.5600 691.9340
ZROD    86              0.0000   0.0000   -59.6265 263.5600 48.9945
ZROD    87              0.0000   0.0000   -10.6320 263.5600 48.9945
ZROD    88              0.0000   0.0000   38.3625  263.5600 48.9945
ZROD    89              0.0000   0.0000   87.3570  263.5600 48.9945
ZROD    90              0.0000   0.0000   136.3515 263.5600 48.9945
ZROD    91              0.0000   0.0000   185.3460 263.5600 48.9945
ZROD    92              0.0000   0.0000   234.3405 263.5600 48.9945
ZROD    93              0.0000   0.0000   283.3350 263.5600 48.9945
ZROD    94              0.0000   0.0000   332.3295 263.5600 48.9945
ZROD    95              0.0000   0.0000   381.3240 263.5600 48.9945
ZROD    96              0.0000   0.0000   430.3185 263.5600 48.9945
ZROD    97              0.0000   0.0000   479.3130 263.5600 48.9945
* Radial Detector DRD (2m) Bodies
ZROD    98              0.0000   0.0000   -164.6265         362.5600 792.9340
ZROD    99              0.0000   0.0000   -59.6265 363.5600 34.3967
ZROD    100             0.0000   0.0000   -25.2298 363.5600 34.3967
ZROD    101             0.0000   0.0000   9.1669   363.5600 34.3967
ZROD    102             0.0000   0.0000   43.5636  363.5600 34.3967
ZROD    103             0.0000   0.0000   77.9603  363.5600 34.3967
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
ZROD     104              0.0000   0.0000   112.3570 363.5600 34.3967
ZROD     105              0.0000   0.0000   146.7537 363.5600 34.3967
ZROD     106              0.0000   0.0000   181.1504 363.5600 34.3967
ZROD     107              0.0000   0.0000   215.5471 363.5600 34.3967
ZROD     108              0.0000   0.0000   249.9438 363.5600 34.3967
ZROD     109              0.0000   0.0000   284.3405 363.5600 34.3967
ZROD     110              0.0000   0.0000   318.7372 363.5600 34.3967
ZROD     111              0.0000   0.0000   353.1339 363.5600 34.3967
ZROD     112              0.0000   0.0000   387.5306 363.5600 34.3967
ZROD     113              0.0000   0.0000   421.9273 363.5600 34.3967
ZROD     114              0.0000   0.0000   456.3240 363.5600 34.3967
ZROD     115              0.0000   0.0000   490.7207 363.5600 34.3967
ZROD     116              0.0000   0.0000   525.1174 363.5600 34.3967
ZROD     117              0.0000   0.0000   559.5141 363.5600 34.3967
ZROD     118              0.0000   0.0000   593.9108 363.5600 34.3967
* Radial Detector DRE (4m) Bodies
ZROD     119              0.0000   0.0000   -165.6265        562.5600 993.9340
ZROD     120              0.0000   0.0000   -59.6265 563.5600 44.3967
ZROD     121              0.0000   0.0000   -15.2298 563.5600 44.3967
ZROD     122              0.0000   0.0000   29.1669  563.5600 44.3967
ZROD     123              0.0000   0.0000   73.5636  563.5600 44.3967
ZROD     124              0.0000   0.0000   117.9603 563.5600 44.3967
ZROD     125              0.0000   0.0000   162.3570 563.5600 44.3967
ZROD     126              0.0000   0.0000   206.7537 563.5600 44.3967
ZROD     127              0.0000   0.0000   251.1504 563.5600 44.3967
ZROD     128              0.0000   0.0000   295.5471 563.5600 44.3967
ZROD     129              0.0000   0.0000   339.9438 563.5600 44.3967
ZROD     130              0.0000   0.0000   384.3405 563.5600 44.3967
ZROD     131              0.0000   0.0000   428.7372 563.5600 44.3967
ZROD     132              0.0000   0.0000   473.1339 563.5600 44.3967
ZROD     133              0.0000   0.0000   517.5306 563.5600 44.3967
ZROD     134              0.0000   0.0000   561.9273 563.5600 44.3967
ZROD     135              0.0000   0.0000   606.3240 563.5600 44.3967
ZROD     136              0.0000   0.0000   650.7207 563.5600 44.3967
ZROD     137              0.0000   0.0000   695.1174 563.5600 44.3967
ZROD     138              0.0000   0.0000   739.5141 563.5600 44.3967
ZROD     139              0.0000   0.0000   783.9108 563.5600 44.3967
* World
ZROD     140              0.0000   0.0000   -215.6265        612.5600 1093.9340
* External Void
ZROD     141              0.0000   0.0000   -265.6265        662.5600 1193.9340

ZONES
/StorageCask/    P15      +1
* Detector DRA (Surface)
/DRA01/  M0       +2       -1
/DRA02/  M0       +3       -1
/DRA03/  M0       +4       -1
/DRA04/  M0       +5       -1
/DRA05/  M0       +6       -1
/DRA06/  M0       +7       -1
/DRA07/  M0       +8       -1
/DRA08/  M0       +9       -1
/DRA09/  M0       +10      -1
/DRA10/  M0       +11      -1
/DRA11/  M0       +12      -1
/DRA12/  M0       +13      -1
/Void/   M0       +14      -1
                  -2       -3       -4       -5       -6       -7
                  -8       -9       -10      -11      -12      -13
* Detector DRAA (TopVent)
/DRAA0101/        M0       +15
/DRAA0102/        M0       +16
/DRAA0103/        M0       +17
/DRAA0104/        M0       +18
/DRAA0105/        M0       +19
/DRAA0106/        M0       +20
/DRAA0107/        M0       +21
/DRAA0108/        M0       +22
/DRAA0109/        M0       +23
/DRAA0110/        M0       +24
/DRAA0111/        M0       +25
/DRAA0112/        M0       +26
/DRAA0113/        M0       +27
/DRAA0114/        M0       +28
/DRAA0115/        M0       +29
/DRAA0116/        M0       +30
/DRAA0117/        M0       +31
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
/DRAA0118/       M0      +32
/DRAA0119/       M0      +33
/DRAA0120/       M0      +34
/Void/   M0      +35     -14
                 -15     -16     -17     -18     -19     -20
                 -21     -22     -23     -24     -25     -26
                 -27     -28     -29     -30     -31     -32
                 -33     -34
* Detector DRAB (BotVent)
/DRAB0101/       M0      +36
/DRAB0102/       M0      +37
/DRAB0103/       M0      +38
/DRAB0104/       M0      +39
/DRAB0105/       M0      +40
/DRAB0106/       M0      +41
/DRAB0107/       M0      +42
/DRAB0108/       M0      +43
/DRAB0109/       M0      +44
/DRAB0110/       M0      +45
/DRAB0111/       M0      +46
/DRAB0112/       M0      +47
/DRAB0113/       M0      +48
/DRAB0114/       M0      +49
/DRAB0115/       M0      +50
/DRAB0116/       M0      +51
/DRAB0117/       M0      +52
/DRAB0118/       M0      +53
/DRAB0119/       M0      +54
/DRAB0120/       M0      +55
/DRAB0121/       M0      +56
/DRAB0122/       M0      +57
/DRAB0123/       M0      +58
/DRAB0124/       M0      +59
/DRAB0125/       M0      +60
/DRAB0126/       M0      +61
/DRAB0127/       M0      +62
/DRAB0128/       M0      +63
/DRAB0129/       M0      +64
/DRAB0130/       M0      +65
/DRAB0131/       M0      +66
/DRAB0132/       M0      +67
/DRAB0133/       M0      +68
/DRAB0134/       M0      +69
/DRAB0135/       M0      +70
/DRAB0136/       M0      +71
/Void/   M0      +72     -35
                 -36     -37     -38     -39     -40     -41
                 -42     -43     -44     -45     -46     -47
                 -48     -49     -50     -51     -52     -53
                 -54     -55     -56     -57     -58     -59
                 -60     -61     -62     -63     -64     -65
                 -66     -67     -68     -69     -70     -71
* Detector DRB (1ft)
/DRB01/  M0      +73     -72
/DRB02/  M0      +74     -72
/DRB03/  M0      +75     -72
/DRB04/  M0      +76     -72
/DRB05/  M0      +77     -72
/DRB06/  M0      +78     -72
/DRB07/  M0      +79     -72
/DRB08/  M0      +80     -72
/DRB09/  M0      +81     -72
/DRB10/  M0      +82     -72
/DRB11/  M0      +83     -72
/DRB12/  M0      +84     -72
/Void/   M0      +85     -72
                 -73     -74     -75     -76     -77     -78
                 -79     -80     -81     -82     -83     -84
* Detector DRC (1m)
/DRC01/  M0      +86     -85
/DRC02/  M0      +87     -85
/DRC03/  M0      +88     -85
/DRC04/  M0      +89     -85
/DRC05/  M0      +90     -85
/DRC06/  M0      +91     -85
/DRC07/  M0      +92     -85
/DRC08/  M0      +93     -85
/DRC09/  M0      +94     -85
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
/DRC10/  M0      +95      -85
/DRC11/  M0      +96      -85
/DRC12/  M0      +97      -85
/Void/   M0      +98      -85
                 -86      -87      -88      -89      -90      -91
                 -92      -93      -94      -95      -96      -97
* Detector DRD (2m)
/DRD01/  M0      +99      -98
/DRD02/  M0      +100     -98
/DRD03/  M0      +101     -98
/DRD04/  M0      +102     -98
/DRD05/  M0      +103     -98
/DRD06/  M0      +104     -98
/DRD07/  M0      +105     -98
/DRD08/  M0      +106     -98
/DRD09/  M0      +107     -98
/DRD10/  M0      +108     -98
/DRD11/  M0      +109     -98
/DRD12/  M0      +110     -98
/DRD13/  M0      +111     -98
/DRD14/  M0      +112     -98
/DRD15/  M0      +113     -98
/DRD16/  M0      +114     -98
/DRD17/  M0      +115     -98
/DRD18/  M0      +116     -98
/DRD19/  M0      +117     -98
/DRD20/  M0      +118     -98
/Void/   M0      +119     -98
                 -99      -100     -101     -102     -103     -104
                 -105     -106     -107     -108     -109     -110
                 -111     -112     -113     -114     -115     -116
                 -117     -118
* Detector DRE (4m)
/DRE01/  M0      +120     -119
/DRE02/  M0      +121     -119
/DRE03/  M0      +122     -119
/DRE04/  M0      +123     -119
/DRE05/  M0      +124     -119
/DRE06/  M0      +125     -119
/DRE07/  M0      +126     -119
/DRE08/  M0      +127     -119
/DRE09/  M0      +128     -119
/DRE10/  M0      +129     -119
/DRE11/  M0      +130     -119
/DRE12/  M0      +131     -119
/DRE13/  M0      +132     -119
/DRE14/  M0      +133     -119
/DRE15/  M0      +134     -119
/DRE16/  M0      +135     -119
/DRE17/  M0      +136     -119
/DRE18/  M0      +137     -119
/DRE19/  M0      +138     -119
/DRE20/  M0      +139     -119
/Void/   M0      +140     -119
                 -120     -121     -122     -123     -124     -125
                 -126     -127     -128     -129     -130     -131
                 -132     -133     -134     -135     -136     -137
                 -138     -139
/ExtVoid/        M-2000   +141     -140
Volumes
                 1.0      12*4.1659E+04    1.0      20*5.0795E+02    1.0      36*8.0491E+02
                 1.0      12*5.2535E+04    1.0      12*8.0981E+04    1.0      20*7.8465E+04
                 1.0      20*1.5707E+05    1.0      1.0
end

*
* Unit 5 Splitting Geometry for Radial Detectors - Gamma
*
begin splitting geometry
r    39    fill    0.0000
n    10    87.5284
n    2    100.3300
n    7    109.2200
n    18    162.5600
n    1    163.5600
n    1    168.5600
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
z    76    fill    -159.6265
n    1    -69.6265
n    4    -59.6265
n    2    -57.0865
n    4    -11.1125
n    8    0.0000
n    4    4.4450
n    3    14.2824
n    13    323.6544
n    1    332.6706
n    2    335.3308
n    3    352.5774
n    1    365.1250
n    9    377.8250
n    6    385.4450
n    1    399.7325
n    7    409.2575
n    1    421.0050
n    1    421.9575
n    1    424.4975
n    3    428.3075
n    1    429.3075
end
*
* Unit 6 - Source Geometry for Fuel Gamma
*
begin source geometry
r    10    fill    0.0000    n    10    87.5284
z    13
14.2824    22.0167    29.7510    37.4853    45.2196    52.9539
60.6882    277.2486    284.9829    292.7172    300.4515    308.1858
315.9201    323.6544
end

*
* Unit 7
*
begin energy data
gamma    dice
importance    standard    22    groups
scoring    as    importance
simple    source    histogram    weighting    automatic
end

*
* Unit 8 Importance Map - Radial
*
begin importance map
calculate
targets    12
part    16
zones
2    3    4    5    6    7
8    9    10    11    12    13
strengths
1.0E+03    1.0E+02    1.0E+02    1.0E+01    1.0E+00    1.0E+00
1.0E+00    1.0E+00    1.0E+01    1.0E+02    1.0E+02    1.0E+03
defer mixing
void density    0.10
track
!    coupled source
!    write gamma importances to 32
!    write unformatted file to 31
!    use method d
end

*
* Unit 9 Scoring Data - Radial
*
begin scoring data
flux
part    16
from    2    to    13    ! DRA
from    15    to    34    ! DRAA
from    36    to    71    ! DRAB
from    73    to    84    ! DRB
from    86    to    97    ! DRC
from    99    to    118    ! DRD
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
from    120    to    139    ! DRE
responses    sos    ditto
contributions to responses        ditto
! score distribution for response
! weight distribution    total
end

*
* Unit 10 Response Data
*
begin response data
* Scaled to mrem/hr
/ansi ans-6.1.1-1977 photon flux-dose conversion factors - mcnp table h.2 - mrem/
        function pairs
        1.5000E+01        1.3300E-02
        1.4787E+01        1.3142E-02
        1.4577E+01        1.2985E-02
        1.4370E+01        1.2831E-02
        1.4166E+01        1.2678E-02
        1.3964E+01        1.2528E-02
        1.3766E+01        1.2379E-02
        1.3570E+01        1.2231E-02
        1.3377E+01        1.2086E-02
        1.3187E+01        1.1942E-02
        1.3000E+01        1.1800E-02
        1.2785E+01        1.1641E-02
        1.2573E+01        1.1483E-02
        1.2365E+01        1.1328E-02
        1.2160E+01        1.1175E-02
        1.1958E+01        1.1025E-02
        1.1760E+01        1.0876E-02
        1.1565E+01        1.0729E-02
        1.1374E+01        1.0584E-02
        1.1185E+01        1.0441E-02
        1.1000E+01        1.0300E-02
        1.0781E+01        1.0136E-02
        1.0567E+01        9.9740E-03
        1.0357E+01        9.8149E-03
        1.0152E+01        9.6583E-03
        9.9499E+00        9.5043E-03
        9.7522E+00        9.3526E-03
        9.5585E+00        9.2035E-03
        9.3686E+00        9.0566E-03
        9.1824E+00        8.9122E-03
        9.0000E+00        8.7700E-03
        8.8374E+00        8.6521E-03
        8.6777E+00        8.5358E-03
        8.5210E+00        8.4211E-03
        8.3670E+00        8.3079E-03
        8.2158E+00        8.1962E-03
        8.0674E+00        8.0861E-03
        7.9216E+00        7.9774E-03
        7.7785E+00        7.8701E-03
        7.6380E+00        7.7644E-03
        7.5000E+00        7.6600E-03
        7.4214E+00        7.6031E-03
        7.3436E+00        7.5467E-03
        7.2666E+00        7.4907E-03
        7.1905E+00        7.4351E-03
        7.1151E+00        7.3799E-03
        7.0406E+00        7.3251E-03
        6.9668E+00        7.2707E-03
        6.8937E+00        7.2167E-03
        6.8215E+00        7.1632E-03
        6.7500E+00        7.1100E-03
        6.6983E+00        7.0721E-03
        6.6469E+00        7.0344E-03
        6.5959E+00        6.9969E-03
        6.5454E+00        6.9596E-03
        6.4952E+00        6.9225E-03
        6.4454E+00        6.8856E-03
        6.3960E+00        6.8489E-03
        6.3469E+00        6.8124E-03
        6.2983E+00        6.7761E-03
        6.2500E+00        6.7400E-03
        6.1981E+00        6.7021E-03
        6.1466E+00        6.6643E-03
        6.0956E+00        6.6268E-03
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
6.0450E+00      6.5895E-03
5.9948E+00      6.5524E-03
5.9450E+00      6.5155E-03
5.8956E+00      6.4788E-03
5.8467E+00      6.4423E-03
5.7981E+00      6.4061E-03
5.7500E+00      6.3700E-03
5.6979E+00      6.3331E-03
5.6463E+00      6.2963E-03
5.5952E+00      6.2598E-03
5.5445E+00      6.2235E-03
5.4943E+00      6.1874E-03
5.4446E+00      6.1515E-03
5.3953E+00      6.1158E-03
5.3464E+00      6.0803E-03
5.2980E+00      6.0451E-03
5.2500E+00      6.0100E-03
5.2244E+00      5.9887E-03
5.1990E+00      5.9674E-03
5.1737E+00      5.9462E-03
5.1485E+00      5.9251E-03
5.1235E+00      5.9041E-03
5.0985E+00      5.8831E-03
5.0737E+00      5.8622E-03
5.0490E+00      5.8414E-03
5.0245E+00      5.8207E-03
5.0000E+00      5.8000E-03
4.9744E+00      5.7797E-03
4.9490E+00      5.7594E-03
4.9236E+00      5.7393E-03
4.8985E+00      5.7192E-03
4.8734E+00      5.6991E-03
4.8485E+00      5.6792E-03
4.8237E+00      5.6593E-03
4.7990E+00      5.6394E-03
4.7744E+00      5.6197E-03
4.7500E+00      5.6000E-03
4.6975E+00      5.5619E-03
4.6455E+00      5.5240E-03
4.5941E+00      5.4863E-03
4.5433E+00      5.4490E-03
4.4931E+00      5.4118E-03
4.4434E+00      5.3750E-03
4.3942E+00      5.3384E-03
4.3456E+00      5.3020E-03
4.2975E+00      5.2659E-03
4.2500E+00      5.2300E-03
4.1971E+00      5.1886E-03
4.1449E+00      5.1474E-03
4.0934E+00      5.1066E-03
4.0425E+00      5.0662E-03
3.9922E+00      5.0260E-03
3.9425E+00      4.9862E-03
3.8935E+00      4.9467E-03
3.8451E+00      4.9075E-03
3.7972E+00      4.8686E-03
3.7500E+00      4.8300E-03
3.6967E+00      4.7863E-03
3.6442E+00      4.7429E-03
3.5924E+00      4.7000E-03
3.5414E+00      4.6574E-03
3.4911E+00      4.6152E-03
3.4415E+00      4.5734E-03
3.3926E+00      4.5320E-03
3.3444E+00      4.4910E-03
3.2968E+00      4.4503E-03
3.2500E+00      4.4100E-03
3.2019E+00      4.3683E-03
3.1546E+00      4.3269E-03
3.1079E+00      4.2860E-03
3.0619E+00      4.2454E-03
3.0166E+00      4.2052E-03
2.9720E+00      4.1655E-03
2.9280E+00      4.1260E-03
2.8847E+00      4.0870E-03
2.8420E+00      4.0483E-03
2.8000E+00      4.0100E-03
2.7793E+00      3.9906E-03
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
2.7588E+00      3.9713E-03
2.7384E+00      3.9520E-03
2.7182E+00      3.9329E-03
2.6981E+00      3.9138E-03
2.6782E+00      3.8949E-03
2.6585E+00      3.8760E-03
2.6388E+00      3.8573E-03
2.6193E+00      3.8386E-03
2.6000E+00      3.8200E-03
2.5569E+00      3.7780E-03
2.5146E+00      3.7364E-03
2.4729E+00      3.6953E-03
2.4319E+00      3.6547E-03
2.3917E+00      3.6145E-03
2.3520E+00      3.5747E-03
2.3131E+00      3.5354E-03
2.2747E+00      3.4965E-03
2.2371E+00      3.4580E-03
2.2000E+00      3.4200E-03
2.1563E+00      3.3744E-03
2.1135E+00      3.3293E-03
2.0715E+00      3.2849E-03
2.0303E+00      3.2410E-03
1.9900E+00      3.1978E-03
1.9504E+00      3.1551E-03
1.9117E+00      3.1130E-03
1.8737E+00      3.0714E-03
1.8365E+00      3.0304E-03
1.8000E+00      2.9900E-03
1.7553E+00      2.9381E-03
1.7118E+00      2.8872E-03
1.6693E+00      2.8371E-03
1.6279E+00      2.7879E-03
1.5875E+00      2.7395E-03
1.5481E+00      2.6920E-03
1.5096E+00      2.6453E-03
1.4722E+00      2.5994E-03
1.4356E+00      2.5543E-03
1.4000E+00      2.5100E-03
1.3537E+00      2.4512E-03
1.3089E+00      2.3937E-03
1.2656E+00      2.3376E-03
1.2237E+00      2.2828E-03
1.1832E+00      2.2293E-03
1.1441E+00      2.1771E-03
1.1062E+00      2.1260E-03
1.0696E+00      2.0762E-03
1.0342E+00      2.0275E-03
1.0000E+00      1.9800E-03
9.7793E-01      1.9477E-03
9.5635E-01      1.9160E-03
9.3525E-01      1.8848E-03
9.1461E-01      1.8541E-03
8.9443E-01      1.8238E-03
8.7469E-01      1.7941E-03
8.5539E-01      1.7649E-03
8.3651E-01      1.7361E-03
8.1805E-01      1.7078E-03
8.0000E-01      1.6800E-03
7.8939E-01      1.6633E-03
7.7892E-01      1.6467E-03
7.6859E-01      1.6303E-03
7.5839E-01      1.6141E-03
7.4833E-01      1.5980E-03
7.3841E-01      1.5821E-03
7.2861E-01      1.5663E-03
7.1895E-01      1.5507E-03
7.0941E-01      1.5353E-03
7.0000E-01      1.5200E-03
6.9483E-01      1.5118E-03
6.8970E-01      1.5037E-03
6.8461E-01      1.4955E-03
6.7955E-01      1.4875E-03
6.7454E-01      1.4795E-03
6.6956E-01      1.4715E-03
6.6461E-01      1.4635E-03
6.5971E-01      1.4557E-03
6.5483E-01      1.4478E-03
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
6.5000E-01      1.4400E-03
6.4482E-01      1.4318E-03
6.3968E-01      1.4236E-03
6.3458E-01      1.4155E-03
6.2952E-01      1.4075E-03
6.2450E-01      1.3994E-03
6.1952E-01      1.3915E-03
6.1458E-01      1.3835E-03
6.0968E-01      1.3756E-03
6.0482E-01      1.3678E-03
6.0000E-01      1.3600E-03
5.9480E-01      1.3507E-03
5.8965E-01      1.3415E-03
5.8454E-01      1.3324E-03
5.7948E-01      1.3233E-03
5.7446E-01      1.3142E-03
5.6948E-01      1.3053E-03
5.6455E-01      1.2964E-03
5.5966E-01      1.2875E-03
5.5481E-01      1.2787E-03
5.5000E-01      1.2700E-03
5.4478E-01      1.2596E-03
5.3962E-01      1.2493E-03
5.3450E-01      1.2391E-03
5.2943E-01      1.2290E-03
5.2440E-01      1.2190E-03
5.1943E-01      1.2090E-03
5.1450E-01      1.1991E-03
5.0962E-01      1.1893E-03
5.0479E-01      1.1796E-03
5.0000E-01      1.1700E-03
4.9476E-01      1.1607E-03
4.8957E-01      1.1514E-03
4.8444E-01      1.1422E-03
4.7937E-01      1.1331E-03
4.7434E-01      1.1241E-03
4.6937E-01      1.1151E-03
4.6445E-01      1.1062E-03
4.5958E-01      1.0974E-03
4.5477E-01      1.0887E-03
4.5000E-01      1.0800E-03
4.4473E-01      1.0701E-03
4.3952E-01      1.0603E-03
4.3438E-01      1.0506E-03
4.2929E-01      1.0409E-03
4.2426E-01      1.0314E-03
4.1930E-01      1.0220E-03
4.1439E-01      1.0126E-03
4.0953E-01      1.0033E-03
4.0474E-01      9.9411E-04
4.0000E-01      9.8500E-04
3.9469E-01      9.7374E-04
3.8946E-01      9.6260E-04
3.8429E-01      9.5160E-04
3.7920E-01      9.4072E-04
3.7417E-01      9.2996E-04
3.6920E-01      9.1933E-04
3.6431E-01      9.0882E-04
3.5947E-01      8.9843E-04
3.5470E-01      8.8815E-04
3.5000E-01      8.7800E-04
3.4465E-01      8.6531E-04
3.3937E-01      8.5279E-04
3.3418E-01      8.4046E-04
3.2907E-01      8.2831E-04
3.2404E-01      8.1633E-04
3.1908E-01      8.0453E-04
3.1420E-01      7.9290E-04
3.0939E-01      7.8143E-04
3.0466E-01      7.7014E-04
3.0000E-01      7.5900E-04
2.9458E-01      7.4511E-04
2.8926E-01      7.3147E-04
2.8403E-01      7.1809E-04
2.7890E-01      7.0495E-04
2.7386E-01      6.9205E-04
2.6891E-01      6.7938E-04
2.6405E-01      6.6695E-04
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
          2.5928E-01        6.5474E-04
          2.5460E-01        6.4276E-04
          2.5000E-01        6.3100E-04
          2.4448E-01        6.1661E-04
          2.3909E-01        6.0255E-04
          2.3381E-01        5.8881E-04
          2.2865E-01        5.7538E-04
          2.2361E-01        5.6226E-04
          2.1867E-01        5.4943E-04
          2.1385E-01        5.3690E-04
          2.0913E-01        5.2466E-04
          2.0451E-01        5.1269E-04
          2.0000E-01        5.0100E-04
          1.9433E-01        4.8721E-04
          1.8882E-01        4.7380E-04
          1.8346E-01        4.6076E-04
          1.7826E-01        4.4808E-04
          1.7321E-01        4.3575E-04
          1.6829E-01        4.2376E-04
          1.6352E-01        4.1210E-04
          1.5888E-01        4.0075E-04
          1.5438E-01        3.8973E-04
          1.5000E-01        3.7900E-04
          1.4404E-01        3.6809E-04
          1.3832E-01        3.5749E-04
          1.3282E-01        3.4720E-04
          1.2754E-01        3.3721E-04
          1.2247E-01        3.2750E-04
          1.1761E-01        3.1807E-04
          1.1293E-01        3.0892E-04
          1.0845E-01        3.0002E-04
          1.0414E-01        2.9139E-04
          1.0000E-01        2.8300E-04
          9.6496E-02        2.8039E-04
          9.3115E-02        2.7781E-04
          8.9852E-02        2.7526E-04
          8.6704E-02        2.7272E-04
          8.3666E-02        2.7021E-04
          8.0734E-02        2.6772E-04
          7.7906E-02        2.6526E-04
          7.5176E-02        2.6282E-04
          7.2542E-02        2.6040E-04
          7.0000E-02        2.5800E-04
          6.7684E-02        2.6103E-04
          6.5444E-02        2.6410E-04
          6.3279E-02        2.6721E-04
          6.1185E-02        2.7035E-04
          5.9161E-02        2.7353E-04
          5.7203E-02        2.7675E-04
          5.5311E-02        2.8000E-04
          5.3481E-02        2.8330E-04
          5.1711E-02        2.8663E-04
          5.0000E-02        2.9000E-04
          4.7510E-02        3.1092E-04
          4.5144E-02        3.3335E-04
          4.2896E-02        3.5740E-04
          4.0760E-02        3.8318E-04
          3.8730E-02        4.1083E-04
          3.6801E-02        4.4047E-04
          3.4968E-02        4.7224E-04
          3.3227E-02        5.0631E-04
          3.1572E-02        5.4284E-04
          3.0000E-02        5.8200E-04
          2.6879E-02        7.0502E-04
          2.4082E-02        8.5404E-04
          2.1577E-02        1.0346E-03
          1.9332E-02        1.2532E-03
          1.7321E-02        1.5181E-03
          1.5518E-02        1.8390E-03
          1.3904E-02        2.2277E-03
          1.2457E-02        2.6986E-03
          1.1161E-02        3.2690E-03
          1.0000E-02        3.9600E-03
end

*
* Unit 13 Hole Data
*
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
begin hole data
* Canister Hole Description v2.2
* Hole    1    BORAL Core
PLATE
1    0    0
2
0.1588    12
0.0318    11
12

* Hole    2    General Basket Structure
PLATE
0    0    1
5
343.9414    0            ! Top of Basket
316.0522    -3            ! Top of Highest Support Disk
0.0000    -5            ! Bottom of Lowest Support Disk
-15.4686    -4            ! Bottom of Basket
-15.4686    0            ! Basket Offset
0

* Hole    3    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
86.3346
87.6046
5                ! number of axial intervals
316.0522                ! Top of diskstack
326.6694                ! Bottom of weldment
327.9394                ! Top of weldment plate
337.4537                ! Ullage
342.6714                ! Flange
343.9414                ! Void to top of basket
0    0            ! Material below weldment
14    14            ! Plate Material
0    14            ! Ullage
0    14            ! Flange
0    0            ! Void to top of basket
0                ! Outside material

* Hole    4    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ! number of radial points
87.6046
1                ! number of axial intervals
-11.6586
-10.3886                ! Coordinates inherited from PLATE Hole
14                ! Plate Material
0                ! Outside material

* Hole    5    Support disk and heat transfer disk stack
PLATE
0    0    1
4
CELL    11.6586            ! Sets up a repeating lattice of cells
11.6586    0            ! flood matl
7.0993    0            ! water gap
5.8293    15            ! aluminium disk
1.2700    0            ! water gap
13                ! steel disk

* Hole    6    Flood material model
PLATE
0    0    1
1
352.9223    0            ! Above flooded region
0                ! Flooded region

end

*
* Unit 15 Source Strength - Fuel Gamma
*
* CY 15x15 Stainless Steel Clad - 38 GWD/MTU - 5 Yr - Fuel Gamma
begin source strength
component        7.0184E-06    ! numAssy/volume (26/3.7045E+06)
component    r    10*1.0
component    z
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
5.9142E-01    6.8025E-01    7.6908E-01    8.5792E-01    9.4675E-01    1.0356E+00
1.0800E+00    1.0356E+00    9.4675E-01    8.5792E-01    7.6908E-01    6.8025E-01
5.9142E-01
component    energy
0.0000E+00    4.9793E+03    9.6309E+04    4.5363E+05    2.3127E+06    5.7632E+06
7.8829E+09    6.3481E+10    1.9376E+12    8.5576E+11    5.4210E+12    6.8388E+13
4.4331E+13    2.7622E+14    2.0157E+15    5.9835E+14    5.4394E+13    8.1902E+13
3.0089E+14    3.6139E+14    8.1082E+14    5.5606E+14
end

*
* Unit 16 Simple Source Weights
*
*begin source weights
*
*end

*
* Unit 31 Tabular Output
*
begin tabular output
/Radial Detector DRA - Surface - Response/
response    interim
number    some    1
region    from    171    to    182
output to file    also
/Radial Detector DRAB - BotVent - Response/
response
number    some    1
region    from    205    to    240
output to file    also
/Radial Detector DRB - 1ft - Response/
response
number    some    1
region    from    242    to    253
output to file    also
/Radial Detector DRC - 1m - Response/
response
number    some    1
region    from    255    to    266
output to file    also
/Radial Detector DRD - 2m - Response/
response
number    some    1
region    from    268    to    287
output to file    also
/Radial Detector DRE - 4m - Response/
response
number    some    1
region    from    289    to    308
output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    gamma
nmixtures    4
weight    mixture    1
u235    3.7023E-02
u238    8.4448E-01
o    1.1850E-01
atoms    mixture    2
h    6.6667E-01
o    3.3333E-01
weight    mixture    3
al    5.8260E-01
b10    4.5690E-02
b11    2.7769E-01
c    9.4020E-02
atoms    mixture    4
c    2.8571E-01
h    4.7619E-01
o    2.3810E-01
*
* Materials List - Dry Conditions - v2.4 - Stainless Steel Clad Fuel
*
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
nmaterials    25
volume                                  ! Homogenized CY fuel
material    1
mixture    1    density    10.4120    prop    3.3010E-01    ! UO2 mixture at 4.2%
void                prop    9.5568E-03    ! Gap
stainless 3041 steel        density    7.9200    prop    6.5962E-02    ! Tube, clad
void                prop    5.9438E-01    ! Interstitial, inside tubes
volume                                  ! Fuel pin cladding
material    2
stainless 3041 steel        density    7.9200    prop    1.0000
volume                                  ! Water In Lattice and Tube
material    3
mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                                  ! Water In Fuel Rod Clad Gap
material    4
mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                                  ! Lower End Plug material
material    5
stainless 3041 steel        density    7.9200    prop    0.3997
void                prop    0.6003
volume                                  ! Upper End Plug Material
material    6
stainless 3041 steel        density    7.9200    prop    0.3997
void                prop    0.6003
volume                                  ! Lower Nozzle Material
material    7
stainless 3041 steel        density    7.9200    prop    0.2996
void                prop    0.7004
volume                                  ! Upper Nozzle Material
material    8
stainless 3041 steel        density    7.9200    prop    0.1787
void                prop    0.8213
volume                                  ! Upper Plenum Material
material    9
stainless 3041 steel        density    7.9200    prop    0.1179
void                prop    0.8821
*
* Materials List - Common Materials - v2.4
*
volume                                  ! Tube wall and cover sheet
material    10
stainless 3041 steel        density    7.9200    prop    1.0000
volume                                  ! BORAL core
material    11
mixture    3    density    2.6226    prop    0.9850    ! mixBORAL
void                prop    0.0150
volume                                  ! BORAL alumnimum clad
material    12
aluminium                prop    1.0000
volume                                  ! Structural Disk Material
material    13
stainless 3041 steel        density    7.9200    prop    1.0000
volume                                  ! Weldment Material
material    14
stainless 3041 steel        density    7.9200    prop    1.0000
volume                                  ! Heat Transfer Disk Material
material    15
aluminium                prop    1.0000
volume                                  ! Canister Material
material    16
stainless 3041 steel        density    7.9200    prop    1.0000
atoms                                   ! Transfer steel
material    17        density    0              !  (SCALE carbonsteel 7.8212 g/cc)
c            prop    3.9250E-03
fe            prop    8.3498E-02
volume                                  ! Lead
material    18
pb        density    11.0400    prop    1.0000
atoms                                   ! NS-4-FR
material    19        density    0              ! 0 means atom/b-cm
b10            prop    8.5500E-05
b11            prop    3.4200E-04
al            prop    7.8000E-03
h            prop    5.8500E-02
o            prop    2.6100E-02
c            prop    2.2600E-02
n            prop    1.3900E-03
volume                                  ! Stainless Steel 304
```

Figure 5.6.2–1 MCBEND Input File for CY-MPC Storage Cask Radial Analysis – Stainless Steel Clad – Fuel Gamma Source (continued)

```
material    20
stainless 304l steel        density    7.9200    prop    1.0000
volume                            ! Vent port middle cylinder
material    21
stainless 304l steel        density    7.9200    prop    0.5000
void                prop    0.5000
atoms                           ! SCALE Concrete
material    22        density    0            ! (density 2.2426 g/cc)
h            prop    1.3401E-02
o            prop    4.4931E-02
na            prop    1.7036E-03
al            prop    1.7018E-03
si            prop    1.6205E-02
ca            prop    1.4826E-03
fe            prop    3.3857E-04
volume                            ! Heat fins for transport cask
material    23
cu        density    8.9200    prop    0.4286
stainless 304l steel        density    7.9200    prop    0.5714
volume                            ! Balsa
material    24
mixture    4    density    0.1250    prop    1.0000
volume                            ! Redwood
material    25
mixture    4    density    0.3870    prop    1.0000
end
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source

```
columns 1 200
*
* CY Transfer Cask - Zr_43b_05y - Fuel Neutron - Top Axial
*   Shield Lid - Ports - With Covers
*   Structural Lid - Weld Shield
*   Dry Conditions
*
*   Model Revision v2.5.2
*

*
* Parameters
*
@samps =    2000000

*
* Unit 1 Control Data
*
begin control data
run
sample limit     @samps
time limit     1000m
seeds    2768    10618
chime every    [@samps/10]    samples
report interim results
sbd    10s
dump intervals    1
end

*
* Unit 3 Output Control
*
*begin output control
*    suppress inflows
*end

*
* Unit 4 Material Geometry
*
begin material geometry
* Fuel Assembly Type A - Zircaloy Clad - v2.1
PART    1    NEST
BOX    M7        0.0000    0.0000    0.0000    21.4605    21.4605    8.0975    ! lower nozzle
BOX    M5        0.0000    0.0000    0.0000    21.4605    21.4605    9.8374    ! bottom end plug
BOX    M1    S    0.0000    0.0000    0.0000    21.4605    21.4605    317.4314    ! fuel
BOX    M9        0.0000    0.0000    0.0000    21.4605    21.4605    328.2256    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    21.4605    21.4605    329.9655    ! top end plug
BOX    M0        0.0000    0.0000    0.0000    21.4605    21.4605    330.8858    ! gap to top nozzle
BOX    M8        0.0000    0.0000    0.0000    21.4605    21.4605    348.1324    ! upper nozzle
* Fuel Assembly Type B - Zircaloy Clad - v2.1
PART    2    NEST
BOX    M7        0.0000    0.0000    0.0000    21.4605    21.4605    8.0975    ! lower nozzle
BOX    M5        0.0000    0.0000    0.0000    21.4605    21.4605    9.8374    ! bottom end plug
BOX    M1    S    0.0000    0.0000    0.0000    21.4605    21.4605    317.4314    ! fuel
BOX    M9        0.0000    0.0000    0.0000    21.4605    21.4605    328.2256    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    21.4605    21.4605    329.9655    ! top end plug
BOX    M0        0.0000    0.0000    0.0000    21.4605    21.4605    330.8858    ! gap to top nozzle
BOX    M8        0.0000    0.0000    0.0000    21.4605    21.4605    348.1324    ! upper nozzle
* BORAL and Cover for Standard Opening v2.0
PART    3    NEST
BOX    BH1    0.0457    0.0000    0.3556    0.1905    20.9042    326.3900    ! BORAL Sheet - Axial
offset from cover sheet bottom
BOX    M0    0.0457    0.0000    0.0000    0.1905    20.9042    328.4220    ! Space under cover sheet
that allows sheet to shift under cover
BOX    M10    0.0000    0.0000    0.0000    0.2362    20.9042    328.4220    ! SS cover sheet for
BORAL
* Fuel Assembly in Tube (Type A) v2.0
PART    4
BOX    1    0.4661    0.4661    0.0000    21.4605    21.4605    348.1324    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.1488    22.1488    360.6800    ! Space inside tube from
can lid to bottom
BOX    3    0.0000    0.0000    5.0800    22.3926    22.3926    335.7880    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.3926    22.3926    360.6800    ! Container body - extent
of basket cavity
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M10    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v2.0
PART    5
BOX    1    0.4661    0.4661    0.0000    21.4605    21.4605    348.1324    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.1488    22.1488    360.6800    ! Space inside tube from
can lid to bottom
BOX    3    0.0000    0.0000    5.0800    22.3926    22.3926    335.7880    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.3926    22.3926    360.6800    ! Container body - extent
of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H6    +2    -1
/Fuel Tube/    M10    +3    -2
/Container/    H6    +4    -3    -2
VOLUMES UNITY
*  Type A Disk Opening with Tube v2.2
PART    6    CLUSTER
BOX    P4    0.4496    0.4496    0.0000    22.3926    22.3926    360.6800    ! Fuel tube type A with
fuel assy
BOX    P3    0.2134    1.1938    7.1120    0.2362    20.9042    328.4220
BOX    P3    23.0785    22.0980    7.1120    0.2362    20.9042    328.4220
ZROT    180.0000
BOX    P3    1.1938    23.0785    7.1120    0.2362    20.9042    328.4220
ZROT    90.0000
BOX    P3    22.0980    0.2134    7.1120    0.2362    20.9042    328.4220
ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    23.2918    23.2918    360.6800    ! Support disk opening
width
*  Type B Disk Opening with Tube v2.2
PART    7    CLUSTER
BOX    P5    0.4496    0.4496    0.0000    22.3926    22.3926    360.6800    ! Fuel tube type B with
fuel assy
BOX    P3    0.2134    1.1938    7.1120    0.2362    20.9042    328.4220
BOX    P3    23.0785    22.0980    7.1120    0.2362    20.9042    328.4220
ZROT    180.0000
BOX    P3    1.1938    23.0785    7.1120    0.2362    20.9042    328.4220
ZROT    90.0000
BOX    P3    22.0980    0.2134    7.1120    0.2362    20.9042    328.4220
ZROT    270.0000
BOX    H6    0.0000    0.0000    0.0000    23.2918    23.2918    360.6800    ! Support disk opening
width
* Canister Cavity v2.2
PART    8
BOX    1    -51.2826    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 1
BOX    2    -25.1968    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 2
BOX    3    1.9050    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 3
BOX    4    27.9908    47.6377    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 4
BOX    5    -77.1144    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 5
BOX    6    -51.2826    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 6
BOX    7    -25.1968    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 7
BOX    8    1.9050    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 8
BOX    9    27.9908    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 9
BOX    10    53.8226    15.4559    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 10
BOX    11    -77.1144    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 11
BOX    12    -51.2826    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 12
BOX    13    -25.1968    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 13
BOX    14    1.9050    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 14
BOX    15    27.9908    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 15
BOX    16    53.8226    -11.6459    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 16
BOX    17    -77.1144    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 17
BOX    18    -51.2826    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 18
BOX    19    -25.1968    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 19
BOX    20    1.9050    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 20
BOX    21    27.9908    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 21
BOX    22    53.8226    -38.7477    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 22
BOX    23    -51.2826    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 23
BOX    24    -25.1968    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 24
BOX    25    1.9050    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 25
BOX    26    27.9908    -70.9295    -15.4686    23.2918    23.2918    360.6800    ! Basket Opening 26
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
BOX    27    53.8226    -67.9577    327.9394    22.0980    27.9400    16.0020    ! Drain Baffle Box A
BOX    28    57.6326    -67.9577    327.9394    18.2880    24.1300    10.9220    ! Drain Baffle Box B
ZROD    29    60.5468    -47.3043    338.8614    2.5400    5.0800        ! Drain Baffle Hole
BOX    30    -77.1144    40.0177    327.9394    22.0980    27.9400    16.0020    ! Vent Baffle Box A
BOX    31    -77.1144    43.8277    327.9394    18.2880    24.1300    10.9220    ! Vent Baffle Box B
ZROD    32    -60.5468    47.3043    338.8614    2.5400    5.0800        ! Vent Baffle Hole
ZROD    33    0.0000    0.0000    -15.4686    86.3346    360.6800        ! Baffle limiting radius
CONTAINER
ZROD    34    0.0000    0.0000    -15.4686    87.5284    360.6800        ! Basket stack to cavity
height
ZONES
/Opening01/    P7    +1
/Opening02/    P6    +2
/Opening03/    P6    +3
/Opening04/    P7    +4
/Opening05/    P6    +5
/Opening06/    P6    +6
/Opening07/    P6    +7
/Opening08/    P6    +8
/Opening09/    P6    +9
/Opening10/    P6    +10
/Opening11/    P6    +11
/Opening12/    P6    +12
/Opening13/    P6    +13
/Opening14/    P6    +14
/Opening15/    P6    +15
/Opening16/    P6    +16
/Opening17/    P6    +17
/Opening18/    P6    +18
/Opening19/    P6    +19
/Opening20/    P6    +20
/Opening21/    P6    +21
/Opening22/    P6    +22
/Opening23/    P7    +23
/Opening24/    P6    +24
/Opening25/    P6    +25
/Opening26/    P7    +26
/DrainBfl/    M16    +27    +33    -28    -29
/DrainBflHole/    H2    +29
/DrainBflInner/    H2    +28    +33
/VentBfl/    M16    +30    +33    -31    -32
/VentBflHole/    H2    +32
/VentBflInner/    H2    +31    +33
/Basket/    H2    +34    -1    -2    -3    -4    -5
-6    -7    -8    -9    -10    -11
-12    -13    -14    -15    -16    -17
-18    -19    -20    -21    -22    -23
-24    -25    -26    -27    -30
/BasketDrain/    H2    +34    +27    -33
/BasketVent/    H2    +34    +30    -33

VOLUMES    UNITY
* Basket in Cask Cavity v2.2
PART    9    NEST
ZROD    P8    0.0000    0.0000    0.0000    87.5284    360.6800        ! Basket inserted - Includes
gap to lid
ZROD    H6    0.0000    0.0000    0.0000    88.1253    360.6800        ! Inserts flood matl to
canister shell
* Canister - Structural Lid - Weld Shield v2.2
PART    10
ZROD    1    0.0000    0.0000    0.0000    88.1253    360.6800        ! Canister cavity contents
ZROD    2    0.0000    0.0000    -4.4450    89.7128    4.4450        ! Canister Bottom Plate
ZROD    3    0.0000    0.0000    360.6800    88.1253    12.7000        ! Shield Lid
ZROD    4    0.0000    0.0000    373.3800    88.1253    7.6200        ! Structural Lid
ZROD    5    0.0000    0.0000    0.0000    88.1253    381.0000        ! Canister Shell Inner
ZROD    6    0.0000    0.0000    0.0000    89.7128    381.0000        ! Canister Shell Outer
ZROD    7    0.0000    0.0000    381.0000    88.1253    3.1750        ! Weld Shield Part A
ZROD    8    0.0000    0.0000    -4.4450    89.7128    388.6200        ! Inner Detector Surface
ZONES
/Cavity/    P9    +1
/BottomPlate/    M16    +2
/ShieldLid/    P11    +3
/StructLid/    M16    +4
/WeldShield/    P13    +7
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
/Shell/    M16    +6    -5
/Canister/    M0    +8    -7    -6    -4    -2
VOLUMES    UNITY
* Shield Lid - With Ports v2.2
PART    11    CLUSTER
ZROD    P12    -60.5468    47.3043    0.0000    7.6200    12.7000        ! Vent port
ZROD    P12    60.5468    -47.3043    0.0000    7.6200    12.7000        ! Drain port
ZROD    M16    0.0000    0.0000    0.0000    88.1253    12.7000        ! Shield Lid
* Vent Port Model - With Covers v2.2
PART    12    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.3843    4.6228        ! Bottom Cylinder
ZROD    M16    0.0000    0.0000    4.6228    5.0800    6.6548        ! Middle Cyclinder
ZROD    M16    0.0000    0.0000    11.2776    7.6200    1.4224        ! Top Cylinder
ZROD    M16    0.0000    0.0000    0.0000    7.6200    12.7000        ! Shield lid material
* Weld Shield Part A Model - Structural Lid - Weld Shield v2.2
PART    13
ZCONE    1    0.0000    0.0000    0.0000    83.0453    79.8703    3.1750    ! Conical Section
ZROD    2    -60.5468    47.3043    0.0000    7.6200    3.1750        ! Vent port clearance
ZROD    3    60.5468    -47.3043    0.0000    7.6200    3.1750        ! Drain port clearance
ZROD    4    0.0000    0.0000    0.0000    88.1253    3.1750        ! Container
ZONES
/VentPort/    M0    +2    +1
/DrainPort/    M0    +3    +1
/WeldShield/    M16    +1    -2    -3
/Container/    M0    +4    -1
VOLUMES    UNITY
* Weld Shield Part B Model - Structural Lid - Weld Shield v2.2
PART    14
ZCONE    1    0.0000    0.0000    0.0000    79.8703    70.3453    9.5250    ! Conical Section
ZROD    2    -60.5468    47.3043    0.0000    7.6200    9.5250        ! Vent port clearance
ZROD    3    60.5468    -47.3043    0.0000    7.6200    9.5250        ! Drain port clearance
ZROD    4    0.0000    0.0000    0.0000    88.1253    9.5250        ! Container
ZONES
/VentPort/    M0    +2    +1
/DrainPort/    M0    +3    +1
/WeldShield/    M16    +1    -2    -3
/Container/    M0    +4    -1
VOLUMES    UNITY
* Transfer Cask Geometry with Weld Shield - v2.5.2
PART    15
ZROD    1    0.0000    0.0000    0.0000    89.7128    388.6200        ! TSC
ZROD    2    0.0000    0.0000    0.0000    90.8050    388.6200        ! Cask cavity
ZROD    3    0.0000    0.0000    0.0000    113.0300    2.5400        ! Bottom plate
ZROD    4    0.0000    0.0000    2.5400    92.7100    381.0000        ! Inner shell
ZROD    5    0.0000    0.0000    2.5400    102.8700    370.8400        ! Lead shell
ZROD    6    0.0000    0.0000    2.5400    109.8550    381.0000        ! NS-4-FR shell
ZROD    7    0.0000    0.0000    2.5400    113.0300    381.0000        ! Outer shell
ZROD    8    0.0000    0.0000    383.5400    113.0300    5.0800        ! Top plate
ZROD    9    0.0000    0.0000    388.6200    88.1253    1.9050        ! Area inside retaining ring
ZROD    10    0.0000    0.0000    388.6200    102.6160    1.9050        ! Retaining ring
ZROD    11    0.0000    0.0000    -24.1300    113.0300    24.1300        ! Shield doors and rails
YP    12    107.3150                        ! Y plane for shield door rail cutoff
YP    13    -107.3150                        ! Y plane for shield door rail cutoff
XROD    14    -123.0300    0.0000    350.5200    12.7000    246.0600        ! Trunions (extended in x)
ZROD    15    0.0000    0.0000    388.6200    88.1253    9.5250        ! Weld Shield Part B
ZROD    16    0.0000    0.0000    -24.1300    113.0300    422.2750        ! Container
ZONES
/TSC/    P10    +1                        ! TSC
/CaskCavity/    M0    +2    -1                        ! Cask cavity
/BottomPlate/    M17    +3    -2                        ! Bottom plate
/InnerShell/    M17    +4    -2    -14                        ! Inner shell
/LeadShell/    M18    +5    -4    -14                        ! Lead shell
/NS-4-FRShell/    M19    +6    -5    -4    -14                        ! NS-4-FR shell
/OuterShell/    M17    +7    -6    -14                        ! Outer shell
/TopPlate/    M17    +8    -2                        ! Top plate
/RetRingInner/    M0    +9    -15                        ! Area inside retaining ring (null)
/RetRing/    M0    +10    -9                        ! Retaining ring
/ShieldDoor/    M17    +11    +13    -12                        ! Shield doors and rails
/ShieldDoorOuter1/    M0    +11    +12                        ! Space outside of shield door
/ShieldDoorOuter2/    M0    +11    -13                        ! Space outside of shield door
/Trunions/    M17    +14    +7    -2                        ! Trunions
/WeldShield/    P14    +15                        ! Weld Shield Part B
/Container/    M0    +16    -15    -11    -3    -7    -8    ! Container
-10
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
VOLUMES UNITY
* Transfer Cask Detector Description v2.5.2
PART    16
* Top Axial Detector DTA (Surface) Bodies
ZROD    1                0.0000   0.0000   -24.1300 113.0300 422.2750
ZROD    2                0.0000   0.0000   398.1450 32.6290  1.0000
ZROD    3                0.0000   0.0000   398.1450 46.1443  1.0000
ZROD    4                0.0000   0.0000   398.1450 56.5150  1.0000
ZROD    5                0.0000   0.0000   398.1450 65.2579  1.0000
ZROD    6                0.0000   0.0000   398.1450 72.9606  1.0000
ZROD    7                0.0000   0.0000   398.1450 79.9243  1.0000
ZROD    8                0.0000   0.0000   398.1450 86.3281  1.0000
ZROD    9                0.0000   0.0000   398.1450 92.2886  1.0000
ZROD    10               0.0000   0.0000   398.1450 97.8869  1.0000
ZROD    11               0.0000   0.0000   398.1450 103.1818 1.0000
ZROD    12               0.0000   0.0000   398.1450 108.2180 1.0000
ZROD    13               0.0000   0.0000   398.1450 113.0300 1.0000
* Top Axial Detector DTAA (VentPortAzi) Bodies
ZROD    14               0.0000   0.0000   -25.1300 114.0300 424.2750
*   Band 1 Bodies
ZSEC    15               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   316.3363 327.5863
ZSEC    16               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   327.5863 338.8363
ZSEC    17               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   338.8363 350.0863
ZSEC    18               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   350.0863 361.3363
ZSEC    19               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   1.3363   12.5863
ZSEC    20               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   12.5863  23.8363
ZSEC    21               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   23.8363  35.0863
ZSEC    22               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   35.0863  46.3363
ZSEC    23               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   46.3363  57.5863
ZSEC    24               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   57.5863  68.8363
ZSEC    25               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   68.8363  80.0863
ZSEC    26               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   80.0863  91.3363
ZSEC    27               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   91.3363  102.5863
ZSEC    28               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   102.5863 113.8363
ZSEC    29               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   113.8363 125.0863
ZSEC    30               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   125.0863 136.3363
ZSEC    31               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   136.3363 147.5863
ZSEC    32               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   147.5863 158.8363
ZSEC    33               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   158.8363 170.0863
ZSEC    34               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   170.0863 181.3363
ZSEC    35               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   181.3363 192.5863
ZSEC    36               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   192.5863 203.8363
ZSEC    37               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   203.8363 215.0863
ZSEC    38               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   215.0863 226.3363
ZSEC    39               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   226.3363 237.5863
ZSEC    40               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   237.5863 248.8363
ZSEC    41               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   248.8363 260.0863
ZSEC    42               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   260.0863 271.3363
ZSEC    43               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   271.3363 282.5863
ZSEC    44               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   282.5863 293.8363
ZSEC    45               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   293.8363 305.0863
ZSEC    46               0.0000   0.0000   399.1450 69.2150  84.4550  1.0000   305.0863 316.3363
* Top Axial Detector DTAB (AnnulusAzi) Bodies
ZROD    47               0.0000   0.0000   -26.1300 115.0300 426.2750
*   Band 1 Bodies
ZSEC    48               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   0.0000   45.0000
ZSEC    49               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   45.0000  90.0000
ZSEC    50               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   90.0000  135.0000
ZSEC    51               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   135.0000 180.0000
ZSEC    52               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   180.0000 225.0000
ZSEC    53               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   225.0000 270.0000
ZSEC    54               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   270.0000 315.0000
ZSEC    55               0.0000   0.0000   400.1450 84.4550  90.8050  1.0000   315.0000 360.0000
* Top Axial Detector DTB (1ft) Bodies
ZROD    56               0.0000   0.0000   -27.1300 143.5100 455.7550
ZROD    57               0.0000   0.0000   428.6250 41.4278  1.0000
ZROD    58               0.0000   0.0000   428.6250 58.5877  1.0000
ZROD    59               0.0000   0.0000   428.6250 71.7550  1.0000
ZROD    60               0.0000   0.0000   428.6250 82.8555  1.0000
ZROD    61               0.0000   0.0000   428.6250 92.6353  1.0000
ZROD    62               0.0000   0.0000   428.6250 101.4769 1.0000
ZROD    63               0.0000   0.0000   428.6250 109.6076 1.0000
ZROD    64               0.0000   0.0000   428.6250 117.1754 1.0000
ZROD    65               0.0000   0.0000   428.6250 124.2833 1.0000
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
ZROD     66                0.0000   0.0000   428.6250 131.0061 1.0000
ZROD     67                0.0000   0.0000   428.6250 137.4004 1.0000
ZROD     68                0.0000   0.0000   428.6250 143.5100 1.0000
* Top Axial Detector DTC (1m) Bodies
ZROD     69                0.0000   0.0000   -28.1300 213.0300 526.2750
ZROD     70                0.0000   0.0000   498.1450 61.4965  1.0000
ZROD     71                0.0000   0.0000   498.1450 86.9691  1.0000
ZROD     72                0.0000   0.0000   498.1450 106.5150 1.0000
ZROD     73                0.0000   0.0000   498.1450 122.9929 1.0000
ZROD     74                0.0000   0.0000   498.1450 137.5103 1.0000
ZROD     75                0.0000   0.0000   498.1450 150.6350 1.0000
ZROD     76                0.0000   0.0000   498.1450 162.7044 1.0000
ZROD     77                0.0000   0.0000   498.1450 173.9383 1.0000
ZROD     78                0.0000   0.0000   498.1450 184.4894 1.0000
ZROD     79                0.0000   0.0000   498.1450 194.4689 1.0000
ZROD     80                0.0000   0.0000   498.1450 203.9607 1.0000
ZROD     81                0.0000   0.0000   498.1450 213.0300 1.0000
* Top Axial Detector DTD (2m) Bodies
ZROD     82                0.0000   0.0000   -29.1300 313.0300 627.2750
ZROD     83                0.0000   0.0000   598.1450 90.3640  1.0000
ZROD     84                0.0000   0.0000   598.1450 127.7940 1.0000
ZROD     85                0.0000   0.0000   598.1450 156.5150 1.0000
ZROD     86                0.0000   0.0000   598.1450 180.7280 1.0000
ZROD     87                0.0000   0.0000   598.1450 202.0600 1.0000
ZROD     88                0.0000   0.0000   598.1450 221.3456 1.0000
ZROD     89                0.0000   0.0000   598.1450 239.0806 1.0000
ZROD     90                0.0000   0.0000   598.1450 255.5879 1.0000
ZROD     91                0.0000   0.0000   598.1450 271.0919 1.0000
ZROD     92                0.0000   0.0000   598.1450 285.7560 1.0000
ZROD     93                0.0000   0.0000   598.1450 299.7034 1.0000
ZROD     94                0.0000   0.0000   598.1450 313.0300 1.0000
* Top Axial Detector DTE (4m) Bodies
ZROD     95                0.0000   0.0000   -30.1300 513.0300 828.2750
ZROD     96                0.0000   0.0000   798.1450 148.0990 1.0000
ZROD     97                0.0000   0.0000   798.1450 209.4436 1.0000
ZROD     98                0.0000   0.0000   798.1450 256.5150 1.0000
ZROD     99                0.0000   0.0000   798.1450 296.1980 1.0000
ZROD     100               0.0000   0.0000   798.1450 331.1594 1.0000
ZROD     101               0.0000   0.0000   798.1450 362.7670 1.0000
ZROD     102               0.0000   0.0000   798.1450 391.8331 1.0000
ZROD     103               0.0000   0.0000   798.1450 418.8872 1.0000
ZROD     104               0.0000   0.0000   798.1450 444.2970 1.0000
ZROD     105               0.0000   0.0000   798.1450 468.3302 1.0000
ZROD     106               0.0000   0.0000   798.1450 491.1888 1.0000
ZROD     107               0.0000   0.0000   798.1450 513.0300 1.0000
* World
ZROD     108               0.0000   0.0000   -74.1300 563.0300 922.2750
* External Void
ZROD     109               0.0000   0.0000   -124.1300         613.0300 1022.2750

ZONES
/TransferCask/   P15      +1
* Detector DTA (Surface)
/DTA01/  M0       +2
/DTA02/  M0       +3       -2
/DTA03/  M0       +4       -3
/DTA04/  M0       +5       -4
/DTA05/  M0       +6       -5
/DTA06/  M0       +7       -6
/DTA07/  M0       +8       -7
/DTA08/  M0       +9       -8
/DTA09/  M0       +10      -9
/DTA10/  M0       +11      -10
/DTA11/  M0       +12      -11
/DTA12/  M0       +13      -12
/Void/   M0       +14      -1
                  -2       -3       -4       -5       -6       -7
                  -8       -9       -10      -11      -12      -13
* Detector DTAA (VentPortAzi)
/DTAA0101/        M0       +15
/DTAA0102/        M0       +16
/DTAA0103/        M0       +17
/DTAA0104/        M0       +18
/DTAA0105/        M0       +19
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
/DTAA0106/        M0       +20
/DTAA0107/        M0       +21
/DTAA0108/        M0       +22
/DTAA0109/        M0       +23
/DTAA0110/        M0       +24
/DTAA0111/        M0       +25
/DTAA0112/        M0       +26
/DTAA0113/        M0       +27
/DTAA0114/        M0       +28
/DTAA0115/        M0       +29
/DTAA0116/        M0       +30
/DTAA0117/        M0       +31
/DTAA0118/        M0       +32
/DTAA0119/        M0       +33
/DTAA0120/        M0       +34
/DTAA0121/        M0       +35
/DTAA0122/        M0       +36
/DTAA0123/        M0       +37
/DTAA0124/        M0       +38
/DTAA0125/        M0       +39
/DTAA0126/        M0       +40
/DTAA0127/        M0       +41
/DTAA0128/        M0       +42
/DTAA0129/        M0       +43
/DTAA0130/        M0       +44
/DTAA0131/        M0       +45
/DTAA0132/        M0       +46
/Void/   M0       +47      -14
                  -15      -16      -17      -18      -19      -20
                  -21      -22      -23      -24      -25      -26
                  -27      -28      -29      -30      -31      -32
                  -33      -34      -35      -36      -37      -38
                  -39      -40      -41      -42      -43      -44
                  -45      -46
* Detector DTAB (AnnulusAzi)
/DTAB0101/        M0       +48
/DTAB0102/        M0       +49
/DTAB0103/        M0       +50
/DTAB0104/        M0       +51
/DTAB0105/        M0       +52
/DTAB0106/        M0       +53
/DTAB0107/        M0       +54
/DTAB0108/        M0       +55
/Void/   M0       +56      -47
                  -48      -49      -50      -51      -52      -53
                  -54      -55
* Detector DTB (1ft)
/DTB01/  M0       +57
/DTB02/  M0       +58      -57
/DTB03/  M0       +59      -58
/DTB04/  M0       +60      -59
/DTB05/  M0       +61      -60
/DTB06/  M0       +62      -61
/DTB07/  M0       +63      -62
/DTB08/  M0       +64      -63
/DTB09/  M0       +65      -64
/DTB10/  M0       +66      -65
/DTB11/  M0       +67      -66
/DTB12/  M0       +68      -67
/Void/   M0       +69      -56
                  -57      -58      -59      -60      -61      -62
                  -63      -64      -65      -66      -67      -68
* Detector DTC (1m)
/DTC01/  M0       +70
/DTC02/  M0       +71      -70
/DTC03/  M0       +72      -71
/DTC04/  M0       +73      -72
/DTC05/  M0       +74      -73
/DTC06/  M0       +75      -74
/DTC07/  M0       +76      -75
/DTC08/  M0       +77      -76
/DTC09/  M0       +78      -77
/DTC10/  M0       +79      -78
/DTC11/  M0       +80      -79
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
/DTC12/  M0      +81      -80
/Void/   M0      +82      -69
                 -70      -71      -72      -73      -74      -75
                 -76      -77      -78      -79      -80      -81
* Detector DTD (2m)
/DTD01/  M0      +83
/DTD02/  M0      +84      -83
/DTD03/  M0      +85      -84
/DTD04/  M0      +86      -85
/DTD05/  M0      +87      -86
/DTD06/  M0      +88      -87
/DTD07/  M0      +89      -88
/DTD08/  M0      +90      -89
/DTD09/  M0      +91      -90
/DTD10/  M0      +92      -91
/DTD11/  M0      +93      -92
/DTD12/  M0      +94      -93
/Void/   M0      +95      -82
                 -83      -84      -85      -86      -87      -88
                 -89      -90      -91      -92      -93      -94
* Detector DTE (4m)
/DTE01/  M0      +96
/DTE02/  M0      +97      -96
/DTE03/  M0      +98      -97
/DTE04/  M0      +99      -98
/DTE05/  M0      +100     -99
/DTE06/  M0      +101     -100
/DTE07/  M0      +102     -101
/DTE08/  M0      +103     -102
/DTE09/  M0      +104     -103
/DTE10/  M0      +105     -104
/DTE11/  M0      +106     -105
/DTE12/  M0      +107     -106
/Void/   M0      +108     -95
                 -96      -97      -98      -99      -100     -101
                 -102     -103     -104     -105     -106     -107
/ExtVoid/        M-2000   +109    -108
Volumes
                 1.0      12*3.3447E+03    1.0      32*2.2992E+02    1.0      8*4.3704E+02
                 1.0      12*5.3918E+03    1.0      12*1.1881E+04    1.0      12*2.5653E+04
                 1.0      12*6.8906E+04    1.0      1.0
end

*
* Unit 5 Splitting Geometry for Top Axial Detectors - Neutron
*
begin splitting geometry
r    20    fill    0.0000
n    10    87.5284
n    1    92.7100
n    2    102.8700
n    5    109.8550
n    1    113.0300
n    1    163.0300


z    31    fill    -34.1300
n    1    -24.1300
n    1    0.0000
n    1    4.4450
n    1    14.2824
n    5    168.0794
n    5    291.8764
n    5    321.8764
n    1    332.6706
n    1    335.3308
n    1    352.5774
n    1    365.1250
n    2    377.8250
n    2    385.4450
n    2    398.1450
!    n    0    398.1450
n    1    399.1450
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
n    1    799.1450

end
*
* Unit 6 - Source Geometry for Fuel Neutron
*
begin source geometry
r    10    fill    0.0000    n    10    87.5284
z    13
14.2824    21.9723    29.6621    37.3520    45.0418    52.7317
60.4215    275.7373    283.4272    291.1170    298.8069    306.4967
314.1866    321.8764
end

*
* Unit 7
*
begin energy data
neutron
thermal treatment none
importance    standard    28    groups
scoring    as    importance
simple    source    histogram    weighting    automatic
end

*
* Unit 8 Importance Map - Top Axial
*
begin importance map
calculate
targets    12
part    16
zones    2    3    4    5    6
7    8    9    10    11
12    13
strengths    1.0E+00    1.0E+00    1.0E+01    1.0E+01    1.0E+02
1.0E+02    1.0E+04    1.0E+03    1.0E+03    1.0E+03
1.0E+02    1.0E+02
defer mixing
void density    0.10
track
!    coupled source
!    write gamma importances to 32
!    write unformatted file to 31
!    use method d
end

*
* Unit 9 Scoring Data - Top Axial
*
begin scoring data
flux
part    16
from    2    to    13    ! DTA
from    15    to    46    ! DTAA
from    48    to    55    ! DTAB
from    57    to    68    ! DTB
from    70    to    81    ! DTC
from    83    to    94    ! DTD
from    96    to    107    ! DTE
responses    sos    ditto
contributions to responses        ditto
! score distribution for response
! weight distribution    total
end

*
* Unit 10 Response Data
*
begin response data
* Scale to mrem/hr
/ncrp38 - ansi ans-6.1.1-1977 neutron flux-dose conversion factors - mcnp table h.1 - mrem/
function pairs
        2.0000E+01        2.2700E-01
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
1.9299E+01      2.2502E-01
1.8623E+01      2.2307E-01
1.7970E+01      2.2112E-01
1.7341E+01      2.1920E-01
1.6733E+01      2.1729E-01
1.6147E+01      2.1540E-01
1.5581E+01      2.1353E-01
1.5035E+01      2.1167E-01
1.4508E+01      2.0983E-01
1.4000E+01      2.0800E-01
1.3537E+01      2.0090E-01
1.3089E+01      1.9405E-01
1.2656E+01      1.8743E-01
1.2237E+01      1.8104E-01
1.1832E+01      1.7486E-01
1.1441E+01      1.6889E-01
1.1062E+01      1.6313E-01
1.0696E+01      1.5757E-01
1.0342E+01      1.5219E-01
1.0000E+01      1.4700E-01
7.0000E+00      1.4700E-01
6.7684E+00      1.4788E-01
6.5444E+00      1.4876E-01
6.3279E+00      1.4964E-01
6.1185E+00      1.5054E-01
5.9161E+00      1.5143E-01
5.7203E+00      1.5234E-01
5.5311E+00      1.5324E-01
5.3481E+00      1.5416E-01
5.1711E+00      1.5508E-01
5.0000E+00      1.5600E-01
4.6652E+00      1.5258E-01
4.3528E+00      1.4924E-01
4.0613E+00      1.4597E-01
3.7893E+00      1.4277E-01
3.5355E+00      1.3964E-01
3.2988E+00      1.3658E-01
3.0779E+00      1.3359E-01
2.8717E+00      1.3066E-01
2.6794E+00      1.2780E-01
2.5000E+00      1.2500E-01
2.2811E+00      1.2568E-01
2.0814E+00      1.2637E-01
1.8991E+00      1.2706E-01
1.7329E+00      1.2775E-01
1.5811E+00      1.2845E-01
1.4427E+00      1.2915E-01
1.3164E+00      1.2986E-01
1.2011E+00      1.3057E-01
1.0960E+00      1.3128E-01
1.0000E+00      1.3200E-01
9.3303E-01      1.2740E-01
8.7055E-01      1.2296E-01
8.1225E-01      1.1868E-01
7.5786E-01      1.1455E-01
7.0711E-01      1.1056E-01
6.5975E-01      1.0671E-01
6.1557E-01      1.0299E-01
5.7435E-01      9.9404E-02
5.3589E-01      9.5942E-02
5.0000E-01      9.2600E-02
4.2567E-01      8.0093E-02
3.6239E-01      6.9276E-02
3.0852E-01      5.9919E-02
2.6265E-01      5.1826E-02
2.2361E-01      4.4827E-02
1.9037E-01      3.8772E-02
1.6207E-01      3.3536E-02
1.3797E-01      2.9006E-02
1.1746E-01      2.5089E-02
1.0000E-01      2.1700E-02
7.9433E-02      1.8112E-02
6.3096E-02      1.5117E-02
5.0119E-02      1.2617E-02
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
        3.9811E-02      1.0531E-02
        3.1623E-02      8.7893E-03
        2.5119E-02      7.3359E-03
        1.9953E-02      6.1228E-03
        1.5849E-02      5.1104E-03
        1.2589E-02      4.2653E-03
        1.0000E-02      3.5600E-03
        7.9433E-03      3.5795E-03
        6.3096E-03      3.5991E-03
        5.0119E-03      3.6189E-03
        3.9811E-03      3.6387E-03
        3.1623E-03      3.6586E-03
        2.5119E-03      3.6787E-03
        1.9953E-03      3.6988E-03
        1.5849E-03      3.7191E-03
        1.2589E-03      3.7395E-03
        1.0000E-03      3.7600E-03
        7.9433E-04      3.8000E-03
        6.3096E-04      3.8405E-03
        5.0119E-04      3.8814E-03
        3.9811E-04      3.9227E-03
        3.1623E-04      3.9644E-03
        2.5119E-04      4.0066E-03
        1.9953E-04      4.0493E-03
        1.5849E-04      4.0924E-03
        1.2589E-04      4.1360E-03
        1.0000E-04      4.1800E-03
        7.9433E-05      4.2147E-03
        6.3096E-05      4.2496E-03
        5.0119E-05      4.2849E-03
        3.9811E-05      4.3204E-03
        3.1623E-05      4.3563E-03
        2.5119E-05      4.3924E-03
        1.9953E-05      4.4289E-03
        1.5849E-05      4.4656E-03
        1.2589E-05      4.5026E-03
        1.0000E-05      4.5400E-03
        7.9433E-06      4.5319E-03
        6.3096E-06      4.5239E-03
        5.0119E-06      4.5159E-03
        3.9811E-06      4.5078E-03
        3.1623E-06      4.4998E-03
        2.5119E-06      4.4918E-03
        1.9953E-06      4.4839E-03
        1.5849E-06      4.4759E-03
        1.2589E-06      4.4679E-03
        1.0000E-06      4.4600E-03
        7.9433E-07      4.3739E-03
        6.3096E-07      4.2894E-03
        5.0119E-07      4.2066E-03
        3.9811E-07      4.1254E-03
        3.1623E-07      4.0458E-03
        2.5119E-07      3.9677E-03
        1.9953E-07      3.8910E-03
        1.5849E-07      3.8159E-03
        1.2589E-07      3.7423E-03
        1.0000E-07      3.6700E-03
        2.5000E-08      3.6700E-03
end

*
* Unit 13 Hole Data
*
begin hole data
* Canister Hole Description v2.2
* Hole    1    BORAL Core
PLATE
1    0    0
2
0.1588    12
0.0318    11
12

* Hole    2    General Basket Structure
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
PLATE
0    0    1
5
343.9414    0            ! Top of Basket
316.0522    -3            ! Top of Highest Support Disk
0.0000    -5            ! Bottom of Lowest Support Disk
-15.4686    -4            ! Bottom of Basket
-15.4686    0            ! Basket Offset
0

* Hole    3    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
86.3346
87.6046
5                ! number of axial intervals
316.0522                ! Top of diskstack
326.6694                ! Bottom of weldment
327.9394                ! Top of weldment plate
337.4537                ! Ullage
342.6714                ! Flange
343.9414                ! Void to top of basket
0    0            ! Material below weldment
14    14            ! Plate Material
0    14            ! Ullage
0    14            ! Flange
0    0            ! Void to top of basket
0                ! Outside material

* Hole    4    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ! number of radial points
87.6046
1                ! number of axial intervals
-11.6586
-10.3886                ! Coordinates inherited from PLATE Hole
14                ! Plate Material
0                ! Outside material

* Hole    5    Support disk and heat transfer disk stack
PLATE
0    0    1
4
CELL    11.6586            ! Sets up a repeating lattice of cells
11.6586    0            ! flood matl
7.0993    0            ! water gap
5.8293    15            ! aluminium disk
1.2700    0            ! water gap
13                ! steel disk

* Hole    6    Flood material model
PLATE
0    0    1
1
352.9223    0            ! Above flooded region
0                ! Flooded region

end

*
* Unit 15 Source Strength - Fuel Neutron
*
* CY 15x15 Zircaloy Clad - 43 GWD/MTU - 5 Yr - Fuel Neutron
begin source strength
component        1.6667E+00    ! Subcritical multiplication factor
component        7.0590E-06    ! numAssy/volume (26/3.6832E+06)
component    r    10*1.0
component    z
1.1317E-01    2.0243E-01    3.3771E-01    5.3331E-01    8.0568E-01    1.1735E+00
1.3837E+00    1.1735E+00    8.0568E-01    5.3331E-01    3.3771E-01    2.0243E-01
1.1317E-01
component    energy
0.0000E+00    1.6330E+04    6.8020E+04    2.2600E+05    5.1350E+05    2.0990E+06
3.2850E+06    1.0990E+07    1.8680E+07    2.5310E+07    6.0200E+07    9.7620E+07
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
2.0390E+07    8.4530E+06    2.4950E+02    0.0000E+00    0.0000E+00    0.0000E+00
0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
end

*
* Unit 16 Simple Source Weights
*
*begin source weights
*
*end

*
* Unit 31 Tabular Output
*
begin tabular output
/Top Axial Detector DTA - Surface - Response/
response   interim
number    some    1
region    from    114    to    125
output to file    also
/Top Axial Detector DTAA - VentPortAzi - Response/
response
number    some    1
region    from    127    to    158
output to file    also
/Top Axial Detector DTB - 1ft - Response/
response
number    some    1
region    from    169    to    180
output to file    also
/Top Axial Detector DTC - 1m - Response/
response
number    some    1
region    from    182    to    193
output to file    also
/Top Axial Detector DTD - 2m - Response/
response
number    some    1
region    from    195    to    206
output to file    also
/Top Axial Detector DTE - 4m - Response/
response
number    some    1
region    from    208    to    219
output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    dice
nmixtures    4
weight    mixture    1
u235    3.7023E-02
u238    8.4448E-01
o    1.1850E-01
atoms    mixture    2
h    6.6667E-01
o    3.3333E-01
weight    mixture    3
al    5.8260E-01
b10    4.5690E-02
b11    2.7769E-01
c    9.4020E-02
atoms    mixture    4
c    2.8571E-01
h    4.7619E-01
o    2.3810E-01
*
* Materials List - Dry Conditions - v2.4 - Zircaloy Clad Fuel
*
nmaterials    25
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
volume                                  ! Homogenized CY fuel
material    1
mixture    1    density    10.4120    prop    3.0394E-01    ! UO2 mixture at 4.2%
void                prop    9.0410E-03    ! Gap
zircalloy        density    6.5500    prop    9.7684E-02    ! Tube, clad
void                prop    5.8934E-01    ! Interstitial, inside tubes
volume                                  ! Fuel pin cladding
material    2
zircalloy        density    6.5500    prop    1.0000
volume                                  ! Water In Lattice and Tube
material    3
mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                                  ! Water In Fuel Rod Clad Gap
material    4
mixture    2    density    0.9982    prop    1.0000    ! mixH2O
volume                                  ! Lower End Plug material
material    5
zircalloy        density    6.5500    prop    0.4026
void                prop    0.5974
volume                                  ! Upper End Plug Material
material    6
zircalloy        density    6.5500    prop    0.4026
void                prop    0.5974
volume                                  ! Lower Nozzle Material
material    7
stainless 304l steel        density    7.9200    prop    0.1842
void                prop    0.8158
volume                                  ! Upper Nozzle Material
material    8
stainless 304l steel        density    7.9200    prop    0.1882
void                prop    0.8118
volume                                  ! Upper Plenum Material
material    9
stainless 304l steel        density    7.9200    prop    0.1305
void                prop    0.8695
*
* Materials List - Common Materials - v2.4
*
volume                                  ! Tube wall and cover sheet
material    10
stainless 304l steel        density    7.9200    prop    1.0000
volume                                  ! BORAL core
material    11
mixture    3    density    2.6226    prop    0.9850    ! mixBORAL
void                prop    0.0150
volume                                  ! BORAL alumnimum clad
material    12
aluminium                prop    1.0000
volume                                  ! Structural Disk Material
material    13
stainless 304l steel        density    7.9200    prop    1.0000
volume                                  ! Weldment Material
material    14
stainless 304l steel        density    7.9200    prop    1.0000
volume                                  ! Heat Transfer Disk Material
material    15
aluminium                prop    1.0000
volume                                  ! Canister Material
material    16
stainless 304l steel        density    7.9200    prop    1.0000
atoms                                   ! Transfer steel
material    17        density    0            !  (SCALE carbonsteel 7.8212 g/cc)
c            prop    3.9250E-03
fe            prop    8.3498E-02
volume                                  ! Lead
material    18
pb        density    11.0400    prop    1.0000
atoms                                   ! NS-4-FR
material    19        density    0            ! 0 means atom/b-cm
b10            prop    8.5500E-05
b11            prop    3.4200E-04
al            prop    7.8000E-03
h            prop    5.8500E-02
o            prop    2.6100E-02
```

Figure 5.6.2–2 MCBEND Input File for CY-MPC Transfer Cask Top Axial Analysis – Structural Lid with Weld Shield Model (Stw) – Zircaloy Clad Fuel – Fuel Neutron Source (continued)

```
c           prop    2.2600E-02
n           prop    1.3900E-03
volume                              ! Stainless Steel 304
material    20
stainless 304l steel        density    7.9200    prop    1.0000
volume                              ! Vent port middle cylinder
material    21
stainless 304l steel        density    7.9200    prop    0.5000
void                prop    0.5000
atoms                               ! SCALE Concrete
material    22        density    0            ! (density 2.2426 g/cc)
h           prop    1.3401E-02
o           prop    4.4931E-02
na           prop    1.7036E-03
al           prop    1.7018E-03
si           prop    1.6205E-02
ca           prop    1.4826E-03
fe           prop    3.3857E-04
volume                              ! Heat fins for transport cask
material    23
cu        density    8.9200    prop    0.4286
stainless 304l steel        density    7.9200    prop    0.5714
volume                              ! Balsa
material    24
mixture    4    density    0.1250    prop    1.0000
volume                              ! Redwood
material    25
mixture    4    density    0.3870    prop    1.0000
end
```

Appendix 5.A SHIELDING EVALUATION – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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5.A SHIELDING EVALUATION FOR THE MPC-LACBWR STORAGE SYSTEM

This section provides the shielding evaluation of the MPC-LACBWR storage system. The MPC-LACBWR is designed to store up to 68 Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies with up to 32 LACBWR damaged fuel cans. The analysis of the LACBWR spent fuel is performed using the SAS2H module of the SCALE package for source terms and MCNP for shielding.

The regulation governing spent fuel storage, 10 CFR 72, does not establish specific cask dose rate limits. However, 10 CFR 72.104 and 10 CFR 72.106 specify that for an array of casks in an Independent Spent Fuel Storage Installation (ISFSI), the annual dose to an individual outside the controlled area boundary must not exceed 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other organ during normal operations. In the case of a design basis accident, the dose to an individual outside the controlled area boundary must not exceed 5 rem to the whole body or any organ. The ISFSI must be at least 100 meters from the owner controlled area boundary. In addition, the occupational dose limits and radiation dose limits for individual members of the public in 10 CFR Part 20 (Subparts C and D) must be met. Chapter 10, Section 10.A.3, demonstrates MPC-LACBWR compliance with the requirements of 10 CFR 72 with regard to annual and occupational doses at the owner controlled area boundary. This appendix presents the shielding evaluations of the MPC-LACBWR storage system. Dose rate profiles are calculated as a function of distance from the side, top, and bottom of the MPC-LACBWR storage and transfer casks.

5.A.1 Shielding Discussion and Results for the MPC-LACBWR Storage System

This section provides a summary of the results of the shielding evaluation of the MPC-LACBWR system. Results are provided for the transfer cask and vertical concrete cask components.

The MPC-LACBWR storage system is comprised of a transportable storage canister, a transfer cask, and a vertical concrete storage cask. License drawings for these items are provided in Section 1.A.7. The transfer cask containing the canister and the basket is loaded under water in the spent fuel pool. Once filled with fuel, the closure lid is placed on top of the canister and the transfer cask is removed from the pool. After draining approximately 50 gallons of water from the canister, the closure lid is welded, the closure ring is inserted and welded, and the canister is drained and dried. Finally, the port covers are welded in place. The transfer cask is then used to transfer the canister to the storage cask where it is stored dry until transport. Shielding evaluations are performed for the transfer cask with both a wet and dry canister cavity as would occur during the welding of the closure lid. Shielding evaluations are performed for the storage cask with the cavity dry.

The MPC-LACBWR transfer cask has a multi-wall radial shield comprised of 0.75 inch of carbon steel, 3.5 inches of lead, 2 inches of solid borated polymer (NS-4-FR), and 1.25 inches of carbon steel. An additional 0.5 inch of stainless steel shielding is provided radially by the canister shell. Gamma shielding is provided primarily by the steel and lead layers, and neutron shielding is provided primarily by the NS-4-FR. The transfer cask bottom shield design is a solid section of 9.5 inches of low alloy steel. The top shielding is provided by the stainless steel closure lid, which is 7 inches thick. Temporary shielding may be used during welding, draining, drying, and helium backfill operations but is not credited in the shielding analysis. Temporary shielding is removed prior to storage.

The storage cask radial shield design is comprised of a 2.5-inch-thick carbon steel inner liner surrounded by a 22-inch thickness of concrete. Gamma shielding is provided by both the carbon steel and the concrete. Neutron shielding is provided primarily by the concrete. As in the transfer cask, an additional 0.5-inch thickness of stainless steel radial gamma shielding is provided by the canister shell. The storage cask top shielding design is comprised of 7 inches of stainless steel from the canister closure lid, 1.875 inches of carbon steel from the storage cask lid and 8 inches of concrete from the storage cask lid. Since the bottom of the storage cask sits on a concrete pad, the storage cask bottom shielding is comprised of the 1-inch thick stainless steel canister bottom plate, the 2-inch-thick carbon steel weldment base plate and its 0.25-inch-thick stainless steel cover, and the 1-inch thick carbon steel cask bottom plate. The base plate and bottom plate are

structural components that position the canister above the air inlets. The cask bottom plate supports the storage cask during lifting and forms the cooling air inlet channels at the cask bottom.

The MPC-LACBWR accommodates up to 68 stainless steel clad LACBWR spent fuel assemblies. LACBWR fuel assemblies were fabricated by two vendors, Allis Chalmers (AC) and Exxon Nuclear Company (ENC). The loading pattern evaluated for these fuel assemblies is illustrated in Figure 5.A.1-1. The physical parameters of the LACBWR fuel assemblies are presented in Table 5.A.2-1

The fuel inventory at LACBWR contains a significant quantity of Allis Chalmers fuel classified as damaged due to concerns on clad stability. The MPC-LACBWR basket was, therefore, designed to contain up to 32 damaged fuel cans positioned in the peripheral locations in the basket. Due to criticality constraints, the Allis Chalmers fuel will not be permitted for loading in the canister interior locations. Fuel inventory at the LACBWR site allows for the split of Exxon fuel into the canister interior locations (Slot A in Figure 5.A.1-1) and Allis Chalmers fuel into the exterior locations (Slot B in Figure 5.A.1-1). The fuel inventory division resulted in initial shielding evaluations being based on undamaged Exxon fuel in the Slot A locations, with undamaged Allis Chalmers fuel in Slot B locations. The result of this evaluation is summarized in Section 5.A.1.1.

Undamaged Allis Chalmers fuel is evaluated, as the typical Allis Chalmers fuel assembly retains its nominal shape and retains the majority of the spent fuel within the fuel rod clad. As damaged fuel may not retain its geometry during transfer and storage operations, Section 5.A.1.2 results include dose rates for reconfigured/damaged Allis Chalmers fuel in Slot B locations. To allow for the contingency of loading Exxon fuel into an exterior slot/damaged fuel can, Section 5.A.4.7 provides the justification that the relative source change and, therefore, dose effects are minor. While this discussion is limited to one Exxon fuel assembly per basket, the minor change in source is not considered significant and additional Exxon fuel assemblies may be placed into the basket periphery.

The MPC-LACBWR damaged fuel can may hold a complete fuel assembly. Since the shielding evaluation conservatively assumes that the damaged fuel cans are not present in the canister, the additional shielding provided by the wall of the can would serve to reduce external dose rates.

Shielding evaluations of the MPC-LACBWR transfer and storage casks are performed using the MCNP5, Release 1.30, Monte Carlo transport code [A1]. Fuel source terms are developed using the SCALE isotopics sequence SAS2H (Herman). Source terms include fuel neutron, fuel

gamma, fuel n-gamma, and activated hardware gamma. Dose rate evaluations include the effect of axial fuel burnup peaking on fuel neutron and gamma source terms.

The resulting dose rate profiles, along with the maximum and average radial and axial dose rates are presented for the storage cask and transfer cask analyses in Section 5.A.4.

5.A.1.1 Undamaged Fuel Dose Rates

The maximum dose rates for the storage cask with undamaged fuel are summarized in Table 5.A.1-1 and Table 5.A.1-2. The standard deviation resulting from the Monte Carlo evaluation used by MCNP (1σ) is indicated in the tables. The storage cask maximum side dose rate is 28.9 (1.3%) mrem/hr slightly below the fuel midplane elevation. The maximum storage cask top axial surface dose rate is 18.7 (6.9%) mrem/hr on the top lid surface just above the annulus between the canister and the storage cask liner. Since the storage cask is vertical during normal storage operation, the bottom is inaccessible. Therefore, no bottom axial dose rates are presented. The average dose rates at the inlets and outlets are 38.3 (1.4%) mrem/hr and 2.0 (0.5%) mrem/hr, respectively.

Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 278 mrem/hr at the impact location and 105 mrem/hr at a distance of 1 meter from the surface. There are no design basis accidents that result in a tip-over of the MPC-LACBWR storage cask.

The maximum dose rates for undamaged fuel in the transfer cask for the wet and dry canister cavity configurations encountered during canister closure operations are presented in Table 5.A.1-3 and Table 5.A.1-4, respectively.

With a wet canister cavity (no port covers), the maximum dose rates are 68.2 (2.3%) and 471.2 (1.7%) mrem/hr on the radial surface and top axial surface, respectively. The bottom surface of the cask has a maximum dose rate of 23.8 (2.2%) mrem/hr.

With a dry canister cavity (port covers installed), the maximum dose rates are 102.2 (5.2%) mrem/hr and 598.7 (1.4%) mrem/hr on the radial and top axial surfaces, respectively. The bottom surface of the cask has a maximum dose rate of 54.2 (2.2%) mrem/hr.

5.A.1.2 Damaged Fuel Dose Rates

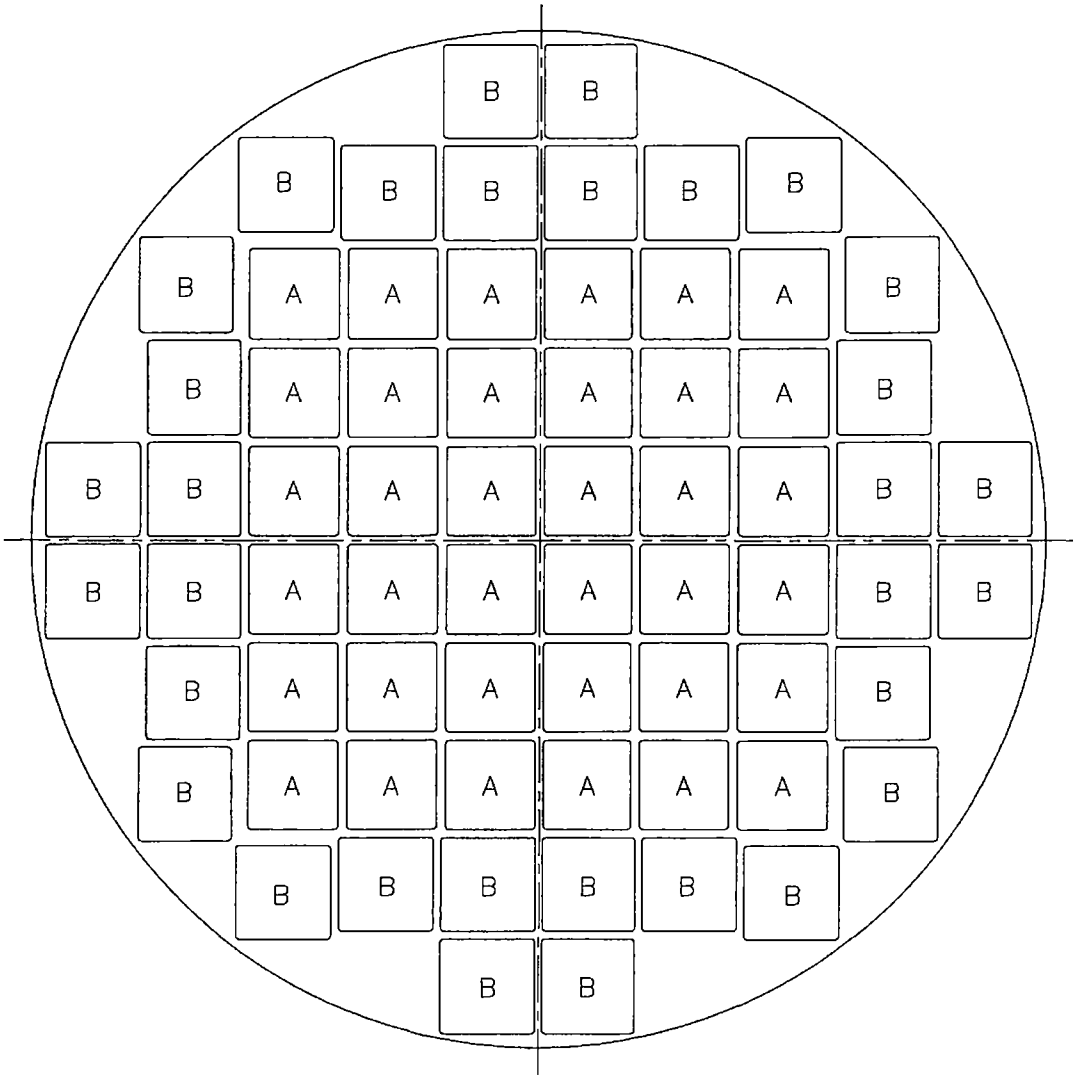
To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated for the 32 peripheral basket locations.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel rod interstitial volume with UO_2 and increasing the fuel neutron, gamma, and n-gamma source consistent with this increase in mass. A comparison of dose rate profiles for the 68 assembly intact fuel results and 36 intact and 32 damaged assemblies in Section 5.A.4 demonstrates that the damaged fuel model dose rates are less due to the increase in self-shielding from the 32 peripheral assemblies compensating for the increase in source strength.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. However, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region. In this case, storage cask inlet and transfer cask bottom surface dose rates increase due to the addition of damaged fuel. The storage cask inlet dose rate increase is 36.7 mrem/hr, effectively doubling the air inlet dose rate. The transfer cask bottom axial dose rate increase is 22.1 mrem/hr, increasing the bottom axial dose rate by approximately 41%. Note that the radial location of the maximum dose rate at the bottom of the transfer cask differs between the undamaged and damaged fuel models.

Damaged fuel maximum dose rates are summarized in Table 5.A.1-5 and Table 5.A.1-6.

Figure 5.A.1-1 MPC-LACBWR Loading Pattern



Slot A: Undamaged Exxon fuel

Slot B: Undamaged or damaged Exxon or Allis Chalmers fuel (maximum of four Exxon fuel assemblies)

Fuel Type	Max. Burnup [MWd/MTU]	Min. Initial Enrichment [wt % ^{235}U]	Min. Cool Time [years]
Allis Chalmers	22,000	3.6	28
Exxon Nuclear Company	21,000	3.6	23

Table 5.A.1-1 Summary of MPC-LACBWR Storage Cask Maximum Dose Rates – Undamaged Fuel

Location	Source	Surface		1 meter	
		mrem/hr	FSD	mrem/hr	FSD
Top Axial	Neutron	0.5	6.9%	0.1	6.8%
	Gamma	18.2	7.1%	5.5	3.6%
	Total	18.7	6.9%	5.6	3.5%
Side (Normal)	Neutron	0.2	2.0%	0.1	1.5%
	Gamma	28.7	1.3%	11.4	0.9%
	Total	28.9	1.3%	11.5	0.9%
Side (Accident)	Neutron	0.7	1.7%	0.2	1.4%
	Gamma	277.1	1.1%	104.5	0.8%
	Total	277.8	1.1%	104.7	0.8%

Table 5.A.1-2 Summary of MPC-LACBWR Storage Cask Inlet/Outlet Maximum Dose Rates – Undamaged Fuel

Source	Inlet Average		Outlet Average	
	mrem/hr	FSD	mrem/hr	FSD
Fuel Neutron	1.3	1.4%	0.1	1.2%
Fuel Gamma	6.8	6.5%	0.1	7.6%
Fuel Hardware	3.2	3.6%	0.1	2.6%
Lower End Fitting	27.0	0.9%	--	--
Upper Plenum	--	--	1.2	0.4%
Upper End Fitting	--	--	0.5	0.5%
Total	38.3	1.4%	2.0	0.5%

Table 5.A.1-3 Summary of MPC-LACBWR Transfer Cask Maximum Dose Rates – Wet (Port Covers Off) – Undamaged Fuel

Location	Source	Surface		1 meter	
		mrem/hr	FSD	mrem/hr	FSD
Top	Neutron	0.2	8.5%	0.1	6.9%
	Gamma	471.0	1.7%	205.7	2.0%
	Total	471.2	1.7%	205.8	2.0%
Side	Neutron	22.0	4.9%	4.7	3.7%
	Gamma	46.2	2.5%	16.7	1.5%
	Total	68.2	2.3%	21.4	1.4%
Bottom	Neutron	0.1	13.6%	0.1	10.4%
	Gamma	23.7	2.2%	10.0	1.5%
	Total	23.8	2.2%	10.1	1.4%

Table 5.A.1-4 Summary of MPC-LACBWR Transfer Cask Maximum Dose Rates – Dry (Port Covers On) – Undamaged Fuel

Location	Source	Surface		1 meter	
		mrem/hr	FSD	mrem/hr	FSD
Top	Neutron	7.9	3.1%	2.4	2.5%
	Gamma	590.8	1.4%	251.7	1.4%
	Total	598.7	1.4%	254.1	1.4%
Side	Neutron	19.6	3.3%	4.4	2.9%
	Gamma	82.6	6.4%	31.1	2.7%
	Total	102.2	5.2%	35.5	2.4%
Bottom	Neutron	17.6	2.0%	4.9	1.2%
	Gamma	36.6	3.1%	15.4	1.1%
	Total	54.2	2.2%	20.3	0.9%

Table 5.A.1-5 Summary of MPC-LACBWR Storage Cask Maximum Dose Rates – Damaged Fuel

Source	Inlet Average	
	mrem/hr	FSD
Undamaged Fuel	38.3	1.4%
Damaged Neutron	2.3	0.3%
Damaged Gamma	34.4	3.5%
Total	75.0	1.8%

Table 5.A.1-6 Summary of MPC-LACBWR Transfer Cask Maximum Dose Rates – Dry (Port Covers On) – Damaged Fuel

Location	Source	Surface	
		mrem/hr	FSD
Bottom	Undamaged Fuel	45.1	0.8%
	Damaged Neutron	28.5	0.4%
	Damaged Gamma	2.6	8.6%
	Total	76.2	0.6%

5.A.2 MPC-LACBWR Fuel Source Term Specification

The MPC-LACBWR system is designed to safely transfer and store LACBWR spent fuel assemblies. The spent fuel inventory consists of stainless steel clad Allis Chalmers and Exxon Nuclear Company fuel assemblies. Due to differences in source terms, these two fuel types are treated separately in the analysis. Based on the fuel inventory, limiting combinations of burnup, initial enrichment, and cool time for the two fuel types have been identified as shown:

Fuel Type	Max. Burnup [MWd/MTU]	Min. Initial Enrichment [wt % ^{235}U]	Min. Cool Time [years]
Allis Chalmers	22,000	3.6	28
Exxon Nuclear Company	21,000	3.6	23

Minimum initial enrichment produces the maximum source due to spectral hardening.

Cross-sectional sketches of the modeled LACBWR fuel assemblies are shown in Figure 5.A.2-1. The physical parameters of the LACBWR fuel assemblies are presented in Table 5.A.2-1.

The SAS2H code sequence (Herman) is used to generate source terms. This code sequence is part of the SCALE 4.3 code package for the PC (ORNL). SAS2H includes an XSDRNPM (Greene) neutronics model of the fuel assembly and ORIGEN-S (Herman) fuel depletion/source term calculations. Reactor operating conditions assumed for the analysis are shown in Table 5.A.2-2. Source terms are generated for the fuel and fuel assembly hardware. The hardware activation is calculated by light element transmutation using the incore neutron flux spectrum produced by the SAS2H neutronics model.

The 27-group library (27GROUPNDF4) is composed primarily of ENDF/B-IV cross-sections with pre-release ENDF/B-V data for a large number of fission product isotopes. The cross-section set is collapsed using an LWR spectrum. References [A7] through [A11] contain extensive SAS2H validation for PWR burnups up to 47 GWd/MTU and BWR burnups up to 57 GWd/MTU.

The LACBWR design basis fuel source terms are presented in Table 5.A.2-3 through Table 5.A.2-5. The activated hardware source term is provided on a per unit mass basis. Source strengths are defined for four source regions: active fuel, upper end fitting, upper plenum, and lower end fitting. The fuel assembly length, active fuel region length, and fuel assembly hardware lengths are shown for the design basis fuel assemblies in Figure 5.A.2-1.

5.A.2.1 MPC-LACBWR Fuel Gamma Source

The design basis fuel and hardware gamma source spectra are shown in Table 5.A.2-4 and Table 5.A.2-5. The fuel gamma source contains contributions from both fission products and actinides. The spectra are presented in a more discrete 22 group structure than the 18 group SCALE default. The hardware gamma spectra contain contributions primarily from ^{60}Co due to the activation of Type 304 stainless steel with 2 g/kg ^{59}Co impurity and with some minor contributions from ^{59}Ni and ^{58}Fe. The 2 g/kg ^{59}Co impurity represents the maximum cobalt impurity allowed per manufacturer specifications. The magnitudes of these spectra are based on the irradiation of 1 kg of stainless steel in the incore flux spectrum produced by the SAS2H neutronics calculation.

The activated fuel assembly hardware source strength for a given source region is determined as the product of the hardware source strength per unit mass (Table 5.A.2-5), the mass of the hardware (Table 5.A.2-6), and a regional flux activation ratio (Table 5.A.2-6). Table 5.A.2-6 includes the product of the hardware mass and the regional flux activation ratio, which is the "effective" hardware mass. This effective mass is used to compute the light element decay heat (output from SAS2H on a per kilogram basis), which is then added to the actinide and fission product decay heat as shown in Table 5.A.2-7.

The regional flux activation ratio accounts for the effects of both magnitude and spectrum variation on hardware activation. These ratios are based on empirical data (Luksic). A flux ratio of 0.2 is applied to the upper plenum and a flux ratio of 0.1 is applied to the upper end fitting region. A flux ratio of 0.15 is applied to the lower end fitting region.

5.A.2.2 MPC-LACBWR Fuel Neutron Source

The neutron source results from actinide spontaneous fission and from (α,n) reactions with the oxygen in UO_2. The isotopes ^{242}Cm and ^{244}Cm characteristically produce all but a few percent of the spontaneous fission neutrons and (α,n) source in light water reactor fuel. The next largest contribution is from (α,n) reactions from ^{238}Pu. The neutron spectra from spontaneous fission are based on fission spectrum measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions is based on Po-α-O source measurements. These spectra are included in the ORIGEN-S nuclear data libraries of the SCALE 4.3 code package. The spectra are automatically collapsed from the energy group structure of the data library into a 28 group structure more discrete than that of the default SCALE 22 group format.

The effect of subcritical neutron multiplication is not directly computed in the MCNP analysis conducted here, due to difficulties in adequately biasing the calculation. Instead, neutron source

rates are scaled by a subcritical multiplication factor (scale factor) based on the system multiplication factor, k_{eff}:

$$\text{Scale Factor} = \frac{1}{1 - k_{eff}}$$

For dry cask conditions, the system k_{eff} is taken as 0.4, with a resulting scale factor of 1.67. For wet conditions, the system k_{eff} is assumed to be the maximum allowable value of 0.95, resulting in a scale factor of 20. The scale factor is a direct input value in the MCNP input file (on the tally cards) to account for system thermal neutron subcritical multiplication.

5.A.2.3 MPC-LACBWR Fuel Source Axial Profile

An enveloping axial burnup shape for three-dimensional shielding and thermal evaluations is created based on measured burnup profile data for LACBWR fuel. The measured axial burnup profiles for Allis Chalmers and Exxon Nuclear Company fuel were reviewed and a bounding profile was constructed. The bounding profile produces a burnup peak of 1.36 as shown in Figure 5.A.2-2.

Neutron and gamma source profiles are computed based on an assumed relation between burnup, B, and source strength, S, in the form:

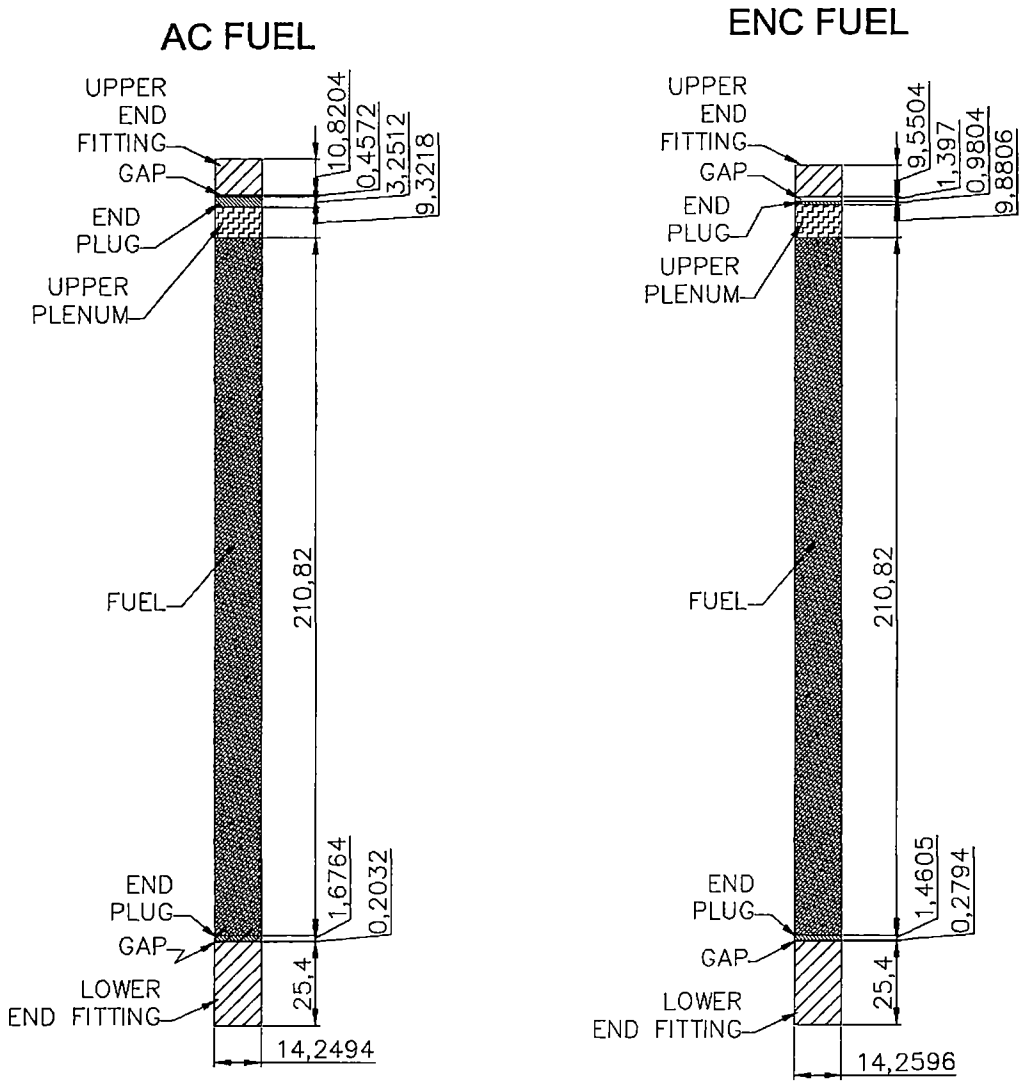
$$S = aB^b$$

Parameters a and b are determined by plotting the neutron or gamma source strength calculated by SAS2H against burnup on a log-log scale for various values of burnup. The resulting points are a line having a slope of value "b." The parameter a is a scaling factor. For neutron source strengths, which are non-linear with burnup, the value of b is determined by ORIGEN-S SASH evaluations at various burnups and is 4.22. For gamma source strengths, the value of b is 1.0, reflecting the linear relation between burnup and source rate. Table 5.A.2-8 gives the resulting source rate profiles. The relative source strength in each axial interval is shown, and these values are used directly in the MCNP source strength description. A plot of the axial source profiles is shown in Figure 5.A.2-3.

The axial source profile applied in the shielding evaluation is based on a single in-lattice (core outlet) and out-lattice (core inlet) moderator density (see Table 5.A.2-2). In order to evaluate the effect of axially varying moderator density on the design basis source terms computed in Sections 5.A.2.1 and 5.A.2.2, the design basis source terms are compared to the source terms generated using the axial power and moderator density profile for the bounding LACBWR fuel assembly (based on the assembly with the largest axial peaking factor). Table 5.A.2-9

summarizes the axial burnup and moderator density values used for this study. As shown in Table 5.A.2-10, the design basis source used in the evaluation bounds the node-specific source. Note that Table 5.A.2-10 corrects the design basis neutron source for the integral of the axial neutron source profile, which is slightly less than the 1.822 factor in Table 5.A.2-8 given the use of an actual axial profile rather than a bounding profile. Figure 5.A.2-4 through Figure 5.A.2-6 demonstrate the bounding nature of the design basis source terms in graphical format.

Figure 5.A.2-1 MPC-LACBWR Fuel Assembly Source Regions and Elevations



(Dimensions in centimeters)

Figure 5.A.2-2 MPC-LACBWR Fuel Bounding Axial Burnup Profile in Active Fuel Region

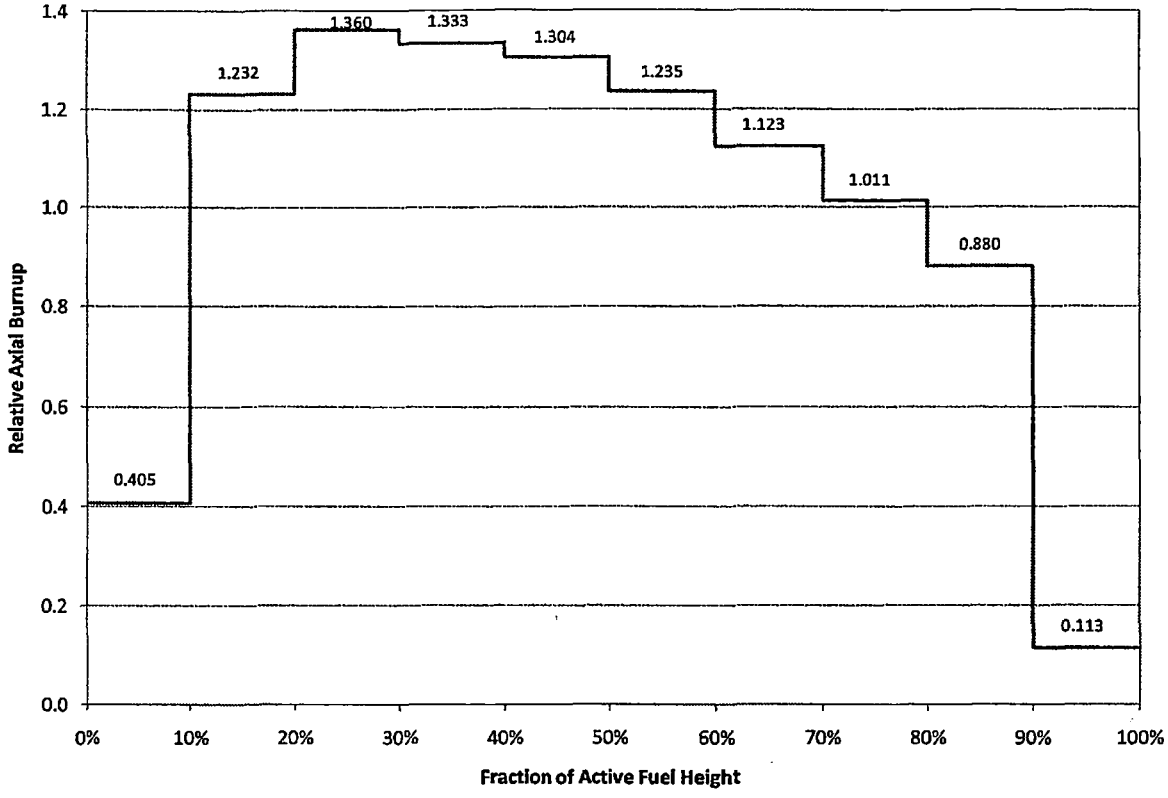


Figure 5.A.2-3 MPC-LACBWR Fuel Axial Neutron and Gamma Source Profiles in Active Fuel Region

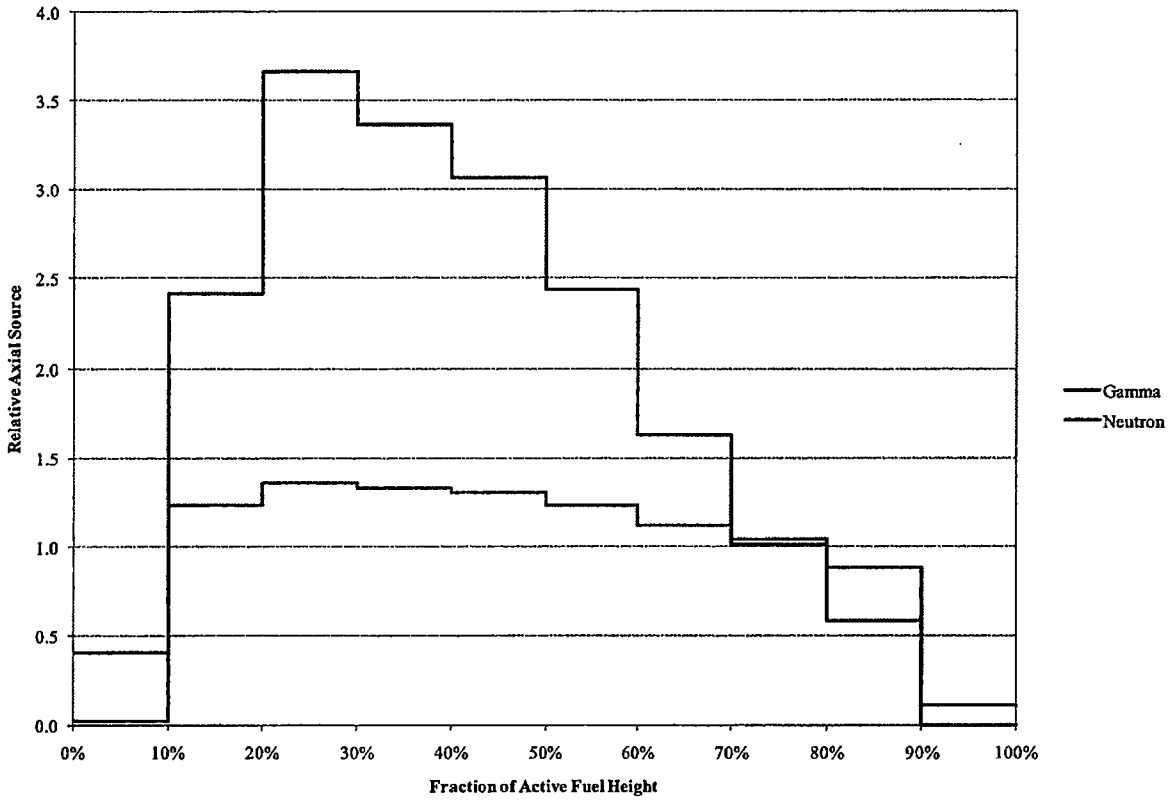


Figure 5.A.2-4 Axial Moderator Density Study Neutron Source Comparison

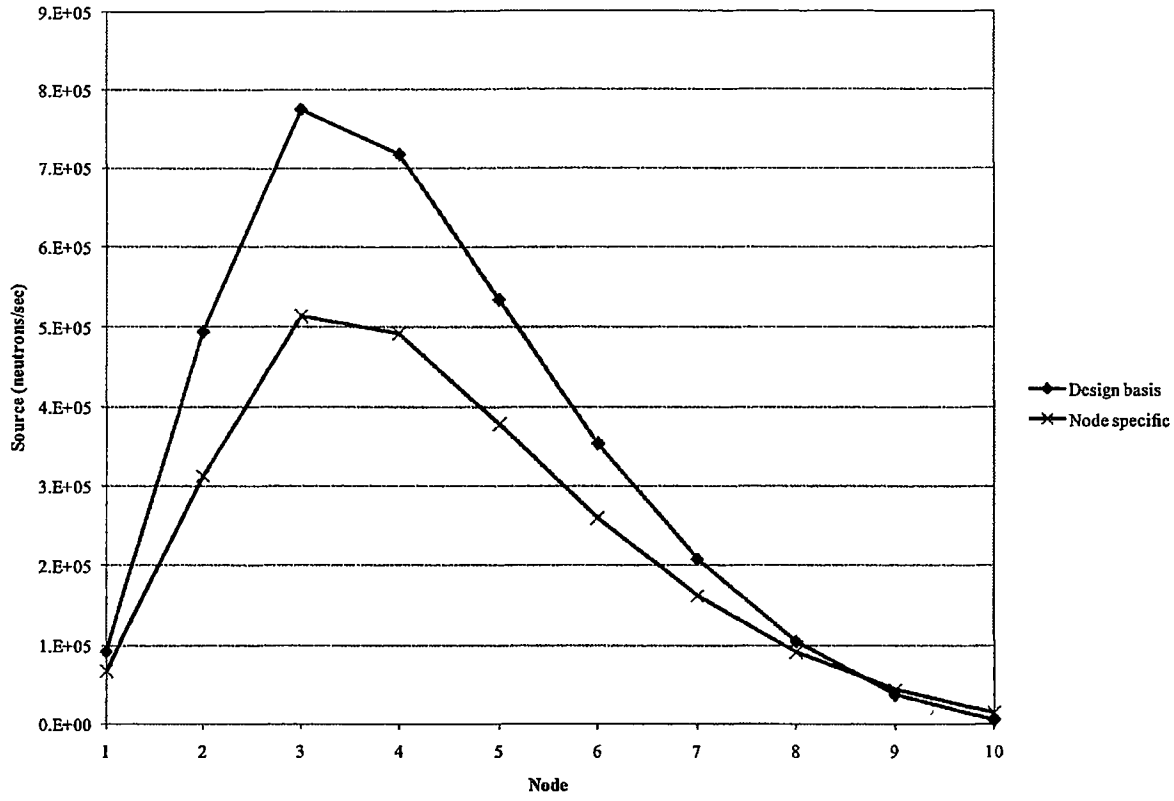


Figure 5.A.2-5 Axial Moderator Density Study Gamma Source Comparison

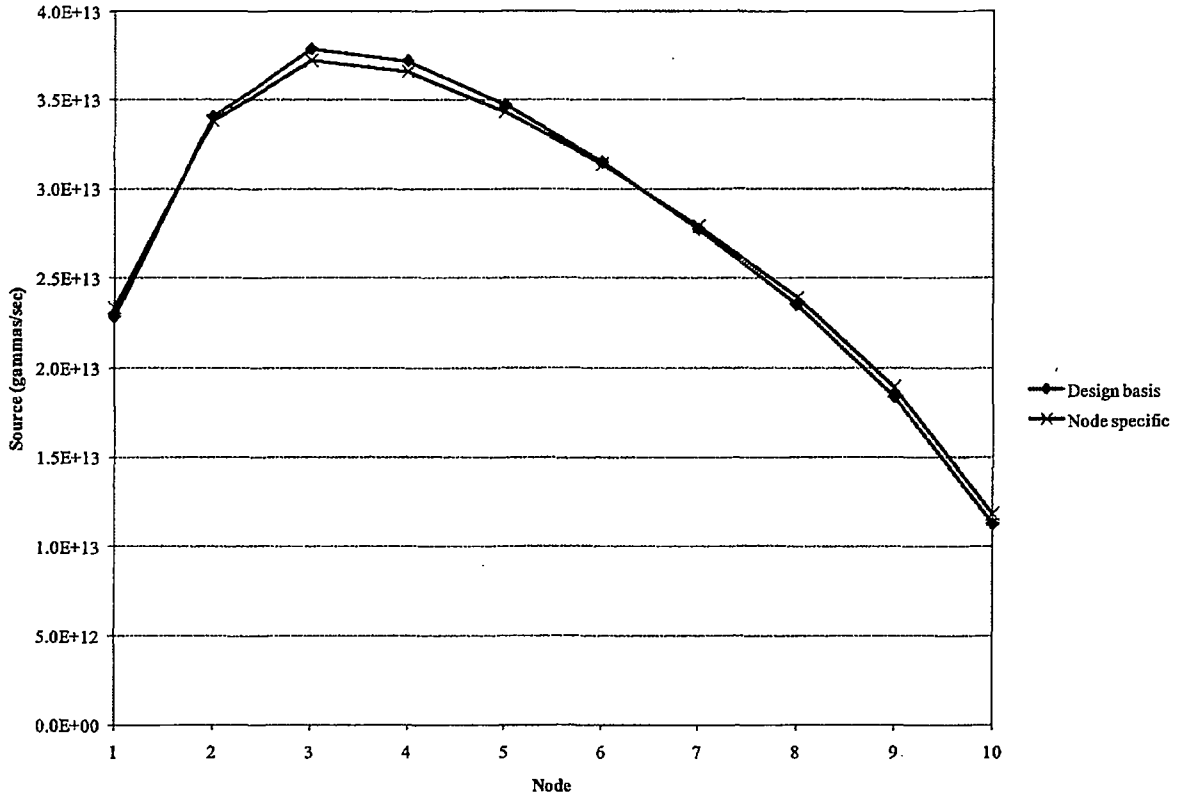


Figure 5.A.2-6 Axial Moderator Density Study Hardware Source Comparison

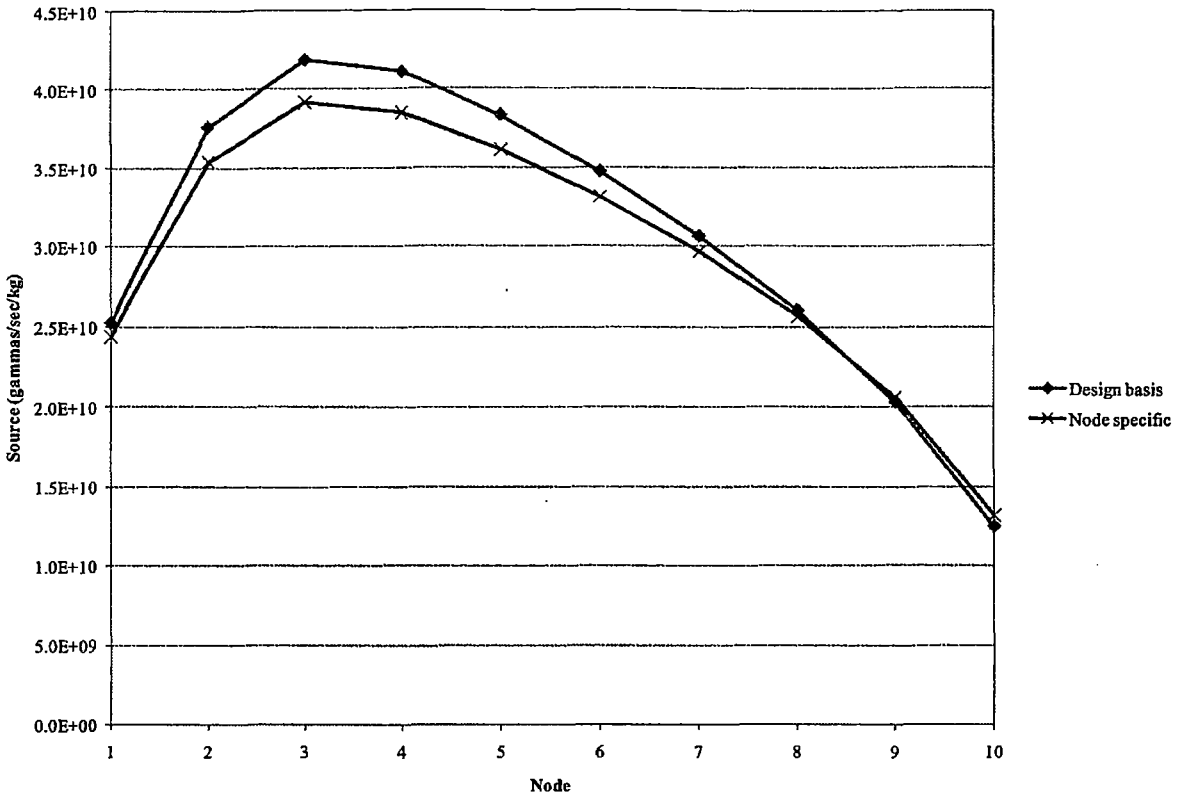


Table 5.A.2-1 MPC-LACBWR Fuel Characteristics for Shielding Evaluations

Parameter	AC Fuel	ENC Fuel
Upper End Fitting Height [cm]	10.8204	9.5504
Gap Fuel Rod to Upper End Fitting [cm]	0.4572	1.3970
Top End-Cap Height [cm]	3.2512	0.9804
Upper Plenum Region Height [cm]	9.3218	9.8806
Active Length [cm]	210.8200	210.8200
Bottom End-Cap Height [cm]	1.6764	1.4605
Gap Fuel Rod to Lower End Fitting [cm]	0.2032	0.2794
Lower End Fitting Height [cm]	25.4000	25.4000
Fuel Rod Height [cm]	223.0628	223.5962
Fuel Assembly Height [cm]	259.9436	260.2230
Fuel Assembly Width [cm]	14.2494	14.2596
Rod Diameter [cm]	1.0058	1.0008
Clad Thickness [cm]	0.0508	0.0559
Pellet Diameter [cm]	0.8890	0.8712
Pitch [cm]	1.4351	1.4148
Number of Fuel Rods	100	96
Number of Inert Rods	0	4
Fuel Loading [MTU]	0.1201	0.1107

Table 5.A.2-2 MPC-LACBWR Fuel Reactor Operating Conditions

Parameter	AC Fuel	ENC Fuel
Fuel Temperature [K]	814	814
Clad Temperature [K]	594	594
Inlet Moderator Temperature [K]	569	569
Outlet Moderator Temperature [K]	576	576
Inlet Moderator Density (0% void) [g/cm^3]	0.723	0.723
Outlet Moderator Density (40% void) [g/cm^3]	0.434	0.434
Modeled Power Level [MW/assy]	2.41	2.41
Assembly Average Fuel Burnup [MWd/MTU]	22,000	21,000
Initial Enrichment [wt % ^{235}U]	3.6	3.6
Minimum Cool Time [years]	28	23
Number of Cycles	2	2
Burnup Cycle [days]	549.03	483.05
Down Time [days]	60	60

Table 5.A.2-3 MPC-LACBWR Fuel Assembly Neutron Spectra

Group	E Lower [MeV]	E Upper [MeV]	Fuel Neutron Source [neutrons/sec/assy]	
			AC Fuel	ENC Fuel
1	1.360E+01	1.460E+01	0.000E+00	0.000E+00
2	1.250E+01	1.360E+01	1.160E+02	8.336E+01
3	1.125E+01	1.250E+01	4.835E+02	3.474E+02
4	1.000E+01	1.125E+01	1.606E+03	1.154E+03
5	8.250E+00	1.000E+01	5.038E+03	3.619E+03
6	7.000E+00	8.250E+00	1.353E+04	9.719E+03
7	6.070E+00	7.000E+00	2.335E+04	1.678E+04
8	4.720E+00	6.070E+00	7.813E+04	5.613E+04
9	3.680E+00	4.720E+00	1.466E+05	1.055E+05
10	2.870E+00	3.680E+00	2.603E+05	1.883E+05
11	1.740E+00	2.870E+00	6.263E+05	4.534E+05
12	6.400E-01	1.740E+00	7.396E+05	5.327E+05
13	3.900E-01	6.400E-01	1.762E+05	1.266E+05
14	1.100E-01	3.900E-01	6.135E+04	4.409E+04
15	6.740E-02	1.100E-01	2.485E+01	1.826E+01
16	2.480E-02	6.740E-02	0.000E+00	0.000E+00
17	9.120E-03	2.480E-02	0.000E+00	0.000E+00
18	2.950E-03	9.120E-03	0.000E+00	0.000E+00
19	9.610E-04	2.950E-03	0.000E+00	0.000E+00
20	3.540E-04	9.610E-04	0.000E+00	0.000E+00
21	1.660E-04	3.540E-04	0.000E+00	0.000E+00
22	4.810E-05	1.660E-04	0.000E+00	0.000E+00
23	1.600E-05	4.810E-05	0.000E+00	0.000E+00
24	4.000E-06	1.600E-05	0.000E+00	0.000E+00
25	1.500E-06	4.000E-06	0.000E+00	0.000E+00
26	5.500E-07	1.500E-06	0.000E+00	0.000E+00
27	7.090E-08	5.500E-07	0.000E+00	0.000E+00
28	1.000E-11	7.090E-08	0.000E+00	0.000E+00
		Total	2.133E+06	1.538E+06

Table 5.A.2-4 MPC-LACBWR Fuel Assembly Gamma Spectra

Group	E Lower [MeV]	E Upper [MeV]	Fuel Gamma Source [photons/sec/assy]	
			AC Fuel	ENC Fuel
1	1.20E+01	1.40E+01	0.0000E+00	0.0000E+00
2	1.00E+01	1.20E+01	5.2748E+01	3.7992E+01
3	8.00E+00	1.00E+01	1.0215E+03	7.3577E+02
4	6.50E+00	8.00E+00	4.8213E+03	3.4728E+03
5	5.00E+00	6.50E+00	2.4653E+04	1.7759E+04
6	4.00E+00	5.00E+00	6.1637E+04	4.4405E+04
7	3.00E+00	4.00E+00	1.8349E+05	1.3653E+05
8	2.50E+00	3.00E+00	2.8405E+07	1.9500E+07
9	2.00E+00	2.50E+00	4.2540E+08	4.3660E+08
10	1.66E+00	2.00E+00	8.4076E+09	8.6387E+09
11	1.44E+00	1.66E+00	7.5368E+10	8.4560E+10
12	1.22E+00	1.44E+00	8.2048E+11	9.4881E+11
13	1.00E+00	1.22E+00	5.0505E+11	5.6041E+11
14	8.00E-01	1.00E+00	1.0605E+12	1.2089E+12
15	6.00E-01	8.00E-01	1.3546E+14	1.3482E+14
16	4.00E-01	6.00E-01	2.3939E+12	2.5708E+12
17	3.00E-01	4.00E-01	3.2789E+12	3.3648E+12
18	2.00E-01	3.00E-01	4.7419E+12	4.8793E+12
19	1.00E-01	2.00E-01	1.5283E+13	1.5782E+13
20	5.00E-02	1.00E-01	2.4748E+13	2.4520E+13
21	2.00E-02	5.00E-02	5.1398E+13	5.2381E+13
22	1.00E-02	2.00E-02	3.9346E+13	3.9607E+13
		Total	2.7912E+14	2.8074E+14

Table 5.A.2-5 MPC-LACBWR Activated Hardware Gamma Spectra

Group	E Lower [MeV]	E Upper [MeV]	Hardware Source [photons/sec/kg]	
			AC Fuel	ENC Fuel
1	1.20E+01	1.40E+01	0.0000E+00	0.0000E+00
2	1.00E+01	1.20E+01	0.0000E+00	0.0000E+00
3	8.00E+00	1.00E+01	0.0000E+00	0.0000E+00
4	6.50E+00	8.00E+00	0.0000E+00	0.0000E+00
5	5.00E+00	6.50E+00	0.0000E+00	0.0000E+00
6	4.00E+00	5.00E+00	0.0000E+00	0.0000E+00
7	3.00E+00	4.00E+00	6.7528E-17	5.3279E-17
8	2.50E+00	3.00E+00	2.4089E+03	4.4665E+03
9	2.00E+00	2.50E+00	1.5535E+06	2.8805E+06
10	1.66E+00	2.00E+00	1.3627E-14	1.0752E-14
11	1.44E+00	1.66E+00	4.1293E-01	7.6567E-01
12	1.22E+00	1.44E+00	1.4717E+11	2.7288E+11
13	1.00E+00	1.22E+00	1.5512E+11	2.8763E+11
14	8.00E-01	1.00E+00	1.0327E+07	1.9159E+07
15	6.00E-01	8.00E-01	2.7388E+05	5.0783E+05
16	4.00E-01	6.00E-01	7.8863E+05	1.4623E+06
17	3.00E-01	4.00E-01	1.2478E+07	2.3137E+07
18	2.00E-01	3.00E-01	9.5103E+06	1.7634E+07
19	1.00E-01	2.00E-01	1.9153E+08	3.5514E+08
20	5.00E-02	1.00E-01	7.9407E+08	1.4722E+09
21	2.00E-02	5.00E-02	2.3122E+09	4.2486E+09
22	1.00E-02	2.00E-02	2.8706E+09	5.1599E+09
		Total	3.0849E+11	5.7181E+11

Table 5.A.2-6 MPC-LACBWR Fuel Assembly Activated Hardware Mass and Mass Scale Factors by Source Region

Allis Chalmers			
Source Region	**Hardware Mass [kg]**	**Flux Factor**	**Effective Mass [kg]**
Lower End Fitting	7.607	0.15	1.141
Active Fuel	25.999	1	25.999
Upper Plenum	3.588	0.2	0.718
Upper End Fitting	1.952	0.1	0.195
		Total	28.053
Exxon Nuclear Company			
Source Region	**Hardware Mass [kg]**	**Flux Factor**	**Effective Mass [kg]**
Lower End Fitting	11.372	0.15	1.706
Active Fuel	28.381	1	28.381
Upper Plenum	2.614	0.2	0.523
Upper End Fitting	1.350	0.1	0.135
		Total	30.745

Table 5.A.2-7 MPC-LACBWR Fuel Assembly Decay Heat

Source	AC Fuel	ENC Fuel
Actinides [W/assy]	1.590E+01	1.170E+01
Fission Products [W/assy]	4.530E+01	4.590E+01
Light Elements [W/kg]	6.160E-02	1.140E-01
Total [W/assy]	62.9	61.1

Table 5.A.2-8 MPC-LACBWR Axial Gamma and Neutron Source Profiles

% Core Height	Elevation [cm]	Burnup Profile	Photon Source	Neutron Source
0%	27.2796	0.000	0.000	0.000E+00
10%	48.3616	0.405	0.405	2.205E-02
20%	69.4436	1.232	1.232	2.412E+00
30%	90.5256	1.360	1.360	3.660E+00
40%	111.6076	1.333	1.333	3.363E+00
50%	132.6896	1.304	1.304	3.065E+00
60%	153.7716	1.235	1.235	2.437E+00
70%	174.8536	1.123	1.123	1.632E+00
80%	195.9356	1.011	1.011	1.047E+00
90%	217.0176	0.880	0.880	5.831E-01
100%	238.0996	0.113	0.113	1.009E-04
		Average	1.000	1.822

Table 5.A.2-9 Source Term Input for Axial Moderator Density Study

Description	Burnup [MWd/MTU]	Moderator [g/cm^3]		Cycle Length [days]
		Out-Lattice	In-Lattice	
Node 1	18,005	0.739	0.739	449.32
Node 2	26,847	0.739	0.736	669.98
Node 3	29,869	0.739	0.711	745.42
Node 4	29,324	0.739	0.679	731.80
Node 5	27,350	0.739	0.649	682.55
Node 6	24,801	0.739	0.621	618.92
Node 7	21,864	0.739	0.596	545.62
Node 8	18,559	0.739	0.573	463.16
Node 9	14,498	0.739	0.553	361.81
Node 10	8,879	0.739	0.539	221.59
Design basis	22,000	0.723	0.434	549.03

Table 5.A.2-10 Result Comparison for Axial Moderator Density Study

Description	Neutron [n/sec]	Gamma [γ/sec]	Hardware [γ/sec/kg]
Design basis (DB)	3.32E+06	2.79E+14	3.08E+11
Node-specific	2.33E+06	2.79E+14	2.96E+11
Difference, DB to node-specific	42.3%	0.0%	4.2%

5.A.3 MPC-LACBWR Model Specification

The transfer and concrete casks are evaluated using the MCNP three-dimensional Monte Carlo code. In the MCNP fuel assembly model, the fuel and hardware source regions are homogenized within a volume defined by the fuel assembly width and height. This volume is subdivided axially into active fuel, upper plenum, and upper and lower end fitting source regions. Within these axial volumes, the material masses of the fuel assembly are homogenized. In all models, the cask and TSC shield thicknesses and axial extents are explicitly represented, including streaming paths. Surface detectors are used to estimate the dose profiles at the cask surface and at distances of 1 foot, 1 meter, 2 meter, and 4 meters from the cask surface. The MCNP code employs an automated biasing technique for the Monte Carlo calculation based on weight window adjustments in mesh cells. Radial biasing is performed to estimate dose rates at the transfer cask radial surface and concrete cask radial surface, including air inlets and outlets. Axial biasing is used for cask top and bottom surface dose rates. Angular biasing components are used to capture azimuthal variations in the concrete cask air inlets and outlets.

The geometric description of an MCNP model is based on the combinatorial geometry system embedded in the code. In this system, surfaces and bodies, such as cylinders and rectangular parallelepipeds, and their logical intersections and unions, are used to describe the extent of material zones.

5.A.3.1 MPC-LACBWR Fuel Assembly Model

Based on the fuel assembly parameters provided in Table 5.A.2-1 and Table 5.A.2-6, homogenized treatments are developed for fuel assembly source regions. The homogenized fuel assembly is represented in the model as a stack of boxes with width equal to the fuel assembly width. The height of each box corresponds to the modeled height of the corresponding assembly region, as shown in Figure 5.A.2-1. The fuel model is based on the Allis Chalmers radial and axial geometry. The homogenization of nonfuel regions (upper end fitting, upper plenum, and lower end fitting) is based on the minimum hardware masses of the two designs.

The active fuel region homogenization is shown in Table 5.A.3-1. The interstitial material is a void under dry canister conditions and water (density 0.9982 g/cm^3) under wet canister conditions. The clad region is stainless steel (density 7.94 g/cm^3).

Assembly hardware regions are homogenized as shown in Table 5.A.3-2 based on the minimum regional masses from Table 5.A.2-6. The only material included in the homogenized region is stainless steel. Volume fractions of material are based on the modeled region volume and the volume of stainless steel present as computed from the modeled mass and density (7.94 g/cm^3).

The homogenized fuel region model is applied to both wet and dry cask cavity cases. To address changes in interaction of thermalized neutrons in the wet canister cases, and to demonstrate that the evaluated configuration is conservative a comparison of discretely modeled fuel rod array versus homogenized material was perfomed. For the discretely modeled array the neutron multiplication option of MCNP was activated (i.e., the NONU option was removed from the input file along with the subcritical multiplication factor applied to the source term). The results of this analysis demonstrated an 80% reduction in calculated neutron and n-gamma dose for the explicitly (discreetly) modeled fuel rod array (e.g., average neutron dose decreased from 7.8 mrem/hr in the homogenized case to 1.3 mrem/hr in the discretely modeled rod array).

5.A.3.2 MPC-LACBWR Canister and Basket Model

The MCNP description of the canister and basket elements forms a common sub-model employed in all storage and transfer cask analyses. The key features of the basket model are the detailed representation of fuel tubes, basket support and heat transfer disks, and weldment structures. The key feature of the canister model is the inclusion of the vent and drain ports in the canister shield lid.

The vent and drain ports in the canister shield lid are modeled as a series of three stacked cylinders. The port cover is also modeled, but may or may not be in place depending on the particular operational condition specified. In the axial analysis of the transfer cask, the vent and drain port covers are assumed to be installed when the canister is in a dry condition, and removed when the canister is modeled in a wet condition. Port covers are in place in all storage cask model analyses. The port cover is modeled as a solid piece of stainless steel.

The basket model conservatively omits the uppermost and lowermost support disks and models 33% less absorber sheets than specified in the License drawings.

The closure lid diameter is modeled flush with the canister inner shell diameter, not modeling the gap between the closure lid diameter and the canister shell inner diameter. However, radiation streaming through this gap is not a concern due to the following factors: a) the lid support ring will reduce streaming, b) the lid is welded to the canister shell, and c) the closure ring is welded to the canister shell and the closure lid.

The three-dimensional canister/basket model is shown in Figure 5.A.3-1.

5.A.3.3 MPC-LACBWR Transfer Cask Model

In order to estimate occupational dose rates associated with the canister sealing operation, two operational configurations of the transfer cask are considered for the three-dimensional model of

the upper cask region. These include wet canister conditions without port covers and dry canister conditions with port covers.

The top configuration of the transfer cask is evaluated in detail for the welding, draining, and drying operations. Model features include:

- Vent and drain port openings in the canister shield lid.
- Upper trunnions cut through the radial shield and extend from the inner shell to the outer shell. No credit for the radial extent of the trunnions outside the cask outer shell is taken.
- Lead and neutron shielding overlap at the top as per the transfer cask drawings.
- Termination of the radial shields at the bottom plate.
- An explicit model of the bottom door assembly.

Details of the elevations and radii used in creating the three-dimensional top model are taken directly from the drawings in Section 1.A.7. Elevations associated with the transfer cask three-dimensional features are established with respect to the center bottom of the canister bottom plate for the MCNP combinatorial geometry model. The three-dimensional transfer cask model is shown in Figure 5.A.3-2.

5.A.3.4 MPC-LACBWR Storage Cask Model

The three-dimensional model of the vertical concrete cask is based on the following features of the storage cask:

- Heat transfer annulus.
- Carbon steel weldment with cutouts for inlets and outlets.
- Concrete shield with rebar.
- Inlet and outlet models including carbon steel channel walls.
- Concrete and carbon steel top lid.
- Carbon steel bottom base plate and cover.
- Carbon steel support stand with four cutouts for air flow.
- Carbon steel storage cask bottom.
- Concrete pad below base plate.

Detailed model parameters used in creating the three-dimensional model are taken directly from the drawings in Section 1.A.7. Elevations associated with the concrete cask three-dimensional features are established with respect to the center bottom of the canister for the MCNP combinatorial model. The three-dimensional concrete cask model is shown in Figure 5.A.3-3.

A detailed sketch of the cask outlet model is shown in Figure 5.A.3-4 in terms of labeled key points in the model. Dimensions for the key points are shown in Table 5.A.3-3.

The bottom weldment model is detailed in Figure 5.A.3-5. The figure shows two sections through the bottom weldment assembly model. The portion of the figure to the left of the centerline is a section through an inlet location. The portion to the right of the centerline is a section through a non-inlet location.

5.A.3.5 MPC-LACBWR Detector Mesh Definition

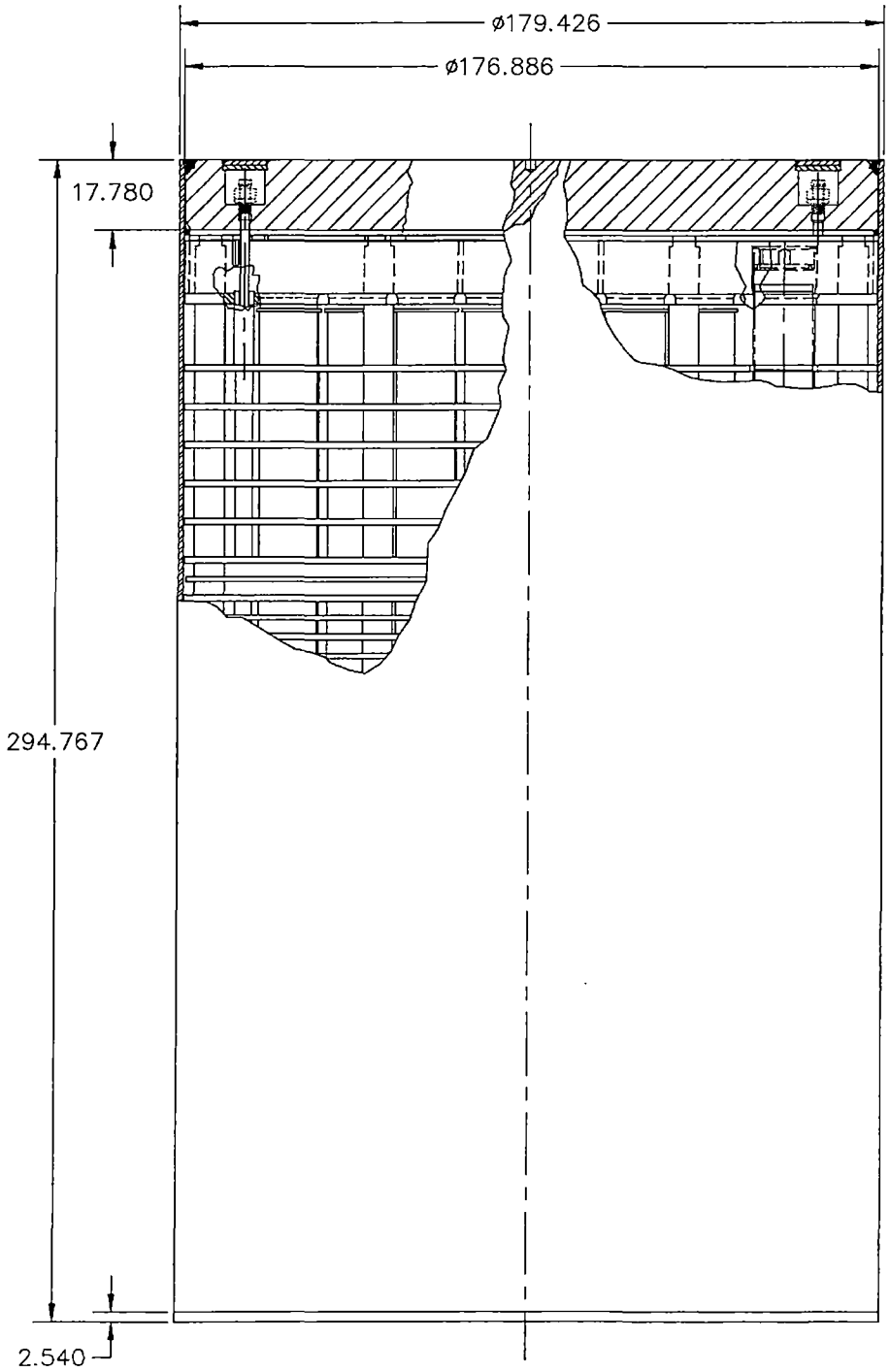
MCNP surface detectors are used to calculate dose rates at various distances from the casks. The surface tallies are subdivided using the FS tally segmentation card. A graphical illustration of the detector overlay on a cask is shown in Figure 5.A.3-6. Depicted are 1 foot, 1 meter, 2 meter, and 4 meter detector surfaces on the concrete cask. For clarity, the cask surface detector and azimuthal (angular) divisions are not shown. Typical detector grids for the transfer and concrete cask analysis are shown in Table 5.A.3-4 through Table 5.A.3-6. The dose rate maps produced by this method completely enclose the accessible cask surfaces and capture all locations necessary for the evaluation of occupational exposures.

5.A.3.6 MPC-LACBWR Shield Regional Densities

Based on the homogenization described in Section 5.A.3.1, the resulting active fuel regional densities are shown in Table 5.A.3-7. Material descriptions are shown for both wet and dry canister conditions. The upper end fitting is modeled as dry under all scenarios to simulate the partial draindown that occurs prior to welding operations.

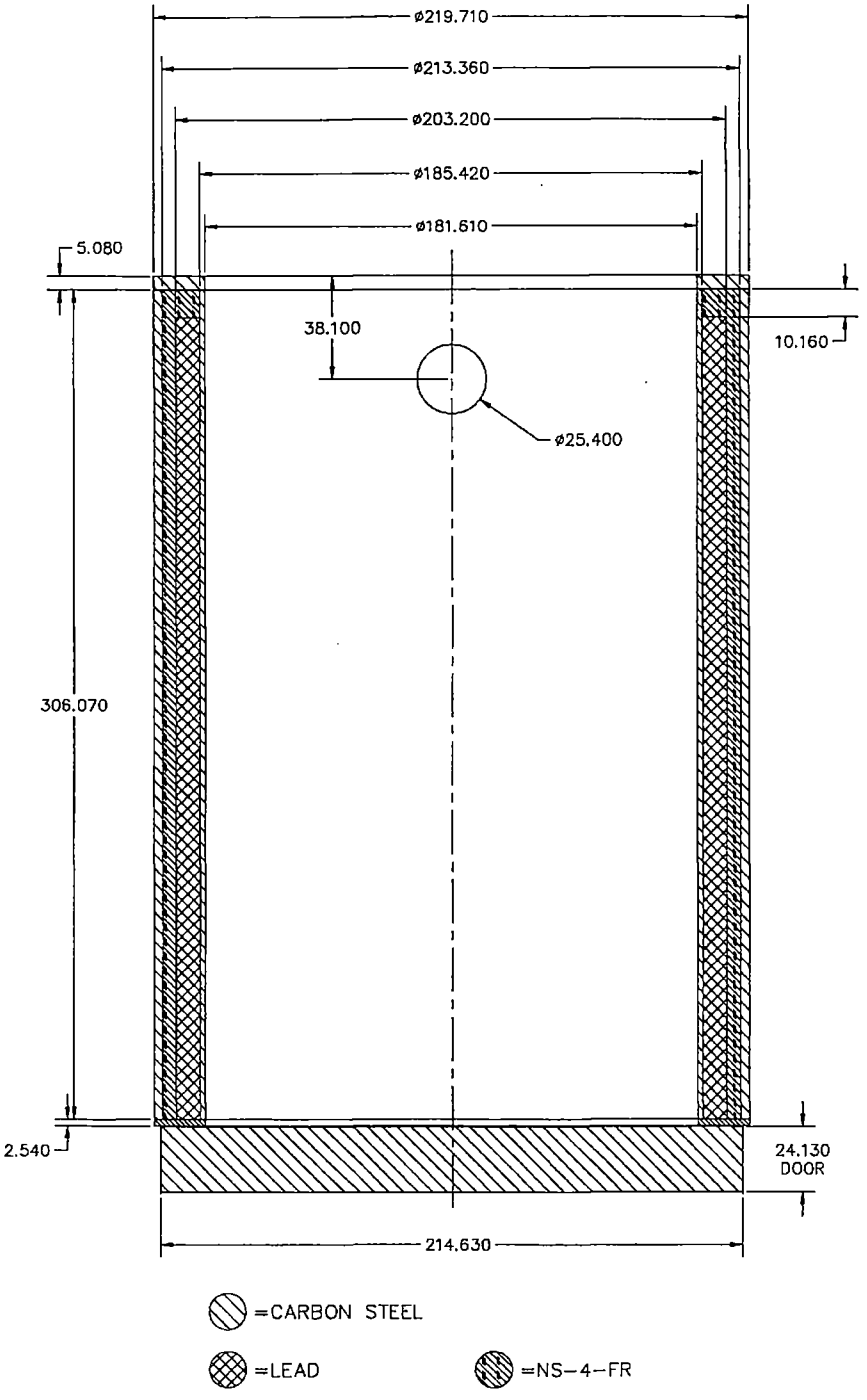
Material compositions for the remaining structural and shield materials are shown in Table 5.A.3-8.

Figure 5.A.3-1 MPC-LACBWR Three-Dimensional Canister/Basket Model Detail



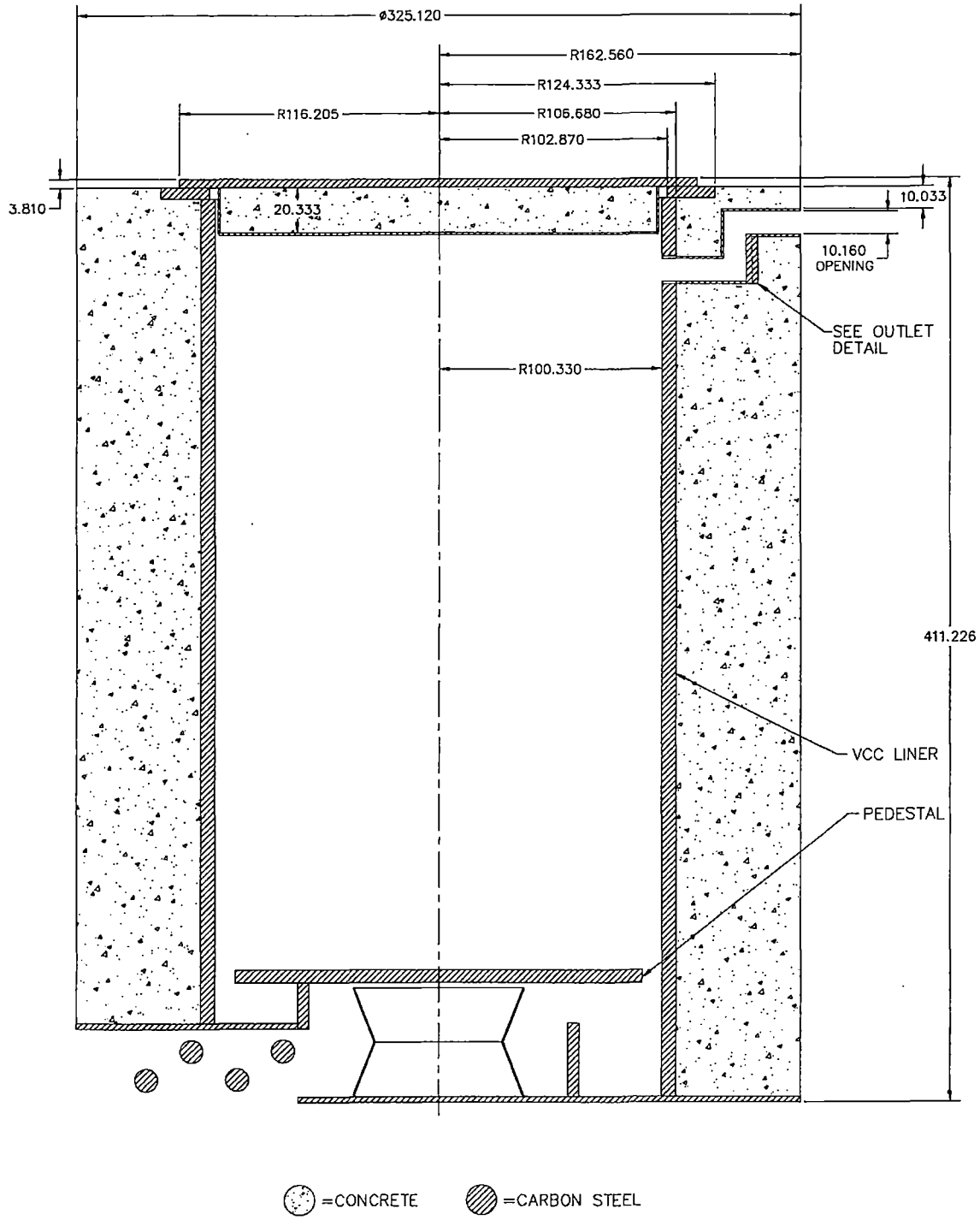
(Dimensions in centimeters)

Figure 5.A.3-2 MPC-LACBWR Three-Dimensional Transfer Cask Model



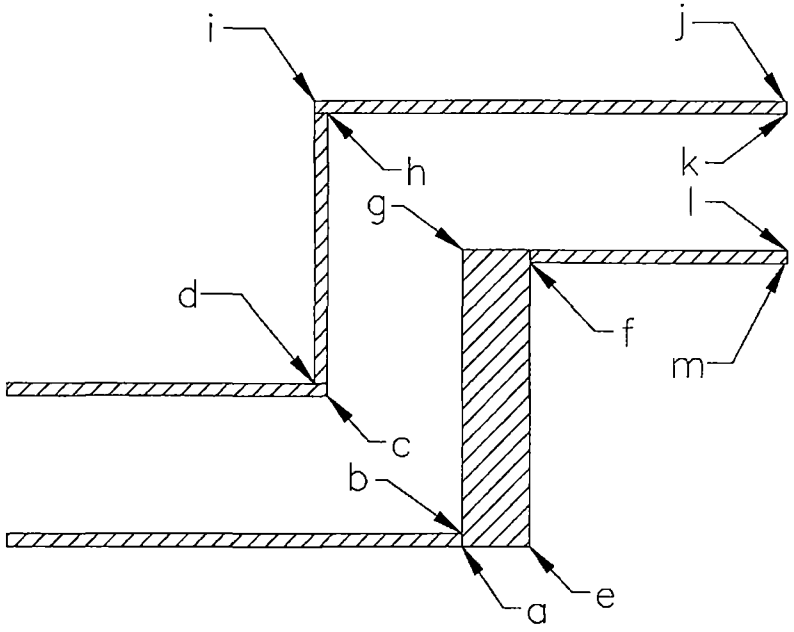
(Dimensions in centimeters)

Figure 5.A.3-3 MPC-LACBWR Three-Dimensional Concrete Cask Model



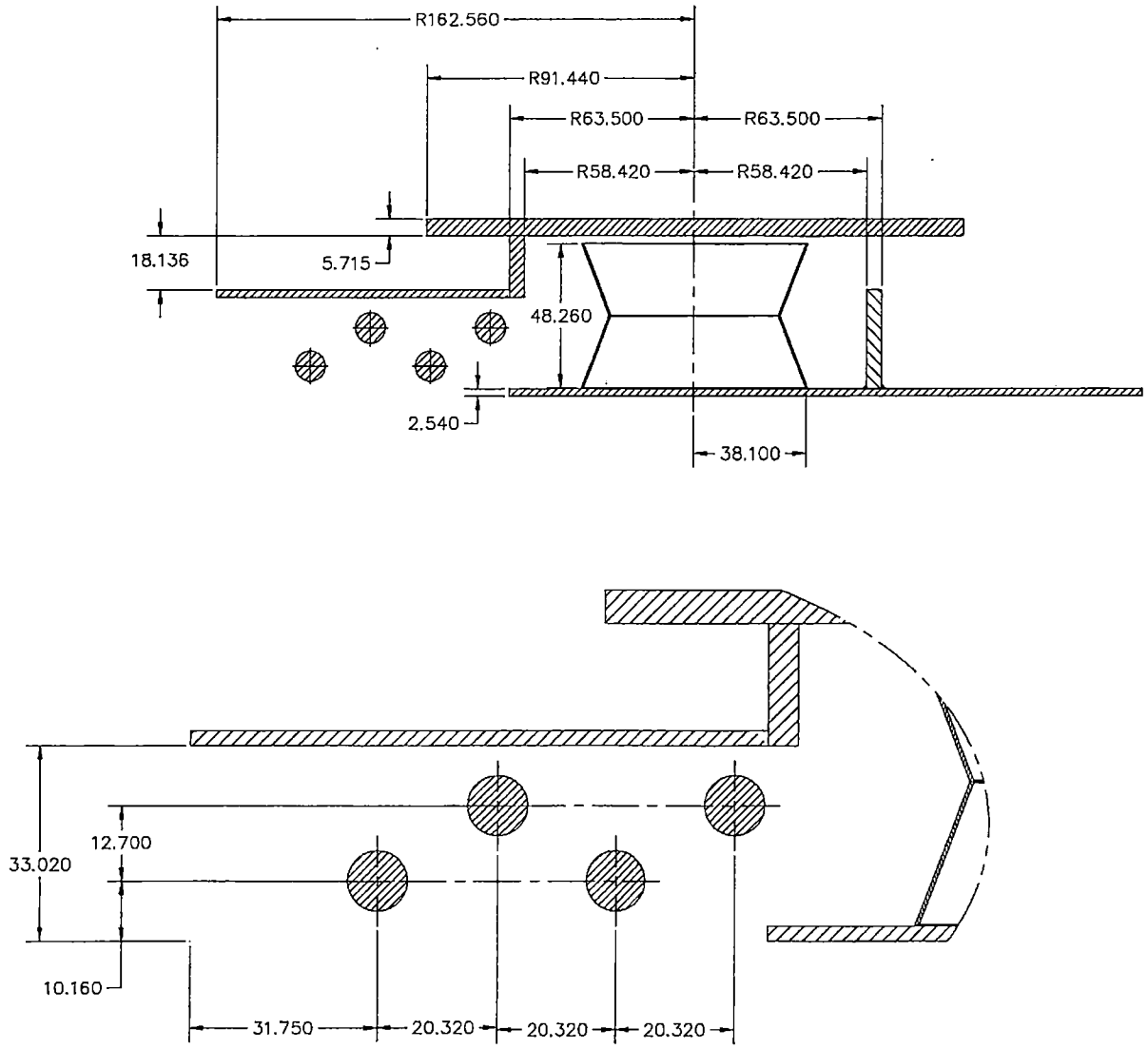
(Dimensions in centimeters)

Figure 5.A.3-4 MPC-LACBWR Three-Dimensional Storage Cask Outlet Model Detail



(See Table 5.A.3-3 for dimensions)

Figure 5.A.3-5 MPC-LACBWR Three-Dimensional Storage Cask Bottom Weldment Model Detail



(Dimensions in centimeters)

Figure 5.A.3-6 MPC-LACBWR Detector Grid Locations for Concrete Cask

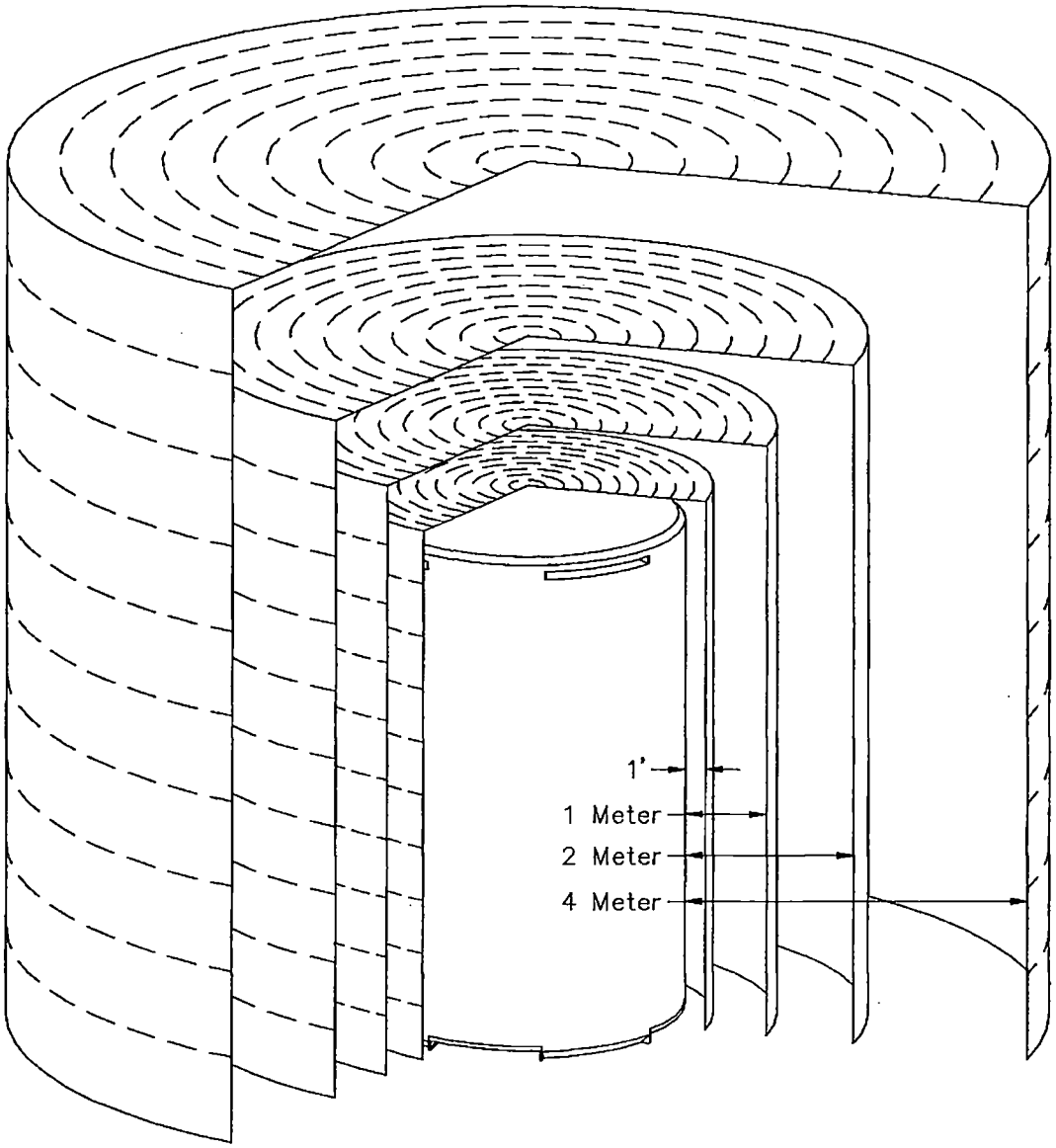


Table 5.A.3-1 MPC-LACBWR Active Fuel Region Homogenization

Component	Volume Fraction of Components			
	UO_2	Void	Clad	Interstitial
Fuel	3.0570E-01	--	--	--
Gap	--	1.0571E-02	--	--
Clad	--	--	7.5066E-02	--
Interstitial	--	--	--	6.0866E-01
Total	3.0570E-01	1.0571E-02	7.5066E-02	6.0866E-01

Table 5.A.3-2 MPC-LACBWR Fuel Assembly Hardware Region Homogenization

Region	Mass SS [kg/assy]	SS Volume [cm^3/assy]	Height [cm]	Volume [cm^3/assy]	Volume Fraction
Lower End Fitting	7.607	9.5806E+02	27.2796	5.5390E+03	1.7297E-01
Upper Plenum	2.614	3.2922E+02	13.0302	2.6457E+03	1.2443E-01
Upper End Fitting	1.350	1.7003E+02	10.8204	2.1970E+03	7.7389E-02

Table 5.A.3-3 MPC-LACBWR Storage Cask Outlet Model Parameters

Key Point[1]	Radial Dimension		Axial Dimension[2]	
	[in]	[cm]	[in]	[cm]
a	54.400	138.176	119.550	303.657
b	54.400	138.176	119.925	304.610
c	50.400	128.016	123.925	314.770
d	50.025	127.064	124.300	315.722
e	56.400	143.256	119.550	303.657
f	56.400	143.256	127.850	324.739
g	54.400	138.176	128.225	325.692
h	50.400	128.016	132.225	335.852
i	50.025	127.064	132.600	336.804
j	64.000	162.560	132.600	336.804
k	64.000	162.560	132.225	335.852
l	64.000	162.560	128.225	325.692
m	64.000	162.560	127.850	324.739

1. Refer to Figure 5.A.3-4.
2. Dimension with respect to bottom of canister bottom plate.

Table 5.A.3-4 MPC-LACBWR Typical Radial Surface Detector Division

Transfer Cask			Concrete Cask		
Location	**Axial Div**	**Azimuthal Div**	**Location**	**Axial Div**	**Azimuthal Div**
Surface	15	1	Surface	12	1
1ft	15	1	1ft	12	1
1m	20	1	1m	12	1
2m	20	1	2m	20	1
4m	20	1	4m	20	1

Table 5.A.3-5 MPC-LACBWR Typical Top Surface Detector Division

Transfer Cask			Concrete Cask		
Location	**Radial Div**	**Azimuthal Div**	**Location**	**Radial Div**	**Azimuthal Div**
Surface	12	1	Surface	10	1
1ft	12	1	1ft	10	1
1m	12	1	1m	10	1
2m	12	1	2m	10	1
4m	12	1	4m	10	1
Port Surface[1]	1	64	Air Outlet[2]	1	20

Table 5.A.3-6 MPC-LACBWR Typical Air Inlet and Outlet Detector Division

Location	**Axial Div[3]**	**Inlet Azimuthal Div**	**Outlet Azimuthal Div**
Surface	1	36	20
1ft	1	36	20

[1] Radial restricted to radial location of vent and drain ports.
[2] Radial restricted to area above air outlets.
[3] Elevation restricted to air inlet and outlet height.

Table 5.A.3-7 MPC-LACBWR Homogenized Fuel Assembly Regional Densities

Material	Nuclide/ Element	Dry Conditions		Wet Conditions	
		Density [atom/-b-cm]	Density [g/cm^3]	Density [atom/-b-cm]	Density [g/cm^3]
Lower End Fitting	Cr	3.0222E-03	1.3734	3.0222E-03	2.1989
	Mn	3.0109E-04		3.0107E-04	
	Fe	1.0293E-02		1.0292E-02	
	Ni	1.3387E-03		1.3386E-03	
	H	--		5.4810E-02	
	O	--		2.7628E-02	
Fuel	Cr	1.3116E-03	3.7790	1.3116E-03	4.3866
	Mn	1.3067E-04		1.3067E-04	
	Fe	4.4666E-03		4.4668E-03	
	Ni	5.8094E-04		5.8095E-04	
	U-235	2.5880E-04		2.5880E-04	
	U-238	6.8424E-03		6.8425E-03	
	O	1.4201E-02		3.4534E-02	
	H	--		4.0339E-02	
Upper Plenum	Cr	2.1741E-03	0.9880	2.1742E-03	1.5956
	Mn	2.1660E-04		2.1660E-04	
	Fe	7.4044E-03		7.4046E-03	
	Ni	9.6302E-04		9.6305E-04	
	H	--		4.0338E-02	
	O	--		2.0333E-02	
Upper End Fitting	Cr	1.3522E-03	0.6145	1.3522E-03	0.6145
	Mn	1.3472E-04		1.3472E-04	
	Fe	4.6052E-03		4.6052E-03	
	Ni	5.9896E-04		5.9896E-04	

Table 5.A.3-8 MPC-LACBWR Structural and Shield Material Regional Densities

Material	Nuclide/ Element	Density [atom/-b-cm]	Density [g/cm^3]
Water	H	6.6752E-02	0.9982
	O	3.3376E-02	
Stainless Steel	Cr	1.7472E-02	7.9400
	Mn	1.7407E-03	
	Fe	5.9505E-02	
	Ni	7.7392E-03	
Carbon Steel	Fe	8.3494E-02	7.8212
	C	3.9250E-03	
Neutron Poison	Al	5.0464E-02	2.6707
	B-10	3.4695E-03	
	B-11	1.4389E-02	
	C	4.4631E-03	
Aluminum	Al	6.0262E-02	2.7000
Lead	Pb	3.2967E-02	11.344
NS-4-FR	B-10	9.1384E-05	1.6316
	Al	7.8002E-03	
	C	2.2621E-02	
	B-11	3.3665E-04	
	H	5.8507E-02	
	N	1.3904E-03	
	O	2.6107E-02	
Concrete	Fe	3.5073E-04	2.3233
	Ca	1.5360E-03	
	Si	1.6788E-02	
	H	1.3882E-02	
	O	4.6535E-02	
	Na	1.7649E-03	
	Al	1.7630E-03	

5.A.4 MPC-LACBWR Storage System Shielding Evaluation

Shielding calculations are performed for the transfer cask and storage cask designs using the source terms from the two design basis fuel types described in Section 5.A.2: Allis Chalmers fuel at 22,000 MWd/MTU and 28 years cool time and Exxon Nuclear Company fuel at 21,000 MWd/MTU and 23 years cool time. The Allis Chalmers fuel source is modeled in the 32 peripheral basket locations and the Exxon Nuclear Company source is modeled in the 36 interior basket locations. The resulting dose rate profiles are reported as a function of distance from the radial and axial surfaces of the MPC-LACBWR storage cask and transfer cask.

5.A.4.1 MPC-LACBWR Calculational Methods

The shielding evaluations of the transfer and concrete cask are performed with MCNP5 [A1]. Source terms include fuel neutron, fuel gamma, and gamma contributions from activated hardware. As described in Section 5.A.2.3, these evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

The MCNP shielding models described in Section 5.A.3 are used with the source terms described in Section 5.A.2 to estimate the dose rate profiles at the cask surface and at distances of 1 foot, 1 meter, 2 meters, and 4 meters. The method of solution is continuous energy Monte Carlo, with a Monte Carlo based weight window generator to accelerate code convergence. Pointwise, continuous energy, neutron libraries generated from ENDF/B-V and VI data [A1] and the MCPLIB04 photoatomic [A1] libraries are employed in the MCNP shielding analysis. Default libraries for each material are obtained from the MCNP XSDIR file and are isotope/element dependent (e.g., the latest ^{10}B data released with the code version used in the analysis is ENDF/B-VI Release 6, 5010.66c, while the ^{238}U data is obtained from ENDF/B-VI Release 9, 92238.69c). Radial or axial biasing is performed, depending on the desired dose location. Azimuthal components are included in the weight window mesh to account for the angular variations in the bulk shielding properties of the concrete cask at the inlets and outlets and at the TSC lid ports (transfer evaluation only).

Significant validation literature is available for MCNP, as it is an industry standard tool for spent fuel cask evaluations. Available literature covers a range of shielding penetration problems ranging from slab geometry to spent fuel cask geometries [A2-A6]. Confirmatory calculations against other validated shielding codes [SCALE (ORNL) and MCBEND (Serco Assurance)] on NAC casks have further validated the use of MCNP for shielding evaluations.

5.A.4.2 MCNP Flux-to-Dose Rate Conversion Factors

The ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors are used in all cask shielding evaluations. Neutron and gamma dose conversion factors are listed in Table 5.A.4-1 and Table 5.A.4-2, respectively.

5.A.4.3 MPC-LACBWR Storage Cask Three-Dimensional Dose Rates

5.A.4.3.1 Undamaged Fuel

Storage cask three-dimensional model side dose rates are presented in Figure 5.A.4-1. The figure shows the dose rate profiles at various radial distances from the cask surface. Figure 5.A.4-2 shows the contributions to the radial surface dose rate from each source component. Figure 5.A.4-3 shows the corresponding top axial dose rate profile at various axial distances from the cask surface and Figure 5.A.4-4 gives the contributions to the top axial surface dose rate from each source type. The azimuthal dose profile at the air inlet elevation is shown in Figure 5.A.4-5. Similarly, the azimuthal dose rate profile at the cask air outlets is shown in Figure 5.A.4-6.

The maximum radial and top axial surface dose rates for the storage cask are 28.9 (1.3%) and 18.7 (6.9%) mrem/hr, respectively. At the inlet locations, the average dose rate of the four symmetric inlet openings is 38.3 (1.4%) mrem/hr. At the outlets, the average dose rate at the four symmetric outlet locations is 2.0 (0.5%) mrem/hr.

Under accident conditions involving a projectile impact and a loss of 6 inches of concrete, the surface dose rate increases to 278 mrem/hr at the impact location and 105 mrem/hr at a distance of 1 meter from the surface.

5.A.4.3.2 Damaged Fuel

To ensure that the worst case configuration is considered, two damaged fuel scenarios are evaluated for the 32 peripheral basket locations.

The first scenario assumes the damaged fuel collects over the active fuel length of the fuel assembly. This scenario is modeled by filling the fuel rod interstitial volume with UO_2 and increasing the fuel neutron, gamma, and n-gamma source consistent with this increase in mass. A comparison of dose rate profiles for the 68 assembly intact fuel results and 36 intact and 32 damaged assemblies, shown in Figure 5.A.4-7 and Figure 5.A.4-8, demonstrates that the damaged fuel model dose rates are less due to the increase in self-shielding from the 32 peripheral assemblies compensating for the increase in source strength.

In the second scenario, damaged fuel is assumed to migrate from the active fuel into the lower end fitting region of the fuel assembly, filling all the modeled void space. In this case, the combined gamma and neutron sources result in a maximum radial dose rate of 4.3 mrem/hr at the bottom of the cask (average increase of 1.0 mrem/hr), shown in Figure 5.A.4-9. The inlet dose rate increase, as shown in Figure 5.A.4-10, is 36.7 mrem/hr, effectively doubling the air inlet dose rate. However, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region.

5.A.4.4 MPC-LACBWR Transfer Cask Three-Dimensional Dose Rates

The MPC-LACBWR transfer cask is analyzed under wet and dry conditions corresponding with the operational configurations associated with loading the canister with spent fuel assemblies in a fuel pool environment. Under wet conditions, the canister is assumed to be filled with water to the top of the upper plenum region. This distance accounts for the removal of water from the canister prior to welding the closure lid to the canister in order to prevent water contamination of the closure lid weld.

Transfer cask dose rates are calculated for two lid configurations. The first configuration consists of the closure lid without port covers with the canister in the wet condition. The second configuration consists of the closure lid with the canister in the dry condition and port covers are installed.

5.A.4.4.1 Undamaged Fuel

For a wet canister cavity and no port covers, dose rate profiles are shown in Figure 5.A.4-11 through Figure 5.A.4-16. The maximum dose rates are 68.2 (2.3%) and 471.2 (1.7%) mrem/hr on the radial surface and top axial surface, respectively. The bottom surface of the cask has a maximum dose rate of 23.8 (2.2%) mrem/hr.

For a dry canister cavity and installed port covers, dose rate profiles are shown in Figure 5.A.4-17 through Figure 5.A.4-22. The maximum dose rates are 102.2 (5.2%) mrem/hr and 598.7 (1.4%) mrem/hr on the radial and top axial surfaces, respectively. The bottom surface of the cask has a maximum dose rate of 54.2 (2.2%) mrem/hr.

5.A.4.4.2 Damaged Fuel

The same damaged fuel scenarios were analyzed for the transfer cask under dry conditions as those described for the storage cask. Like the storage cask (scenario 1), a comparison of dose rate profiles for the 68 assembly intact fuel results and 36 intact and 32 damaged assemblies, shown

in Figure 5.A.4-23 through Figure 5.A.4-25, demonstrates that the damaged fuel model dose rates are less due to the increase in self-shielding from the 32 peripheral assemblies compensating for the increase in source strength. In the second scenario (damaged fuel in the lower end fitting region), the combined gamma and neutron sources result in a maximum radial dose rate of 23.4 mrem/hr at the bottom of the cask (average increase of 3.7 mrem/hr), shown in Figure 5.A.4-26. The bottom axial dose rate increase is 22.1 mrem/hr, shown in Figure 5.A.4-27, increasing the bottom axial dose rate by approximately 41%. As stated previously, no credit is taken for the reduction in lower end fitting hardware dose rate due to the added UO_2 mass and self-shielding nor for the reduction in fuel mass migrated from the active fuel region.

5.A.4.5 Partial Flooding Evaluation

To confirm that the analyzed dry and wet canister conditions bound a partial flooding scenario, additional MCNP inputs were setup to model a canister filled up to 70% of the active fuel region. The results in Figure 5.A.4-28 and Figure 5.A.4-29 demonstrate that the dry canister configuration produces bounding transfer cask dose rates.

5.A.4.6 Validation of Fresh Fuel Material Composition

The validity of the dose rate results summarized herein is based on the ability to apply fresh fuel material composition based MCNP results to spent fuel. To confirm the accuracy of this assumption, radial dose rates are calculated using the SAS2H-calculated isotopic composition of the design basis Allis Chalmers fuel assembly (22,000 MWd/MTU, 3.6 wt % ^{235}U, and 28 years cool time) in the transfer and storage casks and compared to the fresh fuel results. Radial dose rate profiles for fresh and spent fuel isotopics are shown in Figure 5.A.4-30 and Figure 5.A.4-31 and demonstrate the acceptability of the fresh fuel assumption (i.e., there is no significant dose change associated with the fresh fuel model).

5.A.4.7 Justification of Exxon Fuel in DFCs

In the event that an Exxon Nuclear Company fuel assembly is found to be damaged, the assembly may be loaded in a DFC location rather than a standard location. A bounding scenario, under which a basket is loaded with 31 Allis Chalmers assemblies and 37 Exxon Nuclear Company assemblies (36 undamaged and 1 damaged), the change in 68-assembly source is as follows.

Source	31/37 vs. 32/36 Change
Fuel Neutron	-0.5%
Fuel N-Gamma	-0.5%
Fuel Gamma	0.0%
Fuel Hardware	1.0%
Lower End Fitting	1.3%
Upper Plenum	0.4%
Upper End Fitting	0.4%

While a slight azimuthal increase in gamma dose rate may be present at the radial location of the DFC under this scenario, there is no significant change in cask average dose rates when loading Exxon fuel assemblies into DFCs.

Figure 5.A.4-1 MPC-LACBWR Storage Cask Radial Dose Rate Profiles – Undamaged Fuel

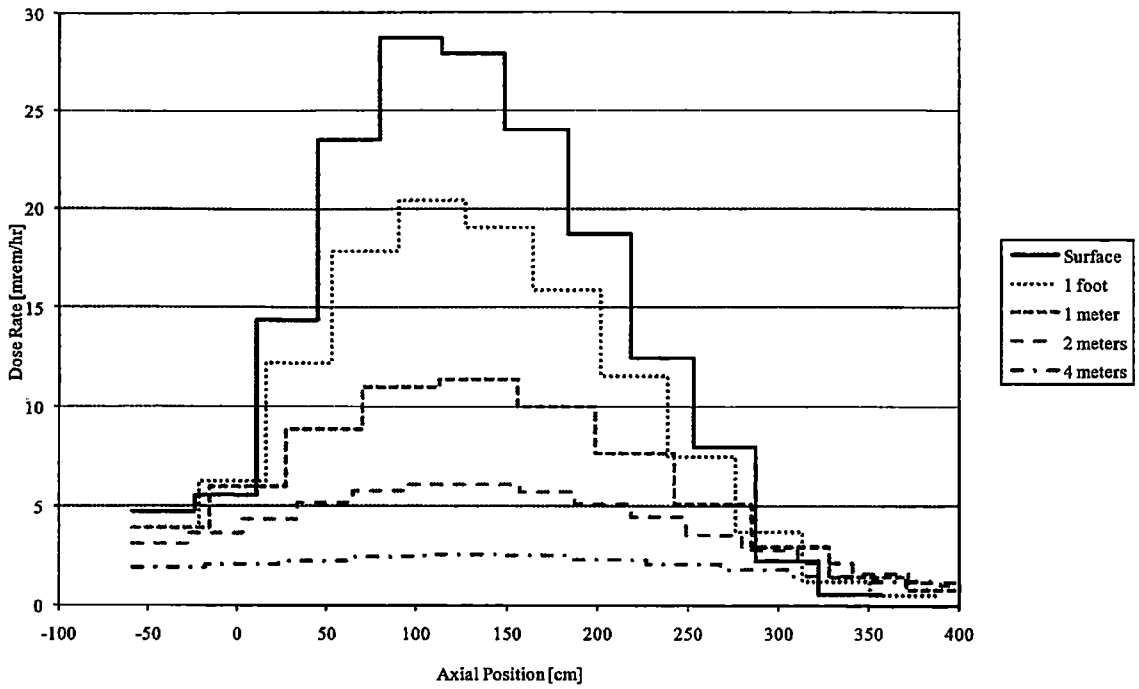


Figure 5.A.4-2 MPC-LACBWR Storage Cask Radial Surface Dose Rate Profile by Source Type – Undamaged Fuel

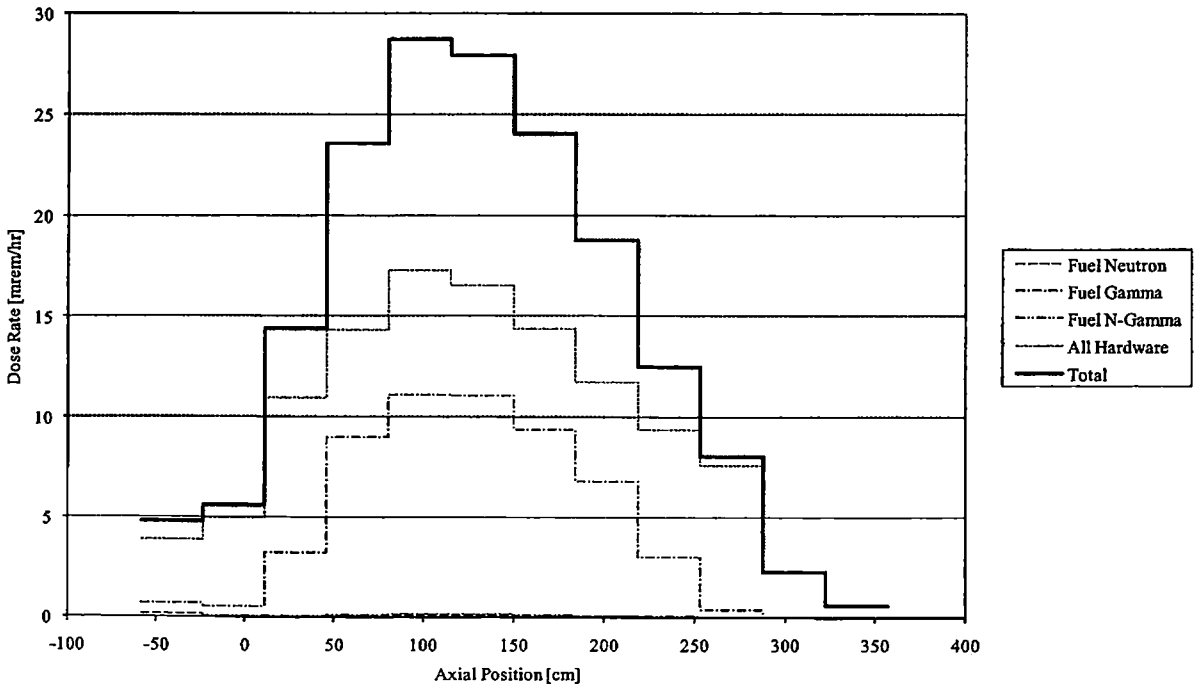


Figure 5.A.4-3 MPC-LACBWR Storage Cask Top Axial Dose Rate Profiles – Undamaged Fuel

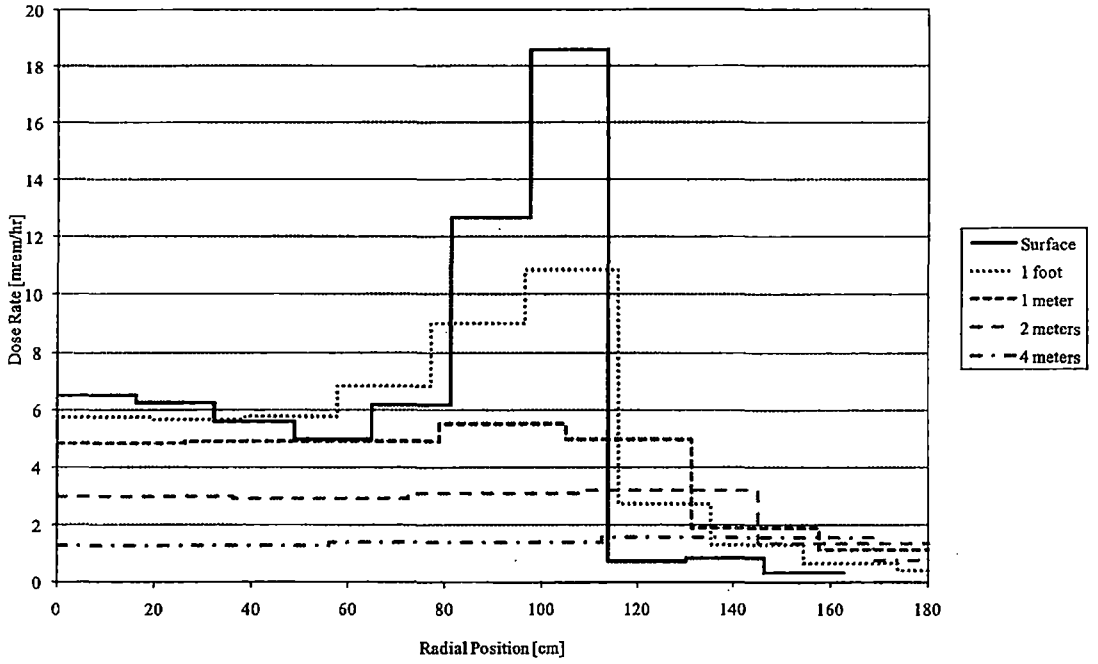


Figure 5.A.4-4 MPC-LACBWR Storage Cask Top Axial Surface Dose Rate Profile by Source Type – Undamaged Fuel

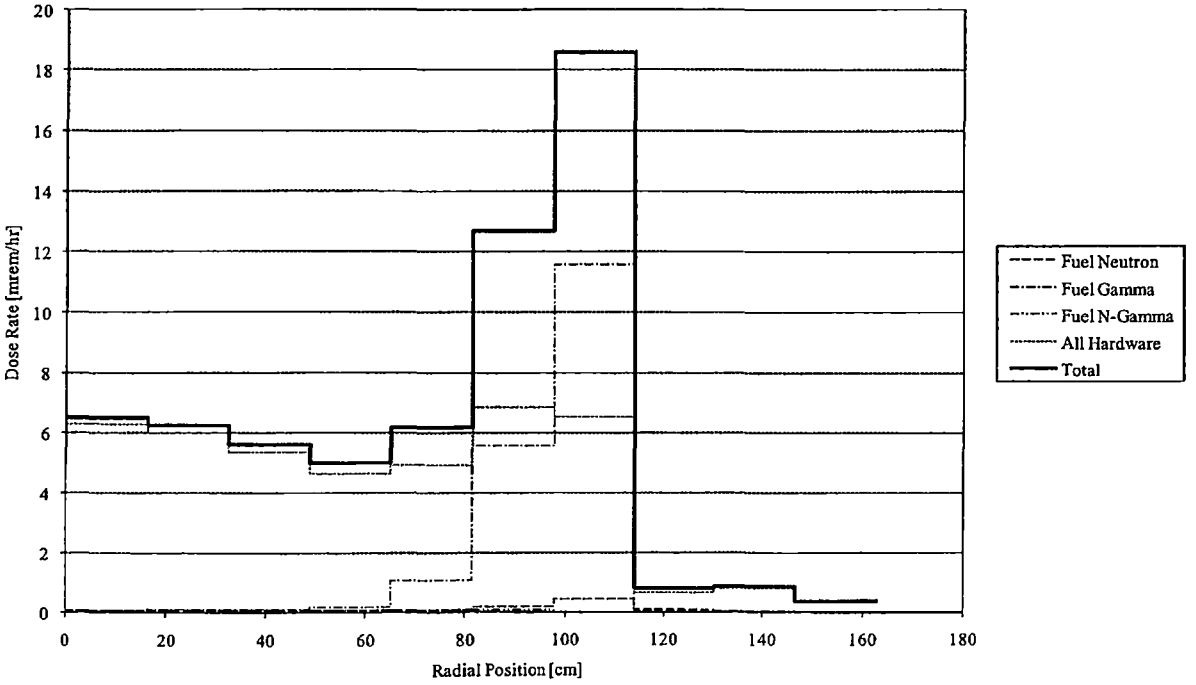


Figure 5.A.4-5 MPC-LACBWR Storage Cask Azimuthal Dose Rate Profile at Air Inlet Elevation – Undamaged Fuel

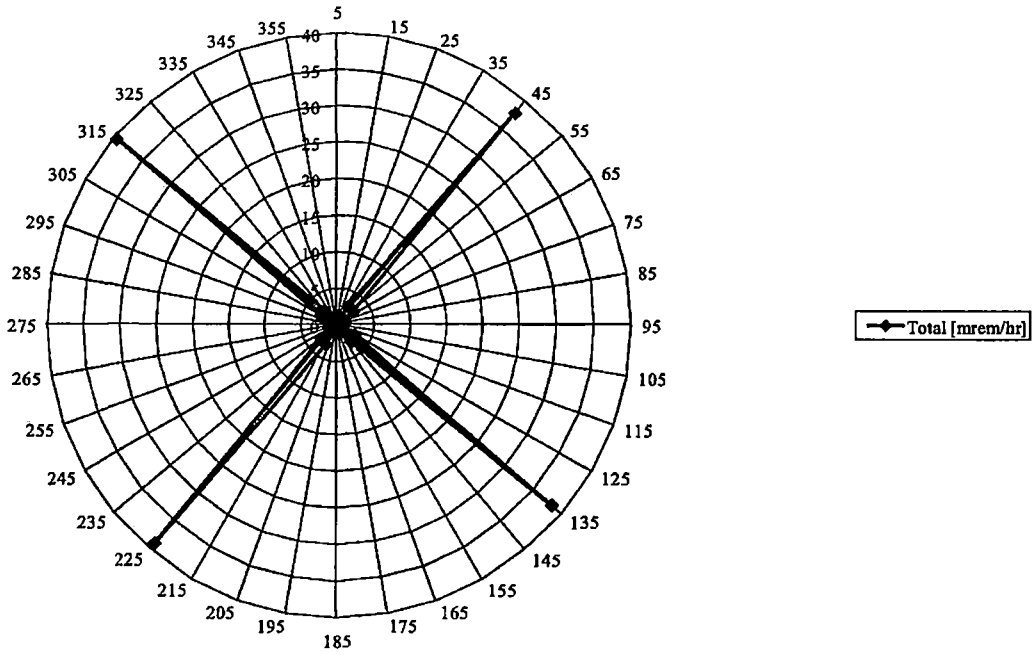


Figure 5.A.4-6 MPC-LACBWR Storage Cask Azimuthal Dose Rate Profile at Air Outlet Elevation – Undamaged Fuel

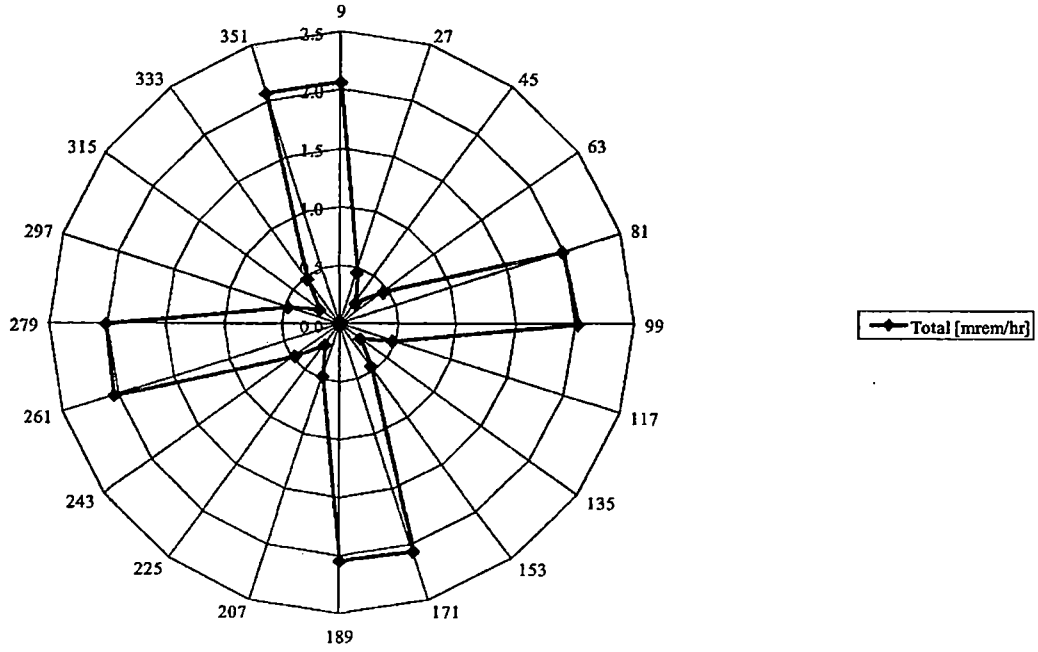


Figure 5.A.4-7 Dose Rate Profile Comparison at Radial Surface of Storage Cask – Active Fuel Damaged Fuel

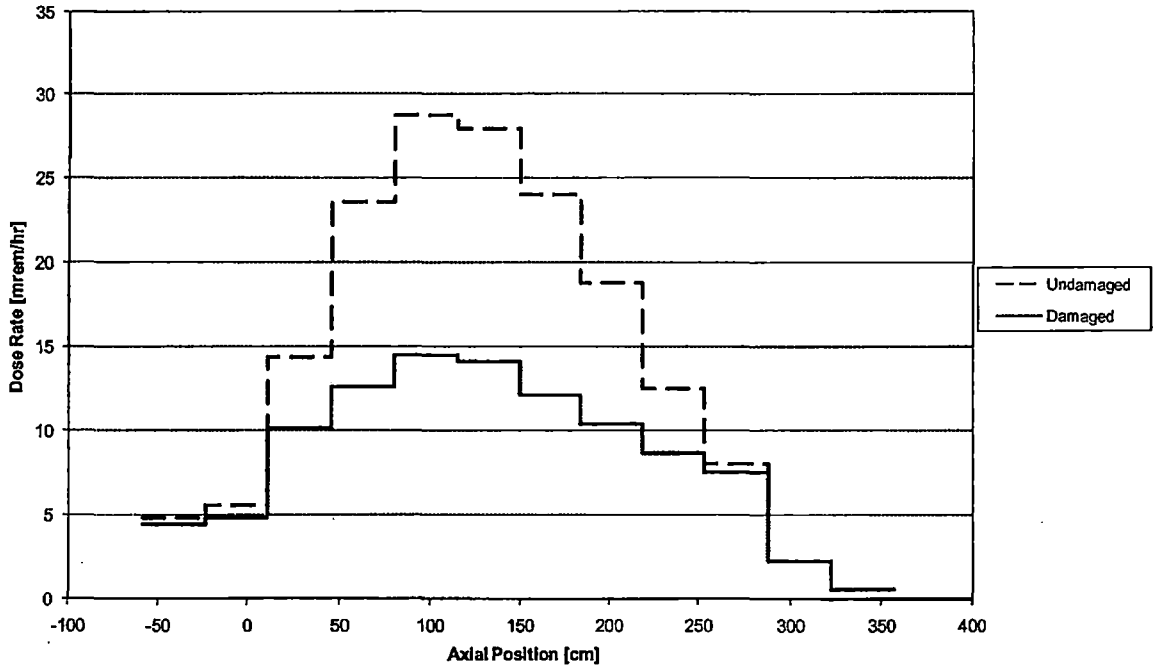


Figure 5.A.4-8 Dose Rate Profile Comparison at Top Axial Surface of Storage Cask – Active Fuel Damaged Fuel

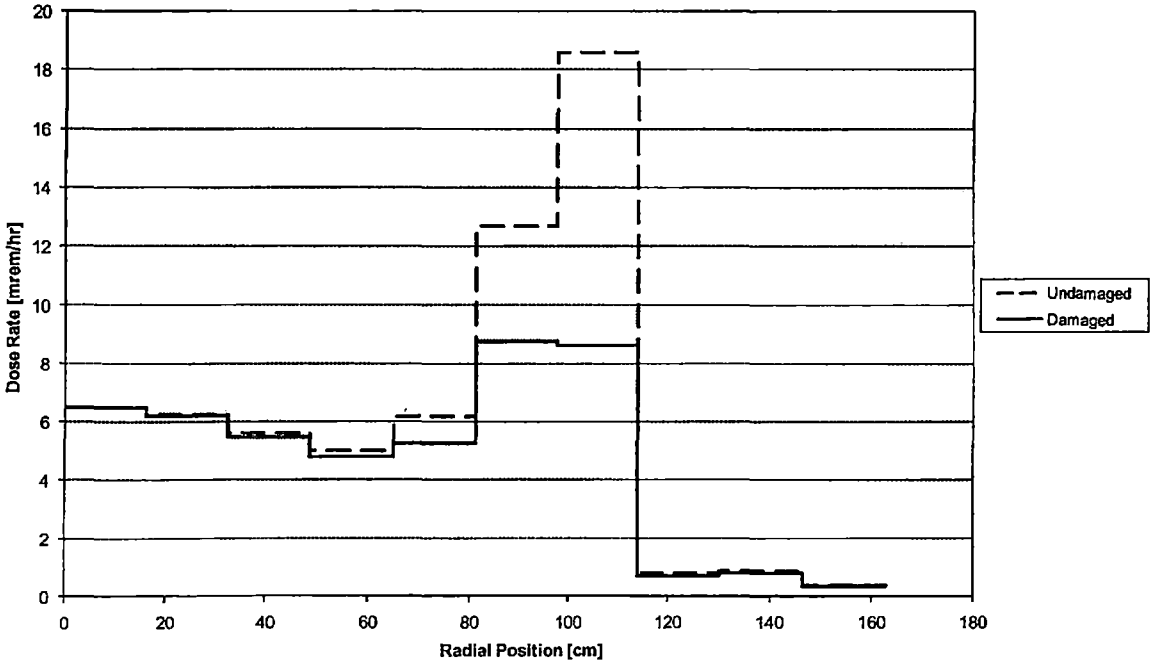


Figure 5.A.4-9 Dose Rate Profile at Radial Surface of Storage Cask – Lower End Fitting Damaged Fuel

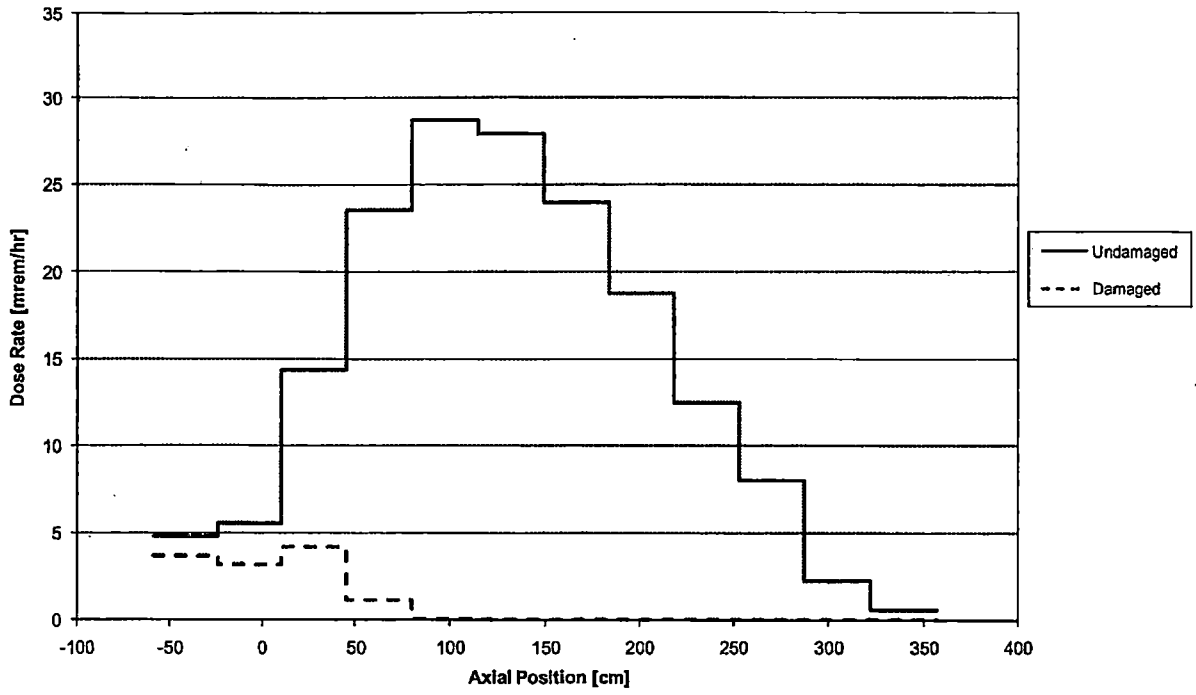


Figure 5.A.4-10 Storage Cask Inlet Dose Rate Profile – Lower End Fitting Damaged Fuel

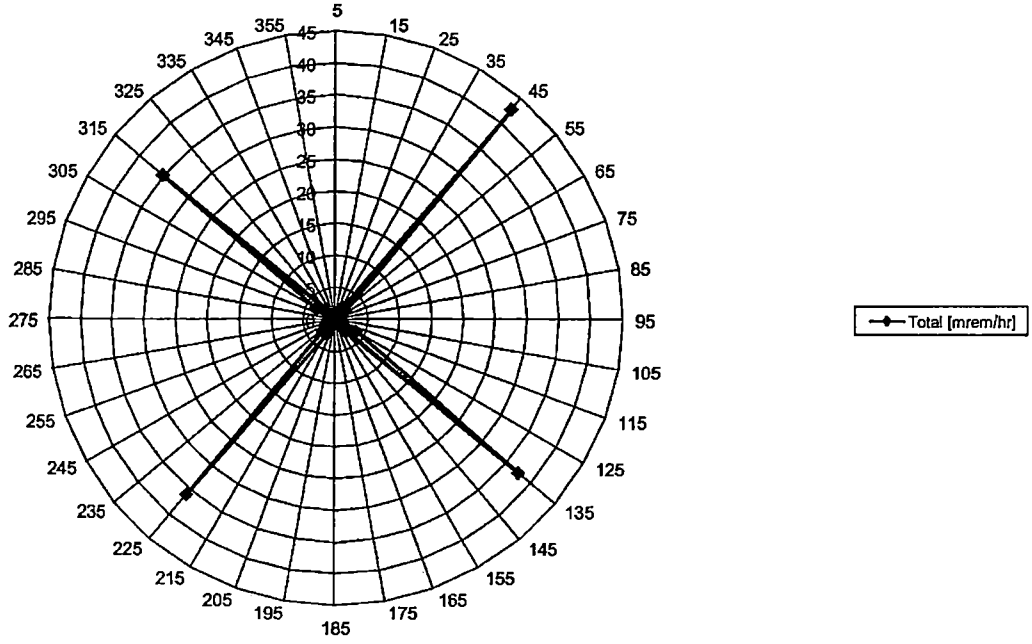


Figure 5.A.4-11 MPC-LACBWR Transfer Cask Top Axial Dose Rate Profiles – Wet Conditions w/o Port Covers – Undamaged Fuel

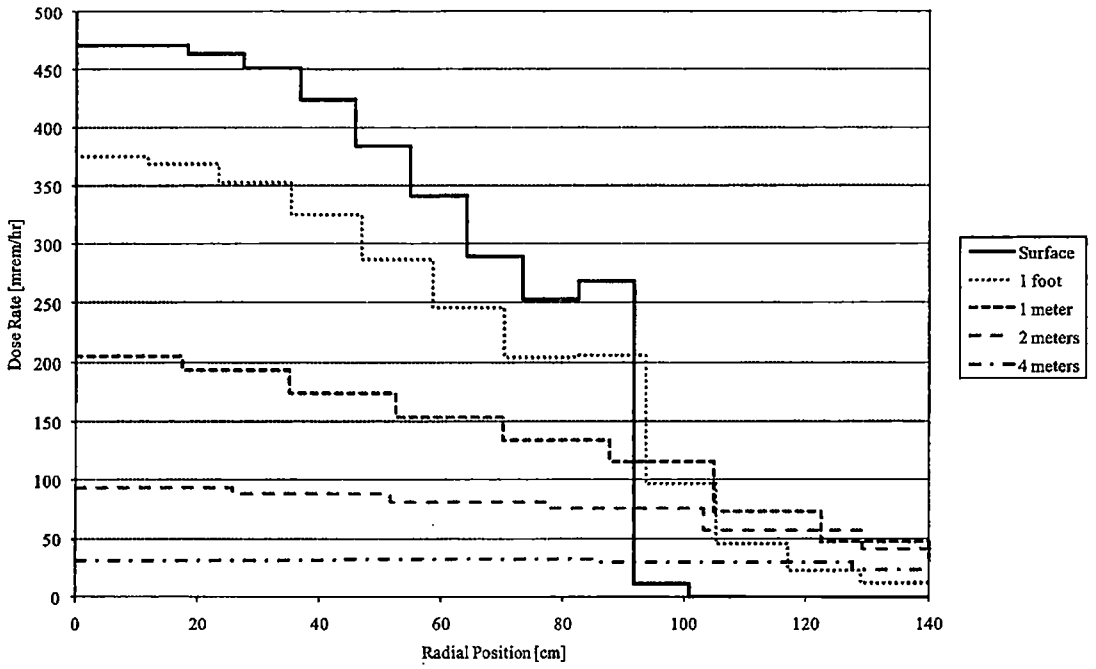


Figure 5.A.4-12 MPC-LACBWR Transfer Cask Top Axial Surface Dose Rate Profile by Source Type – Wet Conditions w/o Port Covers – Undamaged Fuel

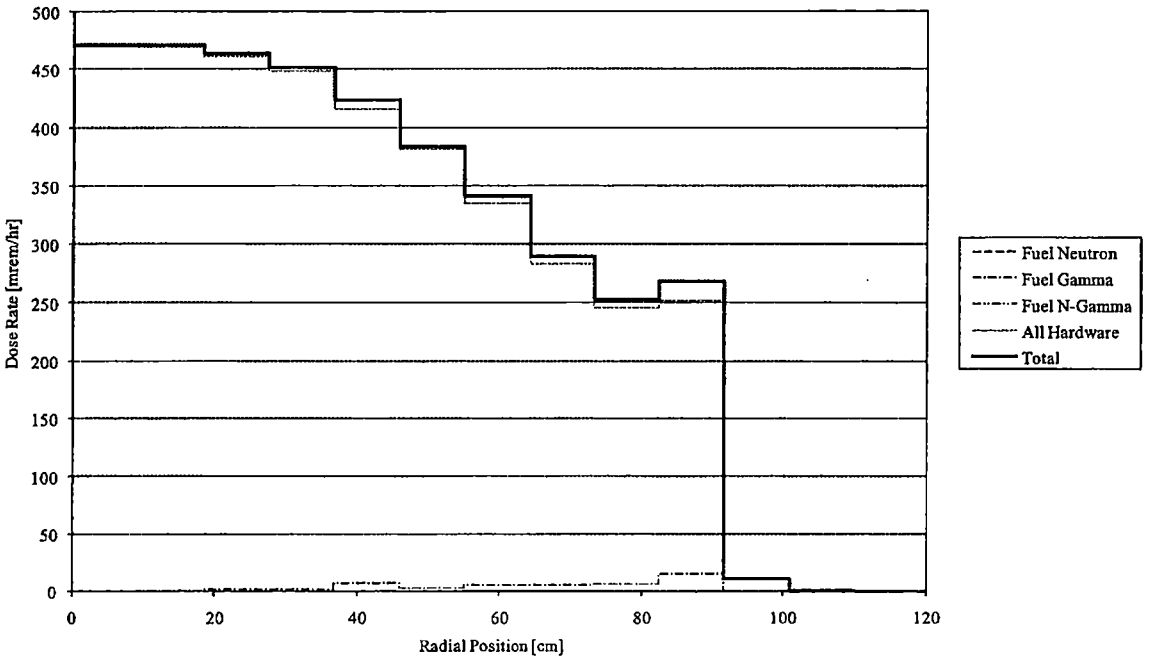


Figure 5.A.4-13 MPC-LACBWR Transfer Cask Radial Dose Rate Profiles – Wet Conditions w/o Port Covers – Undamaged Fuel

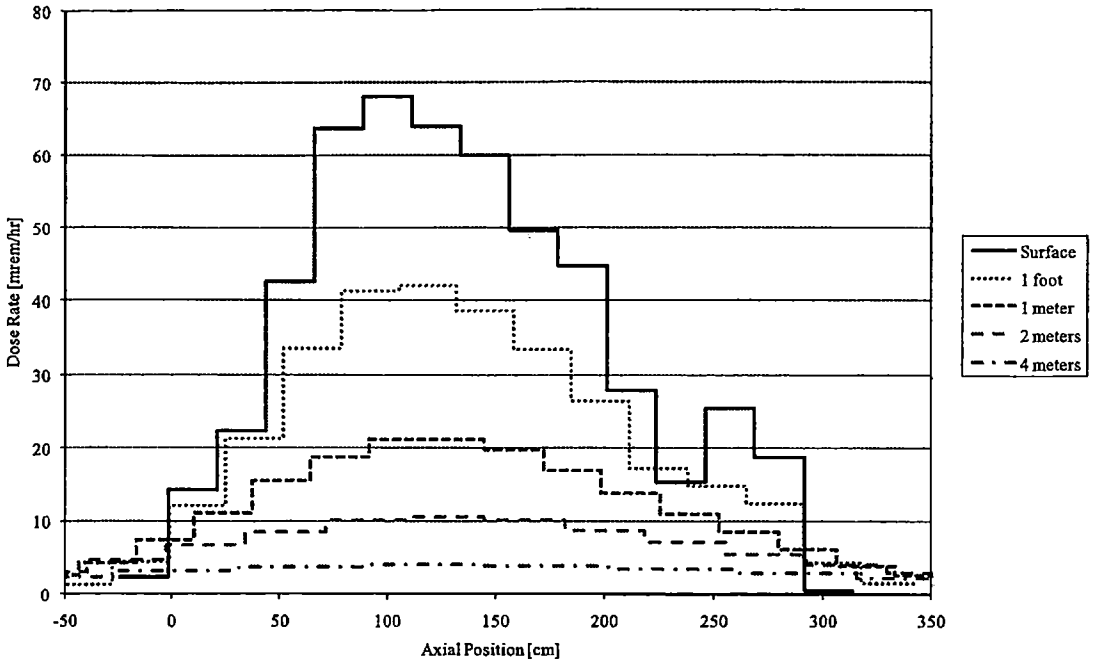


Figure 5.A.4-14 MPC-LACBWR Transfer Cask Radial Surface Dose Rate Profile – Wet Conditions w/o Port Covers – Undamaged Fuel

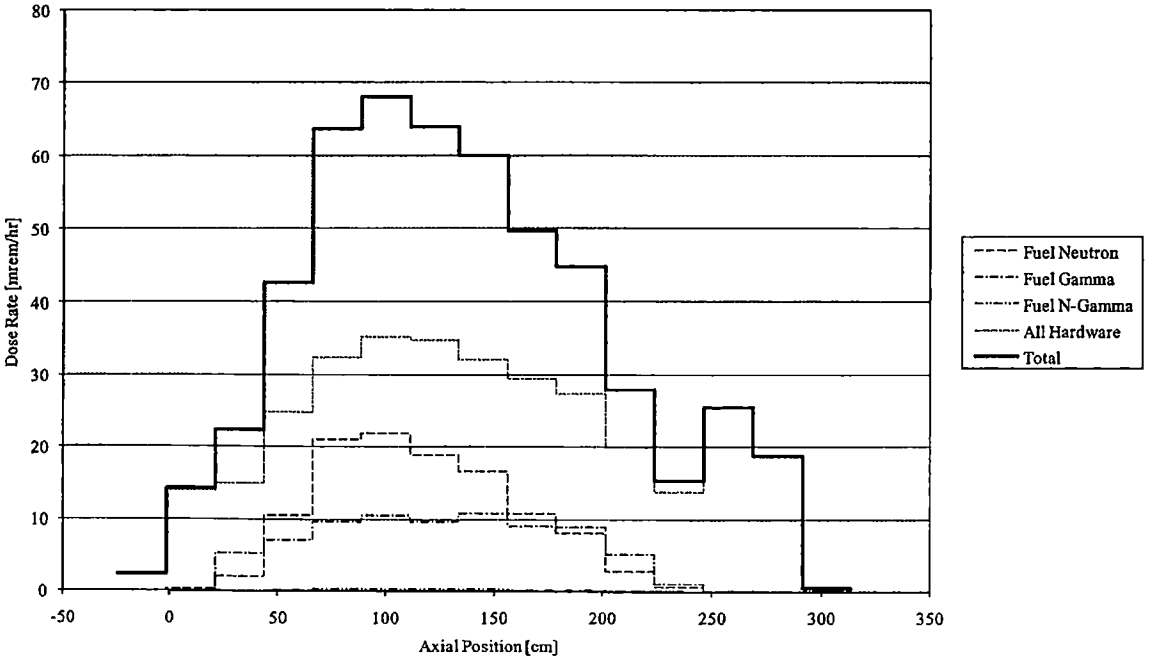


Figure 5.A.4-15 MPC-LACBWR Transfer Cask Bottom Axial Dose Rate Profiles – Wet Conditions w/o Port Covers – Undamaged Fuel

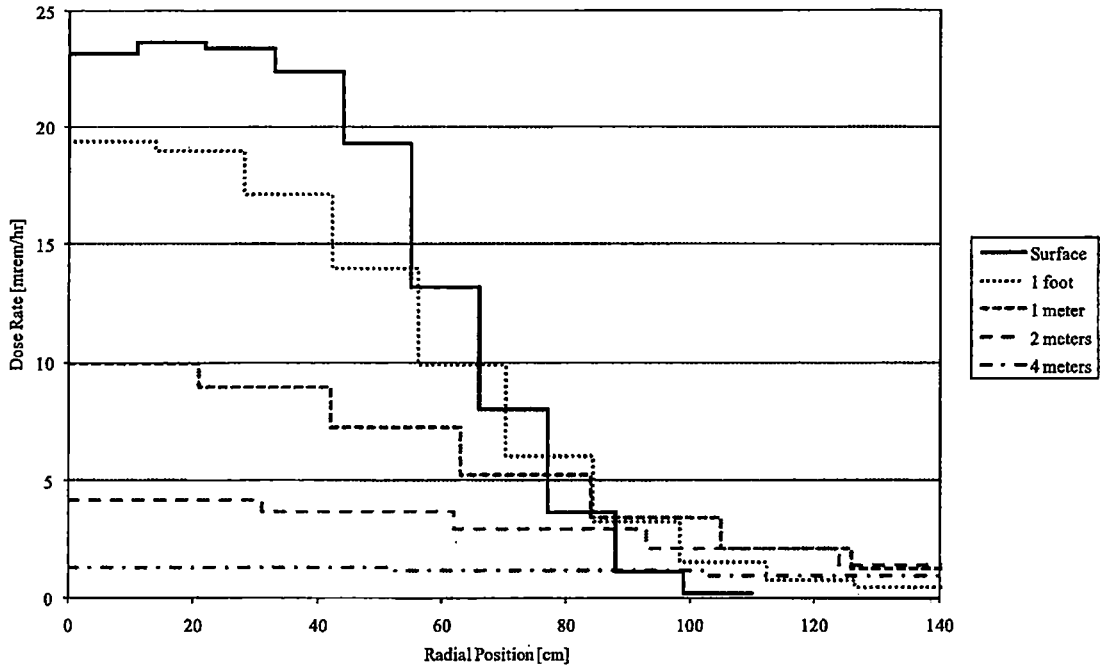


Figure 5.A.4-16 MPC-LACBWR Transfer Cask Bottom Axial Surface Dose Rate Profile by Source Type – Wet Conditions w/o Port Covers – Undamaged Fuel

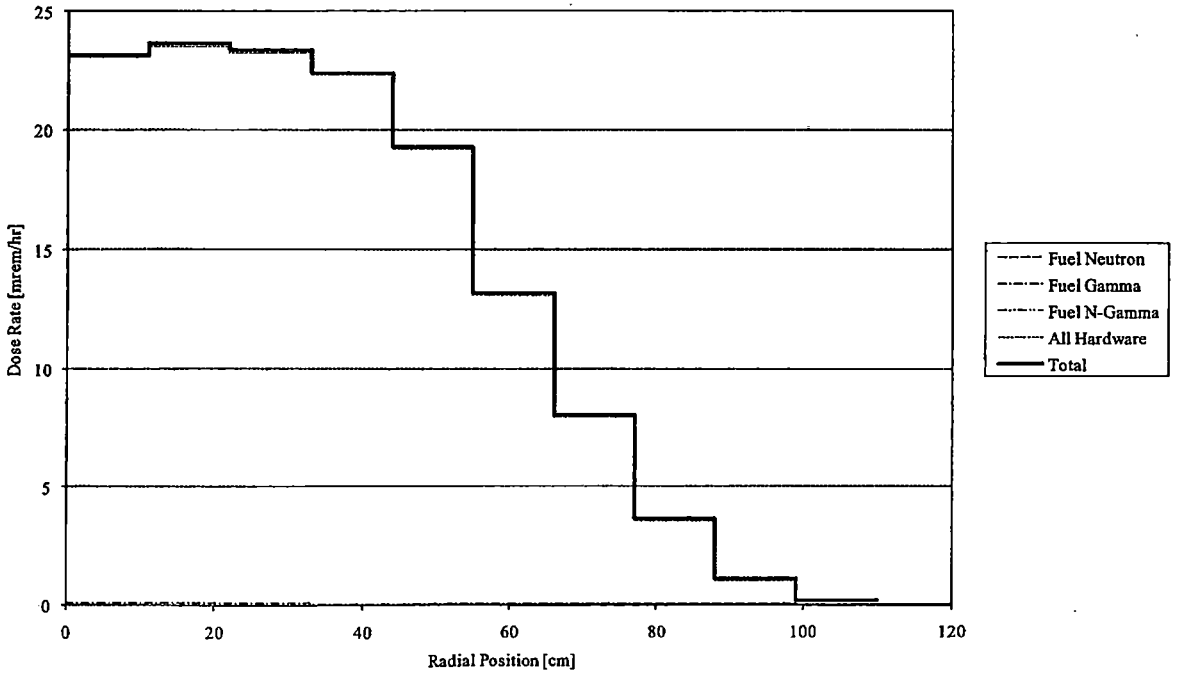


Figure 5.A.4-17 MPC-LACBWR Transfer Cask Top Axial Dose Rate Profiles – Dry Conditions w/Port Covers – Undamaged Fuel

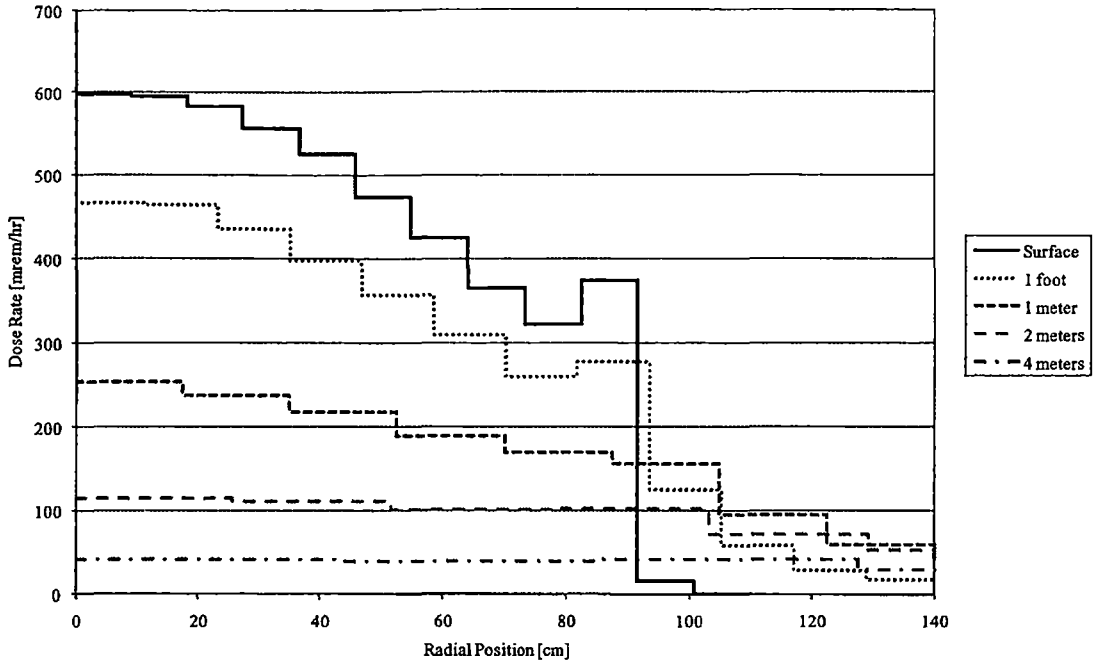


Figure 5.A.4-18 MPC-LACBWR Transfer Cask Top Axial Surface Dose Rate Profile by Source Type – Dry Conditions w/Port Covers – Undamaged Fuel

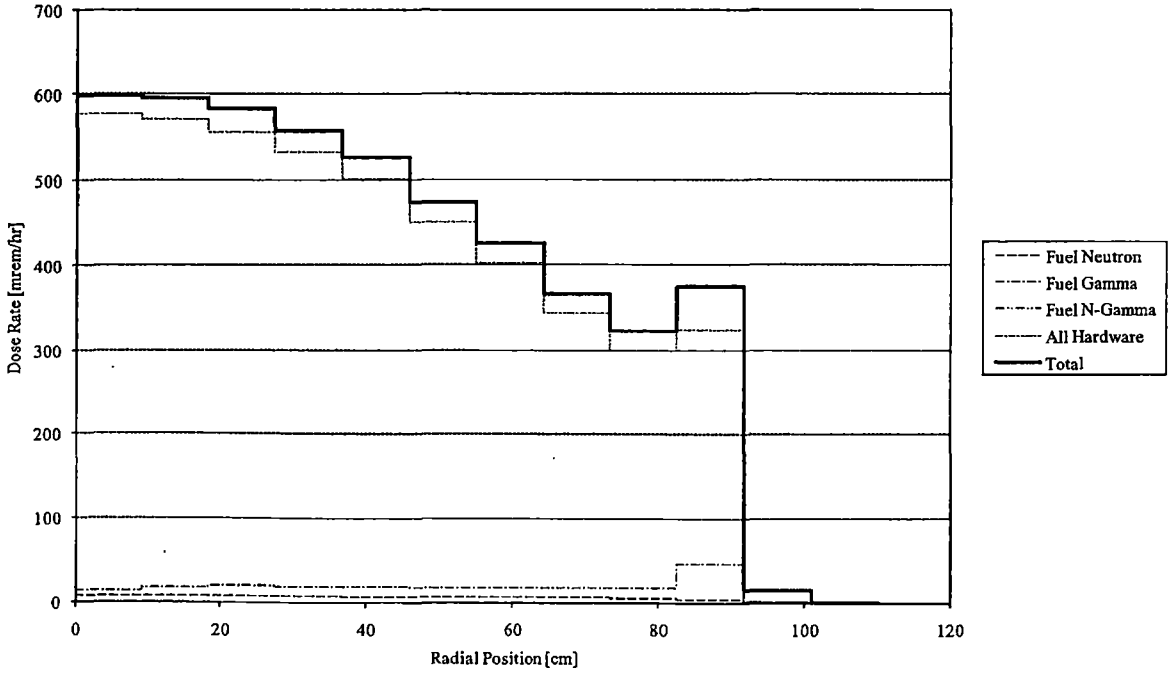


Figure 5.A.4-19 MPC-LACBWR Transfer Cask Radial Dose Rate Profiles – Dry Conditions w/Port Covers – Undamaged Fuel

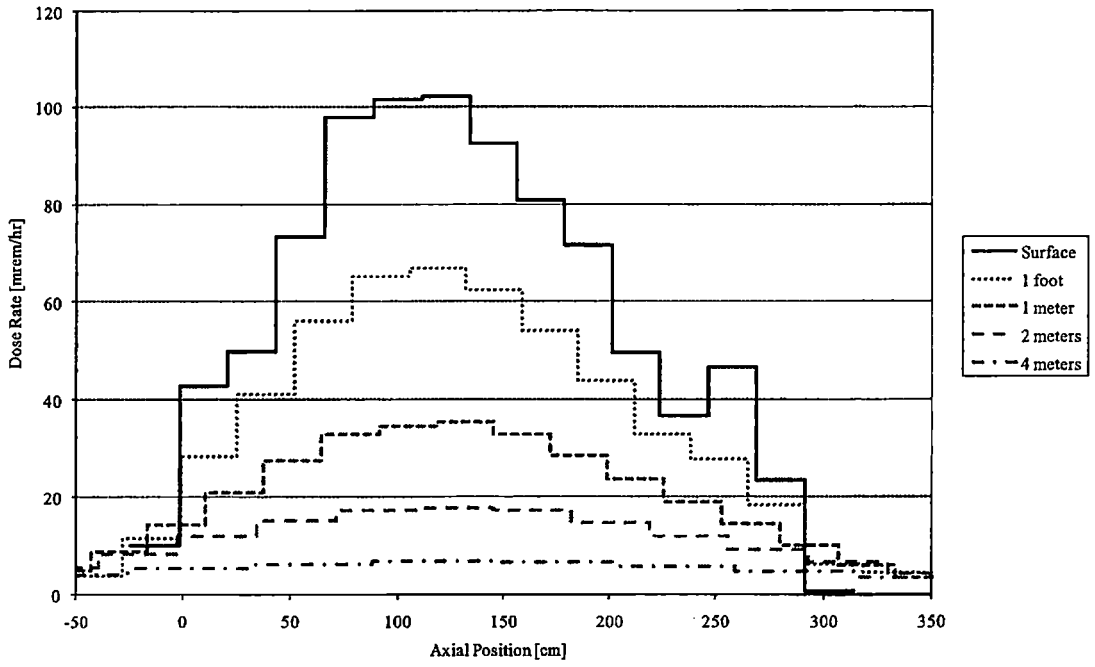


Figure 5.A.4-20 MPC-LACBWR Transfer Cask Radial Surface Dose Rate Profile – Dry Conditions w/Port Covers – Undamaged Fuel

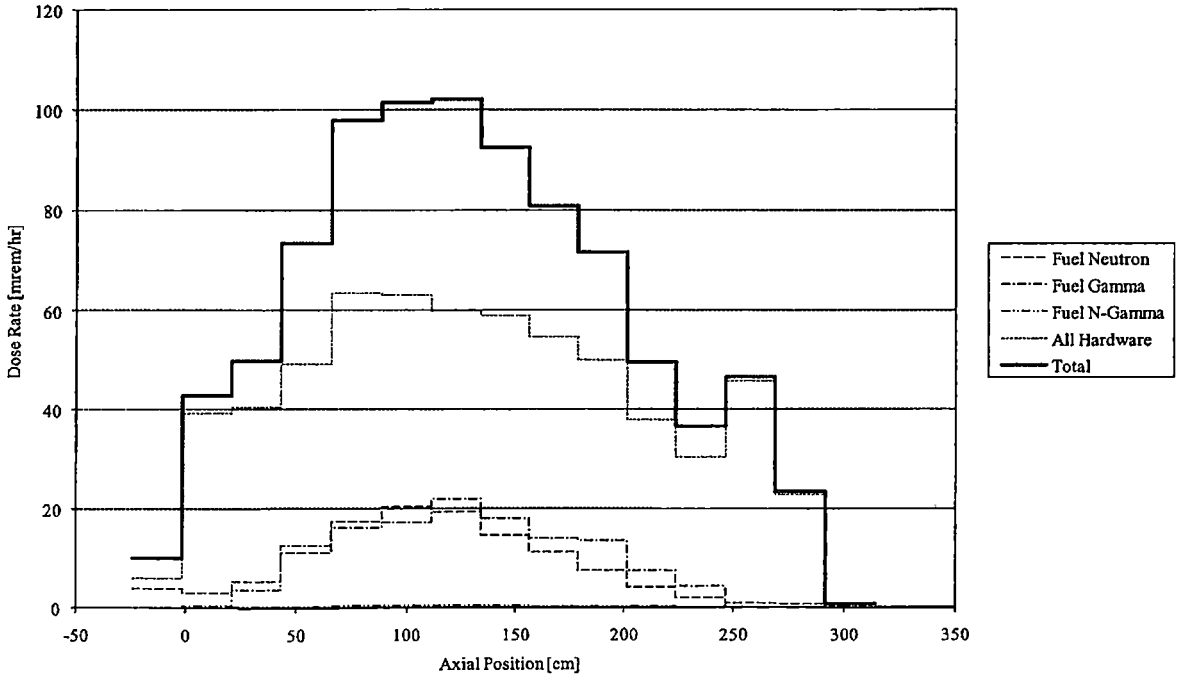


Figure 5.A.4-21 MPC-LACBWR Transfer Cask Bottom Axial Dose Rate Profiles – Dry Conditions w/Port Covers – Undamaged Fuel

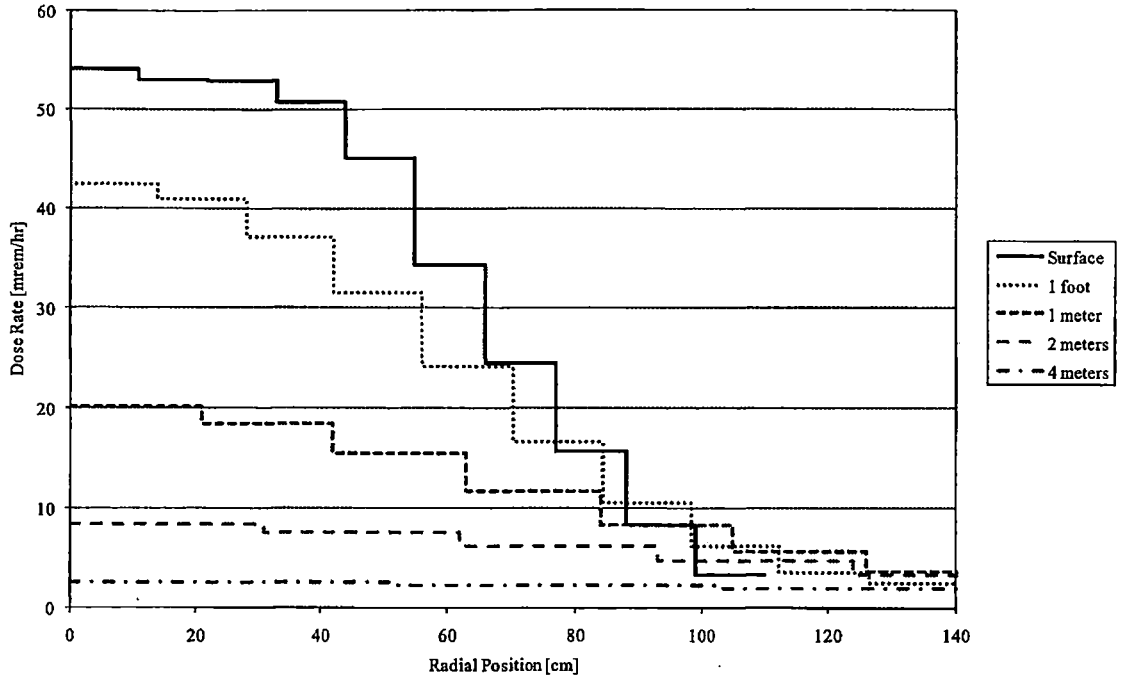


Figure 5.A.4-22 MPC-LACBWR Transfer Cask Bottom Axial Surface Dose Rate Profile by Source Type – Dry Conditions w/Port Covers – Undamaged Fuel

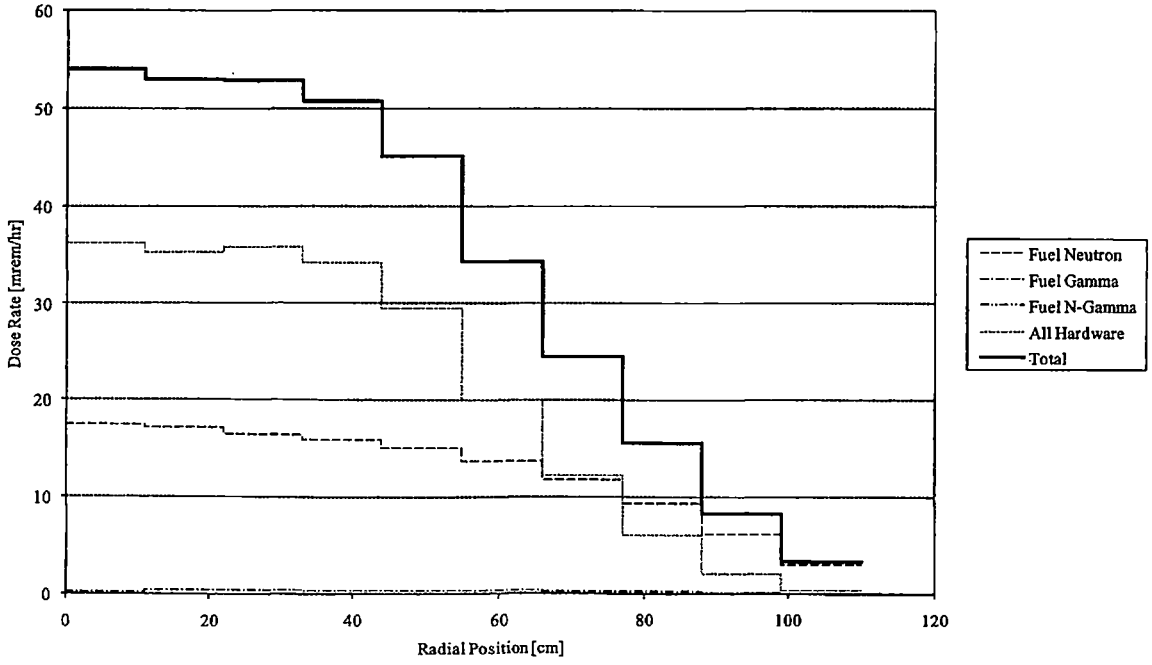


Figure 5.A.4-23 Dose Rate Profile Comparison at Radial Surface of Transfer Cask – Active Fuel Damaged Fuel

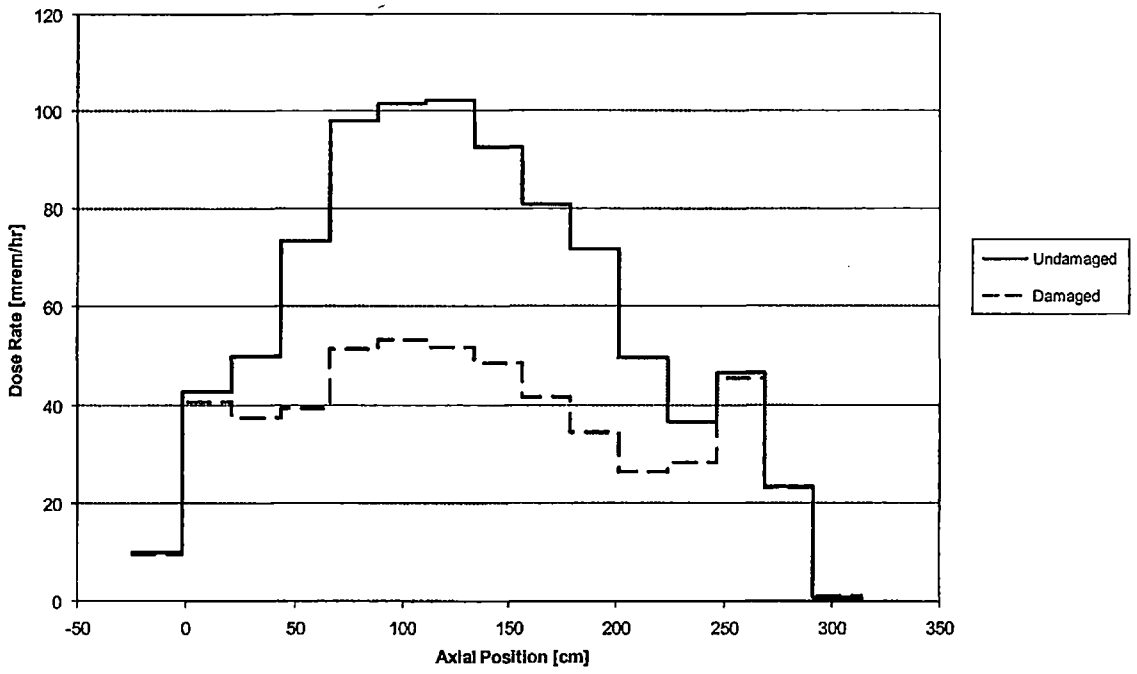


Figure 5.A.4-24 Dose Rate Profile Comparison at Top Axial Surface of Transfer Cask – Active Fuel Damaged Fuel

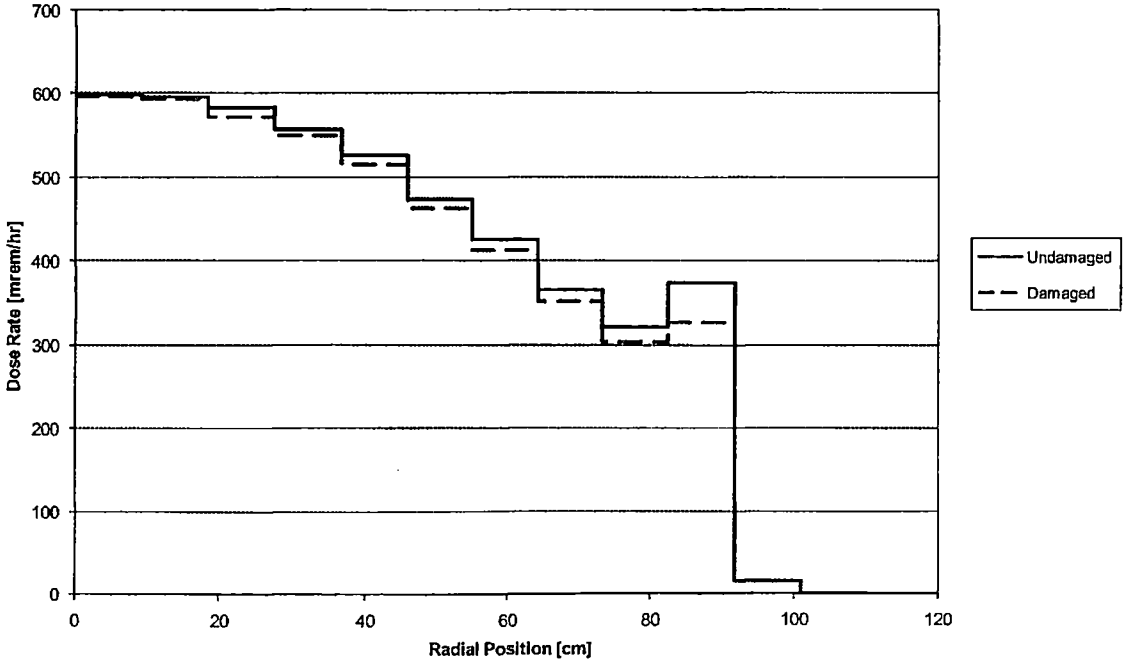


Figure 5.A.4-25 Dose Rate Profile Comparison at Bottom Axial Surface of Transfer Cask – Active Fuel Damaged Fuel

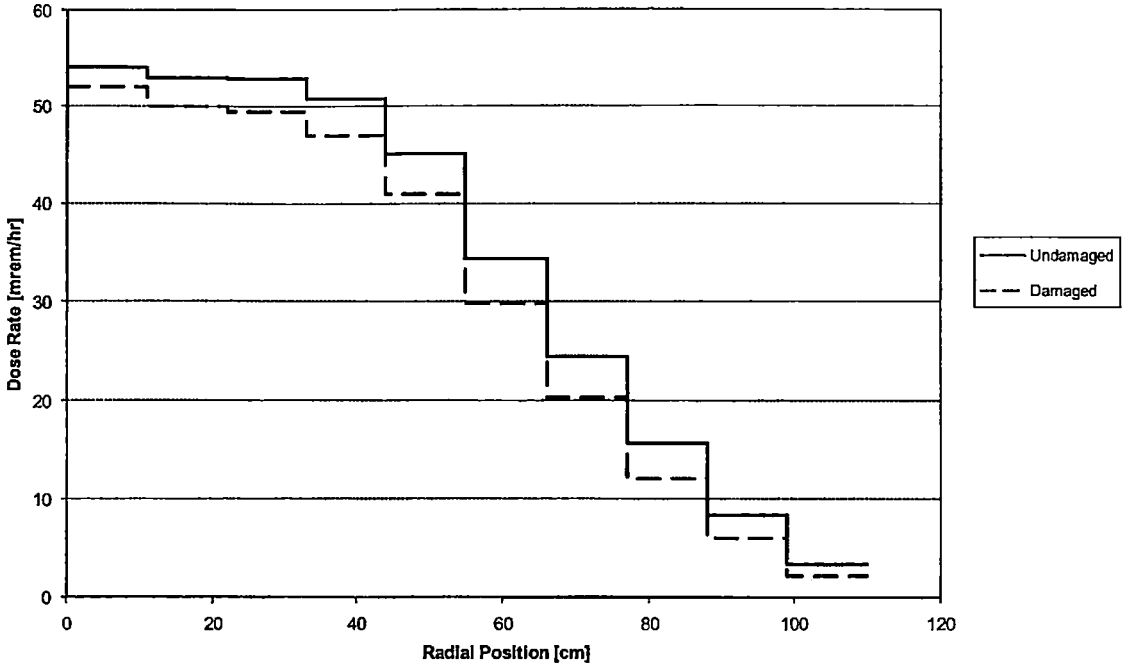


Figure 5.A.4-26 Dose Rate Profile at Radial Surface of Transfer Cask – Lower End Fitting Damaged Fuel

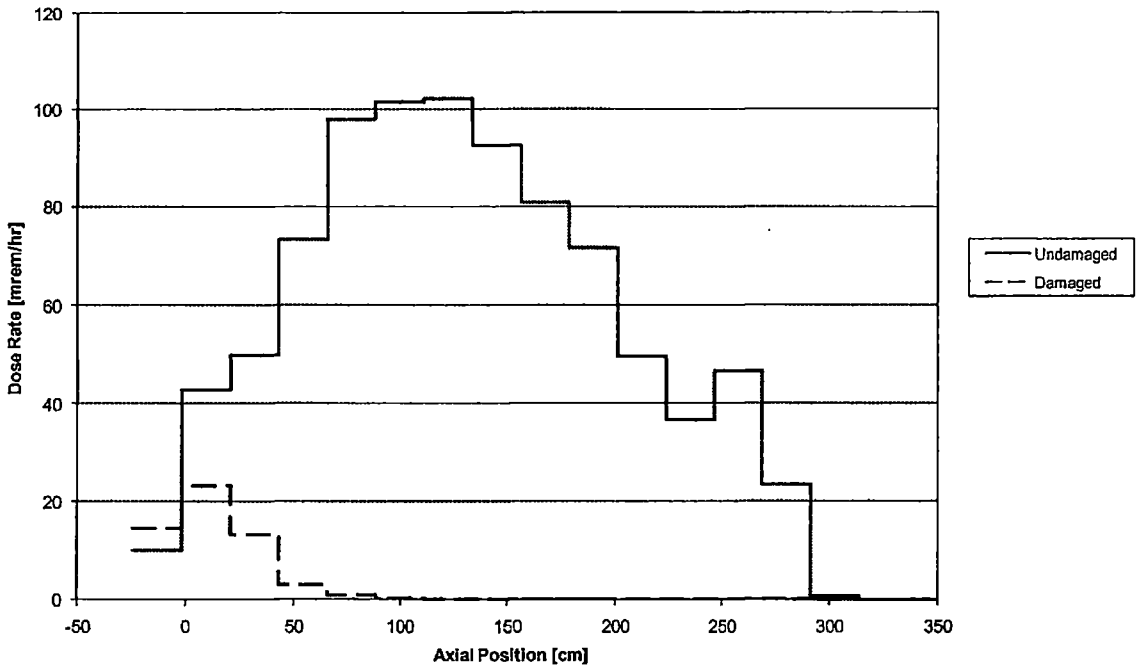


Figure 5.A.4-27 Dose Rate Profile at Bottom Axial Surface of Transfer Cask – Lower End Fitting Damaged Fuel

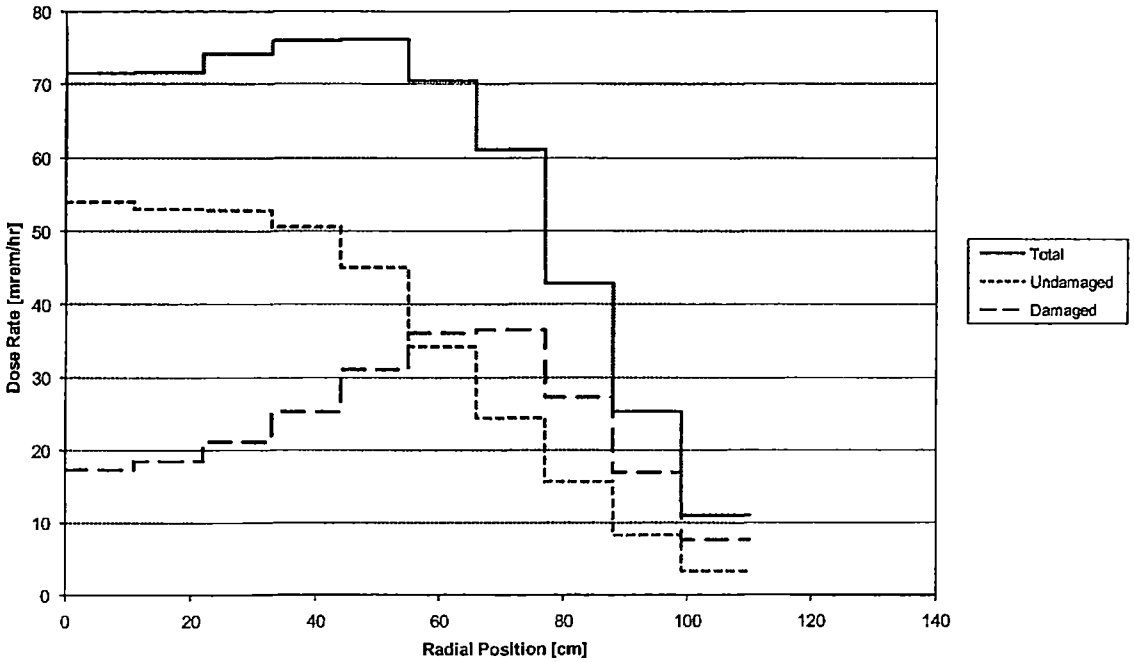


Figure 5.A.4-28 Canister Flood Study – Transfer Cask Radial Surface Dose Rate Profile

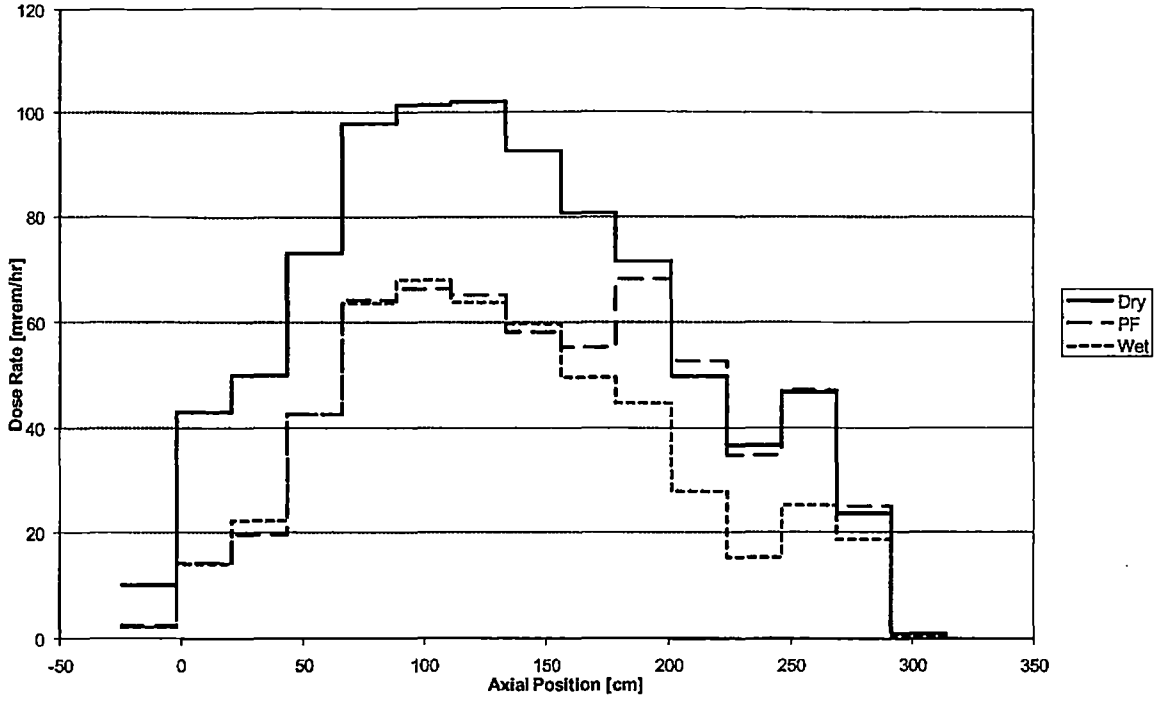


Figure 5.A.4-29 Canister Flood Study – Transfer Cask Radial Surface Dose Rate Profile

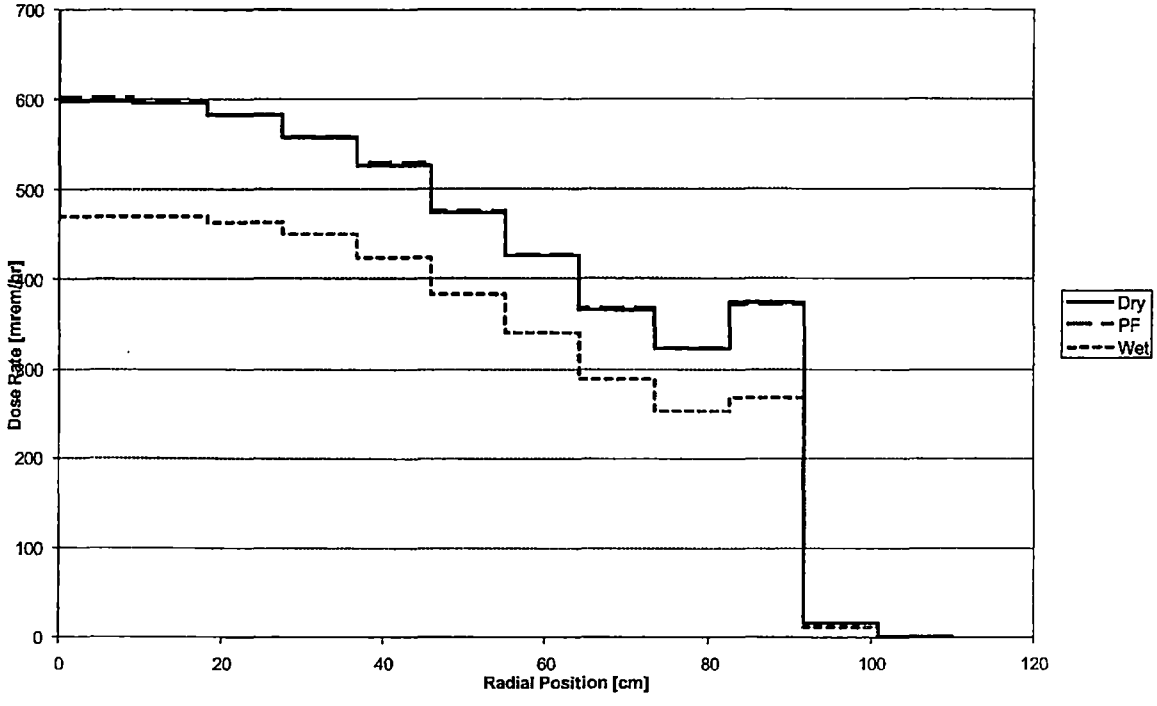


Figure 5.A.4-30 Transfer Cask Radial Dose Rates– Fresh Fuel versus Spent Fuel Isotopics

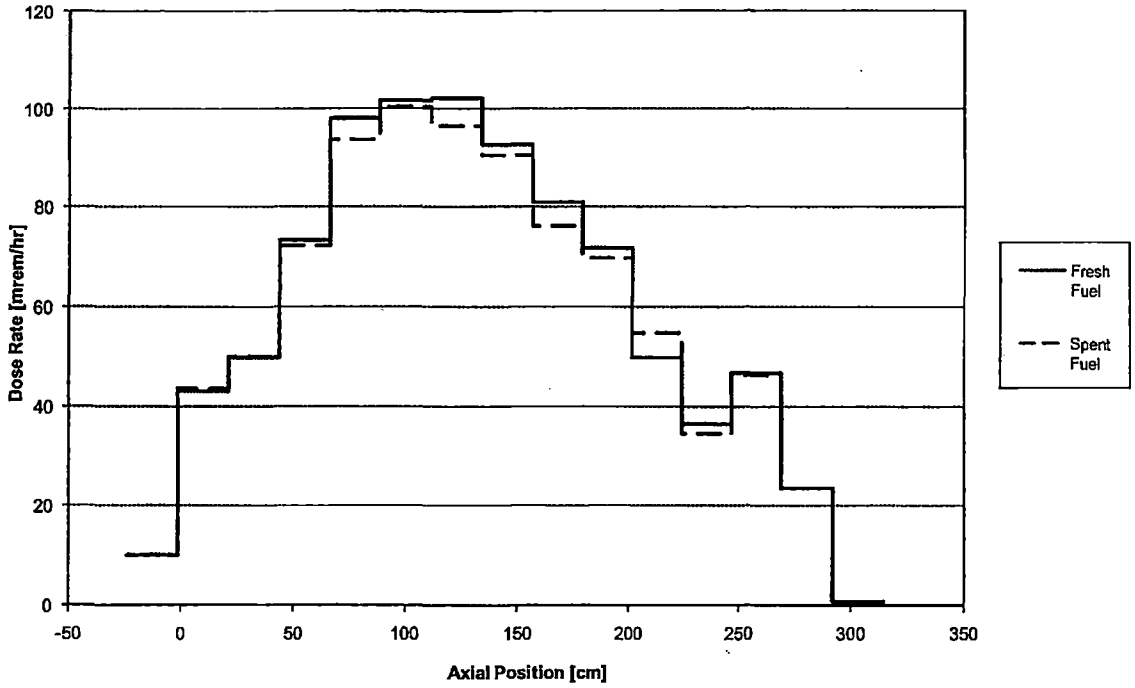


Figure 5.A.4-31 Concrete Cask Radial Dose Rates– Fresh Fuel versus Spent Fuel Isotopics

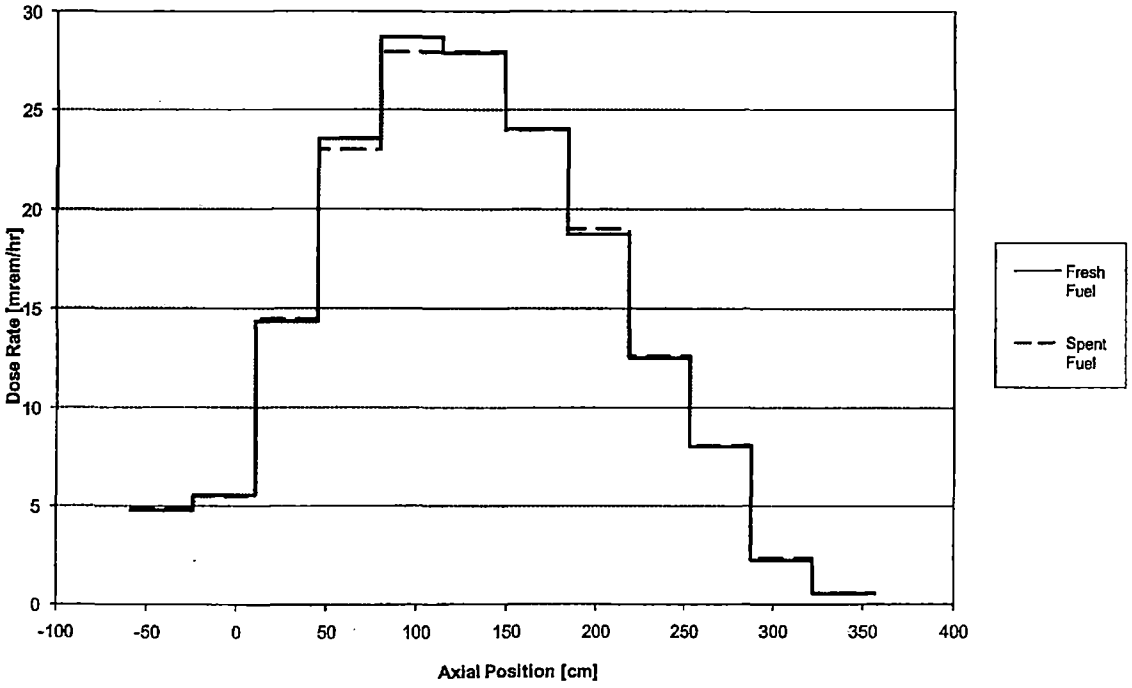


Table 5.A.4-1 ANSI Standard Neutron Flux-To-Dose Rate Factors

Energy (MeV)	(rem/hr)/(n/cm^2/sec)
2.5E-08	3.67E-06
1.0E-07	3.67E-06
1.0E-06	4.46E-06
1.0E-05	4.54E-06
1.0E-04	4.18E-06
1.0E-03	3.76E-06
1.0E-02	3.56E-06
1.0E-01	2.17E-05
5.0E-01	9.26E-05
1.0	1.32E-04
2.5	1.25E-04
5.0	1.56E-04
7.0	1.47E-04
10.0	1.47E-04
14.0	2.08E-04
20.0	2.27E-04

Table 5.A.4-2 ANSI Standard Gamma Flux-To-Dose Rate Factors

Energy (MeV)	(rem/hr)/(γ/cm^2/sec)	Energy (MeV)	(rem/hr)/(γ/cm^2/sec)
0.01	3.96E-06	1.4	2.51E-06
0.03	5.82E-07	1.8	2.99E-06
0.05	2.90E-07	2.2	3.42E-06
0.07	2.58E-07	2.6	3.82E-06
0.1	2.83E-07	2.8	4.01E-06
0.15	3.79E-07	3.25	4.41E-06
0.2	5.01E-07	3.75	4.83E-06
0.25	6.31E-07	4.25	5.23E-06
0.3	7.59E-07	4.75	5.60E-06
0.35	8.78E-07	5	5.80E-06
0.4	9.85E-07	5.25	6.01E-06
0.45	1.08E-06	5.75	6.37E-06
0.5	1.17E-06	6.25	6.74E-06
0.55	1.27E-06	6.75	7.11E-06
0.6	1.36E-06	7.5	7.66E-06
0.65	1.44E-06	9	8.77E-06
0.7	1.52E-06	11	1.03E-05
0.8	1.68E-06	13	1.18E-05
1	1.98E-06	15	1.33E-05

5.A.5 References

[A1] "MCNP – A General Monte Carlo N-Particle Transport Code, Version 5," X-5 Monte Carlo Team, Los Alamos National Laboratory, Los Alamos, NM, April 24, 2003.

[A2] D. J. Whalen, *et al.*, "MCNP: Photon Benchmark Problems," LA-12196, September 1991.

[A3] D. J. Whalen, *et al.*, "MCNP: Neutron Benchmark Problems," LA-12212, September 1991.

[A4] NUREG/CR-6802, "Recommendations for Shielding Evaluations for Transport and Storage Packages," U.S. Nuclear Regulatory Commission, Washington, DC, May 2003.

[A5] EPRI TR-104329, "Evaluation of Shielding Analysis Methods in Spent Fuel Cask Environments," B. L. Broadhead, *et al.*, Electric Power Research Institute, Palo Alto, CA, May 1995.

[A6] NEACRP-L-339, "Summary of the Results of the Comparison of Calculations and Measurements for the TN 12 Flask Carried Out Under the NEACRP Intercomparison of Shielding Codes," H. F. Locke, Nuclear Energy Agency, Paris, France, 1992.

[A7] ORNL/TM-12667, "Validation of the SCALE System for PWR Spent Fuel Isotopic Composition Analyses," Oak Ridge National Laboratory, March 1995.

[A8] ORNL/TM-13317, "An Extension of the Validation of SCALE (SAS2H) Isotopic Prediction for PWR Spent Fuel," Oak Ridge National Laboratory, September 1996.

[A9] NUREG/CR-6798, "Isotopic Analysis of High Burnup PWR Spent Fuel Samples from the Takahama-3 Reactor," US Nuclear Regulatory Commission, January 2003.

[A10] ORNL/TM-13315, "Validation of SCALE (SAS2H) Isotopic Predictions for BWR Spent Fuel," Oak Ridge National Laboratory, September 1998.

[A11] ORNL/TM-13687, "Prediction of the Isotopic Composition of UO2 Fuel from a BWR: Analysis of the DU1 Sample from the Dodewaard Reactor," Oak Ridge National Laboratory, October 1998.

5.A.6 MPC-LACBWR Storage System Sample Input Files

Sample input files are included here. Figure 5.A.6-1 and Figure 5.A.6-2 show the SAS2H input for Allis Chalmers and Exxon Nuclear Company fuel, respectively. Figure 5.A.6-3 shows the MCNP input file for the storage cask radial analysis for the fuel gamma source. Figure 5.A.6-4 shows the MCNP input file for the transfer cask wet canister model for a top axial analysis of the fuel neutron source. Figure 5.A.6-5 shows the MCNP input file for the transfer cask dry canister model for a bottom axial analysis of the lower end fitting source. Figure 5.A.6-6 shows the MCNP input file for the storage cask model for a damaged fuel gamma source. Figure 5.A.6-7 shows the MCNP input file for the transfer cask dry canister model for a bottom axial analysis of the lower end fitting damaged fuel neutron source.

Figure 5.A.6-1 MPC-LACBWR SAS2H Input File for Allis Chalmers Fuel

```
=SAS2H       PARM=(HALT04,SKIPSHIPDATA)
LACBWR - 3.6 wt % U-235, 22000 MWD/MTU, 28 years cool time
27GROUPNDF4 LATTICECELL
UO2   1 0.950 814 92235 3.6 92238 96.4 END
SS304 2 1.0 594 END
H2O   3 DEN=0.434 1.0 576 END
H2O   4 DEN=0.723 1.0 569 END
SS304 5 1.0 569 END
H2O   6 DEN=0.434 1.0 576 END
END COMP
SQUAREPITCH 1.4351 0.8890 1 3 1.0058 2 0.9042 0 END
NPIN=100 FUEL=210.820 NCYC=2 NLIB=2 PRIN=6 LIGH=5
INPL=2 NUMZ=5 END
6 0.0001 500 8.0967 6 8.2113 5 8.4349 4 9.1285
POWER=2.4063 BURN=549.0286 DOWN=60 END
POWER=2.4063 BURN=549.0286 DOWN=1461 END
FE 0.673 CR 0.1900 NI 0.1150 MN 0.0200 CO 0.002
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 28 YEARS AND FISSION PRODUCT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 28 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 28
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F6
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT SPECTRA
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 28 YEARS AND ACTINIDE GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 28 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 28
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F5
```

Figure 5.A.6-1 MPC-LACBWR SAS2H Input File for Allis Chalmers Fuel

```
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
ACTINIDE SPECTRA
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 28 YEARS AND LIGHT ELEMENT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 28 YEARS AND LIGHT ELEMENT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 28
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F4
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
LIGHT ELEMENT SPECTRA
56$$ F0  T
END
```

Figure 5.A.6-2 MPC-LACBWR SAS2H Input File for Exxon Nuclear Company Fuel

```
=SAS2H       PARM=(HALT02,SKIPSHIPDATA)
LACBWR - 3.6 wt % U-235, 21000 MWD/MTU, 23 years cool time
27GROUPNDF4 LATTICECELL
UO2   1 0.950 814 92235 3.6 92238 96.4 END
SS304 2 1.0 594 END
H2O   3 DEN=0.434 1.0 576 END
H2O   4 DEN=0.723 1.0 569 END
ZIRCALLOY 5 1.0 569 END
H2O   6 DEN=0.434 1.0 576 END
SS304 7 1.0 569 END
ZIRCALLOY 8 1.0 569 END
END COMP
SQUAREPITCH 1.4148 0.8712 1 3 1.0008 2 0.8890 0 END
NPIN=96 FUEL=210.820 NCYC=2 NLIB=1 PRIN=6 LIGH=5
INPL=2 NUMZ=7 END
8 0.8890 7 1.0008 6 1.1284 500 7.9820 6 8.0967 5 8.3260 4 9.1285
POWER=2.4063 BURN=483.0545 DOWN=60 END
POWER=2.4063 BURN=483.0545 DOWN=1461 END
FE 0.673 CR 0.1900 NI 0.1150 MN 0.0200 CO 0.002
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 23 YEARS AND FISSION PRODUCT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 23 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 23
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F6
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT SPECTRA
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 23 YEARS AND ACTINIDE GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 23 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 23
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
```

Figure 5.A.6-2 MPC-LACBWR SAS2H Input File for Exxon Nuclear Company Fuel

```
81$$  2 51 26 1 E
82$$  F5
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
ACTINIDE SPECTRA
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 23 YEARS AND LIGHT ELEMENT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 1 A13 -2 5 3 E
57**  4.0 E T
COOLING 23 YEARS AND LIGHT ELEMENT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 23
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
81$$  2 51 26 1 E
82$$  F4
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
LIGHT ELEMENT SPECTRA
56$$ F0  T
END
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
LACBWR VCC - strShlDryRadFg_Pref
C Radial Biasing - Fuel Gamma Source
C Fuel Assembly Cells - v1.0
1 1 -1.3734 -1 -2    u=10 $ Lower Nozzle
2 2 -3.7790 -1 +2 -3   u=10 $ Fuel
3 3 -0.9880 -1 +3 -4   u=10 $ Upper Plenum
4 4 -0.6145 -1 +4    u=10 $ Upper Nozzle
5 0         +1     u=10 $ Outside
C Cells - Standard Fuel Tube  v1.0
101 0         -101       u=5 $ Tube void
102 6 -7.9400 -102 +101      u=5 $ Tube
103 8 -2.6707 -103       u=5 $ Absorber +Y
104 6 -7.9400 -104       u=5 $ Cladding +Y
105 8 -2.6707 -105       u=5 $ Absorber +X
106 6 -7.9400 -106       u=5 $ Cladding +X
107 0         +101 +102 +103 +104 +106 +105  u=5 $ Void
C Cells - DFC Fuel Tube Absorber 2 Sides v1.0
108 0         -107       u=6 $ Tube void
109 6 -7.9400 -108 +107      u=6 $ Tube
110 8 -2.6707 -109       u=6 $ Absorber +Y
111 6 -7.9400 -110       u=6 $ Cladding +Y
112 8 -2.6707 -111       u=6 $ Absorber +X
113 6 -7.9400 -112       u=6 $ Cladding +X
114 0         +107 +108 +109 +110 +112 +111  u=6 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (Y) v1.0
115 0         -107       u=7 $ Tube void
116 6 -7.9400 -108 +107      u=7 $ Tube
117 8 -2.6707 -109       u=7 $ Absorber +Y
118 6 -7.9400 -110       u=7 $ Cladding +Y
119 0         +107 +108 +109 +110    u=7 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (X) v1.0
120 0         -107       u=8 $ Tube void
121 6 -7.9400 -108 +107      u=8 $ Tube
122 8 -2.6707 -111       u=8 $ Absorber +X
123 6 -7.9400 -112       u=8 $ Cladding +X
124 0         +107 +108 +111 +112    u=8 $ Void
C Cells - DFC Fuel Tube No Absorber v1.0
125 0         -107       u=9 $ Tube void
126 6 -7.9400 -108 +107      u=9 $ Tube
127 0         +107 +108      u=9 $ Void
c Cell Cards - Disk Stack v1.0
201 6 -7.94 -203 trcl = ( 0.0000 0.0000 2.5400 )    u=4 $ Bottom weldment disk
202 6 -7.94 -201 trcl = ( 0.0000 0.0000 15.0368 )    u=4 $ Support disk 1
203 like 202 but   trcl = ( 0.0000 0.0000 24.7650 )    u=4 $ Support disk 2
204 like 202 but   trcl = ( 0.0000 0.0000 34.4932 )    u=4 $ Support disk 3
205 like 202 but   trcl = ( 0.0000 0.0000 44.2214 )    u=4 $ Support disk 4
206 like 202 but   trcl = ( 0.0000 0.0000 53.9496 )    u=4 $ Support disk 5
207 9 -2.70 -202 trcl = ( 0.0000 0.0000 58.9788 )    u=4 $ Heat transfer disk 1
208 like 202 but   trcl = ( 0.0000 0.0000 63.6778 )    u=4 $ Support disk 6
209 like 207 but   trcl = ( 0.0000 0.0000 68.7070 )    u=4 $ Heat transfer disk 2
210 like 202 but   trcl = ( 0.0000 0.0000 73.4060 )    u=4 $ Support disk 7
211 like 207 but   trcl = ( 0.0000 0.0000 78.4352 )    u=4 $ Heat transfer disk 3
212 like 202 but   trcl = ( 0.0000 0.0000 83.1342 )    u=4 $ Support disk 8
213 like 207 but   trcl = ( 0.0000 0.0000 88.1634 )    u=4 $ Heat transfer disk 4
214 like 202 but   trcl = ( 0.0000 0.0000 92.8624 )    u=4 $ Support disk 9
215 like 207 but   trcl = ( 0.0000 0.0000 97.8916 )    u=4 $ Heat transfer disk 5
216 like 202 but   trcl = ( 0.0000 0.0000 102.5906 )    u=4 $ Support disk 10
217 like 207 but   trcl = ( 0.0000 0.0000 107.6198 )    u=4 $ Heat transfer disk 6
218 like 202 but   trcl = ( 0.0000 0.0000 112.3188 )    u=4 $ Support disk 11
219 like 207 but   trcl = ( 0.0000 0.0000 117.3480 )    u=4 $ Heat transfer disk 7
220 like 202 but   trcl = ( 0.0000 0.0000 122.0470 )    u=4 $ Support disk 12
221 like 207 but   trcl = ( 0.0000 0.0000 127.0762 )    u=4 $ Heat transfer disk 8
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
222 like 202 but   trcl = ( 0.0000 0.0000 131.7752 )    u=4 $ Support disk 13
223 like 207 but   trcl = ( 0.0000 0.0000 136.8044 )    u=4 $ Heat transfer disk 9
224 like 202 but   trcl = ( 0.0000 0.0000 141.5034 )    u=4 $ Support disk 14
225 like 207 but   trcl = ( 0.0000 0.0000 146.5326 )    u=4 $ Heat transfer disk 10
226 like 202 but   trcl = ( 0.0000 0.0000 151.2316 )    u=4 $ Support disk 15
227 like 207 but   trcl = ( 0.0000 0.0000 156.2608 )    u=4 $ Heat transfer disk 11
228 like 202 but   trcl = ( 0.0000 0.0000 160.9598 )    u=4 $ Support disk 16
229 like 207 but   trcl = ( 0.0000 0.0000 165.9890 )    u=4 $ Heat transfer disk 12
230 like 202 but   trcl = ( 0.0000 0.0000 170.6880 )    u=4 $ Support disk 17
231 like 207 but   trcl = ( 0.0000 0.0000 175.7172 )    u=4 $ Heat transfer disk 13
232 like 202 but   trcl = ( 0.0000 0.0000 180.4162 )    u=4 $ Support disk 18
233 like 207 but   trcl = ( 0.0000 0.0000 185.4454 )    u=4 $ Heat transfer disk 14
234 like 202 but   trcl = ( 0.0000 0.0000 190.1444 )    u=4 $ Support disk 19
235 like 202 but   trcl = ( 0.0000 0.0000 199.8726 )    u=4 $ Support disk 20
236 like 202 but   trcl = ( 0.0000 0.0000 209.6008 )    u=4 $ Support disk 21
237 like 202 but   trcl = ( 0.0000 0.0000 219.3290 )    u=4 $ Support disk 22
238 like 202 but   trcl = ( 0.0000 0.0000 229.0572 )    u=4 $ Support disk 23
239 like 202 but   trcl = ( 0.0000 0.0000 238.7854 )    u=4 $ Support disk 24
240 like 201 but   trcl = ( 0.0000 0.0000 255.8796 )    u=4 $ Top weldment disk
241 0              $ Outside Disks
      #201 #202 #203 #204 #205 #206 #207 #208 #209 #210
      #211 #212 #213 #214 #215 #216 #217 #218 #219 #220
      #221 #222 #223 #224 #225 #226 #227 #228 #229 #230
      #231 #232 #233 #234 #235 #236 #237 #238 #239
      #240        u=4
c Cell Cards - Basket v1.0
301 0          -302 #302  fill=8 ( -8.8265 77.5233 0.0000 )      $ Tube/Disk 1
           trcl = ( -8.8265 77.5233 0.0000 )     u=3
302 0          -1  fill=10 trcl = ( -8.8265 77.5233 0.0000 )     u=3 $ Assembly 1
303 0          -302 #304  fill=9 ( 8.8265 77.5233 0.0000 )      $ Tube/Disk 2
           trcl = ( 8.8265 77.5233 0.0000 )     u=3
304 like 302 but     trcl = ( 8.8265 77.5233 0.0000 )     u=3 $ Assembly 2
305 0          -302 #306  fill=8 ( -44.1274 61.2699 0.0000 )      $ Tube/Disk 3
           trcl = ( -44.1274 61.2699 0.0000 )     u=3
306 like 302 but     trcl = ( -44.1274 61.2699 0.0000 )     u=3 $ Assembly 3
307 0          -302 #308  fill=8 ( -26.4770 59.8729 0.0000 )      $ Tube/Disk 4
           trcl = ( -26.4770 59.8729 0.0000 )     u=3
308 like 302 but     trcl = ( -26.4770 59.8729 0.0000 )     u=3 $ Assembly 4
309 0          -302 #310  fill=6 ( -8.8265 59.8729 0.0000 )      $ Tube/Disk 5
           trcl = ( -8.8265 59.8729 0.0000 )     u=3
310 like 302 but     trcl = ( -8.8265 59.8729 0.0000 )     u=3 $ Assembly 5
311 0          -302 #312  fill=6 ( 8.8265 59.8729 0.0000 )      $ Tube/Disk 6
           trcl = ( 8.8265 59.8729 0.0000 )     u=3
312 like 302 but     trcl = ( 8.8265 59.8729 0.0000 )     u=3 $ Assembly 6
313 0          -302 #314  fill=8 ( 26.4770 59.8729 0.0000 )      $ Tube/Disk 7
           trcl = ( 26.4770 59.8729 0.0000 )     u=3
314 like 302 but     trcl = ( 26.4770 59.8729 0.0000 )     u=3 $ Assembly 7
315 0          -302 #316  fill=9 ( 44.1274 61.2699 0.0000 )      $ Tube/Disk 8
           trcl = ( 44.1274 61.2699 0.0000 )     u=3
316 like 302 but     trcl = ( 44.1274 61.2699 0.0000 )     u=3 $ Assembly 8
317 0          -302 #318  fill=8 ( -61.2699 44.1274 0.0000 )      $ Tube/Disk 9
           trcl = ( -61.2699 44.1274 0.0000 )     u=3
318 like 302 but     trcl = ( -61.2699 44.1274 0.0000 )     u=3 $ Assembly 9
319 0          -301 #320  fill=5 ( -42.5399 42.5399 0.0000 )      $ Tube/Disk 10
           trcl = ( -42.5399 42.5399 0.0000 )     u=3
320 like 302 but     trcl = ( -42.5399 42.5399 0.0000 )     u=3 $ Assembly 10
321 0          -301 #322  fill=5 ( -25.5245 42.5399 0.0000 )      $ Tube/Disk 11
           trcl = ( -25.5245 42.5399 0.0000 )     u=3
322 like 302 but     trcl = ( -25.5245 42.5399 0.0000 )     u=3 $ Assembly 11
323 0          -301 #324  fill=5 ( -8.5090 42.5399 0.0000 )      $ Tube/Disk 12
           trcl = ( -8.5090 42.5399 0.0000 )     u=3
324 like 302 but     trcl = ( -8.5090 42.5399 0.0000 )     u=3 $ Assembly 12
325 0          -301 #326  fill=5 ( 8.5090 42.5399 0.0000 )      $ Tube/Disk 13
           trcl = ( 8.5090 42.5399 0.0000 )     u=3
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
326 like 302 but     trcl = ( 8.5090 42.5399 0.0000 )      u=3 $ Assembly 13
327 0         -301 #328  fill=5 ( 25.5245 42.5399 0.0000 )       $ Tube/Disk 14
          trcl = ( 25.5245 42.5399 0.0000 )      u=3
328 like 302 but     trcl = ( 25.5245 42.5399 0.0000 )      u=3 $ Assembly 14
329 0         -301 #330  fill=5 ( 42.5399 42.5399 0.0000 )       $ Tube/Disk 15
          trcl = ( 42.5399 42.5399 0.0000 )      u=3
330 like 302 but     trcl = ( 42.5399 42.5399 0.0000 )      u=3 $ Assembly 15
331 0         -302 #332  fill=9 ( 61.2699 44.1274 0.0000 )       $ Tube/Disk 16
          trcl = ( 61.2699 44.1274 0.0000 )      u=3
332 like 302 but     trcl = ( 61.2699 44.1274 0.0000 )      u=3 $ Assembly 16
333 0         -302 #334  fill=6 ( -59.8729 26.4770 0.0000 )       $ Tube/Disk 17
          trcl = ( -59.8729 26.4770 0.0000 )      u=3
334 like 302 but     trcl = ( -59.8729 26.4770 0.0000 )      u=3 $ Assembly 17
335 0         -301 #336  fill=5 ( -42.5399 25.5245 0.0000 )       $ Tube/Disk 18
          trcl = ( -42.5399 25.5245 0.0000 )      u=3
336 like 302 but     trcl = ( -42.5399 25.5245 0.0000 )      u=3 $ Assembly 18
337 0         -301 #338  fill=5 ( -25.5245 25.5245 0.0000 )       $ Tube/Disk 19
          trcl = ( -25.5245 25.5245 0.0000 )      u=3
338 like 302 but     trcl = ( -25.5245 25.5245 0.0000 )      u=3 $ Assembly 19
339 0         -301 #340  fill=5 ( -8.5090 25.5245 0.0000 )       $ Tube/Disk 20
          trcl = ( -8.5090 25.5245 0.0000 )      u=3
340 like 302 but     trcl = ( -8.5090 25.5245 0.0000 )      u=3 $ Assembly 20
341 0         -301 #342  fill=5 ( 8.5090 25.5245 0.0000 )       $ Tube/Disk 21
          trcl = ( 8.5090 25.5245 0.0000 )      u=3
342 like 302 but     trcl = ( 8.5090 25.5245 0.0000 )      u=3 $ Assembly 21
343 0         -301 #344  fill=5 ( 25.5245 25.5245 0.0000 )       $ Tube/Disk 22
          trcl = ( 25.5245 25.5245 0.0000 )      u=3
344 like 302 but     trcl = ( 25.5245 25.5245 0.0000 )      u=3 $ Assembly 22
345 0         -301 #346  fill=5 ( 42.5399 25.5245 0.0000 )       $ Tube/Disk 23
          trcl = ( 42.5399 25.5245 0.0000 )      u=3
346 like 302 but     trcl = ( 42.5399 25.5245 0.0000 )      u=3 $ Assembly 23
347 0         -302 #348  fill=7 ( 59.8729 26.4770 0.0000 )       $ Tube/Disk 24
          trcl = ( 59.8729 26.4770 0.0000 )      u=3
348 like 302 but     trcl = ( 59.8729 26.4770 0.0000 )      u=3 $ Assembly 24
349 0         -302 #350  fill=8 ( -77.5233 8.8265 0.0000 )       $ Tube/Disk 25
          trcl = ( -77.5233 8.8265 0.0000 )      u=3
350 like 302 but     trcl = ( -77.5233 8.8265 0.0000 )      u=3 $ Assembly 25
351 0         -302 #352  fill=6 ( -59.8729 8.8265 0.0000 )       $ Tube/Disk 26
          trcl = ( -59.8729 8.8265 0.0000 )      u=3
352 like 302 but     trcl = ( -59.8729 8.8265 0.0000 )      u=3 $ Assembly 26
353 0         -301 #354  fill=5 ( -42.5399 8.5090 0.0000 )       $ Tube/Disk 27
          trcl = ( -42.5399 8.5090 0.0000 )      u=3
354 like 302 but     trcl = ( -42.5399 8.5090 0.0000 )      u=3 $ Assembly 27
355 0         -301 #356  fill=5 ( -25.5245 8.5090 0.0000 )       $ Tube/Disk 28
          trcl = ( -25.5245 8.5090 0.0000 )      u=3
356 like 302 but     trcl = ( -25.5245 8.5090 0.0000 )      u=3 $ Assembly 28
357 0         -301 #358  fill=5 ( -8.5090 8.5090 0.0000 )       $ Tube/Disk 29
          trcl = ( -8.5090 8.5090 0.0000 )      u=3
358 like 302 but     trcl = ( -8.5090 8.5090 0.0000 )      u=3 $ Assembly 29
359 0         -301 #360  fill=5 ( 8.5090 8.5090 0.0000 )       $ Tube/Disk 30
          trcl = ( 8.5090 8.5090 0.0000 )      u=3
360 like 302 but     trcl = ( 8.5090 8.5090 0.0000 )      u=3 $ Assembly 30
361 0         -301 #362  fill=5 ( 25.5245 8.5090 0.0000 )       $ Tube/Disk 31
          trcl = ( 25.5245 8.5090 0.0000 )      u=3
362 like 302 but     trcl = ( 25.5245 8.5090 0.0000 )      u=3 $ Assembly 31
363 0         -301 #364  fill=5 ( 42.5399 8.5090 0.0000 )       $ Tube/Disk 32
          trcl = ( 42.5399 8.5090 0.0000 )      u=3
364 like 302 but     trcl = ( 42.5399 8.5090 0.0000 )      u=3 $ Assembly 32
365 0         -302 #366  fill=6 ( 59.8729 8.8265 0.0000 )       $ Tube/Disk 33
          trcl = ( 59.8729 8.8265 0.0000 )      u=3
366 like 302 but     trcl = ( 59.8729 8.8265 0.0000 )      u=3 $ Assembly 33
367 0         -302 #368  fill=9 ( 77.5233 8.8265 0.0000 )       $ Tube/Disk 34
          trcl = ( 77.5233 8.8265 0.0000 )      u=3
368 like 302 but     trcl = ( 77.5233 8.8265 0.0000 )      u=3 $ Assembly 34
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
369 0          -302 #370  fill=6 ( -77.5233 -8.8265 0.0000 )      $ Tube/Disk 35
           trcl = ( -77.5233 -8.8265 0.0000 )      u=3
370 like 302 but      trcl = ( -77.5233 -8.8265 0.0000 )      u=3 $ Assembly 35
371 0          -302 #372  fill=6 ( -59.8729 -8.8265 0.0000 )      $ Tube/Disk 36
           trcl = ( -59.8729 -8.8265 0.0000 )      u=3
372 like 302 but      trcl = ( -59.8729 -8.8265 0.0000 )      u=3 $ Assembly 36
373 0          -301 #374  fill=5 ( -42.5399 -8.5090 0.0000 )      $ Tube/Disk 37
           trcl = ( -42.5399 -8.5090 0.0000 )      u=3
374 like 302 but      trcl = ( -42.5399 -8.5090 0.0000 )      u=3 $ Assembly 37
375 0          -301 #376  fill=5 ( -25.5245 -8.5090 0.0000 )      $ Tube/Disk 38
           trcl = ( -25.5245 -8.5090 0.0000 )      u=3
376 like 302 but      trcl = ( -25.5245 -8.5090 0.0000 )      u=3 $ Assembly 38
377 0          -301 #378  fill=5 ( -8.5090 -8.5090 0.0000 )      $ Tube/Disk 39
           trcl = ( -8.5090 -8.5090 0.0000 )      u=3
378 like 302 but      trcl = ( -8.5090 -8.5090 0.0000 )      u=3 $ Assembly 39
379 0          -301 #380  fill=5 ( 8.5090 -8.5090 0.0000 )      $ Tube/Disk 40
           trcl = ( 8.5090 -8.5090 0.0000 )      u=3
380 like 302 but      trcl = ( 8.5090 -8.5090 0.0000 )      u=3 $ Assembly 40
381 0          -301 #382  fill=5 ( 25.5245 -8.5090 0.0000 )      $ Tube/Disk 41
           trcl = ( 25.5245 -8.5090 0.0000 )      u=3
382 like 302 but      trcl = ( 25.5245 -8.5090 0.0000 )      u=3 $ Assembly 41
383 0          -301 #384  fill=5 ( 42.5399 -8.5090 0.0000 )      $ Tube/Disk 42
           trcl = ( 42.5399 -8.5090 0.0000 )      u=3
384 like 302 but      trcl = ( 42.5399 -8.5090 0.0000 )      u=3 $ Assembly 42
385 0          -302 #386  fill=6 ( 59.8729 -8.8265 0.0000 )      $ Tube/Disk 43
           trcl = ( 59.8729 -8.8265 0.0000 )      u=3
386 like 302 but      trcl = ( 59.8729 -8.8265 0.0000 )      u=3 $ Assembly 43
387 0          -302 #388  fill=7 ( 77.5233 -8.8265 0.0000 )      $ Tube/Disk 44
           trcl = ( 77.5233 -8.8265 0.0000 )      u=3
388 like 302 but      trcl = ( 77.5233 -8.8265 0.0000 )      u=3 $ Assembly 44
389 0          -302 #390  fill=6 ( -59.8729 -26.4770 0.0000 )      $ Tube/Disk 45
           trcl = ( -59.8729 -26.4770 0.0000 )      u=3
390 like 302 but      trcl = ( -59.8729 -26.4770 0.0000 )      u=3 $ Assembly 45
391 0          -301 #392  fill=5 ( -42.5399 -25.5245 0.0000 )      $ Tube/Disk 46
           trcl = ( -42.5399 -25.5245 0.0000 )      u=3
392 like 302 but      trcl = ( -42.5399 -25.5245 0.0000 )      u=3 $ Assembly 46
393 0          -301 #394  fill=5 ( -25.5245 -25.5245 0.0000 )      $ Tube/Disk 47
           trcl = ( -25.5245 -25.5245 0.0000 )      u=3
394 like 302 but      trcl = ( -25.5245 -25.5245 0.0000 )      u=3 $ Assembly 47
395 0          -301 #396  fill=5 ( -8.5090 -25.5245 0.0000 )      $ Tube/Disk 48
           trcl = ( -8.5090 -25.5245 0.0000 )      u=3
396 like 302 but      trcl = ( -8.5090 -25.5245 0.0000 )      u=3 $ Assembly 48
397 0          -301 #398  fill=5 ( 8.5090 -25.5245 0.0000 )      $ Tube/Disk 49
           trcl = ( 8.5090 -25.5245 0.0000 )      u=3
398 like 302 but      trcl = ( 8.5090 -25.5245 0.0000 )      u=3 $ Assembly 49
399 0          -301 #400  fill=5 ( 25.5245 -25.5245 0.0000 )      $ Tube/Disk 50
           trcl = ( 25.5245 -25.5245 0.0000 )      u=3
400 like 302 but      trcl = ( 25.5245 -25.5245 0.0000 )      u=3 $ Assembly 50
401 0          -301 #402  fill=5 ( 42.5399 -25.5245 0.0000 )      $ Tube/Disk 51
           trcl = ( 42.5399 -25.5245 0.0000 )      u=3
402 like 302 but      trcl = ( 42.5399 -25.5245 0.0000 )      u=3 $ Assembly 51
403 0          -302 #404  fill=7 ( 59.8729 -26.4770 0.0000 )      $ Tube/Disk 52
           trcl = ( 59.8729 -26.4770 0.0000 )      u=3
404 like 302 but      trcl = ( 59.8729 -26.4770 0.0000 )      u=3 $ Assembly 52
405 0          -302 #406  fill=6 ( -61.2699 -44.1274 0.0000 )      $ Tube/Disk 53
           trcl = ( -61.2699 -44.1274 0.0000 )      u=3
406 like 302 but      trcl = ( -61.2699 -44.1274 0.0000 )      u=3 $ Assembly 53
407 0          -301 #408  fill=5 ( -42.5399 -42.5399 0.0000 )      $ Tube/Disk 54
           trcl = ( -42.5399 -42.5399 0.0000 )      u=3
408 like 302 but      trcl = ( -42.5399 -42.5399 0.0000 )      u=3 $ Assembly 54
409 0          -301 #410  fill=5 ( -25.5245 -42.5399 0.0000 )      $ Tube/Disk 55
           trcl = ( -25.5245 -42.5399 0.0000 )      u=3
410 like 302 but      trcl = ( -25.5245 -42.5399 0.0000 )      u=3 $ Assembly 55
411 0          -301 #412  fill=5 ( -8.5090 -42.5399 0.0000 )      $ Tube/Disk 56
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
          trcl = ( -8.5090 -42.5399 0.0000 )      u=3
412 like 302 but      trcl = ( -8.5090 -42.5399 0.0000 )      u=3 $ Assembly 56
413 0          -301 #414  fill=5 ( 8.5090 -42.5399 0.0000 )      $ Tube/Disk 57
          trcl = ( 8.5090 -42.5399 0.0000 )      u=3
414 like 302 but      trcl = ( 8.5090 -42.5399 0.0000 )      u=3 $ Assembly 57
415 0          -301 #416  fill=5 ( 25.5245 -42.5399 0.0000 )      $ Tube/Disk 58
          trcl = ( 25.5245 -42.5399 0.0000 )      u=3
416 like 302 but      trcl = ( 25.5245 -42.5399 0.0000 )      u=3 $ Assembly 58
417 0          -301 #418  fill=5 ( 42.5399 -42.5399 0.0000 )      $ Tube/Disk 59
          trcl = ( 42.5399 -42.5399 0.0000 )      u=3
418 like 302 but      trcl = ( 42.5399 -42.5399 0.0000 )      u=3 $ Assembly 59
419 0          -302 #420  fill=7 ( 61.2699 -44.1274 0.0000 )      $ Tube/Disk 60
          trcl = ( 61.2699 -44.1274 0.0000 )      u=3
420 like 302 but      trcl = ( 61.2699 -44.1274 0.0000 )      u=3 $ Assembly 60
421 0          -302 #422  fill=6 ( -44.1274 -61.2699 0.0000 )      $ Tube/Disk 61
          trcl = ( -44.1274 -61.2699 0.0000 )      u=3
422 like 302 but      trcl = ( -44.1274 -61.2699 0.0000 )      u=3 $ Assembly 61
423 0          -302 #424  fill=6 ( -26.4770 -59.8729 0.0000 )      $ Tube/Disk 62
          trcl = ( -26.4770 -59.8729 0.0000 )      u=3
424 like 302 but      trcl = ( -26.4770 -59.8729 0.0000 )      u=3 $ Assembly 62
425 0          -302 #426  fill=6 ( -8.8265 -59.8729 0.0000 )      $ Tube/Disk 63
          trcl = ( -8.8265 -59.8729 0.0000 )      u=3
426 like 302 but      trcl = ( -8.8265 -59.8729 0.0000 )      u=3 $ Assembly 63
427 0          -302 #428  fill=6 ( 8.8265 -59.8729 0.0000 )      $ Tube/Disk 64
          trcl = ( 8.8265 -59.8729 0.0000 )      u=3
428 like 302 but      trcl = ( 8.8265 -59.8729 0.0000 )      u=3 $ Assembly 64
429 0          -302 #430  fill=6 ( 26.4770 -59.8729 0.0000 )      $ Tube/Disk 65
          trcl = ( 26.4770 -59.8729 0.0000 )      u=3
430 like 302 but      trcl = ( 26.4770 -59.8729 0.0000 )      u=3 $ Assembly 65
431 0          -302 #432  fill=7 ( 44.1274 -61.2699 0.0000 )      $ Tube/Disk 66
          trcl = ( 44.1274 -61.2699 0.0000 )      u=3
432 like 302 but      trcl = ( 44.1274 -61.2699 0.0000 )      u=3 $ Assembly 66
433 0          -302 #434  fill=7 ( -8.8265 -77.5233 0.0000 )      $ Tube/Disk 67
          trcl = ( -8.8265 -77.5233 0.0000 )      u=3
434 like 302 but      trcl = ( -8.8265 -77.5233 0.0000 )      u=3 $ Assembly 67
435 0          -302 #436  fill=7 ( 8.8265 -77.5233 0.0000 )      $ Tube/Disk 68
          trcl = ( 8.8265 -77.5233 0.0000 )      u=3
436 like 302 but      trcl = ( 8.8265 -77.5233 0.0000 )      u=3 $ Assembly 68
437 0          +303 +304        $ Canister Cavity Q1
      #303 #311 #313 #315 #325 #327 #329 #331 #341
      #304 #312 #314 #316 #326 #328 #330 #332 #342
      #343 #345 #347 #359 #361 #363 #365 #367
      #344 #346 #348 #360 #362 #364 #366 #368
          fill=4      u=3
438 0          +303 -304        $ Canister Cavity Q2
      #301 #305 #307 #309 #317 #319 #321 #323 #333
      #302 #306 #308 #310 #318 #320 #322 #324 #334
      #335 #337 #339 #349 #351 #353 #355 #357
      #336 #338 #340 #350 #352 #354 #356 #358
          fill=4      u=3
439 0          -303 -304        $ Canister Cavity Q3
      #369 #371 #373 #375 #377 #389 #391 #393 #395
      #370 #372 #374 #376 #378 #390 #392 #394 #396
      #405 #407 #409 #411 #421 #423 #425 #433
      #406 #408 #410 #412 #422 #424 #426 #434
          fill=4      u=3
440 0          -303 +304        $ Canister Cavity Q4
      #379 #381 #383 #385 #387 #397 #399 #401 #403
      #380 #382 #384 #386 #388 #398 #400 #402 #404
      #413 #415 #417 #419 #427 #429 #431 #435
      #414 #416 #418 #420 #428 #430 #432 #436
          fill=4      u=3
C Cells - Canister v1.0
501 0          -501 fill=3      u=2 $ Cavity
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
502 6 -7.9400 -507 +501.3      u=2 $ Canister Bottom
503 0         -502 +501.2 -505 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Bottom Drain Port
504 0         -503 +505 -506 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Middle Drain Port
505 6 -7.9400 -504 +506 -507.2 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Top Drain Port
506 like 503 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Bottom Vent Port
507 like 504 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Middle Vent Port
508 like 505 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Top Vent Port
509 6 -7.9400 -507 -501.3 +501.1     u=2 $ Canister Shell
510 6 -7.9400 -507 -501.1 +501.2 #503 #504 #505 #506 #507 #508     u=2 $ Lid
511 0         +507       u=2 $ Outside
c Cell Cards - Storage Cask Geometry v4.0
601 7 -7.8212 -605        u=1 $ Base Plate
602 0         (-614 +612 -601         $ Air Inlet Channel Void
              +643 +644 +645 +646
              +651 +652 +653 +654) :
              (-614 +613 -612 +618)        u=1
603 7 -7.8212 -615 +614 +612 -601     u=1 $ Air Inlet Channel Mat
604 0         (-616 +612 -601         $ Air Inlet Channel Void
              +647 +648 +649 +650
              +655 +656 +657 +658) :
              (-616 +613 -612 +618)        u=1
605 7 -7.8212 -617 +616 +612 -601     u=1 $ Air Inlet Channel Mat
606 0         -619 -612 +613      u=1 $ Stand Cut-Out Top
607 like 606 but *trcl = (0 0 0 90 180 90 0 90 90 90 90 0)      u=1 $ Stand Cut-Out Top
608 7 -7.8212 -601 -612 +613 +618 +605 +614 +616 #606 #607  u=1 $ Stand Material
609 7 -7.8212 (-601 -612 -618) : (-601 +612 -618 +615 +617)        u=1 $ Bottom Plate
610 7 -7.8212 (-606 +607 +618 -610) : (-608 +609 +610 -611)        u=1 $ Baffle Cone Mat
611 0         (-607 +618 -610) : (-609 +610 -611)        u=1 $ Baffle Cone Int. Void
612 0         -613 +618 -611 +606 +608    u=1 $ Void inside stand - A
613 0         -601 -613 +611 +605     u=1 $ Void inside stand - B
614 0         -601 -603 +612 +618 +605 +615 +617  u=1 $ Void stand to liner
615 7 -7.8212 -601 -604 +603 +618 +615 +617   u=1 $ Liner
616 12 -2.3233 -601 +604 +618 +615 +617    u=1 $ Concrete
617 7 -7.8212 -620        u=1 $ VCC Lid
618 7 -7.8212 -621 +622       u=1 $ TopFlange
619 0         -621 -622 +603 +623     u=1 $ Void Cavity to Flange
620 12 -2.3233 -624        u=1 $ Lid Concrete
621 7 -7.8212 -623 +624       u=1 $ Lid Cover
622 12 -2.3233 (-626 +604) : (-627 -602 +628)        u=1 $ Concrete - Outlet Box
623 0         (-629 +630 +604) : (-631 +629 -602)        u=1 $ Air Outlet Void
624 7 -7.8212 -625 -602 +604 #622 #623      u=1 $ Air Outlet Steel
625 12 -2.3233 (-633 +604) : (-634 -602 +635)        u=1 $ Concrete - Outlet Box
626 0         (-636 +637 +604) : (-638 +636 -602)        u=1 $ Air Outlet Void
627 7 -7.8212 -632 -602 +604 #625 #626      u=1 $ Air Outlet Steel
628 12 -2.3233 -602 +604 +621 #622 #623 #624 #625 #626 #627    fill=11  u=1 $ Concrete
629 0         (-639 -641 +603) : (-640 -604 +641)        u=1 $ Air Outlet Liner Void
630 like 629 but *trcl = (0 0 0 90 180 90 0 90 90 90 90 0)      u=1 $ Air Outlet Liner Void
631 7 -7.8212 -602 -604 +603 +621 #629 #630     u=1 $ Liner Minus Voids
632 0         -602 -603 +623  fill=2 ( 0.0000 0.0000 2.5400 )    u=1 $ Cavity
633 12 -2.3233 -642        u=1 $ Concrete pad
634 7 -7.8212 -643 : -644 : -645 : -646        u=1 $ Air inlet pipes +x+y
635 7 -7.8212 -647 : -648 : -649 : -650        u=1 $ Air inlet pipes -x-y
636 7 -7.8212 -651 : -652 : -653 : -654        u=1 $ Air inlet pipes -x+y
637 7 -7.8212 -655 : -656 : -657 : -658        u=1 $ Air inlet pipes +x-y
638 0         +601 +602 +620 +642 #602 #603 #604 #605     u=1 $ Container
C VCC Rebar Cells - v4.0
639 7 -7.8212 -659      u=11 $ Inner hoop 1
640 7 -7.8212 -660      u=11 $ Inner hoop 2
641 7 -7.8212 -661      u=11 $ Inner hoop 3
642 7 -7.8212 -662      u=11 $ Inner hoop 4
643 7 -7.8212 -663      u=11 $ Inner hoop 5
644 7 -7.8212 -664      u=11 $ Inner hoop 6
645 7 -7.8212 -665      u=11 $ Inner hoop 7
646 7 -7.8212 -666      u=11 $ Inner hoop 8
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
647 7 -7.8212 -667      u=11 $ Inner hoop 9
648 7 -7.8212 -668      u=11 $ Inner hoop 10
649 7 -7.8212 -669      u=11 $ Inner hoop 11
650 7 -7.8212 -670      u=11 $ Inner hoop 12
651 7 -7.8212 -671      u=11 $ Inner hoop 13
652 7 -7.8212 -672      u=11 $ Inner hoop 14
653 7 -7.8212 -673      u=11 $ Inner hoop 15
654 7 -7.8212 -674      u=11 $ Inner hoop 16
655 7 -7.8212 -675      u=11 $ Inner hoop 17
656 7 -7.8212 -676      u=11 $ Outer hoop 1
657 7 -7.8212 -677      u=11 $ Outer hoop 2
658 7 -7.8212 -678      u=11 $ Outer hoop 3
659 7 -7.8212 -679      u=11 $ Outer hoop 4
660 7 -7.8212 -680      u=11 $ Outer hoop 5
661 7 -7.8212 -681      u=11 $ Outer hoop 6
662 7 -7.8212 -682      u=11 $ Outer hoop 7
663 7 -7.8212 -683      u=11 $ Outer hoop 8
664 7 -7.8212 -684      u=11 $ Outer hoop 9
665 7 -7.8212 -685      u=11 $ Outer hoop 10
666 7 -7.8212 -686      u=11 $ Outer hoop 11
667 7 -7.8212 -687      u=11 $ Outer hoop 12
668 7 -7.8212 -688      u=11 $ Outer hoop 13
669 7 -7.8212 -689      u=11 $ Outer hoop 14
670 7 -7.8212 -690      u=11 $ Outer hoop 15
671 7 -7.8212 -691      u=11 $ Outer hoop 16
672 7 -7.8212 -692      u=11 $ Outer hoop 17
673 7 -7.8212 -693      u=11 $ Outer hoop 18
674 7 -7.8212 -694      u=11 $ Outer hoop 19
675 7 -7.8212 -695      u=11 $ Outer hoop 20
676 7 -7.8212 -696      u=11 $ Outer hoop 21
677 7 -7.8212 -697      u=11 $ Outer hoop 22
678 7 -7.8212 -698      u=11 $ Outer hoop 23
679 7 -7.8212 -699      u=11 $ Outer hoop 24
680 7 -7.8212 -700      u=11 $ Outer hoop 25
681 7 -7.8212 -701      u=11 $ Outer hoop 26
682 7 -7.8212 -702      u=11 $ Outer hoop 27
683 7 -7.8212 -703      u=11 $ Outer hoop 28
684 7 -7.8212 -704      u=11 $ Outer hoop 29
685 7 -7.8212 -705      u=11 $ Outer hoop 30
686 7 -7.8212 -706      u=11 $ Outer hoop 31
687 7 -7.8212 -707      u=11 $ Outer hoop 32
688 7 -7.8212 -708      u=11 $ Outer hoop 33
689 7 -7.8212 -709      u=11 $ Outer hoop 34
690 12 -2.3233 #639 #640 #641 #642 #643 #644 #645 #646 #647 #648        $ Concrete
               #649 #650 #651 #652 #653 #654 #655 #656 #657 #658
               #659 #660 #661 #662 #663 #664 #665 #666 #667 #668
               #669 #670 #671 #672 #673 #674 #675 #676 #677 #678
               #679 #680 #681 #682 #683 #684 #685 #686 #687 #688
               #689      fill=12 u=11
691 7 -7.8212 -710  trcl = ( 115.2525 0.0000 0.0000 )    u=12 $ Inner bar 1
692 like 691 but  trcl = ( 113.5016 20.0134 0.0000 )    u=12 $ Inner bar 2
693 like 691 but  trcl = ( 108.3019 39.4187 0.0000 )    u=12 $ Inner bar 3
694 like 691 but  trcl = ( 99.8116 57.6263 0.0000 )    u=12 $ Inner bar 4
695 like 691 but  trcl = ( 88.2885 74.0829 0.0000 )    u=12 $ Inner bar 5
696 like 691 but  trcl = ( 74.0829 88.2885 0.0000 )    u=12 $ Inner bar 6
697 like 691 but  trcl = ( 57.6263 99.8116 0.0000 )    u=12 $ Inner bar 7
698 like 691 but  trcl = ( 39.4187 108.3019 0.0000 )    u=12 $ Inner bar 8
699 like 691 but  trcl = ( 20.0134 113.5016 0.0000 )    u=12 $ Inner bar 9
700 like 691 but  trcl = ( 0.0000 115.2525 0.0000 )    u=12 $ Inner bar 10
701 like 691 but  trcl = ( -20.0134 113.5016 0.0000 )    u=12 $ Inner bar 11
702 like 691 but  trcl = ( -39.4187 108.3019 0.0000 )    u=12 $ Inner bar 12
703 like 691 but  trcl = ( -57.6263 99.8116 0.0000 )    u=12 $ Inner bar 13
704 like 691 but  trcl = ( -74.0829 88.2885 0.0000 )    u=12 $ Inner bar 14
705 like 691 but  trcl = ( -88.2885 74.0829 0.0000 )    u=12 $ Inner bar 15
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
706 like 691 but  trcl = ( -99.8116 57.6263 0.0000 )    u=12 $ Inner bar 16
707 like 691 but  trcl = ( -108.3019 39.4187 0.0000 )    u=12 $ Inner bar 17
708 like 691 but  trcl = ( -113.5016 20.0134 0.0000 )    u=12 $ Inner bar 18
709 like 691 but  trcl = ( -115.2525 0.0000 0.0000 )    u=12 $ Inner bar 19
710 like 691 but  trcl = ( -113.5016 -20.0134 0.0000 )    u=12 $ Inner bar 20
711 like 691 but  trcl = ( -108.3019 -39.4187 0.0000 )    u=12 $ Inner bar 21
712 like 691 but  trcl = ( -99.8116 -57.6262 0.0000 )    u=12 $ Inner bar 22
713 like 691 but  trcl = ( -88.2885 -74.0829 0.0000 )    u=12 $ Inner bar 23
714 like 691 but  trcl = ( -74.0829 -88.2885 0.0000 )    u=12 $ Inner bar 24
715 like 691 but  trcl = ( -57.6263 -99.8116 0.0000 )    u=12 $ Inner bar 25
716 like 691 but  trcl = ( -39.4187 -108.3019 0.0000 )    u=12 $ Inner bar 26
717 like 691 but  trcl = ( -20.0134 -113.5016 0.0000 )    u=12 $ Inner bar 27
718 like 691 but  trcl = ( 0.0000 -115.2525 0.0000 )    u=12 $ Inner bar 28
719 like 691 but  trcl = ( 20.0134 -113.5016 0.0000 )    u=12 $ Inner bar 29
720 like 691 but  trcl = ( 39.4187 -108.3019 0.0000 )    u=12 $ Inner bar 30
721 like 691 but  trcl = ( 57.6262 -99.8116 0.0000 )    u=12 $ Inner bar 31
722 like 691 but  trcl = ( 74.0829 -88.2885 0.0000 )    u=12 $ Inner bar 32
723 like 691 but  trcl = ( 88.2885 -74.0829 0.0000 )    u=12 $ Inner bar 33
724 like 691 but  trcl = ( 99.8116 -57.6263 0.0000 )    u=12 $ Inner bar 34
725 like 691 but  trcl = ( 108.3019 -39.4187 0.0000 )    u=12 $ Inner bar 35
726 like 691 but  trcl = ( 113.5016 -20.0134 0.0000 )    u=12 $ Inner bar 36
727 like 691 but  trcl = ( 149.5425 0.0000 0.0000 )    u=12 $ Outer bar 1
728 like 691 but  trcl = ( 148.6022 16.7434 0.0000 )    u=12 $ Outer bar 2
729 like 691 but  trcl = ( 145.7932 33.2763 0.0000 )    u=12 $ Outer bar 3
730 like 691 but  trcl = ( 141.1507 49.3908 0.0000 )    u=12 $ Outer bar 4
731 like 691 but  trcl = ( 134.7331 64.8841 0.0000 )    u=12 $ Outer bar 5
732 like 691 but  trcl = ( 126.6213 79.5614 0.0000 )    u=12 $ Outer bar 6
733 like 691 but  trcl = ( 116.9170 93.2382 0.0000 )    u=12 $ Outer bar 7
734 like 691 but  trcl = ( 105.7425 105.7425 0.0000 )    u=12 $ Outer bar 8
735 like 691 but  trcl = ( 93.2382 116.9170 0.0000 )    u=12 $ Outer bar 9
736 like 691 but  trcl = ( 79.5614 126.6213 0.0000 )    u=12 $ Outer bar 10
737 like 691 but  trcl = ( 64.8841 134.7331 0.0000 )    u=12 $ Outer bar 11
738 like 691 but  trcl = ( 49.3908 141.1507 0.0000 )    u=12 $ Outer bar 12
739 like 691 but  trcl = ( 33.2763 145.7932 0.0000 )    u=12 $ Outer bar 13
740 like 691 but  trcl = ( 16.7434 148.6022 0.0000 )    u=12 $ Outer bar 14
741 like 691 but  trcl = ( 0.0000 149.5425 0.0000 )    u=12 $ Outer bar 15
742 like 691 but  trcl = ( -16.7434 148.6022 0.0000 )    u=12 $ Outer bar 16
743 like 691 but  trcl = ( -33.2763 145.7932 0.0000 )    u=12 $ Outer bar 17
744 like 691 but  trcl = ( -49.3908 141.1507 0.0000 )    u=12 $ Outer bar 18
745 like 691 but  trcl = ( -64.8841 134.7331 0.0000 )    u=12 $ Outer bar 19
746 like 691 but  trcl = ( -79.5614 126.6213 0.0000 )    u=12 $ Outer bar 20
747 like 691 but  trcl = ( -93.2382 116.9170 0.0000 )    u=12 $ Outer bar 21
748 like 691 but  trcl = ( -105.7425 105.7425 0.0000 )    u=12 $ Outer bar 22
749 like 691 but  trcl = ( -116.9170 93.2382 0.0000 )    u=12 $ Outer bar 23
750 like 691 but  trcl = ( -126.6213 79.5614 0.0000 )    u=12 $ Outer bar 24
751 like 691 but  trcl = ( -134.7331 64.8841 0.0000 )    u=12 $ Outer bar 25
752 like 691 but  trcl = ( -141.1507 49.3908 0.0000 )    u=12 $ Outer bar 26
753 like 691 but  trcl = ( -145.7932 33.2763 0.0000 )    u=12 $ Outer bar 27
754 like 691 but  trcl = ( -148.6022 16.7434 0.0000 )    u=12 $ Outer bar 28
755 like 691 but  trcl = ( -149.5425 0.0000 0.0000 )    u=12 $ Outer bar 29
756 like 691 but  trcl = ( -148.6022 -16.7434 0.0000 )    u=12 $ Outer bar 30
757 like 691 but  trcl = ( -145.7932 -33.2763 0.0000 )    u=12 $ Outer bar 31
758 like 691 but  trcl = ( -141.1507 -49.3908 0.0000 )    u=12 $ Outer bar 32
759 like 691 but  trcl = ( -134.7331 -64.8841 0.0000 )    u=12 $ Outer bar 33
760 like 691 but  trcl = ( -126.6213 -79.5614 0.0000 )    u=12 $ Outer bar 34
761 like 691 but  trcl = ( -116.9170 -93.2382 0.0000 )    u=12 $ Outer bar 35
762 like 691 but  trcl = ( -105.7425 -105.7425 0.0000 )    u=12 $ Outer bar 36
763 like 691 but  trcl = ( -93.2382 -116.9170 0.0000 )    u=12 $ Outer bar 37
764 like 691 but  trcl = ( -79.5614 -126.6213 0.0000 )    u=12 $ Outer bar 38
765 like 691 but  trcl = ( -64.8841 -134.7331 0.0000 )    u=12 $ Outer bar 39
766 like 691 but  trcl = ( -49.3908 -141.1507 0.0000 )    u=12 $ Outer bar 40
767 like 691 but  trcl = ( -33.2763 -145.7932 0.0000 )    u=12 $ Outer bar 41
768 like 691 but  trcl = ( -16.7434 -148.6022 0.0000 )    u=12 $ Outer bar 42
769 like 691 but  trcl = ( 0.0000 -149.5425 0.0000 )    u=12 $ Outer bar 43
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
770 like 691 but  trcl = ( 16.7434 -148.6022 0.0000 )    u=12 $ Outer bar 44
771 like 691 but  trcl = ( 33.2763 -145.7932 0.0000 )    u=12 $ Outer bar 45
772 like 691 but  trcl = ( 49.3908 -141.1507 0.0000 )    u=12 $ Outer bar 46
773 like 691 but  trcl = ( 64.8841 -134.7331 0.0000 )    u=12 $ Outer bar 47
774 like 691 but  trcl = ( 79.5614 -126.6213 0.0000 )    u=12 $ Outer bar 48
775 like 691 but  trcl = ( 93.2382 -116.9170 0.0000 )    u=12 $ Outer bar 49
776 like 691 but  trcl = ( 105.7425 -105.7425 0.0000 )    u=12 $ Outer bar 50
777 like 691 but  trcl = ( 116.9170 -93.2382 0.0000 )    u=12 $ Outer bar 51
778 like 691 but  trcl = ( 126.6213 -79.5614 0.0000 )    u=12 $ Outer bar 52
779 like 691 but  trcl = ( 134.7331 -64.8841 0.0000 )    u=12 $ Outer bar 53
780 like 691 but  trcl = ( 141.1507 -49.3908 0.0000 )    u=12 $ Outer bar 54
781 like 691 but  trcl = ( 145.7932 -33.2763 0.0000 )    u=12 $ Outer bar 55
782 like 691 but  trcl = ( 148.6022 -16.7434 0.0000 )    u=12 $ Outer bar 56
783 12 -2.3233 #691 #692 #693 #694 #695 #696 #697 #698 #699        $ Concrete
               #700 #701 #702 #703 #704 #705 #706 #707 #708 #709
               #710 #711 #712 #713 #714 #715 #716 #717 #718 #719
               #720 #721 #722 #723 #724 #725 #726 #727 #728 #729
               #730 #731 #732 #733 #734 #735 #736 #737 #738 #739
               #740 #741 #742 #743 #744 #745 #746 #747 #748 #749
               #750 #751 #752 #753 #754 #755 #756 #757 #758 #759
               #760 #761 #762 #763 #764 #765 #766 #767 #768 #769
               #770 #771 #772 #773 #774 #775 #776 #777 #778 #779
               #780 #781 #782       u=12
C Detector Cells - Radial Biasing
799  0  -799  fill=1  $ Cask
800  0  -800  +799  $ Surface
900  0  -900  +799  +800  $ 1ft
1000  0  -1000  +799  +800  +900  $ 1m
1100  0  -1100  +799  +800  +900  +1000  $ 2m
1200  0  -1200  +799  +800  +900  +1000  +1100  $ 4m
1300  0  +799  +800  +900  +1000  +1100  +1200  $ Exterior

C Fuel Assembly Surfaces - v1.0
1 RPP -7.1247 7.1247 -7.1247 7.1247 0.0000 261.9502  $ Assy
2 PZ 27.2796       $ Lower Nozzle/Fuel
3 PZ 238.0996       $ Fuel/Upper Plenum
4 PZ 251.1298       $ Upper Plenum/Upper Nozzle
C Surfaces - Standard Fuel Tube v1.0
101 RPP -7.3076 7.3076 -7.3076 7.3076 0.0000 274.4470    $ Tube void
102 RPP -7.4295 7.4295 -7.4295 7.4295 0.0000 249.5550    $ Tube
103 RPP -6.5913 6.5913 7.4295 7.6200 2.0320 245.8720    $ Absorber +Y
104 RPP -6.5913 6.5913 7.6200 7.6657 2.0320 245.8720    $ Cladding +Y
105 RPP 7.4295 7.6200 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
106 RPP 7.6200 7.6657 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
C Surfaces - DFC Fuel Tube v1.0
107 RPP -7.6251 7.6251 -7.6251 7.6251 0.0000 274.4470    $ Tube void
108 RPP -7.7470 7.7470 -7.7470 7.7470 0.0000 249.5550    $ Tube
109 RPP -6.5913 6.5913 7.7470 7.9375 2.0320 245.8720    $ Absorber +Y
110 RPP -6.5913 6.5913 7.9375 7.9832 2.0320 245.8720    $ Cladding +Y
111 RPP 7.7470 7.9375 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
112 RPP 7.9375 7.9832 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
c Surface Cards - Disk Stack  v1.0
201 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.1380 $ Structural disk
202 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.2700 87.7951 $ Heat transfer disk
203 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Weldment disk
c Surface Cards - Basket v1.0
301 RPP -7.7711 7.7711 -7.7711 7.7711 0.0000 274.4470  $ Std opening
302 RPP -8.0899 8.0899 -8.0899 8.0899 0.0000 274.4470  $ DFC opening
303 PY 0.0000       $ Cut plane
304 PX 0.0000       $ Cut plane
C Surfaces - Canister v1.0
501 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470 88.4428   $ Cavity
502 CZ 1.3843         $ Bot Cylinder Radius
503 CZ 5.0800         $ Mid Cyclinder Radius
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
504 CZ 5.7150          $ Top Cylinder Radius
505 PZ 282.8798          $ Port plane bot/mid
506 PZ 289.3822          $ Port plane mid/top
507 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670 89.7128   $ Canister
c Surface Cards - Storage Cask Geometry v4.0
601  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 -58.6740 162.5600 $ Bottom Section Container
602  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 352.5520 162.5600 $ Top Section Container (Not VCC
Lid)
603  CZ 100.3300        $ VCC liner inner
604  CZ 106.6800        $ VCC liner outer
605  RCC 0.0000 0.0000 -5.7150 0.0000 0.0000 5.7150 91.4400 $ Base plate/cover
606  KZ 47.2803 0.1357 -1      $ Baffle weldment bot
607  KZ 45.4435 0.1357 -1      $ Baffle weldment bot void
608  KZ -111.2883 0.1357 1      $ Baffle weldment top
609  KZ -109.4515 0.1357 1      $ Baffle weldment top void
610  PZ -32.0040        $ Baffle middle cut surface
611  PZ -7.8740        $ Baffle top cut surface
612  CZ 63.5000        $ Stand outer
613  CZ 58.4200        $ Stand inner
614 1 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
615 1 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
616 2 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
617 2 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
618  PZ -56.1340        $ Bottom plate height
619  RPP -25.6540 25.6540 -63.5001 63.5001 -25.6540 -5.7150  $ Stand top cut box
620  RCC 0.0000 0.0000 352.5520 0.0000 0.0000 3.8100 116.2050 $ VCC lid
621  RCC 0.0000 0.0000 347.4720 0.0000 0.0000 5.0800 124.3330 $ Top flange cylinder
622  CZ 102.8700        $ Top flange inner cut cylinder
623  RCC 0.0000 0.0000 331.2668 0.0000 0.0000 21.2852 99.0600 $ Lid concrete enclosure
624  RCC 0.0000 0.0000 332.2193 0.0000 0.0000 20.3327 98.1075 $ Lid concrete
625  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 336.8040  $ Box for outlet structure
(outside liner)
626  RPP -54.2290 54.2290 -127.0635 127.0635 315.7220 336.8040  $ Upper portion concrete
627  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 324.7390  $ Lower portion concrete
628  RPP -54.2290 54.2290 -143.2560 143.2560 303.6570 324.7390  $ Lower portion concrete cut
surface
629  RPP -53.2765 53.2765 -138.1760 138.1760 304.6095 335.8515  $ Lower/middle outlet void
630  RPP -53.2765 53.2765 -128.0160 128.0160 314.7695 335.8515  $ Cut box for lower/middle void
631  RPP -53.2765 53.2765 -162.5600 162.5600 325.6915 335.8515  $ Upper void
632  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 336.8040  $ Box for outlet structure
(outside liner)
633  RPP -127.0635 127.0635 -54.2290 54.2290 315.7220 336.8040  $ Upper portion concrete
634  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete
635  RPP -143.2560 143.2560 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete cut
surface
636  RPP -138.1760 138.1760 -53.2765 53.2765 304.6095 335.8515  $ Lower/middle outlet void
637  RPP -128.0160 128.0160 -53.2765 53.2765 314.7695 335.8515  $ Cut box for lower/middle void
638  RPP -162.5600 162.5600 -53.2765 53.2765 325.6915 335.8515  $ Upper void
639  RPP -54.2290 54.2290 -106.6800 106.6800 303.6570 315.7220  $ Outlet cut in liner
640  RPP -53.2765 53.2765 -106.6800 106.6800 304.6095 314.7695  $ Portion of outlet in liner
641  CZ 104.1400        $ Air outlet inner radius
642  RCC 0.0000 0.0000 -158.6740 0.0000 0.0000 100.0000 162.5600 $ Concrete pad
643 1 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 +x+y
644 1 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 +x+y
645 1 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 +x+y
646 1 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 +x+y
647 2 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 -x-y
648 2 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 -x-y
649 2 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 -x-y
650 2 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 -x-y
651 3 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 -x+y
652 3 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 -x+y
653 3 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 -x+y
654 3 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 -x+y
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
655 4 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 +x-y
656 4 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 +x-y
657 4 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 +x-y
658 4 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 +x-y
C VCC Rebar Surfaces - v4.0
659  TZ 0.0000 0.0000 2.2860 113.3475 0.9525 0.9525  $ Inner hoop 1
660  TZ 0.0000 0.0000 22.6060 113.3475 0.9525 0.9525  $ Inner hoop 2
661  TZ 0.0000 0.0000 42.9260 113.3475 0.9525 0.9525  $ Inner hoop 3
662  TZ 0.0000 0.0000 63.2460 113.3475 0.9525 0.9525  $ Inner hoop 4
663  TZ 0.0000 0.0000 83.5660 113.3475 0.9525 0.9525  $ Inner hoop 5
664  TZ 0.0000 0.0000 103.8860 113.3475 0.9525 0.9525  $ Inner hoop 6
665  TZ 0.0000 0.0000 124.2060 113.3475 0.9525 0.9525  $ Inner hoop 7
666  TZ 0.0000 0.0000 144.5260 113.3475 0.9525 0.9525  $ Inner hoop 8
667  TZ 0.0000 0.0000 164.8460 113.3475 0.9525 0.9525  $ Inner hoop 9
668  TZ 0.0000 0.0000 185.1660 113.3475 0.9525 0.9525  $ Inner hoop 10
669  TZ 0.0000 0.0000 205.4860 113.3475 0.9525 0.9525  $ Inner hoop 11
670  TZ 0.0000 0.0000 225.8060 113.3475 0.9525 0.9525  $ Inner hoop 12
671  TZ 0.0000 0.0000 246.1260 113.3475 0.9525 0.9525  $ Inner hoop 13
672  TZ 0.0000 0.0000 266.4460 113.3475 0.9525 0.9525  $ Inner hoop 14
673  TZ 0.0000 0.0000 286.7660 113.3475 0.9525 0.9525  $ Inner hoop 15
674  TZ 0.0000 0.0000 307.0860 113.3475 0.9525 0.9525  $ Inner hoop 16
675  TZ 0.0000 0.0000 327.4060 113.3475 0.9525 0.9525  $ Inner hoop 17
676  TZ 0.0000 0.0000 2.2860 151.4475 0.9525 0.9525  $ Outer hoop 1
677  TZ 0.0000 0.0000 12.4460 151.4475 0.9525 0.9525  $ Outer hoop 2
678  TZ 0.0000 0.0000 22.6060 151.4475 0.9525 0.9525  $ Outer hoop 3
679  TZ 0.0000 0.0000 32.7660 151.4475 0.9525 0.9525  $ Outer hoop 4
680  TZ 0.0000 0.0000 42.9260 151.4475 0.9525 0.9525  $ Outer hoop 5
681  TZ 0.0000 0.0000 53.0860 151.4475 0.9525 0.9525  $ Outer hoop 6
682  TZ 0.0000 0.0000 63.2460 151.4475 0.9525 0.9525  $ Outer hoop 7
683  TZ 0.0000 0.0000 73.4060 151.4475 0.9525 0.9525  $ Outer hoop 8
684  TZ 0.0000 0.0000 83.5660 151.4475 0.9525 0.9525  $ Outer hoop 9
685  TZ 0.0000 0.0000 93.7260 151.4475 0.9525 0.9525  $ Outer hoop 10
686  TZ 0.0000 0.0000 103.8860 151.4475 0.9525 0.9525  $ Outer hoop 11
687  TZ 0.0000 0.0000 114.0460 151.4475 0.9525 0.9525  $ Outer hoop 12
688  TZ 0.0000 0.0000 124.2060 151.4475 0.9525 0.9525  $ Outer hoop 13
689  TZ 0.0000 0.0000 134.3660 151.4475 0.9525 0.9525  $ Outer hoop 14
690  TZ 0.0000 0.0000 144.5260 151.4475 0.9525 0.9525  $ Outer hoop 15
691  TZ 0.0000 0.0000 154.6860 151.4475 0.9525 0.9525  $ Outer hoop 16
692  TZ 0.0000 0.0000 164.8460 151.4475 0.9525 0.9525  $ Outer hoop 17
693  TZ 0.0000 0.0000 175.0060 151.4475 0.9525 0.9525  $ Outer hoop 18
694  TZ 0.0000 0.0000 185.1660 151.4475 0.9525 0.9525  $ Outer hoop 19
695  TZ 0.0000 0.0000 195.3260 151.4475 0.9525 0.9525  $ Outer hoop 20
696  TZ 0.0000 0.0000 205.4860 151.4475 0.9525 0.9525  $ Outer hoop 21
697  TZ 0.0000 0.0000 215.6460 151.4475 0.9525 0.9525  $ Outer hoop 22
698  TZ 0.0000 0.0000 225.8060 151.4475 0.9525 0.9525  $ Outer hoop 23
699  TZ 0.0000 0.0000 235.9660 151.4475 0.9525 0.9525  $ Outer hoop 24
700  TZ 0.0000 0.0000 246.1260 151.4475 0.9525 0.9525  $ Outer hoop 25
701  TZ 0.0000 0.0000 256.2860 151.4475 0.9525 0.9525  $ Outer hoop 26
702  TZ 0.0000 0.0000 266.4460 151.4475 0.9525 0.9525  $ Outer hoop 27
703  TZ 0.0000 0.0000 276.6060 151.4475 0.9525 0.9525  $ Outer hoop 28
704  TZ 0.0000 0.0000 286.7660 151.4475 0.9525 0.9525  $ Outer hoop 29
705  TZ 0.0000 0.0000 296.9260 151.4475 0.9525 0.9525  $ Outer hoop 30
706  TZ 0.0000 0.0000 307.0860 151.4475 0.9525 0.9525  $ Outer hoop 31
707  TZ 0.0000 0.0000 317.2460 151.4475 0.9525 0.9525  $ Outer hoop 32
708  TZ 0.0000 0.0000 327.4060 151.4475 0.9525 0.9525  $ Outer hoop 33
709  TZ 0.0000 0.0000 337.5660 151.4475 0.9525 0.9525  $ Outer hoop 34
710  RCC 0.0000 0.0000 2.2860 0.0000 0.0000 332.7400 0.9525 $ Bar
C Storage Cask & Pad Container
799  RCC  0.0000  0.0000  -158.6740  0.0000  0.0000  515.0360  162.5601
C Radial Detector DRA (Surface)
800  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  415.1360  162.6601
801  PZ  -24.0793
802  PZ  10.5153
803  PZ  45.1100
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
804  PZ  79.7047
805  PZ  114.2993
806  PZ  148.8940
807  PZ  183.4887
808  PZ  218.0833
809  PZ  252.6780
810  PZ  287.2727
811  PZ  321.8673
C Radial Detector DRB (1ft)
900  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  445.6160  193.0401
901  PZ  -21.5393
902  PZ  15.5953
903  PZ  52.7300
904  PZ  89.8647
905  PZ  126.9993
906  PZ  164.1340
907  PZ  201.2687
908  PZ  238.4033
909  PZ  275.5380
910  PZ  312.6727
911  PZ  349.8073
C Radial Detector DRC (1m)
1000  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  515.1360  262.5601
1001  PZ  -15.7460
1002  PZ  27.1820
1003  PZ  70.1100
1004  PZ  113.0380
1005  PZ  155.9660
1006  PZ  198.8940
1007  PZ  241.8220
1008  PZ  284.7500
1009  PZ  327.6780
1010  PZ  370.6060
1011  PZ  413.5340
C Radial Detector DRD (2m)
1100  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  615.1360  362.5601
1101  PZ  -27.9172
1102  PZ  2.8396
1103  PZ  33.5964
1104  PZ  64.3532
1105  PZ  95.1100
1106  PZ  125.8668
1107  PZ  156.6236
1108  PZ  187.3804
1109  PZ  218.1372
1110  PZ  248.8940
1111  PZ  279.6508
1112  PZ  310.4076
1113  PZ  341.1644
1114  PZ  371.9212
1115  PZ  402.6780
1116  PZ  433.4348
1117  PZ  464.1916
1118  PZ  494.9484
1119  PZ  525.7052
C Radial Detector DRE (4m)
1200  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  815.1360  562.5601
1201  PZ  -17.9172
1202  PZ  22.8396
1203  PZ  63.5964
1204  PZ  104.3532
1205  PZ  145.1100
1206  PZ  185.8668
1207  PZ  226.6236
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
1208  PZ  267.3804
1209  PZ  308.1372
1210  PZ  348.8940
1211  PZ  389.6508
1212  PZ  430.4076
1213  PZ  471.1644
1214  PZ  511.9212
1215  PZ  552.6780
1216  PZ  593.4348
1217  PZ  634.1916
1218  PZ  674.9484
1219  PZ  715.7052

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized UO2 Fuel
m2     24000 -2.9967E-02
       25055 -3.1544E-03
       26000 -1.0961E-01
       28000 -1.4983E-02
       92235 -2.6729E-02
       92238 -7.1574E-01
        8016 -9.9810E-02
C Homogenized Upper Plenum
m3     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized Upper Nozzle
m4     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Water
m5     1001 2 8016 1
C Stainless Steel
m6     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m7     26000 -0.99 6012 -0.01
C Neutron Poison
m8     13027 -0.8466  5010 -0.0216  5011 -0.0985
        6012 -0.0333
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11     5010 -9.3127E-04 13027 -2.1420E-01  6012 -2.7627E-01
        5011 -3.7721E-03  1001 -6.0012E-02  7014 -1.9815E-02
        8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
C Vent Port Middle Cylinder
m13    24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
phys:p 100 0 0 0 1    $ Disable Doppler energy broadening
C
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
C Cell Importances
C
imp:p 1 412r 0
C
C BWR Source Definition - Fuel Gamma - Pref
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=799:632:501:d5:2
si1   -7.1247 7.1247
sp1   0 1
si2   -7.1247 7.1247
sp2   0 1
si3   27.2796 48.3616 69.4436 90.5256 111.6076 132.6896 153.7716
      174.8536 195.9356 217.0176 238.0996
sp3   0.0000 0.4050 1.2320 1.3600 1.3330 1.3040 1.2350
      1.1230 1.0110 0.8800 0.1130
si4   1.000E-02 2.000E-02 5.000E-02 1.000E-01 2.000E-01 3.000E-01
      4.000E-01 6.000E-01 8.000E-01 1.000E+00 1.220E+00 1.440E+00
      1.660E+00 2.000E+00 2.500E+00 3.000E+00 4.000E+00 5.000E+00
      6.500E+00 8.000E+00 1.000E+01 1.200E+01 1.400E+01
sp4   0.0000E+00 3.9346E+13 5.1398E+13 2.4748E+13 1.5283E+13 4.7419E+12
      3.2789E+12 2.3939E+12 1.3546E+14 1.0605E+12 5.0505E+11 8.2048E+11
      7.5368E+10 8.4076E+09 4.2540E+08 2.8405E+07 1.8349E+05 6.1637E+04
      2.4653E+04 4.8213E+03 1.0215E+03 5.2748E+01 0.0000E+00
C Source Information
si5 l                 302 304
               306 308 310 312 314 316
           318 320 322 324 326 328 330 332
           334 336 338 340 342 344 346 348
       350 352 354 356 358 360 362 364 366 368
       370 372 374 376 378 380 382 384 386 388
           390 392 394 396 398 400 402 404
           406 408 410 412 414 416 418 420
               422 424 426 428 430 432
                 434 436
C Source Probability
sp5                     0.99 0.99
               0.99 0.99 0.99 0.99 0.99 0.99
           0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99
           0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99
      0.99 0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99
      0.99 0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99 0.99
           0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99
           0.99 1.00 1.00 1.00 1.00 1.00 1.00 0.99
               0.99 0.99 0.99 0.99 0.99 0.99
                         0.99 0.99
mode p
nps 400000000
C
C ANSI/ANS-6.1.1-1977 - Gamma Flux-to-Dose Conversion Factors
C (mrem/hr)/(photons/cm2-sec)
C
de0   0.01 0.03 0.05 0.07 0.1 0.15 0.2
      0.25 0.3 0.35 0.4 0.45 0.5 0.55
      0.6 0.65 0.7 0.8 1 1.4 1.8
      2.2 2.6 2.8 3.25 3.75 4.25 4.75
      5 5.25 5.75 6.25 6.75 7.5 9
      11 13 15
df0   3.96E-03 5.82E-04 2.90E-04 2.58E-04 2.83E-04 3.79E-04 5.01E-04
      6.31E-04 7.59E-04 8.78E-04 9.85E-04 1.08E-03 1.17E-03 1.27E-03
      1.36E-03 1.44E-03 1.52E-03 1.68E-03 1.98E-03 2.51E-03 2.99E-03
      3.42E-03 3.82E-03 4.01E-03 4.41E-03 4.83E-03 5.23E-03 5.60E-03
      5.80E-03 6.01E-03 6.37E-03 6.74E-03 7.11E-03 7.66E-03 8.77E-03
      1.03E-02 1.18E-02 1.33E-02
C
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
C Weight Window Generation - Radial
C
wwg 2 0 0 0 0
wwp:p 5 3 5 0 -1 0
mesh geom=cyl ref=78 9 135 origin=0.1 0.1 -160
     imesh 88.4 89.7 100.3 106.7 162.6 662.6
     iints 5 1 1 2 4 1
     jmesh 101 104 134 137 154 162 189 400 424 437 454 491 512 516 1016
     jints 1 1 1 1 1 2 2 10 1 1 3 1 2 1 1
     kmesh 1
     kints 1
wwge:p  1e-3 1 20
fc2 Radial Surface Tally
f2:p +800.1
fm2 1.9038E+16
fs2  -801  -802  -803  -804  -805  -806
     -807  -808  -809  -810  -811  T
tf2
fc12 Radial 1ft Tally
f12:p +900.1
fm12 1.9038E+16
fs12  -901  -902  -903  -904  -905  -906
     -907  -908  -909  -910  -911  T
tf12
fc22 Radial 1m Tally
f22:p +1000.1
fm22 1.9038E+16
fs22  -1001  -1002  -1003  -1004  -1005  -1006
     -1007  -1008  -1009  -1010  -1011  T
tf22
fc32 Radial 2m Tally
f32:p +1100.1
fm32 1.9038E+16
fs32  -1101  -1102  -1103  -1104  -1105  -1106
     -1107  -1108  -1109  -1110  -1111  -1112
     -1113  -1114  -1115  -1116  -1117  -1118
     -1119  T
tf32
fc42 Radial 4m Tally
f42:p +1200.1
fm42 1.9038E+16
fs42  -1201  -1202  -1203  -1204  -1205  -1206
     -1207  -1208  -1209  -1210  -1211  -1212
     -1213  -1214  -1215  -1216  -1217  -1218
     -1219  T
tf42
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 45 degree rotation around z-axis
*TR1 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0
C 135 degree rotation around z-axis
*TR2 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0
C 225 degree rotation around z-axis
```

Figure 5.A.6-3 MPC-LACBWR MCNP Input File for Storage Cask Radial Biasing – Fuel Gamma Source

```
*TR3 0.0 0.0 0.0 225 315 90 135 225 90 90 90 0
C 315 degree rotation around z-axis
*TR4 0.0 0.0 0.0 315 405 90 225 315 90 90 90 0
C 10 degree rotation around z-axis
*TR5 0.0 0.0 0.0 10 100 90 -80 10 90 90 90 0
C 20 degree rotation around z-axis
*TR6 0.0 0.0 0.0 20 110 90 -70 20 90 90 90 0
C 30 degree rotation around z-axis
*TR7 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0
C 40 degree rotation around z-axis
*TR8 0.0 0.0 0.0 40 130 90 -50 40 90 90 90 0
C 50 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50 140 90 -40 50 90 90 90 0
C 60 degree rotation around z-axis
*TR10 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0
C 70 degree rotation around z-axis
*TR11 0.0 0.0 0.0 70 160 90 -20 70 90 90 90 0
C 80 degree rotation around z-axis
*TR12 0.0 0.0 0.0 80 170 90 -10 80 90 90 90 0
C 100 degree rotation around z-axis
*TR13 0.0 0.0 0.0 100 190 90 10 100 90 90 90 0
C 110 degree rotation around z-axis
*TR14 0.0 0.0 0.0 110 200 90 20 110 90 90 90 0
C 120 degree rotation around z-axis
*TR15 0.0 0.0 0.0 120 210 90 30 120 90 90 90 0
C 130 degree rotation around z-axis
*TR16 0.0 0.0 0.0 130 220 90 40 130 90 90 90 0
C 140 degree rotation around z-axis
*TR17 0.0 0.0 0.0 140 230 90 50 140 90 90 90 0
C 150 degree rotation around z-axis
*TR18 0.0 0.0 0.0 150 240 90 60 150 90 90 90 0
C 160 degree rotation around z-axis
*TR19 0.0 0.0 0.0 160 250 90 70 160 90 90 90 0
C 170 degree rotation around z-axis
*TR20 0.0 0.0 0.0 170 260 90 80 170 90 90 90 0
C 18 degree rotation around z-axis
*TR21 0.0 0.0 0.0 18 108 90 -72 18 90 90 90 0
C 36 degree rotation around z-axis
*TR22 0.0 0.0 0.0 36 126 90 -54 36 90 90 90 0
C 54 degree rotation around z-axis
*TR23 0.0 0.0 0.0 54 144 90 -36 54 90 90 90 0
C 72 degree rotation around z-axis
*TR24 0.0 0.0 0.0 72 162 90 -18 72 90 90 90 0
C 108 degree rotation around z-axis
*TR25 0.0 0.0 0.0 108 198 90 18 108 90 90 90 0
C 126 degree rotation around z-axis
*TR26 0.0 0.0 0.0 126 216 90 36 126 90 90 90 0
C 144 degree rotation around z-axis
*TR27 0.0 0.0 0.0 144 234 90 54 144 90 90 90 0
C 162 degree rotation around z-axis
*TR28 0.0 0.0 0.0 162 252 90 72 162 90 90 90 0
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
LACBWR Transfer Cask - trfShwWetTopFn_Pref
C Top Axial Biasing - Fuel Neutron Source
C Fuel Assembly Cells - v1.0
1 1 -2.1989 -1 -2    u=11 $ Lower Nozzle
2 2 -4.3866 -1 +2 -3   u=11 $ Fuel
3 3 -1.5956 -1 +3 -4   u=11 $ Upper Plenum
4 4 -0.6145 -1 +4    u=11 $ Upper Nozzle
5 0         +1     u=11 $ Outside
C Flood Elevation Cells
6 5 -0.9982 -5     u=10 $ Below flood elevation
7 0         5     u=10 $ Above flood elevation
C Cells - Standard Fuel Tube  v1.0
101 0         -101 fill=10      u=5 $ Tube void
102 6 -7.9400 -102 +101      u=5 $ Tube
103 8 -2.6707 -103       u=5 $ Absorber +Y
104 6 -7.9400 -104       u=5 $ Cladding +Y
105 8 -2.6707 -105       u=5 $ Absorber +X
106 6 -7.9400 -106       u=5 $ Cladding +X
107 0         +101 +102 +103 +104 +106 +105 fill=10 u=5 $ Void
C Cells - DFC Fuel Tube Absorber 2 Sides v1.0
108 0         -107 fill=10      u=6 $ Tube void
109 6 -7.9400 -108 +107      u=6 $ Tube
110 8 -2.6707 -109       u=6 $ Absorber +Y
111 6 -7.9400 -110       u=6 $ Cladding +Y
112 8 -2.6707 -111       u=6 $ Absorber +X
113 6 -7.9400 -112       u=6 $ Cladding +X
114 0         +107 +108 +109 +110 +112 +111 fill=10 u=6 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (Y) v1.0
115 0         -107 fill=10      u=7 $ Tube void
116 6 -7.9400 -108 +107      u=7 $ Tube
117 8 -2.6707 -109       u=7 $ Absorber +Y
118 6 -7.9400 -110       u=7 $ Cladding +Y
119 0         +107 +108 +109 +110   fill=10 u=7 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (X) v1.0
120 0         -107 fill=10      u=8 $ Tube void
121 6 -7.9400 -108 +107      u=8 $ Tube
122 8 -2.6707 -111       u=8 $ Absorber +X
123 6 -7.9400 -112       u=8 $ Cladding +X
124 0         +107 +108 +111 +112   fill=10 u=8 $ Void
C Cells - DFC Fuel Tube No Absorber v1.0
125 0         -107 fill=10      u=9 $ Tube void
126 6 -7.9400 -108 +107      u=9 $ Tube
127 0         +107 +108     fill=10 u=9 $ Void
c Cell Cards - Disk Stack v1.0
201 6 -7.94 -203 trcl = ( 0.0000 0.0000 2.5400 )    u=4 $ Bottom weldment disk
202 6 -7.94 -201 trcl = ( 0.0000 0.0000 15.0368 )    u=4 $ Support disk 1
203 like 202 but   trcl = ( 0.0000 0.0000 24.7650 )    u=4 $ Support disk 2
204 like 202 but   trcl = ( 0.0000 0.0000 34.4932 )    u=4 $ Support disk 3
205 like 202 but   trcl = ( 0.0000 0.0000 44.2214 )    u=4 $ Support disk 4
206 like 202 but   trcl = ( 0.0000 0.0000 53.9496 )    u=4 $ Support disk 5
207 9 -2.70 -202 trcl = ( 0.0000 0.0000 58.9788 )    u=4 $ Heat transfer disk 1
208 like 202 but   trcl = ( 0.0000 0.0000 63.6778 )    u=4 $ Support disk 6
209 like 207 but   trcl = ( 0.0000 0.0000 68.7070 )    u=4 $ Heat transfer disk 2
210 like 202 but   trcl = ( 0.0000 0.0000 73.4060 )    u=4 $ Support disk 7
211 like 207 but   trcl = ( 0.0000 0.0000 78.4352 )    u=4 $ Heat transfer disk 3
212 like 202 but   trcl = ( 0.0000 0.0000 83.1342 )    u=4 $ Support disk 8
213 like 207 but   trcl = ( 0.0000 0.0000 88.1634 )    u=4 $ Heat transfer disk 4
214 like 202 but   trcl = ( 0.0000 0.0000 92.8624 )    u=4 $ Support disk 9
215 like 207 but   trcl = ( 0.0000 0.0000 97.8916 )    u=4 $ Heat transfer disk 5
216 like 202 but   trcl = ( 0.0000 0.0000 102.5906 )    u=4 $ Support disk 10
217 like 207 but   trcl = ( 0.0000 0.0000 107.6198 )    u=4 $ Heat transfer disk 6
218 like 202 but   trcl = ( 0.0000 0.0000 112.3188 )    u=4 $ Support disk 11
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
219 like 207 but   trcl = ( 0.0000 0.0000 117.3480 )    u=4 $ Heat transfer disk 7
220 like 202 but   trcl = ( 0.0000 0.0000 122.0470 )    u=4 $ Support disk 12
221 like 207 but   trcl = ( 0.0000 0.0000 127.0762 )    u=4 $ Heat transfer disk 8
222 like 202 but   trcl = ( 0.0000 0.0000 131.7752 )    u=4 $ Support disk 13
223 like 207 but   trcl = ( 0.0000 0.0000 136.8044 )    u=4 $ Heat transfer disk 9
224 like 202 but   trcl = ( 0.0000 0.0000 141.5034 )    u=4 $ Support disk 14
225 like 207 but   trcl = ( 0.0000 0.0000 146.5326 )    u=4 $ Heat transfer disk 10
226 like 202 but   trcl = ( 0.0000 0.0000 151.2316 )    u=4 $ Support disk 15
227 like 207 but   trcl = ( 0.0000 0.0000 156.2608 )    u=4 $ Heat transfer disk 11
228 like 202 but   trcl = ( 0.0000 0.0000 160.9598 )    u=4 $ Support disk 16
229 like 207 but   trcl = ( 0.0000 0.0000 165.9890 )    u=4 $ Heat transfer disk 12
230 like 202 but   trcl = ( 0.0000 0.0000 170.6880 )    u=4 $ Support disk 1
231 like 207 but   trcl = ( 0.0000 0.0000 175.7172 )    u=4 $ Heat transfer disk 13
232 like 202 but   trcl = ( 0.0000 0.0000 180.4162 )    u=4 $ Support disk 18
233 like 207 but   trcl = ( 0.0000 0.0000 185.4454 )    u=4 $ Heat transfer disk 14
234 like 202 but   trcl = ( 0.0000 0.0000 190.1444 )    u=4 $ Support disk 19
235 like 202 but   trcl = ( 0.0000 0.0000 199.8726 )    u=4 $ Support disk 20
236 like 202 but   trcl = ( 0.0000 0.0000 209.6008 )    u=4 $ Support disk 21
237 like 202 but   trcl = ( 0.0000 0.0000 219.3290 )    u=4 $ Support disk 22
238 like 202 but   trcl = ( 0.0000 0.0000 229.0572 )    u=4 $ Support disk 23
239 like 202 but   trcl = ( 0.0000 0.0000 238.7854 )    u=4 $ Support disk 24
240 like 201 but   trcl = ( 0.0000 0.0000 255.8796 )    u=4 $ Top weldment disk
241 0               $ Outside Disks
      #201 #202 #203 #204 #205 #206 #207 #208 #209 #210
      #211 #212 #213 #214 #215 #216 #217 #218 #219 #220
      #221 #222 #223 #224 #225 #226 #227 #228 #229 #230
      #231 #232 #233 #234 #235 #236 #237 #238 #239
      #240        fill=10 u=4
c Cell Cards - Basket v1.0
301 0          -302 #302  fill=8 ( -8.8265 77.5233 0.0000 )      $ Tube/Disk 1
           trcl = ( -8.8265 77.5233 0.0000 )      u=3
302 0          -1  fill=11 trcl = ( -8.8265 77.5233 0.0000 )     u=3 $ Assembly 1
303 0          -302 #304  fill=9 ( 8.8265 77.5233 0.0000 )      $ Tube/Disk 2
           trcl = ( 8.8265 77.5233 0.0000 )      u=3
304 like 302 but     trcl = ( 8.8265 77.5233 0.0000 )     u=3 $ Assembly 2
305 0          -302 #306  fill=8 ( -44.1274 61.2699 0.0000 )      $ Tube/Disk 3
           trcl = ( -44.1274 61.2699 0.0000 )      u=3
306 like 302 but     trcl = ( -44.1274 61.2699 0.0000 )     u=3 $ Assembly 3
307 0          -302 #308  fill=8 ( -26.4770 59.8729 0.0000 )      $ Tube/Disk 4
           trcl = ( -26.4770 59.8729 0.0000 )      u=3
308 like 302 but     trcl = ( -26.4770 59.8729 0.0000 )     u=3 $ Assembly 4
309 0          -302 #310  fill=6 ( -8.8265 59.8729 0.0000 )      $ Tube/Disk 5
           trcl = ( -8.8265 59.8729 0.0000 )      u=3
310 like 302 but     trcl = ( -8.8265 59.8729 0.0000 )     u=3 $ Assembly 5
311 0          -302 #312  fill=6 ( 8.8265 59.8729 0.0000 )      $ Tube/Disk 6
           trcl = ( 8.8265 59.8729 0.0000 )      u=3
312 like 302 but     trcl = ( 8.8265 59.8729 0.0000 )     u=3 $ Assembly 6
313 0          -302 #314  fill=8 ( 26.4770 59.8729 0.0000 )      $ Tube/Disk 7
           trcl = ( 26.4770 59.8729 0.0000 )      u=3
314 like 302 but     trcl = ( 26.4770 59.8729 0.0000 )     u=3 $ Assembly 7
315 0          -302 #316  fill=9 ( 44.1274 61.2699 0.0000 )      $ Tube/Disk 8
           trcl = ( 44.1274 61.2699 0.0000 )      u=3
316 like 302 but     trcl = ( 44.1274 61.2699 0.0000 )     u=3 $ Assembly 8
317 0          -302 #318  fill=8 ( -61.2699 44.1274 0.0000 )      $ Tube/Disk 9
           trcl = ( -61.2699 44.1274 0.0000 )      u=3
318 like 302 but     trcl = ( -61.2699 44.1274 0.0000 )     u=3 $ Assembly 9
319 0          -301 #320  fill=5 ( -42.5399 42.5399 0.0000 )      $ Tube/Disk 10
           trcl = ( -42.5399 42.5399 0.0000 )      u=3
320 like 302 but     trcl = ( -42.5399 42.5399 0.0000 )     u=3 $ Assembly 10
321 0          -301 #322  fill=5 ( -25.5245 42.5399 0.0000 )      $ Tube/Disk 11
           trcl = ( -25.5245 42.5399 0.0000 )      u=3
322 like 302 but     trcl = ( -25.5245 42.5399 0.0000 )     u=3 $ Assembly 11
323 0          -301 #324  fill=5 ( -8.5090 42.5399 0.0000 )      $ Tube/Disk 12
           trcl = ( -8.5090 42.5399 0.0000 )      u=3
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
324 like 302 but     trcl = ( -8.5090 42.5399 0.0000 )     u=3 $ Assembly 12
325 0         -301 #326  fill=5 ( 8.5090 42.5399 0.0000 )      $ Tube/Disk 13
          trcl = ( 8.5090 42.5399 0.0000 )     u=3
326 like 302 but     trcl = ( 8.5090 42.5399 0.0000 )     u=3 $ Assembly 13
327 0         -301 #328  fill=5 ( 25.5245 42.5399 0.0000 )      $ Tube/Disk 14
          trcl = ( 25.5245 42.5399 0.0000 )     u=3
328 like 302 but     trcl = ( 25.5245 42.5399 0.0000 )     u=3 $ Assembly 14
329 0         -301 #330  fill=5 ( 42.5399 42.5399 0.0000 )      $ Tube/Disk 15
          trcl = ( 42.5399 42.5399 0.0000 )     u=3
330 like 302 but     trcl = ( 42.5399 42.5399 0.0000 )     u=3 $ Assembly 15
331 0         -302 #332  fill=9 ( 61.2699 44.1274 0.0000 )      $ Tube/Disk 16
          trcl = ( 61.2699 44.1274 0.0000 )     u=3
332 like 302 but     trcl = ( 61.2699 44.1274 0.0000 )     u=3 $ Assembly 16
333 0         -302 #334  fill=6 ( -59.8729 26.4770 0.0000 )      $ Tube/Disk 17
          trcl = ( -59.8729 26.4770 0.0000 )     u=3
334 like 302 but     trcl = ( -59.8729 26.4770 0.0000 )     u=3 $ Assembly 17
335 0         -301 #336  fill=5 ( -42.5399 25.5245 0.0000 )      $ Tube/Disk 18
          trcl = ( -42.5399 25.5245 0.0000 )     u=3
336 like 302 but     trcl = ( -42.5399 25.5245 0.0000 )     u=3 $ Assembly 18
337 0         -301 #338  fill=5 ( -25.5245 25.5245 0.0000 )      $ Tube/Disk 19
          trcl = ( -25.5245 25.5245 0.0000 )     u=3
338 like 302 but     trcl = ( -25.5245 25.5245 0.0000 )     u=3 $ Assembly 19
339 0         -301 #340  fill=5 ( -8.5090 25.5245 0.0000 )      $ Tube/Disk 20
          trcl = ( -8.5090 25.5245 0.0000 )     u=3
340 like 302 but     trcl = ( -8.5090 25.5245 0.0000 )     u=3 $ Assembly 20
341 0         -301 #342  fill=5 ( 8.5090 25.5245 0.0000 )      $ Tube/Disk 21
          trcl = ( 8.5090 25.5245 0.0000 )     u=3
342 like 302 but     trcl = ( 8.5090 25.5245 0.0000 )     u=3 $ Assembly 21
343 0         -301 #344  fill=5 ( 25.5245 25.5245 0.0000 )      $ Tube/Disk 22
          trcl = ( 25.5245 25.5245 0.0000 )     u=3
344 like 302 but     trcl = ( 25.5245 25.5245 0.0000 )     u=3 $ Assembly 22
345 0         -301 #346  fill=5 ( 42.5399 25.5245 0.0000 )      $ Tube/Disk 23
          trcl = ( 42.5399 25.5245 0.0000 )     u=3
346 like 302 but     trcl = ( 42.5399 25.5245 0.0000 )     u=3 $ Assembly 23
347 0         -302 #348  fill=7 ( 59.8729 26.4770 0.0000 )      $ Tube/Disk 24
          trcl = ( 59.8729 26.4770 0.0000 )     u=3
348 like 302 but     trcl = ( 59.8729 26.4770 0.0000 )     u=3 $ Assembly 24
349 0         -302 #350  fill=8 ( -77.5233 8.8265 0.0000 )      $ Tube/Disk 25
          trcl = ( -77.5233 8.8265 0.0000 )     u=3
350 like 302 but     trcl = ( -77.5233 8.8265 0.0000 )     u=3 $ Assembly 25
351 0         -302 #352  fill=6 ( -59.8729 8.8265 0.0000 )      $ Tube/Disk 26
          trcl = ( -59.8729 8.8265 0.0000 )     u=3
352 like 302 but     trcl = ( -59.8729 8.8265 0.0000 )     u=3 $ Assembly 26
353 0         -301 #354  fill=5 ( -42.5399 8.5090 0.0000 )      $ Tube/Disk 27
          trcl = ( -42.5399 8.5090 0.0000 )     u=3
354 like 302 but     trcl = ( -42.5399 8.5090 0.0000 )     u=3 $ Assembly 27
355 0         -301 #356  fill=5 ( -25.5245 8.5090 0.0000 )      $ Tube/Disk 28
          trcl = ( -25.5245 8.5090 0.0000 )     u=3
356 like 302 but     trcl = ( -25.5245 8.5090 0.0000 )     u=3 $ Assembly 28
357 0         -301 #358  fill=5 ( -8.5090 8.5090 0.0000 )      $ Tube/Disk 29
          trcl = ( -8.5090 8.5090 0.0000 )     u=3
358 like 302 but     trcl = ( -8.5090 8.5090 0.0000 )     u=3 $ Assembly 29
359 0         -301 #360  fill=5 ( 8.5090 8.5090 0.0000 )      $ Tube/Disk 30
          trcl = ( 8.5090 8.5090 0.0000 )     u=3
360 like 302 but     trcl = ( 8.5090 8.5090 0.0000 )     u=3 $ Assembly 30
361 0         -301 #362  fill=5 ( 25.5245 8.5090 0.0000 )      $ Tube/Disk 31
          trcl = ( 25.5245 8.5090 0.0000 )     u=3
362 like 302 but     trcl = ( 25.5245 8.5090 0.0000 )     u=3 $ Assembly 31
363 0         -301 #364  fill=5 ( 42.5399 8.5090 0.0000 )      $ Tube/Disk 32
          trcl = ( 42.5399 8.5090 0.0000 )     u=3
364 like 302 but     trcl = ( 42.5399 8.5090 0.0000 )     u=3 $ Assembly 32
365 0         -302 #366  fill=6 ( 59.8729 8.8265 0.0000 )      $ Tube/Disk 33
          trcl = ( 59.8729 8.8265 0.0000 )     u=3
366 like 302 but     trcl = ( 59.8729 8.8265 0.0000 )     u=3 $ Assembly 33
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
367 0          -302 #368  fill=9 ( 77.5233 8.8265 0.0000 )       $ Tube/Disk 34
           trcl = ( 77.5233 8.8265 0.0000 )      u=3
368 like 302 but      trcl = ( 77.5233 8.8265 0.0000 )      u=3 $ Assembly 34
369 0          -302 #370  fill=6 ( -77.5233 -8.8265 0.0000 )       $ Tube/Disk 35
           trcl = ( -77.5233 -8.8265 0.0000 )      u=3
370 like 302 but      trcl = ( -77.5233 -8.8265 0.0000 )      u=3 $ Assembly 35
371 0          -302 #372  fill=6 ( -59.8729 -8.8265 0.0000 )       $ Tube/Disk 36
           trcl = ( -59.8729 -8.8265 0.0000 )      u=3
372 like 302 but      trcl = ( -59.8729 -8.8265 0.0000 )      u=3 $ Assembly 36
373 0          -301 #374  fill=5 ( -42.5399 -8.5090 0.0000 )       $ Tube/Disk 37
           trcl = ( -42.5399 -8.5090 0.0000 )      u=3
374 like 302 but      trcl = ( -42.5399 -8.5090 0.0000 )      u=3 $ Assembly 37
375 0          -301 #376  fill=5 ( -25.5245 -8.5090 0.0000 )       $ Tube/Disk 38
           trcl = ( -25.5245 -8.5090 0.0000 )      u=3
376 like 302 but      trcl = ( -25.5245 -8.5090 0.0000 )      u=3 $ Assembly 38
377 0          -301 #378  fill=5 ( -8.5090 -8.5090 0.0000 )       $ Tube/Disk 39
           trcl = ( -8.5090 -8.5090 0.0000 )      u=3
378 like 302 but      trcl = ( -8.5090 -8.5090 0.0000 )      u=3 $ Assembly 39
379 0          -301 #380  fill=5 ( 8.5090 -8.5090 0.0000 )       $ Tube/Disk 40
           trcl = ( 8.5090 -8.5090 0.0000 )      u=3
380 like 302 but      trcl = ( 8.5090 -8.5090 0.0000 )      u=3 $ Assembly 40
381 0          -301 #382  fill=5 ( 25.5245 -8.5090 0.0000 )       $ Tube/Disk 41
           trcl = ( 25.5245 -8.5090 0.0000 )      u=3
382 like 302 but      trcl = ( 25.5245 -8.5090 0.0000 )      u=3 $ Assembly 41
383 0          -301 #384  fill=5 ( 42.5399 -8.5090 0.0000 )       $ Tube/Disk 42
           trcl = ( 42.5399 -8.5090 0.0000 )      u=3
384 like 302 but      trcl = ( 42.5399 -8.5090 0.0000 )      u=3 $ Assembly 42
385 0          -302 #386  fill=6 ( 59.8729 -8.8265 0.0000 )       $ Tube/Disk 43
           trcl = ( 59.8729 -8.8265 0.0000 )      u=3
386 like 302 but      trcl = ( 59.8729 -8.8265 0.0000 )      u=3 $ Assembly 43
387 0          -302 #388  fill=7 ( 77.5233 -8.8265 0.0000 )       $ Tube/Disk 44
           trcl = ( 77.5233 -8.8265 0.0000 )      u=3
388 like 302 but      trcl = ( 77.5233 -8.8265 0.0000 )      u=3 $ Assembly 44
389 0          -302 #390  fill=6 ( -59.8729 -26.4770 0.0000 )       $ Tube/Disk 45
           trcl = ( -59.8729 -26.4770 0.0000 )      u=3
390 like 302 but      trcl = ( -59.8729 -26.4770 0.0000 )      u=3 $ Assembly 45
391 0          -301 #392  fill=5 ( -42.5399 -25.5245 0.0000 )       $ Tube/Disk 46
           trcl = ( -42.5399 -25.5245 0.0000 )      u=3
392 like 302 but      trcl = ( -42.5399 -25.5245 0.0000 )      u=3 $ Assembly 46
393 0          -301 #394  fill=5 ( -25.5245 -25.5245 0.0000 )       $ Tube/Disk 47
           trcl = ( -25.5245 -25.5245 0.0000 )      u=3
394 like 302 but      trcl = ( -25.5245 -25.5245 0.0000 )      u=3 $ Assembly 47
395 0          -301 #396  fill=5 ( -8.5090 -25.5245 0.0000 )       $ Tube/Disk 48
           trcl = ( -8.5090 -25.5245 0.0000 )      u=3
396 like 302 but      trcl = ( -8.5090 -25.5245 0.0000 )      u=3 $ Assembly 48
397 0          -301 #398  fill=5 ( 8.5090 -25.5245 0.0000 )       $ Tube/Disk 49
           trcl = ( 8.5090 -25.5245 0.0000 )      u=3
398 like 302 but      trcl = ( 8.5090 -25.5245 0.0000 )      u=3 $ Assembly 49
399 0          -301 #400  fill=5 ( 25.5245 -25.5245 0.0000 )       $ Tube/Disk 50
           trcl = ( 25.5245 -25.5245 0.0000 )      u=3
400 like 302 but      trcl = ( 25.5245 -25.5245 0.0000 )      u=3 $ Assembly 50
401 0          -301 #402  fill=5 ( 42.5399 -25.5245 0.0000 )       $ Tube/Disk 51
           trcl = ( 42.5399 -25.5245 0.0000 )      u=3
402 like 302 but      trcl = ( 42.5399 -25.5245 0.0000 )      u=3 $ Assembly 51
403 0          -302 #404  fill=7 ( 59.8729 -26.4770 0.0000 )       $ Tube/Disk 52
           trcl = ( 59.8729 -26.4770 0.0000 )      u=3
404 like 302 but      trcl = ( 59.8729 -26.4770 0.0000 )      u=3 $ Assembly 52
405 0          -302 #406  fill=6 ( -61.2699 -44.1274 0.0000 )       $ Tube/Disk 53
           trcl = ( -61.2699 -44.1274 0.0000 )      u=3
406 like 302 but      trcl = ( -61.2699 -44.1274 0.0000 )      u=3 $ Assembly 53
407 0          -301 #408  fill=5 ( -42.5399 -42.5399 0.0000 )       $ Tube/Disk 54
           trcl = ( -42.5399 -42.5399 0.0000 )      u=3
408 like 302 but      trcl = ( -42.5399 -42.5399 0.0000 )      u=3 $ Assembly 54
409 0          -301 #410  fill=5 ( -25.5245 -42.5399 0.0000 )       $ Tube/Disk 55
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
          trcl = ( -25.5245 -42.5399 0.0000 )      u=3
410 like 302 but      trcl = ( -25.5245 -42.5399 0.0000 )      u=3 $ Assembly 55
411 0          -301 #412  fill=5 ( -8.5090 -42.5399 0.0000 )      $ Tube/Disk 56
          trcl = ( -8.5090 -42.5399 0.0000 )      u=3
412 like 302 but      trcl = ( -8.5090 -42.5399 0.0000 )      u=3 $ Assembly 56
413 0          -301 #414  fill=5 ( 8.5090 -42.5399 0.0000 )      $ Tube/Disk 57
          trcl = ( 8.5090 -42.5399 0.0000 )      u=3
414 like 302 but      trcl = ( 8.5090 -42.5399 0.0000 )      u=3 $ Assembly 57
415 0          -301 #416  fill=5 ( 25.5245 -42.5399 0.0000 )      $ Tube/Disk 58
          trcl = ( 25.5245 -42.5399 0.0000 )      u=3
416 like 302 but      trcl = ( 25.5245 -42.5399 0.0000 )      u=3 $ Assembly 58
417 0          -301 #418  fill=5 ( 42.5399 -42.5399 0.0000 )      $ Tube/Disk 59
          trcl = ( 42.5399 -42.5399 0.0000 )      u=3
418 like 302 but      trcl = ( 42.5399 -42.5399 0.0000 )      u=3 $ Assembly 59
419 0          -302 #420  fill=7 ( 61.2699 -44.1274 0.0000 )      $ Tube/Disk 60
          trcl = ( 61.2699 -44.1274 0.0000 )      u=3
420 like 302 but      trcl = ( 61.2699 -44.1274 0.0000 )      u=3 $ Assembly 60
421 0          -302 #422  fill=6 ( -44.1274 -61.2699 0.0000 )      $ Tube/Disk 61
          trcl = ( -44.1274 -61.2699 0.0000 )      u=3
422 like 302 but      trcl = ( -44.1274 -61.2699 0.0000 )      u=3 $ Assembly 61
423 0          -302 #424  fill=6 ( -26.4770 -59.8729 0.0000 )      $ Tube/Disk 62
          trcl = ( -26.4770 -59.8729 0.0000 )      u=3
424 like 302 but      trcl = ( -26.4770 -59.8729 0.0000 )      u=3 $ Assembly 62
425 0          -302 #426  fill=6 ( -8.8265 -59.8729 0.0000 )      $ Tube/Disk 63
          trcl = ( -8.8265 -59.8729 0.0000 )      u=3
426 like 302 but      trcl = ( -8.8265 -59.8729 0.0000 )      u=3 $ Assembly 63
427 0          -302 #428  fill=6 ( 8.8265 -59.8729 0.0000 )      $ Tube/Disk 64
          trcl = ( 8.8265 -59.8729 0.0000 )      u=3
428 like 302 but      trcl = ( 8.8265 -59.8729 0.0000 )      u=3 $ Assembly 64
429 0          -302 #430  fill=6 ( 26.4770 -59.8729 0.0000 )      $ Tube/Disk 65
          trcl = ( 26.4770 -59.8729 0.0000 )      u=3
430 like 302 but      trcl = ( 26.4770 -59.8729 0.0000 )      u=3 $ Assembly 65
431 0          -302 #432  fill=7 ( 44.1274 -61.2699 0.0000 )      $ Tube/Disk 66
          trcl = ( 44.1274 -61.2699 0.0000 )      u=3
432 like 302 but      trcl = ( 44.1274 -61.2699 0.0000 )      u=3 $ Assembly 66
433 0          -302 #434  fill=7 ( -8.8265 -77.5233 0.0000 )      $ Tube/Disk 67
          trcl = ( -8.8265 -77.5233 0.0000 )      u=3
434 like 302 but      trcl = ( -8.8265 -77.5233 0.0000 )      u=3 $ Assembly 67
435 0          -302 #436  fill=7 ( 8.8265 -77.5233 0.0000 )      $ Tube/Disk 68
          trcl = ( 8.8265 -77.5233 0.0000 )      u=3
436 like 302 but      trcl = ( 8.8265 -77.5233 0.0000 )      u=3 $ Assembly 68
437 0          +303 +304        $ Canister Cavity Q1
      #303 #311 #313 #315 #325 #327 #329 #331 #341
      #304 #312 #314 #316 #326 #328 #330 #332 #342
      #343 #345 #347 #359 #361 #363 #365 #367
      #344 #346 #348 #360 #362 #364 #366 #368
          fill=4       u=3
438 0          +303 -304        $ Canister Cavity Q2
      #301 #305 #307 #309 #317 #319 #321 #323 #333
      #302 #306 #308 #310 #318 #320 #322 #324 #334
      #335 #337 #339 #349 #351 #353 #355 #357
      #336 #338 #340 #350 #352 #354 #356 #358
          fill=4       u=3
439 0          -303 -304        $ Canister Cavity Q3
      #369 #371 #373 #375 #377 #389 #391 #393 #395
      #370 #372 #374 #376 #378 #390 #392 #394 #396
      #405 #407 #409 #411 #421 #423 #425 #433
      #406 #408 #410 #412 #422 #424 #426 #434
          fill=4       u=3
440 0          -303 +304        $ Canister Cavity Q4
      #379 #381 #383 #385 #387 #397 #399 #401 #403
      #380 #382 #384 #386 #388 #398 #400 #402 #404
      #413 #415 #417 #419 #427 #429 #431 #435
      #414 #416 #418 #420 #428 #430 #432 #436
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
          fill=4      u=3
C Cells - Canister w/o Port Covers v1.0
501 0          -501   fill=3    u=2 $ Cavity
502 6 -7.9400 -507 +501.3      u=2 $ Canister Bottom
503 0          -502 +501.2 -505 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Bottom Drain Port
504 13 -3.9700 -503 +505 -506 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Middle Drain Port
505 0          -504 +506 -507.2 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Top Drain Port
506 like 503 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Bottom Vent Port
507 like 504 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Middle Vent Port
508 like 505 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Top Vent Port
509 6 -7.9400 -507 -501.3 +501.1     u=2 $ Canister Shell
510 6 -7.9400 -507 -501.1 +501.2 #503 #504 #505 #506 #507 #508     u=2 $ Lid
511 0          +507       u=2 $ Outside
C Transfer Cask Cells - v4.1
601 0          -601 -602  fill=2 ( 0.0000 0.0000 2.5400 )   u=1 $ Cavity
602 7 -7.8212 -601 +602 -606    u=1 $ Bottom forging
603 7 -7.8212 -603 +602 +606 -608 +614  u=1 $ Inner shell
604 10 -11.344 -604 +603 +606 -607 +614  u=1 $ Lead shell
605 11 -1.6316 -604 +603 +607 -608   u=1 $ NS-4-FR above Pb
606 11 -1.6316 -605 +604 +606 -608 +614  u=1 $ NS-4-FR
607 7 -7.8212 -601 +605 +606 -608 +614  u=1 $ Outer shell
608 7 -7.8212 -601 +602 +608    u=1 $ Top forging
609 7 -7.8212 -601 +602 -614    u=1 $ Trunnion
610 7 -7.8212 (-609 +610 -616) : (-609 -611 -616)      u=1 $ Door rail
611 7 -7.8212 -615 -612 +613 -616   u=1 $ Door steel
612 0          +601 #610  #611     u=1 $ Void
C Detector Cells - Axial Biasing
700  0  -700  fill=1  $ Surface
800  0  -800  +700  $ PortAzi
900  0  -900  +700  +800  $ AnnulusAzi
1000  0  -1000  +700  +800  +900  $ 1ft
1100  0  -1100  +700  +800  +900  +1000  $ 1m
1200  0  -1200  +700  +800  +900  +1000  +1100  $ 2m
1300  0  -1300  +700  +800  +900  +1000  +1100  +1200  $ 4m
1400  0  +700  +800  +900  +1000  +1100  +1200  +1300  $ Exterior

C Fuel Assembly Surfaces - v1.0
1 RPP -7.1247 7.1247 -7.1247 7.1247 0.0000 261.9502  $ Assy
2 PZ 27.2796       $ Lower Nozzle/Fuel
3 PZ 238.0996       $ Fuel/Upper Plenum
4 PZ 251.1298       $ Upper Plenum/Upper Nozzle
C Flood Elevation Surface
5 PZ 251.1297
C Surfaces - Standard Fuel Tube v1.0
101 RPP -7.3076 7.3076 -7.3076 7.3076 0.0000 274.4470    $ Tube void
102 RPP -7.4295 7.4295 -7.4295 7.4295 0.0000 249.5550    $ Tube
103 RPP -6.5913 6.5913 7.4295 7.6200 2.0320 245.8720    $ Absorber +Y
104 RPP -6.5913 6.5913 7.6200 7.6657 2.0320 245.8720    $ Cladding +Y
105 RPP 7.4295 7.6200 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
106 RPP 7.6200 7.6657 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
C Surfaces - DFC Fuel Tube v1.0
107 RPP -7.6251 7.6251 -7.6251 7.6251 0.0000 274.4470    $ Tube void
108 RPP -7.7470 7.7470 -7.7470 7.7470 0.0000 249.5550    $ Tube
109 RPP -6.5913 6.5913 7.7470 7.9375 2.0320 245.8720    $ Absorber +Y
110 RPP -6.5913 6.5913 7.9375 7.9832 2.0320 245.8720    $ Cladding +Y
111 RPP 7.7470 7.9375 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
112 RPP 7.9375 7.9832 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
c Surface Cards - Disk Stack  v1.0
201 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.1380 $ Structural disk
202 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.2700 87.7951 $ Heat transfer disk
203 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Weldment disk
c Surface Cards - Basket v1.0
301 RPP -7.7711 7.7711 -7.7711 7.7711 0.0000 274.4470  $ Std opening
302 RPP -8.0899 8.0899 -8.0899 8.0899 0.0000 274.4470  $ DFC opening
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
303 PY 0.0000        $ Cut plane
304 PX 0.0000        $ Cut plane
C Surfaces - Canister v1.0
501 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470 88.4428   $ Cavity
502 CZ 1.3843          $ Bot Cylinder Radius
503 CZ 5.0800          $ Mid Cyclinder Radius
504 CZ 5.7150          $ Top Cylinder Radius
505 PZ 282.8798          $ Port plane bot/mid
506 PZ 289.3822          $ Port plane mid/top
507 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670 89.7128   $ Canister
C Transfer Cask Surfaces - v4.1
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 313.6900 109.8550  $ Cask
602 CZ 90.8050         $ Cavity
603 CZ 92.7100         $ Inner shell OR
604 CZ 101.6000         $ Lead shell OR
605 CZ 106.6800         $ Outer shell IR
606 PZ 2.5400         $ Bottom forging
607 PZ 298.4500         $ Top lead
608 PZ 308.6100         $ Top forging
609 RPP -110.1852 110.1852 -107.3150 107.3150 -24.1300 0.0000   $ Door container
610 PY 95.8850         $ Inside rail +y
611 PY -95.8850         $ Inside rail -y
612 PY 95.4024         $ Door +y
613 PY -95.4024         $ Door -y
614 RCC -109.8550 0.0000 275.5900 219.7100 0.0000 0.0000 12.7000  $ Trunnion
615 RHP 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300   $ Door prism
        109.6679 0.0000 0.0000 87.5826 -66.1670 0.0000
        -87.5826 -66.1670 0.0000
616 RCC 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300 109.8550  $ Door container
C Axial Detector DTA (Surface)
700  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  338.0200  109.9550
701  CZ  9.1629
702  CZ  18.3258
703  CZ  27.4888
704  CZ  36.6517
705  CZ  45.8146
706  CZ  54.9775
707  CZ  64.1404
708  CZ  73.3033
709  CZ  82.4663
710  CZ  91.6292
711  CZ  100.7921
C Axial Detector DTAA (PortAzi)
800  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  338.1200  81.9150
801  CZ  70.4850
802     PX  0.0000
803  1  PX  0.0000
804  2  PX  0.0000
805  3  PX  0.0000
806  4  PX  0.0000
807  5  PX  0.0000
808  6  PX  0.0000
809  7  PX  0.0000
810  8  PX  0.0000
811  9  PX  0.0000
812  10  PX  0.0000
813  11  PX  0.0000
814  12  PX  0.0000
815  13  PX  0.0000
816  14  PX  0.0000
817  15  PX  0.0000
818     PY  0.0000
819  16  PX  0.0000
820  17  PX  0.0000
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
821  18  PX  0.0000
822  19  PX  0.0000
823  20  PX  0.0000
824  21  PX  0.0000
825  22  PX  0.0000
826  23  PX  0.0000
827  24  PX  0.0000
828  25  PX  0.0000
829  26  PX  0.0000
830  27  PX  0.0000
831  28  PX  0.0000
832  29  PX  0.0000
833  30  PX  0.0000
C Axial Detector DTAB (AnnulusAzi)
900  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  338.2200  90.8050
901  CZ  81.9150
902     PX  0.0000
903  8  PX  0.0000
904     PY  0.0000
905  23  PX  0.0000
C Axial Detector DTB (1ft)
1000  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  368.5000  140.4350
1001  CZ  11.7029
1002  CZ  23.4058
1003  CZ  35.1088
1004  CZ  46.8117
1005  CZ  58.5146
1006  CZ  70.2175
1007  CZ  81.9204
1008  CZ  93.6233
1009  CZ  105.3263
1010  CZ  117.0292
1011  CZ  128.7321
C Axial Detector DTC (1m)
1100  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  438.0200  209.9550
1101  CZ  17.4963
1102  CZ  34.9925
1103  CZ  52.4888
1104  CZ  69.9850
1105  CZ  87.4813
1106  CZ  104.9775
1107  CZ  122.4738
1108  CZ  139.9700
1109  CZ  157.4663
1110  CZ  174.9625
1111  CZ  192.4588
C Axial Detector DTD (2m)
1200  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  538.0200  309.9550
1201  CZ  25.8296
1202  CZ  51.6592
1203  CZ  77.4888
1204  CZ  103.3183
1205  CZ  129.1479
1206  CZ  154.9775
1207  CZ  180.8071
1208  CZ  206.6367
1209  CZ  232.4663
1210  CZ  258.2958
1211  CZ  284.1254
C Axial Detector DTE (4m)
1300  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  738.0200  509.9550
1301  CZ  42.4963
1302  CZ  84.9925
1303  CZ  127.4888
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
1304  CZ  169.9850
1305  CZ  212.4813
1306  CZ  254.9775
1307  CZ  297.4738
1308  CZ  339.9700
1309  CZ  382.4663
1310  CZ  424.9625
1311  CZ  467.4588

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.1867E-01
       25055 -1.2491E-02
       26000 -4.3407E-01
       28000 -5.9334E-02
        1001 -4.1715E-02
        8016 -3.3372E-01
C Homogenized UO2 Fuel
m2     24000 -2.5816E-02
       25055 -2.7175E-03
       26000 -9.4433E-02
       28000 -1.2908E-02
       92235 -2.3027E-02
       92238 -6.1661E-01
        8016 -2.0910E-01
        1001 -1.5390E-02
C Homogenized Upper Plenum
m3     24000 -1.1765E-01
       25055 -1.2384E-02
       26000 -4.3036E-01
       28000 -5.8826E-02
        1001 -4.2309E-02
        8016 -3.3847E-01
C Homogenized Upper Nozzle
m4     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Water
m5     1001 2 8016 1
C Stainless Steel
m6     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m7     26000 -0.99 6012 -0.01
C Neutron Poison
m8     13027 -0.8466  5010 -0.0216  5011 -0.0985
        6012 -0.0333
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11     5010 -9.3127E-04 13027 -2.1420E-01  6012 -2.7627E-01
        5011 -3.7721E-03  1001 -6.0012E-02  7014 -1.9815E-02
        8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
C Vent Port Middle Cylinder
m13    24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
nonu                  $ Disable subcritical multiplication
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
C
C Cell Importances
C
imp:n 1 244r 0
C
C BWR Source Definition - Fuel Neutron - Pref
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=700:601:501:d5:2
si1   -7.1247 7.1247
sp1   0 1
si2   -7.1247 7.1247
sp2   0 1
si3   27.2796 48.3616 69.4436 90.5256 111.6076 132.6896 153.7716
      174.8536 195.9356 217.0176 238.0996
sp3   0.000E+00 2.205E-02 2.412E+00 3.660E+00 3.363E+00 3.065E+00 2.437E+00
      1.632E+00 1.047E+00 5.831E-01 1.009E-04
si4   1.000E-11 7.090E-08 5.500E-07 1.500E-06 4.000E-06 1.600E-05
      4.810E-05 1.660E-04 3.540E-04 9.610E-04 2.950E-03 9.120E-03
      2.480E-02 6.740E-02 1.100E-01 3.900E-01 6.400E-01 1.740E+00
      2.870E+00 3.680E+00 4.720E+00 6.070E+00 7.000E+00 8.250E+00
      1.000E+01 1.125E+01 1.250E+01 1.360E+01 1.460E+01
sp4   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
      0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
      0.0000E+00 0.0000E+00 2.4850E+01 6.1350E+04 1.7620E+05 7.3960E+05
      6.2630E+05 2.6030E+05 1.4660E+05 7.8130E+04 2.3350E+04 1.3530E+04
      5.0380E+03 1.6060E+03 4.8350E+02 1.1600E+02 0.0000E+00
C Source Information
si5 1                   302 304
                306 308 310 312 314 316
            318 320 322 324 326 328 330 332
            334 336 338 340 342 344 346 348
        350 352 354 356 358 360 362 364 366 368
        370 372 374 376 378 380 382 384 386 388
            390 392 394 396 398 400 402 404
            406 408 410 412 414 416 418 420
                422 424 426 428 430 432
                        434 436
C Source Probability
sp5                         1.39 1.39
                1.39 1.39 1.39 1.39 1.39 1.39
            1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39
            1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39
      1.39 1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39 1.39
      1.39 1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39 1.39
            1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39
            1.39 1.00 1.00 1.00 1.00 1.00 1.00 1.39
                 1.39 1.39 1.39 1.39 1.39 1.39
                           1.39 1.39
mode n
nps 30000000
C
C ANSI/ANS-6.1.1-1977 - Neutron Flux-to-Dose Conversion Factors
C (mrem/hr)/(neutrons/cm2-sec)
C
de0   2.5E-08 1E-07 1E-06 0.00001 0.0001 0.001 0.01
      0.1 0.5 1 2.5 5 7 10
      14 20
df0   3.67E-03 3.67E-03 4.46E-03 4.54E-03 4.18E-03 3.76E-03 3.56E-03
      2.17E-02 9.26E-02 1.32E-01 1.25E-01 1.56E-01 1.47E-01 1.47E-01
      2.08E-01 2.27E-01
C
C Weight Window Generation - Top Axial
C
wwg 2 0 0 0 0
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
wwp:n 5 3 5 0 -1 0
mesh geom=cyl ref=9 9 240 origin=0.1 0.1 -25
     imesh 88.4 89.7 90.8 92.7 101.6 106.7 109.9 609.9
     iints 5 1 1 1 1 1 1 1
     jmesh 1 25 28 55 266 279 290 302 320 820
     jints 1 1 1 1 10 1 1 1 2 1
     kmesh 1
     kints 1
wwge:n  1e-5 1e-3 1 20
fc2 Axial Surface Tally
f2:n +700.2
fm2 4.5049E+09
fs2  -701  -702  -703  -704  -705  -706
     -707  -708  -709  -710  -711  T
tf2
fc12 Axial PortAzi Tally Q1 (+x+y)
f12:n +800.2
fm12 4.5049E+09
fs12 -801  -802  -818
     +817  +816  +815  +814  +813  +812
     +811  +810  +809  +808  +807  +806
     +805  +804  +803  T
sd12 1.5608E+04  2.7362E+03  1.3681E+03  8.5507E+01  15r  5.4724E+03
tf12
fc22 Axial PortAzi Tally Q2 (-x+y)
f22:n +800.2
fm22 4.5049E+09
fs22 -801  +802  -818
     -833  -832  -831  -830  -829  -828
     -827  -826  -825  -824  -823  -822
     -821  -820  -819  T
sd22 1.5608E+04  2.7362E+03  1.3681E+03  8.5507E+01  15r  5.4724E+03
tf22
fc32 Axial PortAzi Tally Q3 (-x-y)
f32:n +800.2
fm32 4.5049E+09
fs32 -801  +802  +818
     -817  -816  -815  -814  -813  -812
     -811  -810  -809  -808  -807  -806
     -805  -804  -803  T
sd32 1.5608E+04  2.7362E+03  1.3681E+03  8.5507E+01  15r  5.4724E+03
tf32
fc42 Axial PortAzi Tally Q4 (+x-y)
f42:n +800.2
fm42 4.5049E+09
fs42 -801  -802  +818
     +833  +832  +831  +830  +829  +828
     +827  +826  +825  +824  +823  +822
     +821  +820  +819  T
sd42 1.5608E+04  2.7362E+03  1.3681E+03  8.5507E+01  15r  5.4724E+03
tf42
fc52 Axial AnnulusAzi Tally Q1 (+x+y)
f52:n +900.2
fm52 4.5049E+09
fs52 -901  -902  -904
     +903  T
sd52 2.1080E+04  2.4119E+03  1.2060E+03  6.0298E+02  1r  4.8239E+03
tf52
fc62 Axial AnnulusAzi Tally Q2 (-x+y)
f62:n +900.2
fm62 4.5049E+09
fs62 -901  +902  -904
     -905  T
sd62 2.1080E+04  2.4119E+03  1.2060E+03  6.0298E+02  1r  4.8239E+03
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
tf62
fc72 Axial AnnulusAzi Tally Q3 (-x-y)
f72:n +900.2
fm72 4.5049E+09
fs72 -901  +902  +904
     -903  T
sd72 2.1080E+04  2.4119E+03  1.2060E+03  6.0298E+02  1r  4.8239E+03
tf72
fc82 Axial AnnulusAzi Tally Q4 (+x-y)
f82:n +900.2
fm82 4.5049E+09
fs82 -901  -902  +904
     +905  T
sd82 2.1080E+04  2.4119E+03  1.2060E+03  6.0298E+02  1r  4.8239E+03
tf82
fc92 Axial 1ft Tally
f92:n +1000.2
fm92 4.5049E+09
fs92  -1001  -1002  -1003  -1004  -1005  -1006
     -1007  -1008  -1009  -1010  -1011  T
tf92
fc102 Axial 1m Tally
f102:n +1100.2
fm102 4.5049E+09
fs102  -1101  -1102  -1103  -1104  -1105  -1106
     -1107  -1108  -1109  -1110  -1111  T
tf102
fc112 Axial 2m Tally
f112:n +1200.2
fm112 4.5049E+09
fs112  -1201  -1202  -1203  -1204  -1205  -1206
     -1207  -1208  -1209  -1210  -1211  T
tf112
fc122 Axial 4m Tally
f122:n +1300.2
fm122 4.5049E+09
fs122  -1301  -1302  -1303  -1304  -1305  -1306
     -1307  -1308  -1309  -1310  -1311  T
tf122
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 5.625 degree rotation around z-axis
*TR1 0.0 0.0 0.0 5.625 95.625 90 -84.375 5.625 90 90 90 0
C 11.25 degree rotation around z-axis
*TR2 0.0 0.0 0.0 11.250 101.250 90 -78.750 11.250 90 90 90 0
C 16.875 degree rotation around z-axis
*TR3 0.0 0.0 0.0 16.875 106.875 90 -73.125 16.875 90 90 90 0
C 22.5 degree rotation around z-axis
*TR4 0.0 0.0 0.0 22.500 112.500 90 -67.500 22.500 90 90 90 0
C 28.125 degree rotation around z-axis
*TR5 0.0 0.0 0.0 28.125 118.125 90 -61.875 28.125 90 90 90 0
C 33.75 degree rotation around z-axis
*TR6 0.0 0.0 0.0 33.750 123.750 90 -56.250 33.750 90 90 90 0
```

Figure 5.A.6-4 MPC-LACBWR MCNP Input File for Transfer Cask Wet Canister Top Axial Biasing – Fuel Neutron Source

```
C 39.375 degree rotation around z-axis
*TR7 0.0 0.0 0.0 39.375 129.375 90 -50.625 39.375 90 90 90 0
C 45 degree rotation around z-axis
*TR8 0.0 0.0 0.0 45.000 135.000 90 -45.000 45.000 90 90 90 0
C 50.625 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50.625 140.625 90 -39.375 50.625 90 90 90 0
C 56.25 degree rotation around z-axis
*TR10 0.0 0.0 0.0 56.250 146.250 90 -33.750 56.250 90 90 90 0
C 61.875 degree rotation around z-axis
*TR11 0.0 0.0 0.0 61.875 151.875 90 -28.125 61.875 90 90 90 0
C 67.5 degree rotation around z-axis
*TR12 0.0 0.0 0.0 67.500 157.500 90 -22.500 67.500 90 90 90 0
C 73.125 degree rotation around z-axis
*TR13 0.0 0.0 0.0 73.125 163.125 90 -16.875 73.125 90 90 90 0
C 78.75 degree rotation around z-axis
*TR14 0.0 0.0 0.0 78.750 168.750 90 -11.250 78.750 90 90 90 0
C 84.375 degree rotation around z-axis
*TR15 0.0 0.0 0.0 84.375 174.375 90 -5.625 84.375 90 90 90 0
C 95.625 degree rotation around z-axis
*TR16 0.0 0.0 0.0 95.625 185.625 90 5.625 95.625 90 90 90 0
C 101.25 degree rotation around z-axis
*TR17 0.0 0.0 0.0 101.250 191.250 90 11.250 101.250 90 90 90 0
C 106.875 degree rotation around z-axis
*TR18 0.0 0.0 0.0 106.875 196.875 90 16.875 106.875 90 90 90 0
C 112.5 degree rotation around z-axis
*TR19 0.0 0.0 0.0 112.500 202.500 90 22.500 112.500 90 90 90 0
C 118.125 degree rotation around z-axis
*TR20 0.0 0.0 0.0 118.125 208.125 90 28.125 118.125 90 90 90 0
C 123.75 degree rotation around z-axis
*TR21 0.0 0.0 0.0 123.750 213.750 90 33.750 123.750 90 90 90 0
C 129.375 degree rotation around z-axis
*TR22 0.0 0.0 0.0 129.375 219.375 90 39.375 129.375 90 90 90 0
C 135 degree rotation around z-axis
*TR23 0.0 0.0 0.0 135.000 225.000 90 45.000 135.000 90 90 90 0
C 140.625 degree rotation around z-axis
*TR24 0.0 0.0 0.0 140.625 230.625 90 50.625 140.625 90 90 90 0
C 146.25 degree rotation around z-axis
*TR25 0.0 0.0 0.0 146.250 236.250 90 56.250 146.250 90 90 90 0
C 151.875 degree rotation around z-axis
*TR26 0.0 0.0 0.0 151.875 241.875 90 61.875 151.875 90 90 90 0
C 157.5 degree rotation around z-axis
*TR27 0.0 0.0 0.0 157.500 247.500 90 67.500 157.500 90 90 90 0
C 163.125 degree rotation around z-axis
*TR28 0.0 0.0 0.0 163.125 253.125 90 73.125 163.125 90 90 90 0
C 168.75 degree rotation around z-axis
*TR29 0.0 0.0 0.0 168.750 258.750 90 78.750 168.750 90 90 90 0
C 174.375 degree rotation around z-axis
*TR30 0.0 0.0 0.0 174.375 264.375 90 84.375 174.375 90 90 90 0
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
LACBWR Transfer Cask - trfShlDryBotLf_Pref
C Bottom Axial Biasing - Lower Nozzle Source
C Fuel Assembly Cells - v1.0
1 1 -1.3734 -1 -2    u=10 $ Lower Nozzle
2 2 -3.7790 -1 +2 -3   u=10 $ Fuel
3 3 -0.9880 -1 +3 -4   u=10 $ Upper Plenum
4 4 -0.6145 -1 +4    u=10 $ Upper Nozzle
5 0         +1     u=10 $ Outside
C Cells - Standard Fuel Tube  v1.0
101 0         -101       u=5 $ Tube void
102 6 -7.9400 -102 +101      u=5 $ Tube
103 8 -2.6707 -103       u=5 $ Absorber +Y
104 6 -7.9400 -104       u=5 $ Cladding +Y
105 8 -2.6707 -105       u=5 $ Absorber +X
106 6 -7.9400 -106       u=5 $ Cladding +X
107 0         +101 +102 +103 +104 +106 +105  u=5 $ Void
C Cells - DFC Fuel Tube Absorber 2 Sides v1.0
108 0         -107       u=6 $ Tube void
109 6 -7.9400 -108 +107      u=6 $ Tube
110 8 -2.6707 -109       u=6 $ Absorber +Y
111 6 -7.9400 -110       u=6 $ Cladding +Y
112 8 -2.6707 -111       u=6 $ Absorber +X
113 6 -7.9400 -112       u=6 $ Cladding +X
114 0         +107 +108 +109 +110 +112 +111  u=6 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (Y) v1.0
115 0         -107       u=7 $ Tube void
116 6 -7.9400 -108 +107      u=7 $ Tube
117 8 -2.6707 -109       u=7 $ Absorber +Y
118 6 -7.9400 -110       u=7 $ Cladding +Y
119 0         +107 +108 +109 +110    u=7 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (X) v1.0
120 0         -107       u=8 $ Tube void
121 6 -7.9400 -108 +107      u=8 $ Tube
122 8 -2.6707 -111       u=8 $ Absorber +X
123 6 -7.9400 -112       u=8 $ Cladding +X
124 0         +107 +108 +111 +112    u=8 $ Void
C Cells - DFC Fuel Tube No Absorber v1.0
125 0         -107       u=9 $ Tube void
126 6 -7.9400 -108 +107      u=9 $ Tube
127 0         +107 +108      u=9 $ Void
c Cell Cards - Disk Stack v1.0
201 6 -7.94 -203 trcl = ( 0.0000 0.0000 2.5400 )    u=4 $ Bottom weldment disk
202 6 -7.94 -201 trcl = ( 0.0000 0.0000 15.0368 )    u=4 $ Support disk 1
203 like 202 but   trcl = ( 0.0000 0.0000 24.7650 )    u=4 $ Support disk 2
204 like 202 but   trcl = ( 0.0000 0.0000 34.4932 )    u=4 $ Support disk 3
205 like 202 but   trcl = ( 0.0000 0.0000 44.2214 )    u=4 $ Support disk 4
206 like 202 but   trcl = ( 0.0000 0.0000 53.9496 )    u=4 $ Support disk 5
207 9 -2.70 -202 trcl = ( 0.0000 0.0000 58.9788 )    u=4 $ Heat transfer disk 1
208 like 202 but   trcl = ( 0.0000 0.0000 63.6778 )    u=4 $ Support disk 6
209 like 207 but   trcl = ( 0.0000 0.0000 68.7070 )    u=4 $ Heat transfer disk 2
210 like 202 but   trcl = ( 0.0000 0.0000 73.4060 )    u=4 $ Support disk 7
211 like 207 but   trcl = ( 0.0000 0.0000 78.4352 )    u=4 $ Heat transfer disk 3
212 like 202 but   trcl = ( 0.0000 0.0000 83.1342 )    u=4 $ Support disk 8
213 like 207 but   trcl = ( 0.0000 0.0000 88.1634 )    u=4 $ Heat transfer disk 4
214 like 202 but   trcl = ( 0.0000 0.0000 92.8624 )    u=4 $ Support disk 9
215 like 207 but   trcl = ( 0.0000 0.0000 97.8916 )    u=4 $ Heat transfer disk 5
216 like 202 but   trcl = ( 0.0000 0.0000 102.5906 )    u=4 $ Support disk 10
217 like 207 but   trcl = ( 0.0000 0.0000 107.6198 )    u=4 $ Heat transfer disk 6
218 like 202 but   trcl = ( 0.0000 0.0000 112.3188 )    u=4 $ Support disk 11
219 like 207 but   trcl = ( 0.0000 0.0000 117.3480 )    u=4 $ Heat transfer disk 7
220 like 202 but   trcl = ( 0.0000 0.0000 122.0470 )    u=4 $ Support disk 12
221 like 207 but   trcl = ( 0.0000 0.0000 127.0762 )    u=4 $ Heat transfer disk 8
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
222 like 202 but   trcl = ( 0.0000 0.0000 131.7752 )    u=4 $ Support disk 13
223 like 207 but   trcl = ( 0.0000 0.0000 136.8044 )    u=4 $ Heat transfer disk 9
224 like 202 but   trcl = ( 0.0000 0.0000 141.5034 )    u=4 $ Support disk 14
225 like 207 but   trcl = ( 0.0000 0.0000 146.5326 )    u=4 $ Heat transfer disk 10
226 like 202 but   trcl = ( 0.0000 0.0000 151.2316 )    u=4 $ Support disk 15
227 like 207 but   trcl = ( 0.0000 0.0000 156.2608 )    u=4 $ Heat transfer disk 11
228 like 202 but   trcl = ( 0.0000 0.0000 160.9598 )    u=4 $ Support disk 16
229 like 207 but   trcl = ( 0.0000 0.0000 165.9890 )    u=4 $ Heat transfer disk 12
230 like 202 but   trcl = ( 0.0000 0.0000 170.6880 )    u=4 $ Support disk 17
231 like 207 but   trcl = ( 0.0000 0.0000 175.7172 )    u=4 $ Heat transfer disk 13
232 like 202 but   trcl = ( 0.0000 0.0000 180.4162 )    u=4 $ Support disk 18
233 like 207 but   trcl = ( 0.0000 0.0000 185.4454 )    u=4 $ Heat transfer disk 14
234 like 202 but   trcl = ( 0.0000 0.0000 190.1444 )    u=4 $ Support disk 19
235 like 202 but   trcl = ( 0.0000 0.0000 199.8726 )    u=4 $ Support disk 20
236 like 202 but   trcl = ( 0.0000 0.0000 209.6008 )    u=4 $ Support disk 21
237 like 202 but   trcl = ( 0.0000 0.0000 219.3290 )    u=4 $ Support disk 22
238 like 202 but   trcl = ( 0.0000 0.0000 229.0572 )    u=4 $ Support disk 23
239 like 202 but   trcl = ( 0.0000 0.0000 238.7854 )    u=4 $ Support disk 24
240 like 201 but   trcl = ( 0.0000 0.0000 255.8796 )    u=4 $ Top weldment disk
241 0                $ Outside Disks
      #201 #202 #203 #204 #205 #206 #207 #208 #209 #210
      #211 #212 #213 #214 #215 #216 #217 #218 #219 #220
      #221 #222 #223 #224 #225 #226 #227 #228 #229 #230
      #231 #232 #233 #234 #235 #236 #237 #238 #239
      #240        u=4
c Cell Cards - Basket v1.0
301 0          -302 #302  fill=8 ( -8.8265 77.5233 0.0000 )      $ Tube/Disk 1
           trcl = ( -8.8265 77.5233 0.0000 )     u=3
302 0          -1  fill=10 trcl = ( -8.8265 77.5233 0.0000 )     u=3 $ Assembly 1
303 0          -302 #304  fill=9 ( 8.8265 77.5233 0.0000 )      $ Tube/Disk 2
           trcl = ( 8.8265 77.5233 0.0000 )     u=3
304 like 302 but     trcl = ( 8.8265 77.5233 0.0000 )     u=3 $ Assembly 2
305 0          -302 #306  fill=8 ( -44.1274 61.2699 0.0000 )      $ Tube/Disk 3
           trcl = ( -44.1274 61.2699 0.0000 )     u=3
306 like 302 but     trcl = ( -44.1274 61.2699 0.0000 )     u=3 $ Assembly 3
307 0          -302 #308  fill=8 ( -26.4770 59.8729 0.0000 )      $ Tube/Disk 4
           trcl = ( -26.4770 59.8729 0.0000 )     u=3
308 like 302 but     trcl = ( -26.4770 59.8729 0.0000 )     u=3 $ Assembly 4
309 0          -302 #310  fill=6 ( -8.8265 59.8729 0.0000 )      $ Tube/Disk 5
           trcl = ( -8.8265 59.8729 0.0000 )     u=3
310 like 302 but     trcl = ( -8.8265 59.8729 0.0000 )     u=3 $ Assembly 5
311 0          -302 #312  fill=6 ( 8.8265 59.8729 0.0000 )      $ Tube/Disk 6
           trcl = ( 8.8265 59.8729 0.0000 )     u=3
312 like 302 but     trcl = ( 8.8265 59.8729 0.0000 )     u=3 $ Assembly 6
313 0          -302 #314  fill=8 ( 26.4770 59.8729 0.0000 )      $ Tube/Disk 7
           trcl = ( 26.4770 59.8729 0.0000 )     u=3
314 like 302 but     trcl = ( 26.4770 59.8729 0.0000 )     u=3 $ Assembly 7
315 0          -302 #316  fill=9 ( 44.1274 61.2699 0.0000 )      $ Tube/Disk 8
           trcl = ( 44.1274 61.2699 0.0000 )     u=3
316 like 302 but     trcl = ( 44.1274 61.2699 0.0000 )     u=3 $ Assembly 8
317 0          -302 #318  fill=8 ( -61.2699 44.1274 0.0000 )      $ Tube/Disk 9
           trcl = ( -61.2699 44.1274 0.0000 )     u=3
318 like 302 but     trcl = ( -61.2699 44.1274 0.0000 )     u=3 $ Assembly 9
319 0          -301 #320  fill=5 ( -42.5399 42.5399 0.0000 )      $ Tube/Disk 10
           trcl = ( -42.5399 42.5399 0.0000 )     u=3
320 like 302 but     trcl = ( -42.5399 42.5399 0.0000 )     u=3 $ Assembly 10
321 0          -301 #322  fill=5 ( -25.5245 42.5399 0.0000 )      $ Tube/Disk 11
           trcl = ( -25.5245 42.5399 0.0000 )     u=3
322 like 302 but     trcl = ( -25.5245 42.5399 0.0000 )     u=3 $ Assembly 11
323 0          -301 #324  fill=5 ( -8.5090 42.5399 0.0000 )      $ Tube/Disk 12
           trcl = ( -8.5090 42.5399 0.0000 )     u=3
324 like 302 but     trcl = ( -8.5090 42.5399 0.0000 )     u=3 $ Assembly 12
325 0          -301 #326  fill=5 ( 8.5090 42.5399 0.0000 )      $ Tube/Disk 13
           trcl = ( 8.5090 42.5399 0.0000 )     u=3
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
326 like 302 but     trcl = ( 8.5090 42.5399 0.0000 )     u=3 $ Assembly 13
327 0         -301 #328  fill=5 ( 25.5245 42.5399 0.0000 )      $ Tube/Disk 14
          trcl = ( 25.5245 42.5399 0.0000 )     u=3
328 like 302 but     trcl = ( 25.5245 42.5399 0.0000 )     u=3 $ Assembly 14
329 0         -301 #330  fill=5 ( 42.5399 42.5399 0.0000 )      $ Tube/Disk 15
          trcl = ( 42.5399 42.5399 0.0000 )     u=3
330 like 302 but     trcl = ( 42.5399 42.5399 0.0000 )     u=3 $ Assembly 15
331 0         -302 #332  fill=9 ( 61.2699 44.1274 0.0000 )      $ Tube/Disk 16
          trcl = ( 61.2699 44.1274 0.0000 )     u=3
332 like 302 but     trcl = ( 61.2699 44.1274 0.0000 )     u=3 $ Assembly 16
333 0         -302 #334  fill=6 ( -59.8729 26.4770 0.0000 )      $ Tube/Disk 17
          trcl = ( -59.8729 26.4770 0.0000 )     u=3
334 like 302 but     trcl = ( -59.8729 26.4770 0.0000 )     u=3 $ Assembly 17
335 0         -301 #336  fill=5 ( -42.5399 25.5245 0.0000 )      $ Tube/Disk 18
          trcl = ( -42.5399 25.5245 0.0000 )     u=3
336 like 302 but     trcl = ( -42.5399 25.5245 0.0000 )     u=3 $ Assembly 18
337 0         -301 #338  fill=5 ( -25.5245 25.5245 0.0000 )      $ Tube/Disk 19
          trcl = ( -25.5245 25.5245 0.0000 )     u=3
338 like 302 but     trcl = ( -25.5245 25.5245 0.0000 )     u=3 $ Assembly 19
339 0         -301 #340  fill=5 ( -8.5090 25.5245 0.0000 )      $ Tube/Disk 20
          trcl = ( -8.5090 25.5245 0.0000 )     u=3
340 like 302 but     trcl = ( -8.5090 25.5245 0.0000 )     u=3 $ Assembly 20
341 0         -301 #342  fill=5 ( 8.5090 25.5245 0.0000 )      $ Tube/Disk 21
          trcl = ( 8.5090 25.5245 0.0000 )     u=3
342 like 302 but     trcl = ( 8.5090 25.5245 0.0000 )     u=3 $ Assembly 21
343 0         -301 #344  fill=5 ( 25.5245 25.5245 0.0000 )      $ Tube/Disk 22
          trcl = ( 25.5245 25.5245 0.0000 )     u=3
344 like 302 but     trcl = ( 25.5245 25.5245 0.0000 )     u=3 $ Assembly 22
345 0         -301 #346  fill=5 ( 42.5399 25.5245 0.0000 )      $ Tube/Disk 23
          trcl = ( 42.5399 25.5245 0.0000 )     u=3
346 like 302 but     trcl = ( 42.5399 25.5245 0.0000 )     u=3 $ Assembly 23
347 0         -302 #348  fill=7 ( 59.8729 26.4770 0.0000 )      $ Tube/Disk 24
          trcl = ( 59.8729 26.4770 0.0000 )     u=3
348 like 302 but     trcl = ( 59.8729 26.4770 0.0000 )     u=3 $ Assembly 24
349 0         -302 #350  fill=8 ( -77.5233 8.8265 0.0000 )      $ Tube/Disk 25
          trcl = ( -77.5233 8.8265 0.0000 )     u=3
350 like 302 but     trcl = ( -77.5233 8.8265 0.0000 )     u=3 $ Assembly 25
351 0         -302 #352  fill=6 ( -59.8729 8.8265 0.0000 )      $ Tube/Disk 26
          trcl = ( -59.8729 8.8265 0.0000 )     u=3
352 like 302 but     trcl = ( -59.8729 8.8265 0.0000 )     u=3 $ Assembly 26
353 0         -301 #354  fill=5 ( -42.5399 8.5090 0.0000 )      $ Tube/Disk 27
          trcl = ( -42.5399 8.5090 0.0000 )     u=3
354 like 302 but     trcl = ( -42.5399 8.5090 0.0000 )     u=3 $ Assembly 27
355 0         -301 #356  fill=5 ( -25.5245 8.5090 0.0000 )      $ Tube/Disk 28
          trcl = ( -25.5245 8.5090 0.0000 )     u=3
356 like 302 but     trcl = ( -25.5245 8.5090 0.0000 )     u=3 $ Assembly 28
357 0         -301 #358  fill=5 ( -8.5090 8.5090 0.0000 )      $ Tube/Disk 29
          trcl = ( -8.5090 8.5090 0.0000 )     u=3
358 like 302 but     trcl = ( -8.5090 8.5090 0.0000 )     u=3 $ Assembly 29
359 0         -301 #360  fill=5 ( 8.5090 8.5090 0.0000 )      $ Tube/Disk 30
          trcl = ( 8.5090 8.5090 0.0000 )     u=3
360 like 302 but     trcl = ( 8.5090 8.5090 0.0000 )     u=3 $ Assembly 30
361 0         -301 #362  fill=5 ( 25.5245 8.5090 0.0000 )      $ Tube/Disk 31
          trcl = ( 25.5245 8.5090 0.0000 )     u=3
362 like 302 but     trcl = ( 25.5245 8.5090 0.0000 )     u=3 $ Assembly 31
363 0         -301 #364  fill=5 ( 42.5399 8.5090 0.0000 )      $ Tube/Disk 32
          trcl = ( 42.5399 8.5090 0.0000 )     u=3
364 like 302 but     trcl = ( 42.5399 8.5090 0.0000 )     u=3 $ Assembly 32
365 0         -302 #366  fill=6 ( 59.8729 8.8265 0.0000 )      $ Tube/Disk 33
          trcl = ( 59.8729 8.8265 0.0000 )     u=3
366 like 302 but     trcl = ( 59.8729 8.8265 0.0000 )     u=3 $ Assembly 33
367 0         -302 #368  fill=9 ( 77.5233 8.8265 0.0000 )      $ Tube/Disk 34
          trcl = ( 77.5233 8.8265 0.0000 )     u=3
368 like 302 but     trcl = ( 77.5233 8.8265 0.0000 )     u=3 $ Assembly 34
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
369 0          -302 #370  fill=6 ( -77.5233 -8.8265 0.0000 )      $ Tube/Disk 35
           trcl = ( -77.5233 -8.8265 0.0000 )     u=3
370 like 302 but     trcl = ( -77.5233 -8.8265 0.0000 )     u=3 $ Assembly 35
371 0          -302 #372  fill=6 ( -59.8729 -8.8265 0.0000 )      $ Tube/Disk 36
           trcl = ( -59.8729 -8.8265 0.0000 )     u=3
372 like 302 but     trcl = ( -59.8729 -8.8265 0.0000 )     u=3 $ Assembly 36
373 0          -301 #374  fill=5 ( -42.5399 -8.5090 0.0000 )      $ Tube/Disk 37
           trcl = ( -42.5399 -8.5090 0.0000 )     u=3
374 like 302 but     trcl = ( -42.5399 -8.5090 0.0000 )     u=3 $ Assembly 37
375 0          -301 #376  fill=5 ( -25.5245 -8.5090 0.0000 )      $ Tube/Disk 38
           trcl = ( -25.5245 -8.5090 0.0000 )     u=3
376 like 302 but     trcl = ( -25.5245 -8.5090 0.0000 )     u=3 $ Assembly 38
377 0          -301 #378  fill=5 ( -8.5090 -8.5090 0.0000 )      $ Tube/Disk 39
           trcl = ( -8.5090 -8.5090 0.0000 )     u=3
378 like 302 but     trcl = ( -8.5090 -8.5090 0.0000 )     u=3 $ Assembly 39
379 0          -301 #380  fill=5 ( 8.5090 -8.5090 0.0000 )      $ Tube/Disk 40
           trcl = ( 8.5090 -8.5090 0.0000 )     u=3
380 like 302 but     trcl = ( 8.5090 -8.5090 0.0000 )     u=3 $ Assembly 40
381 0          -301 #382  fill=5 ( 25.5245 -8.5090 0.0000 )      $ Tube/Disk 41
           trcl = ( 25.5245 -8.5090 0.0000 )     u=3
382 like 302 but     trcl = ( 25.5245 -8.5090 0.0000 )     u=3 $ Assembly 41
383 0          -301 #384  fill=5 ( 42.5399 -8.5090 0.0000 )      $ Tube/Disk 42
           trcl = ( 42.5399 -8.5090 0.0000 )     u=3
384 like 302 but     trcl = ( 42.5399 -8.5090 0.0000 )     u=3 $ Assembly 42
385 0          -302 #386  fill=6 ( 59.8729 -8.8265 0.0000 )      $ Tube/Disk 43
           trcl = ( 59.8729 -8.8265 0.0000 )     u=3
386 like 302 but     trcl = ( 59.8729 -8.8265 0.0000 )     u=3 $ Assembly 43
387 0          -302 #388  fill=7 ( 77.5233 -8.8265 0.0000 )      $ Tube/Disk 44
           trcl = ( 77.5233 -8.8265 0.0000 )     u=3
388 like 302 but     trcl = ( 77.5233 -8.8265 0.0000 )     u=3 $ Assembly 44
389 0          -302 #390  fill=6 ( -59.8729 -26.4770 0.0000 )      $ Tube/Disk 45
           trcl = ( -59.8729 -26.4770 0.0000 )     u=3
390 like 302 but     trcl = ( -59.8729 -26.4770 0.0000 )     u=3 $ Assembly 45
391 0          -301 #392  fill=5 ( -42.5399 -25.5245 0.0000 )      $ Tube/Disk 46
           trcl = ( -42.5399 -25.5245 0.0000 )     u=3
392 like 302 but     trcl = ( -42.5399 -25.5245 0.0000 )     u=3 $ Assembly 46
393 0          -301 #394  fill=5 ( -25.5245 -25.5245 0.0000 )      $ Tube/Disk 47
           trcl = ( -25.5245 -25.5245 0.0000 )     u=3
394 like 302 but     trcl = ( -25.5245 -25.5245 0.0000 )     u=3 $ Assembly 47
395 0          -301 #396  fill=5 ( -8.5090 -25.5245 0.0000 )      $ Tube/Disk 48
           trcl = ( -8.5090 -25.5245 0.0000 )     u=3
396 like 302 but     trcl = ( -8.5090 -25.5245 0.0000 )     u=3 $ Assembly 48
397 0          -301 #398  fill=5 ( 8.5090 -25.5245 0.0000 )      $ Tube/Disk 49
           trcl = ( 8.5090 -25.5245 0.0000 )     u=3
398 like 302 but     trcl = ( 8.5090 -25.5245 0.0000 )     u=3 $ Assembly 49
399 0          -301 #400  fill=5 ( 25.5245 -25.5245 0.0000 )      $ Tube/Disk 50
           trcl = ( 25.5245 -25.5245 0.0000 )     u=3
400 like 302 but     trcl = ( 25.5245 -25.5245 0.0000 )     u=3 $ Assembly 50
401 0          -301 #402  fill=5 ( 42.5399 -25.5245 0.0000 )      $ Tube/Disk 51
           trcl = ( 42.5399 -25.5245 0.0000 )     u=3
402 like 302 but     trcl = ( 42.5399 -25.5245 0.0000 )     u=3 $ Assembly 51
403 0          -302 #404  fill=7 ( 59.8729 -26.4770 0.0000 )      $ Tube/Disk 52
           trcl = ( 59.8729 -26.4770 0.0000 )     u=3
404 like 302 but     trcl = ( 59.8729 -26.4770 0.0000 )     u=3 $ Assembly 52
405 0          -302 #406  fill=6 ( -61.2699 -44.1274 0.0000 )      $ Tube/Disk 53
           trcl = ( -61.2699 -44.1274 0.0000 )     u=3
406 like 302 but     trcl = ( -61.2699 -44.1274 0.0000 )     u=3 $ Assembly 53
407 0          -301 #408  fill=5 ( -42.5399 -42.5399 0.0000 )      $ Tube/Disk 54
           trcl = ( -42.5399 -42.5399 0.0000 )     u=3
408 like 302 but     trcl = ( -42.5399 -42.5399 0.0000 )     u=3 $ Assembly 54
409 0          -301 #410  fill=5 ( -25.5245 -42.5399 0.0000 )      $ Tube/Disk 55
           trcl = ( -25.5245 -42.5399 0.0000 )     u=3
410 like 302 but     trcl = ( -25.5245 -42.5399 0.0000 )     u=3 $ Assembly 55
411 0          -301 #412  fill=5 ( -8.5090 -42.5399 0.0000 )      $ Tube/Disk 56
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
          trcl = ( -8.5090 -42.5399 0.0000 )      u=3
412 like 302 but      trcl = ( -8.5090 -42.5399 0.0000 )      u=3 $ Assembly 56
413 0          -301 #414  fill=5 ( 8.5090 -42.5399 0.0000 )       $ Tube/Disk 57
          trcl = ( 8.5090 -42.5399 0.0000 )      u=3
414 like 302 but      trcl = ( 8.5090 -42.5399 0.0000 )      u=3 $ Assembly 57
415 0          -301 #416  fill=5 ( 25.5245 -42.5399 0.0000 )       $ Tube/Disk 58
          trcl = ( 25.5245 -42.5399 0.0000 )      u=3
416 like 302 but      trcl = ( 25.5245 -42.5399 0.0000 )      u=3 $ Assembly 58
417 0          -301 #418  fill=5 ( 42.5399 -42.5399 0.0000 )       $ Tube/Disk 59
          trcl = ( 42.5399 -42.5399 0.0000 )      u=3
418 like 302 but      trcl = ( 42.5399 -42.5399 0.0000 )      u=3 $ Assembly 59
419 0          -302 #420  fill=7 ( 61.2699 -44.1274 0.0000 )       $ Tube/Disk 60
          trcl = ( 61.2699 -44.1274 0.0000 )      u=3
420 like 302 but      trcl = ( 61.2699 -44.1274 0.0000 )      u=3 $ Assembly 60
421 0          -302 #422  fill=6 ( -44.1274 -61.2699 0.0000 )       $ Tube/Disk 61
          trcl = ( -44.1274 -61.2699 0.0000 )      u=3
422 like 302 but      trcl = ( -44.1274 -61.2699 0.0000 )      u=3 $ Assembly 61
423 0          -302 #424  fill=6 ( -26.4770 -59.8729 0.0000 )       $ Tube/Disk 62
          trcl = ( -26.4770 -59.8729 0.0000 )      u=3
424 like 302 but      trcl = ( -26.4770 -59.8729 0.0000 )      u=3 $ Assembly 62
425 0          -302 #426  fill=6 ( -8.8265 -59.8729 0.0000 )       $ Tube/Disk 63
          trcl = ( -8.8265 -59.8729 0.0000 )      u=3
426 like 302 but      trcl = ( -8.8265 -59.8729 0.0000 )      u=3 $ Assembly 63
427 0          -302 #428  fill=6 ( 8.8265 -59.8729 0.0000 )       $ Tube/Disk 64
          trcl = ( 8.8265 -59.8729 0.0000 )      u=3
428 like 302 but      trcl = ( 8.8265 -59.8729 0.0000 )      u=3 $ Assembly 64
429 0          -302 #430  fill=6 ( 26.4770 -59.8729 0.0000 )       $ Tube/Disk 65
          trcl = ( 26.4770 -59.8729 0.0000 )      u=3
430 like 302 but      trcl = ( 26.4770 -59.8729 0.0000 )      u=3 $ Assembly 65
431 0          -302 #432  fill=7 ( 44.1274 -61.2699 0.0000 )       $ Tube/Disk 66
          trcl = ( 44.1274 -61.2699 0.0000 )      u=3
432 like 302 but      trcl = ( 44.1274 -61.2699 0.0000 )      u=3 $ Assembly 66
433 0          -302 #434  fill=7 ( -8.8265 -77.5233 0.0000 )       $ Tube/Disk 67
          trcl = ( -8.8265 -77.5233 0.0000 )      u=3
434 like 302 but      trcl = ( -8.8265 -77.5233 0.0000 )      u=3 $ Assembly 67
435 0          -302 #436  fill=7 ( 8.8265 -77.5233 0.0000 )       $ Tube/Disk 68
          trcl = ( 8.8265 -77.5233 0.0000 )      u=3
436 like 302 but      trcl = ( 8.8265 -77.5233 0.0000 )      u=3 $ Assembly 68
437 0          +303 +304         $ Canister Cavity Q1
      #303 #311 #313 #315 #325 #327 #329 #331 #341
      #304 #312 #314 #316 #326 #328 #330 #332 #342
      #343 #345 #347 #359 #361 #363 #365 #367
      #344 #346 #348 #360 #362 #364 #366 #368
          fill=4      u=3
438 0          +303 -304         $ Canister Cavity Q2
      #301 #305 #307 #309 #317 #319 #321 #323 #333
      #302 #306 #308 #310 #318 #320 #322 #324 #334
      #335 #337 #339 #349 #351 #353 #355 #357
      #336 #338 #340 #350 #352 #354 #356 #358
          fill=4      u=3
439 0          -303 -304         $ Canister Cavity Q3
      #369 #371 #373 #375 #377 #389 #391 #393 #395
      #370 #372 #374 #376 #378 #390 #392 #394 #396
      #405 #407 #409 #411 #421 #423 #425 #433
      #406 #408 #410 #412 #422 #424 #426 #434
          fill=4      u=3
440 0          -303 +304         $ Canister Cavity Q4
      #379 #381 #383 #385 #387 #397 #399 #401 #403
      #380 #382 #384 #386 #388 #398 #400 #402 #404
      #413 #415 #417 #419 #427 #429 #431 #435
      #414 #416 #418 #420 #428 #430 #432 #436
          fill=4      u=3
C Cells - Canister v1.0
501 0          -501 fill=3       u=2 $ Cavity
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
502 6 -7.9400 -507 +501.3      u=2 $ Canister Bottom
503 0         -502 +501.2 -505 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Bottom Drain Port
504 0         -503 +505 -506 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Middle Drain Port
505 6 -7.9400 -504 +506 -507.2 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Top Drain Port
506 like 503 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Bottom Vent Port
507 like 504 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Middle Vent Port
508 like 505 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Top Vent Port
509 6 -7.9400 -507 -501.3 +501.1     u=2 $ Canister Shell
510 6 -7.9400 -507 -501.1 +501.2 #503 #504 #505 #506 #507 #508     u=2 $ Lid
511 0         +507       u=2 $ Outside
C Transfer Cask Cells - v4.1
601 0         -601 -602  fill=2 ( 0.0000 0.0000 2.5400 )   u=1 $ Cavity
602 7 -7.8212 -601 +602 -606    u=1 $ Bottom forging
603 7 -7.8212 -603 +602 +606 -608 +614  u=1 $ Inner shell
604 10 -11.344 -604 +603 +606 -607 +614  u=1 $ Lead shell
605 11 -1.6316 -604 +603 +607 -608   u=1 $ NS-4-FR above Pb
606 11 -1.6316 -605 +604 +606 -608 +614  u=1 $ NS-4-FR
607 7 -7.8212 -601 +605 +606 -608 +614  u=1 $ Outer shell
608 7 -7.8212 -601 +602 +608    u=1 $ Top forging
609 7 -7.8212 -601 +602 -614    u=1 $ Trunnion
610 7 -7.8212 (-609 +610 -616) : (-609 -611 -616)      u=1 $ Door rail
611 7 -7.8212 -615 -612 +613 -616   u=1 $ Door steel
612 0         +601 #610  #611     u=1 $ Void
C Detector Cells - Axial Biasing
700  0  -700  fill=1  $ Surface
800  0  -800  +700  $ 1ft
900  0  -900  +700  +800  $ 1m
1000  0  -1000  +700  +800  +900  $ 2m
1100  0  -1100  +700  +800  +900  +1000  $ 4m
1200  0  +700  +800  +900  +1000  +1100  $ Exterior

C Fuel Assembly Surfaces - v1.0
1 RPP -7.1247 7.1247 -7.1247 7.1247 0.0000 261.9502  $ Assy
2 PZ 27.2796       $ Lower Nozzle/Fuel
3 PZ 238.0996       $ Fuel/Upper Plenum
4 PZ 251.1298       $ Upper Plenum/Upper Nozzle
C Surfaces - Standard Fuel Tube v1.0
101 RPP -7.3076 7.3076 -7.3076 7.3076 0.0000 274.4470    $ Tube void
102 RPP -7.4295 7.4295 -7.4295 7.4295 0.0000 249.5550    $ Tube
103 RPP -6.5913 6.5913 7.4295 7.6200 2.0320 245.8720    $ Absorber +Y
104 RPP -6.5913 6.5913 7.6200 7.6657 2.0320 245.8720    $ Cladding +Y
105 RPP 7.4295 7.6200 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
106 RPP 7.6200 7.6657 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
C Surfaces - DFC Fuel Tube v1.0
107 RPP -7.6251 7.6251 -7.6251 7.6251 0.0000 274.4470    $ Tube void
108 RPP -7.7470 7.7470 -7.7470 7.7470 0.0000 249.5550    $ Tube
109 RPP -6.5913 6.5913 7.7470 7.9375 2.0320 245.8720    $ Absorber +Y
110 RPP -6.5913 6.5913 7.9375 7.9832 2.0320 245.8720    $ Cladding +Y
111 RPP 7.7470 7.9375 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
112 RPP 7.9375 7.9832 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
c Surface Cards - Disk Stack  v1.0
201 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.1380 $ Structural disk
202 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.2700 87.7951 $ Heat transfer disk
203 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Weldment disk
c Surface Cards - Basket v1.0
301 RPP -7.7711 7.7711 -7.7711 7.7711 0.0000 274.4470  $ Std opening
302 RPP -8.0899 8.0899 -8.0899 8.0899 0.0000 274.4470  $ DFC opening
303 PY 0.0000       $ Cut plane
304 PX 0.0000       $ Cut plane
C Surfaces - Canister v1.0
501 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470 88.4428   $ Cavity
502 CZ 1.3843         $ Bot Cylinder Radius
503 CZ 5.0800         $ Mid Cyclinder Radius
504 CZ 5.7150         $ Top Cylinder Radius
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
505 PZ 282.8798          $ Port plane bot/mid
506 PZ 289.3822          $ Port plane mid/top
507 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670 89.7128   $ Canister
C Transfer Cask Surfaces - v4.1
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 313.6900 109.8550  $ Cask
602 CZ 90.8050         $ Cavity
603 CZ 92.7100         $ Inner shell OR
604 CZ 101.6000         $ Lead shell OR
605 CZ 106.6800         $ Outer shell IR
606 PZ 2.5400         $ Bottom forging
607 PZ 298.4500         $ Top lead
608 PZ 308.6100         $ Top forging
609 RPP -110.1852 110.1852 -107.3150 107.3150 -24.1300 0.0000   $ Door container
610 PY 95.8850         $ Inside rail +y
611 PY -95.8850         $ Inside rail -y
612 PY 95.4024         $ Door +y
613 PY -95.4024         $ Door -y
614 RCC -109.8550 0.0000 275.5900 219.7100 0.0000 0.0000 12.7000  $ Trunnion
615 RHP 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300   $ Door prism
        109.6679 0.0000 0.0000 87.5826 -66.1670 0.0000
        -87.5826 -66.1670 0.0000
616 RCC 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300 109.8550  $ Door container
C Axial Detector DBA (Surface)
700  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  338.0200  109.9550
701  CZ  10.9955
702  CZ  21.9910
703  CZ  32.9865
704  CZ  43.9820
705  CZ  54.9775
706  CZ  65.9730
707  CZ  76.9685
708  CZ  87.9640
709  CZ  98.9595
C Axial Detector DBB (1ft)
800  RCC  0.0000  0.0000  -54.7100  0.0000  0.0000  368.5000  140.4350
801  CZ  14.0435
802  CZ  28.0870
803  CZ  42.1305
804  CZ  56.1740
805  CZ  70.2175
806  CZ  84.2610
807  CZ  98.3045
808  CZ  112.3480
809  CZ  126.3915
C Axial Detector DBC (1m)
900  RCC  0.0000  0.0000  -124.2300  0.0000  0.0000  438.0200  209.9550
901  CZ  20.9955
902  CZ  41.9910
903  CZ  62.9865
904  CZ  83.9820
905  CZ  104.9775
906  CZ  125.9730
907  CZ  146.9685
908  CZ  167.9640
909  CZ  188.9595
C Axial Detector DBD (2m)
1000  RCC  0.0000  0.0000  -224.2300  0.0000  0.0000  538.0200  309.9550
1001  CZ  30.9955
1002  CZ  61.9910
1003  CZ  92.9865
1004  CZ  123.9820
1005  CZ  154.9775
1006  CZ  185.9730
1007  CZ  216.9685
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
1008  CZ  247.9640
1009  CZ  278.9595
C Axial Detector DBE (4m)
1100  RCC  0.0000  0.0000  -424.2300  0.0000  0.0000  738.0200  509.9550
1101  CZ  50.9955
1102  CZ  101.9910
1103  CZ  152.9865
1104  CZ  203.9820
1105  CZ  254.9775
1106  CZ  305.9730
1107  CZ  356.9685
1108  CZ  407.9640
1109  CZ  458.9595

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized UO2 Fuel
m2     24000 -2.9967E-02
       25055 -3.1544E-03
       26000 -1.0961E-01
       28000 -1.4983E-02
       92235 -2.6729E-02
       92238 -7.1574E-01
        8016 -9.9810E-02
C Homogenized Upper Plenum
m3     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized Upper Nozzle
m4     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Water
m5     1001 2 8016 1
C Stainless Steel
m6     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m7     26000 -0.99 6012 -0.01
C Neutron Poison
m8     13027 -0.8466  5010 -0.0216  5011 -0.0985
        6012 -0.0333
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11     5010 -9.3127E-04 13027 -2.1420E-01  6012 -2.7627E-01
        5011 -3.7721E-03  1001 -6.0012E-02  7014 -1.9815E-02
        8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
C Vent Port Middle Cylinder
m13    24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
phys:p 100 0 0 0 1    $ Disable Doppler energy broadening
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
C
C Cell Importances
C
imp:p 1 240r 0
C
C BWR Source Definition - Lower Nozzle - Pref
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=700:601:501:d5:1
si1   -7.1247 7.1247
sp1   0 1
si2   -7.1247 7.1247
sp2   0 1
si3   0.0000 27.2796
sp3   0 1
si4   1.000E-02 2.000E-02 5.000E-02 1.000E-01 2.000E-01 3.000E-01
      4.000E-01 6.000E-01 8.000E-01 1.000E+00 1.220E+00 1.440E+00
      1.660E+00 2.000E+00 2.500E+00 3.000E+00 4.000E+00 5.000E+00
      6.500E+00 8.000E+00 1.000E+01 1.200E+01 1.400E+01
sp4   0.0000E+00 2.8706E+09 2.3122E+09 7.9407E+08 1.9153E+08 9.5103E+06
      1.2478E+07 7.8863E+05 2.7388E+05 1.0327E+07 1.5512E+11 1.4717E+11
      4.1293E-01 1.3627E-14 1.5535E+06 2.4089E+03 6.7528E-17 0.0000E+00
      0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
C Source Information
si5 l                   302 304
                306 308 310 312 314 316
            318 320 322 324 326 328 330 332
            334 336 338 340 342 344 346 348
        350 352 354 356 358 360 362 364 366 368
        370 372 374 376 378 380 382 384 386 388
            390 392 394 396 398 400 402 404
            406 408 410 412 414 416 418 420
                422 424 426 428 430 432
                        434 436
C Source Probability
sp5                         0.36 0.36
                0.36 0.36 0.36 0.36 0.36 0.36
            0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36
            0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36
      0.36 0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36 0.36
      0.36 0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36 0.36
            0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36
            0.36 1.00 1.00 1.00 1.00 1.00 1.00 0.36
                 0.36 0.36 0.36 0.36 0.36 0.36
                           0.36 0.36
mode p
nps 9100000
C
C ANSI/ANS-6.1.1-1977 - Gamma Flux-to-Dose Conversion Factors
C (mrem/hr)/(photons/cm2-sec)
C
de0   0.01 0.03 0.05 0.07 0.1 0.15 0.2
      0.25 0.3 0.35 0.4 0.45 0.5 0.55
      0.6 0.65 0.7 0.8 1 1.4 1.8
      2.2 2.6 2.8 3.25 3.75 4.25 4.75
      5 5.25 5.75 6.25 6.75 7.5 9
      11 13 15
df0   3.96E-03 5.82E-04 2.90E-04 2.58E-04 2.83E-04 3.79E-04 5.01E-04
      6.31E-04 7.59E-04 8.78E-04 9.85E-04 1.08E-03 1.17E-03 1.27E-03
      1.36E-03 1.44E-03 1.52E-03 1.68E-03 1.98E-03 2.51E-03 2.99E-03
      3.42E-03 3.82E-03 4.01E-03 4.41E-03 4.83E-03 5.23E-03 5.60E-03
      5.80E-03 6.01E-03 6.37E-03 6.74E-03 7.11E-03 7.66E-03 8.77E-03
      1.03E-02 1.18E-02 1.33E-02
C
C Weight Window Generation - Bottom Axial
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
C
wwg 2 0 0 0 0
wwp:p 5 3 5 0 -1 0
mesh geom=cyl ref=9 9 4 origin=0.1 0.1 -524
     imesh 88.4 89.7 90.8 92.7 101.6 106.7 109.9 609.9
     iints 5 1 1 1 3 1 1 1
     jmesh 500 524 527 554 765 778 789 801 819 1319
     jints 1 5 1 2 10 1 1 1 3 1
     kmesh 1
     kints 1
wwge:p  1e-3 1 20
fc2 Axial Surface Tally
f2:p +700.3
fm2 4.6382E+13
fs2  -701  -702  -703  -704  -705  -706
     -707  -708  -709  T
tf2
fc12 Axial 1ft Tally
f12:p +800.3
fm12 4.6382E+13
fs12  -801  -802  -803  -804  -805  -806
     -807  -808  -809  T
tf12
fc22 Axial 1m Tally
f22:p +900.3
fm22 4.6382E+13
fs22  -901  -902  -903  -904  -905  -906
     -907  -908  -909  T
tf22
fc32 Axial 2m Tally
f32:p +1000.3
fm32 4.6382E+13
fs32  -1001  -1002  -1003  -1004  -1005  -1006
     -1007  -1008  -1009  T
tf32
fc42 Axial 4m Tally
f42:p +1100.3
fm42 4.6382E+13
fs42  -1101  -1102  -1103  -1104  -1105  -1106
     -1107  -1108  -1109  T
tf42
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 5.625 degree rotation around z-axis
*TR1 0.0 0.0 0.0 5.625 95.625 90 -84.375 5.625 90 90 90 0
C 11.25 degree rotation around z-axis
*TR2 0.0 0.0 0.0 11.250 101.250 90 -78.750 11.250 90 90 90 0
C 16.875 degree rotation around z-axis
*TR3 0.0 0.0 0.0 16.875 106.875 90 -73.125 16.875 90 90 90 0
C 22.5 degree rotation around z-axis
*TR4 0.0 0.0 0.0 22.500 112.500 90 -67.500 22.500 90 90 90 0
C 28.125 degree rotation around z-axis
*TR5 0.0 0.0 0.0 28.125 118.125 90 -61.875 28.125 90 90 90 0
```

Figure 5.A.6-5 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Source

```
C 33.75 degree rotation around z-axis
*TR6 0.0 0.0 0.0 33.750 123.750 90 -56.250 33.750 90 90 90 0
C 39.375 degree rotation around z-axis
*TR7 0.0 0.0 0.0 39.375 129.375 90 -50.625 39.375 90 90 90 0
C 45 degree rotation around z-axis
*TR8 0.0 0.0 0.0 45.000 135.000 90 -45.000 45.000 90 90 90 0
C 50.625 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50.625 140.625 90 -39.375 50.625 90 90 90 0
C 56.25 degree rotation around z-axis
*TR10 0.0 0.0 0.0 56.250 146.250 90 -33.750 56.250 90 90 90 0
C 61.875 degree rotation around z-axis
*TR11 0.0 0.0 0.0 61.875 151.875 90 -28.125 61.875 90 90 90 0
C 67.5 degree rotation around z-axis
*TR12 0.0 0.0 0.0 67.500 157.500 90 -22.500 67.500 90 90 90 0
C 73.125 degree rotation around z-axis
*TR13 0.0 0.0 0.0 73.125 163.125 90 -16.875 73.125 90 90 90 0
C 78.75 degree rotation around z-axis
*TR14 0.0 0.0 0.0 78.750 168.750 90 -11.250 78.750 90 90 90 0
C 84.375 degree rotation around z-axis
*TR15 0.0 0.0 0.0 84.375 174.375 90 -5.625 84.375 90 90 90 0
C 95.625 degree rotation around z-axis
*TR16 0.0 0.0 0.0 95.625 185.625 90 5.625 95.625 90 90 90 0
C 101.25 degree rotation around z-axis
*TR17 0.0 0.0 0.0 101.250 191.250 90 11.250 101.250 90 90 90 0
C 106.875 degree rotation around z-axis
*TR18 0.0 0.0 0.0 106.875 196.875 90 16.875 106.875 90 90 90 0
C 112.5 degree rotation around z-axis
*TR19 0.0 0.0 0.0 112.500 202.500 90 22.500 112.500 90 90 90 0
C 118.125 degree rotation around z-axis
*TR20 0.0 0.0 0.0 118.125 208.125 90 28.125 118.125 90 90 90 0
C 123.75 degree rotation around z-axis
*TR21 0.0 0.0 0.0 123.750 213.750 90 33.750 123.750 90 90 90 0
C 129.375 degree rotation around z-axis
*TR22 0.0 0.0 0.0 129.375 219.375 90 39.375 129.375 90 90 90 0
C 135 degree rotation around z-axis
*TR23 0.0 0.0 0.0 135.000 225.000 90 45.000 135.000 90 90 90 0
C 140.625 degree rotation around z-axis
*TR24 0.0 0.0 0.0 140.625 230.625 90 50.625 140.625 90 90 90 0
C 146.25 degree rotation around z-axis
*TR25 0.0 0.0 0.0 146.250 236.250 90 56.250 146.250 90 90 90 0
C 151.875 degree rotation around z-axis
*TR26 0.0 0.0 0.0 151.875 241.875 90 61.875 151.875 90 90 90 0
C 157.5 degree rotation around z-axis
*TR27 0.0 0.0 0.0 157.500 247.500 90 67.500 157.500 90 90 90 0
C 163.125 degree rotation around z-axis
*TR28 0.0 0.0 0.0 163.125 253.125 90 73.125 163.125 90 90 90 0
C 168.75 degree rotation around z-axis
*TR29 0.0 0.0 0.0 168.750 258.750 90 78.750 168.750 90 90 90 0
C 174.375 degree rotation around z-axis
*TR30 0.0 0.0 0.0 174.375 264.375 90 84.375 174.375 90 90 90 0
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
LACBWR VCC - strShlDryInlLfg_PrefD
C Inlet Biasing - Lower Nozzle Source
C Fuel Assembly Cells - v1.0
1 1 -1.3734 -1 -2    u=11 $ Lower Nozzle
2 2 -3.7790 -1 +2 -3   u=11 $ Fuel
3 3 -0.9880 -1 +3 -4   u=11 $ Upper Plenum
4 4 -0.6145 -1 +4    u=11 $ Upper Nozzle
5 0         +1     u=11 $ Outside
C Fuel Assembly Cells - v1.0
6 15 -9.5539 -1 -2    u=10 $ Lower Nozzle
7 2 -3.7790 -1 +2 -3   u=10 $ Fuel
8 3 -0.9880 -1 +3 -4   u=10 $ Upper Plenum
9 4 -0.6145 -1 +4    u=10 $ Upper Nozzle
10 0         +1     u=10 $ Outside
C Cells - Standard Fuel Tube  v1.0
101 0         -101       u=5 $ Tube void
102 6 -7.9400 -102 +101      u=5 $ Tube
103 8 -2.6707 -103       u=5 $ Absorber +Y
104 6 -7.9400 -104       u=5 $ Cladding +Y
105 8 -2.6707 -105       u=5 $ Absorber +X
106 6 -7.9400 -106       u=5 $ Cladding +X
107 0         +101 +102 +103 +104 +106 +105  u=5 $ Void
C Cells - DFC Fuel Tube Absorber 2 Sides v1.0
108 0         -107       u=6 $ Tube void
109 6 -7.9400 -108 +107      u=6 $ Tube
110 8 -2.6707 -109       u=6 $ Absorber +Y
111 6 -7.9400 -110       u=6 $ Cladding +Y
112 8 -2.6707 -111       u=6 $ Absorber +X
113 6 -7.9400 -112       u=6 $ Cladding +X
114 0         +107 +108 +109 +110 +112 +111  u=6 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (Y) v1.0
115 0         -107       u=7 $ Tube void
116 6 -7.9400 -108 +107      u=7 $ Tube
117 8 -2.6707 -109       u=7 $ Absorber +Y
118 6 -7.9400 -110       u=7 $ Cladding +Y
119 0         +107 +108 +109 +110    u=7 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (X) v1.0
120 0         -107       u=8 $ Tube void
121 6 -7.9400 -108 +107      u=8 $ Tube
122 8 -2.6707 -111       u=8 $ Absorber +X
123 6 -7.9400 -112       u=8 $ Cladding +X
124 0         +107 +108 +111 +112    u=8 $ Void
C Cells - DFC Fuel Tube No Absorber v1.0
125 0         -107       u=9 $ Tube void
126 6 -7.9400 -108 +107      u=9 $ Tube
127 0         +107 +108      u=9 $ Void
c Cell Cards - Disk Stack v1.0
201 6 -7.94 -203 trcl = ( 0.0000 0.0000 2.5400 )    u=4 $ Bottom weldment disk
202 6 -7.94 -201 trcl = ( 0.0000 0.0000 15.0368 )    u=4 $ Support disk 1
203 like 202 but   trcl = ( 0.0000 0.0000 24.7650 )    u=4 $ Support disk 2
204 like 202 but   trcl = ( 0.0000 0.0000 34.4932 )    u=4 $ Support disk 3
205 like 202 but   trcl = ( 0.0000 0.0000 44.2214 )    u=4 $ Support disk 4
206 like 202 but   trcl = ( 0.0000 0.0000 53.9496 )    u=4 $ Support disk 5
207 9 -2.70 -202 trcl = ( 0.0000 0.0000 58.9788 )    u=4 $ Heat transfer disk 1
208 like 202 but   trcl = ( 0.0000 0.0000 63.6778 )    u=4 $ Support disk 6
209 like 207 but   trcl = ( 0.0000 0.0000 68.7070 )    u=4 $ Heat transfer disk 2
210 like 202 but   trcl = ( 0.0000 0.0000 73.4060 )    u=4 $ Support disk 7
211 like 207 but   trcl = ( 0.0000 0.0000 78.4352 )    u=4 $ Heat transfer disk 3
212 like 202 but   trcl = ( 0.0000 0.0000 83.1342 )    u=4 $ Support disk 8
213 like 207 but   trcl = ( 0.0000 0.0000 88.1634 )    u=4 $ Heat transfer disk 4
214 like 202 but   trcl = ( 0.0000 0.0000 92.8624 )    u=4 $ Support disk 9
215 like 207 but   trcl = ( 0.0000 0.0000 97.8916 )    u=4 $ Heat transfer disk 5
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
216 like 202 but   trcl = ( 0.0000 0.0000 102.5906 )    u=4 $ Support disk 10
217 like 207 but   trcl = ( 0.0000 0.0000 107.6198 )    u=4 $ Heat transfer disk 6
218 like 202 but   trcl = ( 0.0000 0.0000 112.3188 )    u=4 $ Support disk 11
219 like 207 but   trcl = ( 0.0000 0.0000 117.3480 )    u=4 $ Heat transfer disk 7
220 like 202 but   trcl = ( 0.0000 0.0000 122.0470 )    u=4 $ Support disk 12
221 like 207 but   trcl = ( 0.0000 0.0000 127.0762 )    u=4 $ Heat transfer disk 8
222 like 202 but   trcl = ( 0.0000 0.0000 131.7752 )    u=4 $ Support disk 13
223 like 207 but   trcl = ( 0.0000 0.0000 136.8044 )    u=4 $ Heat transfer disk 9
224 like 202 but   trcl = ( 0.0000 0.0000 141.5034 )    u=4 $ Support disk 14
225 like 207 but   trcl = ( 0.0000 0.0000 146.5326 )    u=4 $ Heat transfer disk 10
226 like 202 but   trcl = ( 0.0000 0.0000 151.2316 )    u=4 $ Support disk 15
227 like 207 but   trcl = ( 0.0000 0.0000 156.2608 )    u=4 $ Heat transfer disk 11
228 like 202 but   trcl = ( 0.0000 0.0000 160.9598 )    u=4 $ Support disk 16
229 like 207 but   trcl = ( 0.0000 0.0000 165.9890 )    u=4 $ Heat transfer disk 12
230 like 202 but   trcl = ( 0.0000 0.0000 170.6880 )    u=4 $ Support disk 17
231 like 207 but   trcl = ( 0.0000 0.0000 175.7172 )    u=4 $ Heat transfer disk 13
232 like 202 but   trcl = ( 0.0000 0.0000 180.4162 )    u=4 $ Support disk 18
233 like 207 but   trcl = ( 0.0000 0.0000 185.4454 )    u=4 $ Heat transfer disk 14
234 like 202 but   trcl = ( 0.0000 0.0000 190.1444 )    u=4 $ Support disk 19
235 like 202 but   trcl = ( 0.0000 0.0000 199.8726 )    u=4 $ Support disk 20
236 like 202 but   trcl = ( 0.0000 0.0000 209.6008 )    u=4 $ Support disk 21
237 like 202 but   trcl = ( 0.0000 0.0000 219.3290 )    u=4 $ Support disk 22
238 like 202 but   trcl = ( 0.0000 0.0000 229.0572 )    u=4 $ Support disk 23
239 like 202 but   trcl = ( 0.0000 0.0000 238.7854 )    u=4 $ Support disk 24
240 like 201 but   trcl = ( 0.0000 0.0000 255.8796 )    u=4 $ Top weldment disk
241 0              $ Outside Disks
      #201 #202 #203 #204 #205 #206 #207 #208 #209 #210
      #211 #212 #213 #214 #215 #216 #217 #218 #219 #220
      #221 #222 #223 #224 #225 #226 #227 #228 #229 #230
      #231 #232 #233 #234 #235 #236 #237 #238 #239
      #240        u=4
c Cell Cards - Basket v1.0
301 0          -302 #302  fill=8 ( -8.8265 77.5233 0.0000 )      $ Tube/Disk 1
           trcl = ( -8.8265 77.5233 0.0000 )     u=3
302 0          -1  fill=10 trcl = ( -8.8265 77.5233 0.0000 )     u=3 $ Assembly 1
303 0          -302 #304  fill=9 ( 8.8265 77.5233 0.0000 )      $ Tube/Disk 2
           trcl = ( 8.8265 77.5233 0.0000 )     u=3
304 like 302 but    fill=10 trcl = ( 8.8265 77.5233 0.0000 )     u=3 $ Assembly 2
305 0          -302 #306  fill=8 ( -44.1274 61.2699 0.0000 )      $ Tube/Disk 3
           trcl = ( -44.1274 61.2699 0.0000 )     u=3
306 like 302 but    fill=10 trcl = ( -44.1274 61.2699 0.0000 )     u=3 $ Assembly 3
307 0          -302 #308  fill=8 ( -26.4770 59.8729 0.0000 )      $ Tube/Disk 4
           trcl = ( -26.4770 59.8729 0.0000 )     u=3
308 like 302 but    fill=10 trcl = ( -26.4770 59.8729 0.0000 )     u=3 $ Assembly 4
309 0          -302 #310  fill=6 ( -8.8265 59.8729 0.0000 )      $ Tube/Disk 5
           trcl = ( -8.8265 59.8729 0.0000 )     u=3
310 like 302 but    fill=10 trcl = ( -8.8265 59.8729 0.0000 )     u=3 $ Assembly 5
311 0          -302 #312  fill=6 ( 8.8265 59.8729 0.0000 )      $ Tube/Disk 6
           trcl = ( 8.8265 59.8729 0.0000 )     u=3
312 like 302 but    fill=10 trcl = ( 8.8265 59.8729 0.0000 )     u=3 $ Assembly 6
313 0          -302 #314  fill=8 ( 26.4770 59.8729 0.0000 )      $ Tube/Disk 7
           trcl = ( 26.4770 59.8729 0.0000 )     u=3
314 like 302 but    fill=10 trcl = ( 26.4770 59.8729 0.0000 )     u=3 $ Assembly 7
315 0          -302 #316  fill=9 ( 44.1274 61.2699 0.0000 )      $ Tube/Disk 8
           trcl = ( 44.1274 61.2699 0.0000 )     u=3
316 like 302 but    fill=10 trcl = ( 44.1274 61.2699 0.0000 )     u=3 $ Assembly 8
317 0          -302 #318  fill=8 ( -61.2699 44.1274 0.0000 )      $ Tube/Disk 9
           trcl = ( -61.2699 44.1274 0.0000 )     u=3
318 like 302 but    fill=10 trcl = ( -61.2699 44.1274 0.0000 )     u=3 $ Assembly 9
319 0          -301 #320  fill=5 ( -42.5399 42.5399 0.0000 )      $ Tube/Disk 10
           trcl = ( -42.5399 42.5399 0.0000 )     u=3
320 like 302 but    fill=11 trcl = ( -42.5399 42.5399 0.0000 )     u=3 $ Assembly 10
321 0          -301 #322  fill=5 ( -25.5245 42.5399 0.0000 )      $ Tube/Disk 11
           trcl = ( -25.5245 42.5399 0.0000 )     u=3
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
322 like 302 but    fill=11 trcl = ( -25.5245 42.5399 0.0000 )      u=3 $ Assembly 11
323 0         -301 #324  fill=5 ( -8.5090 42.5399 0.0000 )      $ Tube/Disk 12
          trcl = ( -8.5090 42.5399 0.0000 )     u=3
324 like 302 but    fill=11 trcl = ( -8.5090 42.5399 0.0000 )      u=3 $ Assembly 12
325 0         -301 #326  fill=5 ( 8.5090 42.5399 0.0000 )      $ Tube/Disk 13
          trcl = ( 8.5090 42.5399 0.0000 )     u=3
326 like 302 but    fill=11 trcl = ( 8.5090 42.5399 0.0000 )      u=3 $ Assembly 13
327 0         -301 #328  fill=5 ( 25.5245 42.5399 0.0000 )      $ Tube/Disk 14
          trcl = ( 25.5245 42.5399 0.0000 )     u=3
328 like 302 but    fill=11 trcl = ( 25.5245 42.5399 0.0000 )      u=3 $ Assembly 14
329 0         -301 #330  fill=5 ( 42.5399 42.5399 0.0000 )      $ Tube/Disk 15
          trcl = ( 42.5399 42.5399 0.0000 )     u=3
330 like 302 but    fill=11 trcl = ( 42.5399 42.5399 0.0000 )      u=3 $ Assembly 15
331 0         -302 #332  fill=9 ( 61.2699 44.1274 0.0000 )      $ Tube/Disk 16
          trcl = ( 61.2699 44.1274 0.0000 )     u=3
332 like 302 but    fill=10 trcl = ( 61.2699 44.1274 0.0000 )      u=3 $ Assembly 16
333 0         -302 #334  fill=6 ( -59.8729 26.4770 0.0000 )      $ Tube/Disk 17
          trcl = ( -59.8729 26.4770 0.0000 )     u=3
334 like 302 but    fill=10 trcl = ( -59.8729 26.4770 0.0000 )      u=3 $ Assembly 17
335 0         -301 #336  fill=5 ( -42.5399 25.5245 0.0000 )      $ Tube/Disk 18
          trcl = ( -42.5399 25.5245 0.0000 )     u=3
336 like 302 but    fill=11 trcl = ( -42.5399 25.5245 0.0000 )      u=3 $ Assembly 18
337 0         -301 #338  fill=5 ( -25.5245 25.5245 0.0000 )      $ Tube/Disk 19
          trcl = ( -25.5245 25.5245 0.0000 )     u=3
338 like 302 but    fill=11 trcl = ( -25.5245 25.5245 0.0000 )      u=3 $ Assembly 19
339 0         -301 #340  fill=5 ( -8.5090 25.5245 0.0000 )      $ Tube/Disk 20
          trcl = ( -8.5090 25.5245 0.0000 )     u=3
340 like 302 but    fill=11 trcl = ( -8.5090 25.5245 0.0000 )      u=3 $ Assembly 20
341 0         -301 #342  fill=5 ( 8.5090 25.5245 0.0000 )      $ Tube/Disk 21
          trcl = ( 8.5090 25.5245 0.0000 )     u=3
342 like 302 but    fill=11 trcl = ( 8.5090 25.5245 0.0000 )      u=3 $ Assembly 21
343 0         -301 #344  fill=5 ( 25.5245 25.5245 0.0000 )      $ Tube/Disk 22
          trcl = ( 25.5245 25.5245 0.0000 )     u=3
344 like 302 but    fill=11 trcl = ( 25.5245 25.5245 0.0000 )      u=3 $ Assembly 22
345 0         -301 #346  fill=5 ( 42.5399 25.5245 0.0000 )      $ Tube/Disk 23
          trcl = ( 42.5399 25.5245 0.0000 )     u=3
346 like 302 but    fill=11 trcl = ( 42.5399 25.5245 0.0000 )      u=3 $ Assembly 23
347 0         -302 #348  fill=7 ( 59.8729 26.4770 0.0000 )      $ Tube/Disk 24
          trcl = ( 59.8729 26.4770 0.0000 )     u=3
348 like 302 but    fill=10 trcl = ( 59.8729 26.4770 0.0000 )      u=3 $ Assembly 24
349 0         -302 #350  fill=8 ( -77.5233 8.8265 0.0000 )      $ Tube/Disk 25
          trcl = ( -77.5233 8.8265 0.0000 )     u=3
350 like 302 but    fill=10 trcl = ( -77.5233 8.8265 0.0000 )      u=3 $ Assembly 25
351 0         -302 #352  fill=6 ( -59.8729 8.8265 0.0000 )      $ Tube/Disk 26
          trcl = ( -59.8729 8.8265 0.0000 )     u=3
352 like 302 but    fill=10 trcl = ( -59.8729 8.8265 0.0000 )      u=3 $ Assembly 26
353 0         -301 #354  fill=5 ( -42.5399 8.5090 0.0000 )      $ Tube/Disk 27
          trcl = ( -42.5399 8.5090 0.0000 )     u=3
354 like 302 but    fill=11 trcl = ( -42.5399 8.5090 0.0000 )      u=3 $ Assembly 27
355 0         -301 #356  fill=5 ( -25.5245 8.5090 0.0000 )      $ Tube/Disk 28
          trcl = ( -25.5245 8.5090 0.0000 )     u=3
356 like 302 but    fill=11 trcl = ( -25.5245 8.5090 0.0000 )      u=3 $ Assembly 28
357 0         -301 #358  fill=5 ( -8.5090 8.5090 0.0000 )      $ Tube/Disk 29
          trcl = ( -8.5090 8.5090 0.0000 )     u=3
358 like 302 but    fill=11 trcl = ( -8.5090 8.5090 0.0000 )      u=3 $ Assembly 29
359 0         -301 #360  fill=5 ( 8.5090 8.5090 0.0000 )      $ Tube/Disk 30
          trcl = ( 8.5090 8.5090 0.0000 )     u=3
360 like 302 but    fill=11 trcl = ( 8.5090 8.5090 0.0000 )      u=3 $ Assembly 30
361 0         -301 #362  fill=5 ( 25.5245 8.5090 0.0000 )      $ Tube/Disk 31
          trcl = ( 25.5245 8.5090 0.0000 )     u=3
362 like 302 but    fill=11 trcl = ( 25.5245 8.5090 0.0000 )      u=3 $ Assembly 31
363 0         -301 #364  fill=5 ( 42.5399 8.5090 0.0000 )      $ Tube/Disk 32
          trcl = ( 42.5399 8.5090 0.0000 )     u=3
364 like 302 but    fill=11 trcl = ( 42.5399 8.5090 0.0000 )      u=3 $ Assembly 32
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
365 0          -302 #366  fill=6 ( 59.8729 8.8265 0.0000 )       $ Tube/Disk 33
           trcl = ( 59.8729 8.8265 0.0000 )      u=3
366 like 302 but    fill=10 trcl = ( 59.8729 8.8265 0.0000 )      u=3 $ Assembly 33
367 0          -302 #368  fill=9 ( 77.5233 8.8265 0.0000 )       $ Tube/Disk 34
           trcl = ( 77.5233 8.8265 0.0000 )      u=3
368 like 302 but    fill=10 trcl = ( 77.5233 8.8265 0.0000 )      u=3 $ Assembly 34
369 0          -302 #370  fill=6 ( -77.5233 -8.8265 0.0000 )      $ Tube/Disk 35
           trcl = ( -77.5233 -8.8265 0.0000 )      u=3
370 like 302 but    fill=10 trcl = ( -77.5233 -8.8265 0.0000 )      u=3 $ Assembly 35
371 0          -302 #372  fill=6 ( -59.8729 -8.8265 0.0000 )      $ Tube/Disk 36
           trcl = ( -59.8729 -8.8265 0.0000 )      u=3
372 like 302 but    fill=10 trcl = ( -59.8729 -8.8265 0.0000 )      u=3 $ Assembly 36
373 0          -301 #374  fill=5 ( -42.5399 -8.5090 0.0000 )      $ Tube/Disk 37
           trcl = ( -42.5399 -8.5090 0.0000 )      u=3
374 like 302 but    fill=11 trcl = ( -42.5399 -8.5090 0.0000 )      u=3 $ Assembly 37
375 0          -301 #376  fill=5 ( -25.5245 -8.5090 0.0000 )      $ Tube/Disk 38
           trcl = ( -25.5245 -8.5090 0.0000 )      u=3
376 like 302 but    fill=11 trcl = ( -25.5245 -8.5090 0.0000 )      u=3 $ Assembly 38
377 0          -301 #378  fill=5 ( -8.5090 -8.5090 0.0000 )      $ Tube/Disk 39
           trcl = ( -8.5090 -8.5090 0.0000 )      u=3
378 like 302 but    fill=11 trcl = ( -8.5090 -8.5090 0.0000 )      u=3 $ Assembly 39
379 0          -301 #380  fill=5 ( 8.5090 -8.5090 0.0000 )      $ Tube/Disk 40
           trcl = ( 8.5090 -8.5090 0.0000 )      u=3
380 like 302 but    fill=11 trcl = ( 8.5090 -8.5090 0.0000 )      u=3 $ Assembly 40
381 0          -301 #382  fill=5 ( 25.5245 -8.5090 0.0000 )      $ Tube/Disk 41
           trcl = ( 25.5245 -8.5090 0.0000 )      u=3
382 like 302 but    fill=11 trcl = ( 25.5245 -8.5090 0.0000 )      u=3 $ Assembly 41
383 0          -301 #384  fill=5 ( 42.5399 -8.5090 0.0000 )      $ Tube/Disk 42
           trcl = ( 42.5399 -8.5090 0.0000 )      u=3
384 like 302 but    fill=11 trcl = ( 42.5399 -8.5090 0.0000 )      u=3 $ Assembly 42
385 0          -302 #386  fill=6 ( 59.8729 -8.8265 0.0000 )      $ Tube/Disk 43
           trcl = ( 59.8729 -8.8265 0.0000 )      u=3
386 like 302 but    fill=10 trcl = ( 59.8729 -8.8265 0.0000 )      u=3 $ Assembly 43
387 0          -302 #388  fill=7 ( 77.5233 -8.8265 0.0000 )      $ Tube/Disk 44
           trcl = ( 77.5233 -8.8265 0.0000 )      u=3
388 like 302 but    fill=10 trcl = ( 77.5233 -8.8265 0.0000 )      u=3 $ Assembly 44
389 0          -302 #390  fill=6 ( -59.8729 -26.4770 0.0000 )      $ Tube/Disk 45
           trcl = ( -59.8729 -26.4770 0.0000 )      u=3
390 like 302 but    fill=10 trcl = ( -59.8729 -26.4770 0.0000 )      u=3 $ Assembly 45
391 0          -301 #392  fill=5 ( -42.5399 -25.5245 0.0000 )      $ Tube/Disk 46
           trcl = ( -42.5399 -25.5245 0.0000 )      u=3
392 like 302 but    fill=11 trcl = ( -42.5399 -25.5245 0.0000 )      u=3 $ Assembly 46
393 0          -301 #394  fill=5 ( -25.5245 -25.5245 0.0000 )      $ Tube/Disk 47
           trcl = ( -25.5245 -25.5245 0.0000 )      u=3
394 like 302 but    fill=11 trcl = ( -25.5245 -25.5245 0.0000 )      u=3 $ Assembly 47
395 0          -301 #396  fill=5 ( -8.5090 -25.5245 0.0000 )      $ Tube/Disk 48
           trcl = ( -8.5090 -25.5245 0.0000 )      u=3
396 like 302 but    fill=11 trcl = ( -8.5090 -25.5245 0.0000 )      u=3 $ Assembly 48
397 0          -301 #398  fill=5 ( 8.5090 -25.5245 0.0000 )      $ Tube/Disk 49
           trcl = ( 8.5090 -25.5245 0.0000 )      u=3
398 like 302 but    fill=11 trcl = ( 8.5090 -25.5245 0.0000 )      u=3 $ Assembly 49
399 0          -301 #400  fill=5 ( 25.5245 -25.5245 0.0000 )      $ Tube/Disk 50
           trcl = ( 25.5245 -25.5245 0.0000 )      u=3
400 like 302 but    fill=11 trcl = ( 25.5245 -25.5245 0.0000 )      u=3 $ Assembly 50
401 0          -301 #402  fill=5 ( 42.5399 -25.5245 0.0000 )      $ Tube/Disk 51
           trcl = ( 42.5399 -25.5245 0.0000 )      u=3
402 like 302 but    fill=11 trcl = ( 42.5399 -25.5245 0.0000 )      u=3 $ Assembly 51
403 0          -302 #404  fill=7 ( 59.8729 -26.4770 0.0000 )      $ Tube/Disk 52
           trcl = ( 59.8729 -26.4770 0.0000 )      u=3
404 like 302 but    fill=10 trcl = ( 59.8729 -26.4770 0.0000 )      u=3 $ Assembly 52
405 0          -302 #406  fill=6 ( -61.2699 -44.1274 0.0000 )      $ Tube/Disk 53
           trcl = ( -61.2699 -44.1274 0.0000 )      u=3
406 like 302 but    fill=10 trcl = ( -61.2699 -44.1274 0.0000 )      u=3 $ Assembly 53
407 0          -301 #408  fill=5 ( -42.5399 -42.5399 0.0000 )      $ Tube/Disk 54
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
          trcl = ( -42.5399 -42.5399 0.0000 )      u=3
408 like 302 but    fill=11 trcl = ( -42.5399 -42.5399 0.0000 )      u=3 $ Assembly 54
409 0         -301 #410  fill=5 ( -25.5245 -42.5399 0.0000 )      $ Tube/Disk 55
          trcl = ( -25.5245 -42.5399 0.0000 )      u=3
410 like 302 but    fill=11 trcl = ( -25.5245 -42.5399 0.0000 )      u=3 $ Assembly 55
411 0         -301 #412  fill=5 ( -8.5090 -42.5399 0.0000 )      $ Tube/Disk 56
          trcl = ( -8.5090 -42.5399 0.0000 )      u=3
412 like 302 but    fill=11 trcl = ( -8.5090 -42.5399 0.0000 )      u=3 $ Assembly 56
413 0         -301 #414  fill=5 ( 8.5090 -42.5399 0.0000 )      $ Tube/Disk 57
          trcl = ( 8.5090 -42.5399 0.0000 )      u=3
414 like 302 but    fill=11 trcl = ( 8.5090 -42.5399 0.0000 )      u=3 $ Assembly 57
415 0         -301 #416  fill=5 ( 25.5245 -42.5399 0.0000 )      $ Tube/Disk 58
          trcl = ( 25.5245 -42.5399 0.0000 )      u=3
416 like 302 but    fill=11 trcl = ( 25.5245 -42.5399 0.0000 )      u=3 $ Assembly 58
417 0         -301 #418  fill=5 ( 42.5399 -42.5399 0.0000 )      $ Tube/Disk 59
          trcl = ( 42.5399 -42.5399 0.0000 )      u=3
418 like 302 but    fill=11 trcl = ( 42.5399 -42.5399 0.0000 )      u=3 $ Assembly 59
419 0         -302 #420  fill=7 ( 61.2699 -44.1274 0.0000 )      $ Tube/Disk 60
          trcl = ( 61.2699 -44.1274 0.0000 )      u=3
420 like 302 but    fill=10 trcl = ( 61.2699 -44.1274 0.0000 )      u=3 $ Assembly 60
421 0         -302 #422  fill=6 ( -44.1274 -61.2699 0.0000 )      $ Tube/Disk 61
          trcl = ( -44.1274 -61.2699 0.0000 )      u=3
422 like 302 but    fill=10 trcl = ( -44.1274 -61.2699 0.0000 )      u=3 $ Assembly 61
423 0         -302 #424  fill=6 ( -26.4770 -59.8729 0.0000 )      $ Tube/Disk 62
          trcl = ( -26.4770 -59.8729 0.0000 )      u=3
424 like 302 but    fill=10 trcl = ( -26.4770 -59.8729 0.0000 )      u=3 $ Assembly 62
425 0         -302 #426  fill=6 ( -8.8265 -59.8729 0.0000 )      $ Tube/Disk 63
          trcl = ( -8.8265 -59.8729 0.0000 )      u=3
426 like 302 but    fill=10 trcl = ( -8.8265 -59.8729 0.0000 )      u=3 $ Assembly 63
427 0         -302 #428  fill=6 ( 8.8265 -59.8729 0.0000 )      $ Tube/Disk 64
          trcl = ( 8.8265 -59.8729 0.0000 )      u=3
428 like 302 but    fill=10 trcl = ( 8.8265 -59.8729 0.0000 )      u=3 $ Assembly 64
429 0         -302 #430  fill=6 ( 26.4770 -59.8729 0.0000 )      $ Tube/Disk 65
          trcl = ( 26.4770 -59.8729 0.0000 )      u=3
430 like 302 but    fill=10 trcl = ( 26.4770 -59.8729 0.0000 )      u=3 $ Assembly 65
431 0         -302 #432  fill=7 ( 44.1274 -61.2699 0.0000 )      $ Tube/Disk 66
          trcl = ( 44.1274 -61.2699 0.0000 )      u=3
432 like 302 but    fill=10 trcl = ( 44.1274 -61.2699 0.0000 )      u=3 $ Assembly 66
433 0         -302 #434  fill=7 ( -8.8265 -77.5233 0.0000 )      $ Tube/Disk 67
          trcl = ( -8.8265 -77.5233 0.0000 )      u=3
434 like 302 but    fill=10 trcl = ( -8.8265 -77.5233 0.0000 )      u=3 $ Assembly 67
435 0         -302 #436  fill=7 ( 8.8265 -77.5233 0.0000 )      $ Tube/Disk 68
          trcl = ( 8.8265 -77.5233 0.0000 )      u=3
436 like 302 but    fill=10 trcl = ( 8.8265 -77.5233 0.0000 )      u=3 $ Assembly 68
437 0         +303 +304        $ Canister Cavity Q1
      #303 #311 #313 #315 #325 #327 #329 #331 #341
      #304 #312 #314 #316 #326 #328 #330 #332 #342
      #343 #345 #347 #359 #361 #363 #365 #367
      #344 #346 #348 #360 #362 #364 #366 #368
          fill=4      u=3
438 0         +303 -304        $ Canister Cavity Q2
      #301 #305 #307 #309 #317 #319 #321 #323 #333
      #302 #306 #308 #310 #318 #320 #322 #324 #334
      #335 #337 #339 #349 #351 #353 #355 #357
      #336 #338 #340 #350 #352 #354 #356 #358
          fill=4      u=3
439 0         -303 -304        $ Canister Cavity Q3
      #369 #371 #373 #375 #377 #389 #391 #393 #395
      #370 #372 #374 #376 #378 #390 #392 #394 #396
      #405 #407 #409 #411 #421 #423 #425 #433
      #406 #408 #410 #412 #422 #424 #426 #434
          fill=4      u=3
440 0         -303 +304        $ Canister Cavity Q4
      #379 #381 #383 #385 #387 #397 #399 #401 #403
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
     #380 #382 #384 #386 #388 #398 #400 #402 #404
     #413 #415 #417 #419 #427 #429 #431 #435
     #414 #416 #418 #420 #428 #430 #432 #436
         fill=4      u=3
C Cells - Canister v1.0
501 0          -501 fill=3      u=2 $ Cavity
502 6 -7.9400 -507 +501.3      u=2 $ Canister Bottom
503 0          -502 +501.2 -505 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Bottom Drain Port
504 0          -503 +505 -506 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Middle Drain Port
505 6 -7.9400 -504 +506 -507.2 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Top Drain Port
506 like 503 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Bottom Vent Port
507 like 504 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Middle Vent Port
508 like 505 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Top Vent Port
509 6 -7.9400 -507 -501.3 +501.1     u=2 $ Canister Shell
510 6 -7.9400 -507 -501.1 +501.2 #503 #504 #505 #506 #507 #508     u=2 $ Lid
511 0          +507       u=2 $ Outside
c Cell Cards - Storage Cask Geometry v4.0
601 7 -7.8212 -605        u=1 $ Base Plate
602 0          (-614 +612 -601         $ Air Inlet Channel Void
               +643 +644 +645 +646
               +651 +652 +653 +654) :
               (-614 +613 -612 +618)        u=1
603 7 -7.8212 -615 +614 +612 -601     u=1 $ Air Inlet Channel Mat
604 0          (-616 +612 -601         $ Air Inlet Channel Void
               +647 +648 +649 +650
               +655 +656 +657 +658) :
               (-616 +613 -612 +618)        u=1
605 7 -7.8212 -617 +616 +612 -601     u=1 $ Air Inlet Channel Mat
606 0          -619 -612 +613      u=1 $ Stand Cut-Out Top
607 like 606 but *trcl = (0 0 0 90 180 90 0 90 90 90 90 0)      u=1 $ Stand Cut-Out Top
608 7 -7.8212 -601 -612 +613 +618 +605 +614 +616 #606 #607  u=1 $ Stand Material
609 7 -7.8212 (-601 -612 -618) : (-601 +612 -618 +615 +617)        u=1 $ Bottom Plate
610 7 -7.8212 (-606 +607 +618 -610) : (-608 +609 +610 -611)        u=1 $ Baffle Cone Mat
611 0          (-607 +618 -610) : (-609 +610 -611)        u=1 $ Baffle Cone Int. Void
612 0          -613 +618 -611 +606 +608    u=1 $ Void inside stand - A
613 0          -601 -613 +611 +605     u=1 $ Void inside stand - B
614 0          -601 -603 +612 +618 +605 +615 +617  u=1 $ Void stand to liner
615 7 -7.8212 -601 -604 +603 +618 +615 +617   u=1 $ Liner
616 12 -2.3233 -601 +604 +618 +615 +617    u=1 $ Concrete
617 7 -7.8212 -620        u=1 $ VCC Lid
618 7 -7.8212 -621 +622       u=1 $ TopFlange
619 0          -621 -622 +603 +623     u=1 $ Void Cavity to Flange
620 12 -2.3233 -624        u=1 $ Lid Concrete
621 7 -7.8212 -623 +624       u=1 $ Lid Cover
622 12 -2.3233 (-626 +604) : (-627 -602 +628)        u=1 $ Concrete - Outlet Box
623 0          (-629 +630 +604) : (-631 +629 -602)        u=1 $ Air Outlet Void
624 7 -7.8212 -625 -602 +604 #622 #623      u=1 $ Air Outlet Steel
625 12 -2.3233 (-633 +604) : (-634 -602 +635)        u=1 $ Concrete - Outlet Box
626 0          (-636 +637 +604) : (-638 +636 -602)        u=1 $ Air Outlet Void
627 7 -7.8212 -632 -602 +604 #625 #626      u=1 $ Air Outlet Steel
628 12 -2.3233 -602 +604 +621 #622 #623 #624 #625 #626 #627    fill=12  u=1 $ Concrete
629 0          (-639 -641 +603) : (-640 -604 +641)        u=1 $ Air Outlet Liner Void
630 like 629 but *trcl = (0 0 0 90 180 90 0 90 90 90 90 0)      u=1 $ Air Outlet Liner Void
631 7 -7.8212 -602 -604 +603 +621 #629 #630     u=1 $ Liner Minus Voids
632 0          -602 -603 +623  fill=2 ( 0.0000 0.0000 2.5400 )    u=1 $ Cavity
633 12 -2.3233 -642        u=1 $ Concrete pad
634 7 -7.8212 -643 : -644 : -645 : -646        u=1 $ Air inlet pipes +x+y
635 7 -7.8212 -647 : -648 : -649 : -650        u=1 $ Air inlet pipes -x-y
636 7 -7.8212 -651 : -652 : -653 : -654        u=1 $ Air inlet pipes -x+y
637 7 -7.8212 -655 : -656 : -657 : -658        u=1 $ Air inlet pipes +x-y
638 0         +601 +602 +620 +642 #602 #603 #604 #605     u=1 $ Container
C VCC Rebar Cells - v4.0
639 7 -7.8212 -659      u=12 $ Inner hoop 1
640 7 -7.8212 -660      u=12 $ Inner hoop 2
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
641 7 -7.8212 -661      u=12 $ Inner hoop 3
642 7 -7.8212 -662      u=12 $ Inner hoop 4
643 7 -7.8212 -663      u=12 $ Inner hoop 5
644 7 -7.8212 -664      u=12 $ Inner hoop 6
645 7 -7.8212 -665      u=12 $ Inner hoop 7
646 7 -7.8212 -666      u=12 $ Inner hoop 8
647 7 -7.8212 -667      u=12 $ Inner hoop 9
648 7 -7.8212 -668      u=12 $ Inner hoop 10
649 7 -7.8212 -669      u=12 $ Inner hoop 11
650 7 -7.8212 -670      u=12 $ Inner hoop 12
651 7 -7.8212 -671      u=12 $ Inner hoop 13
652 7 -7.8212 -672      u=12 $ Inner hoop 14
653 7 -7.8212 -673      u=12 $ Inner hoop 15
654 7 -7.8212 -674      u=12 $ Inner hoop 16
655 7 -7.8212 -675      u=12 $ Inner hoop 17
656 7 -7.8212 -676      u=12 $ Outer hoop 1
657 7 -7.8212 -677      u=12 $ Outer hoop 2
658 7 -7.8212 -678      u=12 $ Outer hoop 3
659 7 -7.8212 -679      u=12 $ Outer hoop 4
660 7 -7.8212 -680      u=12 $ Outer hoop 5
661 7 -7.8212 -681      u=12 $ Outer hoop 6
662 7 -7.8212 -682      u=12 $ Outer hoop 7
663 7 -7.8212 -683      u=12 $ Outer hoop 8
664 7 -7.8212 -684      u=12 $ Outer hoop 9
665 7 -7.8212 -685      u=12 $ Outer hoop 10
666 7 -7.8212 -686      u=12 $ Outer hoop 11
667 7 -7.8212 -687      u=12 $ Outer hoop 12
668 7 -7.8212 -688      u=12 $ Outer hoop 13
669 7 -7.8212 -689      u=12 $ Outer hoop 14
670 7 -7.8212 -690      u=12 $ Outer hoop 15
671 7 -7.8212 -691      u=12 $ Outer hoop 16
672 7 -7.8212 -692      u=12 $ Outer hoop 17
673 7 -7.8212 -693      u=12 $ Outer hoop 18
674 7 -7.8212 -694      u=12 $ Outer hoop 19
675 7 -7.8212 -695      u=12 $ Outer hoop 20
676 7 -7.8212 -696      u=12 $ Outer hoop 21
677 7 -7.8212 -697      u=12 $ Outer hoop 22
678 7 -7.8212 -698      u=12 $ Outer hoop 23
679 7 -7.8212 -699      u=12 $ Outer hoop 24
680 7 -7.8212 -700      u=12 $ Outer hoop 25
681 7 -7.8212 -701      u=12 $ Outer hoop 26
682 7 -7.8212 -702      u=12 $ Outer hoop 27
683 7 -7.8212 -703      u=12 $ Outer hoop 28
684 7 -7.8212 -704      u=12 $ Outer hoop 29
685 7 -7.8212 -705      u=12 $ Outer hoop 30
686 7 -7.8212 -706      u=12 $ Outer hoop 31
687 7 -7.8212 -707      u=12 $ Outer hoop 32
688 7 -7.8212 -708      u=12 $ Outer hoop 33
689 7 -7.8212 -709      u=12 $ Outer hoop 34
690 12 -2.3233 #639 #640 #641 #642 #643 #644 #645 #646 #647 #648        $ Concrete
               #649 #650 #651 #652 #653 #654 #655 #656 #657 #658
               #659 #660 #661 #662 #663 #664 #665 #666 #667 #668
               #669 #670 #671 #672 #673 #674 #675 #676 #677 #678
               #679 #680 #681 #682 #683 #684 #685 #686 #687 #688
               #689      fill=13 u=12
691 7 -7.8212 -710  trcl = ( 115.2525 0.0000 0.0000 )    u=13 $ Inner bar 1
692 like 691 but  trcl = ( 113.5016 20.0134 0.0000 )    u=13 $ Inner bar 2
693 like 691 but  trcl = ( 108.3019 39.4187 0.0000 )    u=13 $ Inner bar 3
694 like 691 but  trcl = ( 99.8116 57.6263 0.0000 )    u=13 $ Inner bar 4
695 like 691 but  trcl = ( 88.2885 74.0829 0.0000 )    u=13 $ Inner bar 5
696 like 691 but  trcl = ( 74.0829 88.2885 0.0000 )    u=13 $ Inner bar 6
697 like 691 but  trcl = ( 57.6263 99.8116 0.0000 )    u=13 $ Inner bar 7
698 like 691 but  trcl = ( 39.4187 108.3019 0.0000 )    u=13 $ Inner bar 8
699 like 691 but  trcl = ( 20.0134 113.5016 0.0000 )    u=13 $ Inner bar 9
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
700 like 691 but  trcl = ( 0.0000 115.2525 0.0000 )    u=13 $ Inner bar 10
701 like 691 but  trcl = ( -20.0134 113.5016 0.0000 )    u=13 $ Inner bar 11
702 like 691 but  trcl = ( -39.4187 108.3019 0.0000 )    u=13 $ Inner bar 12
703 like 691 but  trcl = ( -57.6263 99.8116 0.0000 )    u=13 $ Inner bar 13
704 like 691 but  trcl = ( -74.0829 88.2885 0.0000 )    u=13 $ Inner bar 14
705 like 691 but  trcl = ( -88.2885 74.0829 0.0000 )    u=13 $ Inner bar 15
706 like 691 but  trcl = ( -99.8116 57.6263 0.0000 )    u=13 $ Inner bar 16
707 like 691 but  trcl = ( -108.3019 39.4187 0.0000 )    u=13 $ Inner bar 17
708 like 691 but  trcl = ( -113.5016 20.0134 0.0000 )    u=13 $ Inner bar 18
709 like 691 but  trcl = ( -115.2525 0.0000 0.0000 )    u=13 $ Inner bar 19
710 like 691 but  trcl = ( -113.5016 -20.0134 0.0000 )    u=13 $ Inner bar 20
711 like 691 but  trcl = ( -108.3019 -39.4187 0.0000 )    u=13 $ Inner bar 21
712 like 691 but  trcl = ( -99.8116 -57.6262 0.0000 )    u=13 $ Inner bar 22
713 like 691 but  trcl = ( -88.2885 -74.0829 0.0000 )    u=13 $ Inner bar 23
714 like 691 but  trcl = ( -74.0829 -88.2885 0.0000 )    u=13 $ Inner bar 24
715 like 691 but  trcl = ( -57.6263 -99.8116 0.0000 )    u=13 $ Inner bar 25
716 like 691 but  trcl = ( -39.4187 -108.3019 0.0000 )    u=13 $ Inner bar 26
717 like 691 but  trcl = ( -20.0134 -113.5016 0.0000 )    u=13 $ Inner bar 27
718 like 691 but  trcl = ( 0.0000 -115.2525 0.0000 )    u=13 $ Inner bar 28
719 like 691 but  trcl = ( 20.0134 -113.5016 0.0000 )    u=13 $ Inner bar 29
720 like 691 but  trcl = ( 39.4187 -108.3019 0.0000 )    u=13 $ Inner bar 30
721 like 691 but  trcl = ( 57.6262 -99.8116 0.0000 )    u=13 $ Inner bar 31
722 like 691 but  trcl = ( 74.0829 -88.2885 0.0000 )    u=13 $ Inner bar 32
723 like 691 but  trcl = ( 88.2885 -74.0829 0.0000 )    u=13 $ Inner bar 33
724 like 691 but  trcl = ( 99.8116 -57.6263 0.0000 )    u=13 $ Inner bar 34
725 like 691 but  trcl = ( 108.3019 -39.4187 0.0000 )    u=13 $ Inner bar 35
726 like 691 but  trcl = ( 113.5016 -20.0134 0.0000 )    u=13 $ Inner bar 36
727 like 691 but  trcl = ( 149.5425 0.0000 0.0000 )    u=13 $ Outer bar 1
728 like 691 but  trcl = ( 148.6022 16.7434 0.0000 )    u=13 $ Outer bar 2
729 like 691 but  trcl = ( 145.7932 33.2763 0.0000 )    u=13 $ Outer bar 3
730 like 691 but  trcl = ( 141.1507 49.3908 0.0000 )    u=13 $ Outer bar 4
731 like 691 but  trcl = ( 134.7331 64.8841 0.0000 )    u=13 $ Outer bar 5
732 like 691 but  trcl = ( 126.6213 79.5614 0.0000 )    u=13 $ Outer bar 6
733 like 691 but  trcl = ( 116.9170 93.2382 0.0000 )    u=13 $ Outer bar 7
734 like 691 but  trcl = ( 105.7425 105.7425 0.0000 )    u=13 $ Outer bar 8
735 like 691 but  trcl = ( 93.2382 116.9170 0.0000 )    u=13 $ Outer bar 9
736 like 691 but  trcl = ( 79.5614 126.6213 0.0000 )    u=13 $ Outer bar 10
737 like 691 but  trcl = ( 64.8841 134.7331 0.0000 )    u=13 $ Outer bar 11
738 like 691 but  trcl = ( 49.3908 141.1507 0.0000 )    u=13 $ Outer bar 12
739 like 691 but  trcl = ( 33.2763 145.7932 0.0000 )    u=13 $ Outer bar 13
740 like 691 but  trcl = ( 16.7434 148.6022 0.0000 )    u=13 $ Outer bar 14
741 like 691 but  trcl = ( 0.0000 149.5425 0.0000 )    u=13 $ Outer bar 15
742 like 691 but  trcl = ( -16.7434 148.6022 0.0000 )    u=13 $ Outer bar 16
743 like 691 but  trcl = ( -33.2763 145.7932 0.0000 )    u=13 $ Outer bar 17
744 like 691 but  trcl = ( -49.3908 141.1507 0.0000 )    u=13 $ Outer bar 18
745 like 691 but  trcl = ( -64.8841 134.7331 0.0000 )    u=13 $ Outer bar 19
746 like 691 but  trcl = ( -79.5614 126.6213 0.0000 )    u=13 $ Outer bar 20
747 like 691 but  trcl = ( -93.2382 116.9170 0.0000 )    u=13 $ Outer bar 21
748 like 691 but  trcl = ( -105.7425 105.7425 0.0000 )    u=13 $ Outer bar 22
749 like 691 but  trcl = ( -116.9170 93.2382 0.0000 )    u=13 $ Outer bar 23
750 like 691 but  trcl = ( -126.6213 79.5614 0.0000 )    u=13 $ Outer bar 24
751 like 691 but  trcl = ( -134.7331 64.8841 0.0000 )    u=13 $ Outer bar 25
752 like 691 but  trcl = ( -141.1507 49.3908 0.0000 )    u=13 $ Outer bar 26
753 like 691 but  trcl = ( -145.7932 33.2763 0.0000 )    u=13 $ Outer bar 27
754 like 691 but  trcl = ( -148.6022 16.7434 0.0000 )    u=13 $ Outer bar 28
755 like 691 but  trcl = ( -149.5425 0.0000 0.0000 )    u=13 $ Outer bar 29
756 like 691 but  trcl = ( -148.6022 -16.7434 0.0000 )    u=13 $ Outer bar 30
757 like 691 but  trcl = ( -145.7932 -33.2763 0.0000 )    u=13 $ Outer bar 31
758 like 691 but  trcl = ( -141.1507 -49.3908 0.0000 )    u=13 $ Outer bar 32
759 like 691 but  trcl = ( -134.7331 -64.8841 0.0000 )    u=13 $ Outer bar 33
760 like 691 but  trcl = ( -126.6213 -79.5614 0.0000 )    u=13 $ Outer bar 34
761 like 691 but  trcl = ( -116.9170 -93.2382 0.0000 )    u=13 $ Outer bar 35
762 like 691 but  trcl = ( -105.7425 -105.7425 0.0000 )    u=13 $ Outer bar 36
763 like 691 but  trcl = ( -93.2382 -116.9170 0.0000 )    u=13 $ Outer bar 37
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
764 like 691 but  trcl = ( -79.5614 -126.6213 0.0000 )    u=13 $ Outer bar 38
765 like 691 but  trcl = ( -64.8841 -134.7331 0.0000 )    u=13 $ Outer bar 39
766 like 691 but  trcl = ( -49.3908 -141.1507 0.0000 )    u=13 $ Outer bar 40
767 like 691 but  trcl = ( -33.2763 -145.7932 0.0000 )    u=13 $ Outer bar 41
768 like 691 but  trcl = ( -16.7434 -148.6022 0.0000 )    u=13 $ Outer bar 42
769 like 691 but  trcl = ( 0.0000 -149.5425 0.0000 )    u=13 $ Outer bar 43
770 like 691 but  trcl = ( 16.7434 -148.6022 0.0000 )    u=13 $ Outer bar 44
771 like 691 but  trcl = ( 33.2763 -145.7932 0.0000 )    u=13 $ Outer bar 45
772 like 691 but  trcl = ( 49.3908 -141.1507 0.0000 )    u=13 $ Outer bar 46
773 like 691 but  trcl = ( 64.8841 -134.7331 0.0000 )    u=13 $ Outer bar 47
774 like 691 but  trcl = ( 79.5614 -126.6213 0.0000 )    u=13 $ Outer bar 48
775 like 691 but  trcl = ( 93.2382 -116.9170 0.0000 )    u=13 $ Outer bar 49
776 like 691 but  trcl = ( 105.7425 -105.7425 0.0000 )    u=13 $ Outer bar 50
777 like 691 but  trcl = ( 116.9170 -93.2382 0.0000 )    u=13 $ Outer bar 51
778 like 691 but  trcl = ( 126.6213 -79.5614 0.0000 )    u=13 $ Outer bar 52
779 like 691 but  trcl = ( 134.7331 -64.8841 0.0000 )    u=13 $ Outer bar 53
780 like 691 but  trcl = ( 141.1507 -49.3908 0.0000 )    u=13 $ Outer bar 54
781 like 691 but  trcl = ( 145.7932 -33.2763 0.0000 )    u=13 $ Outer bar 55
782 like 691 but  trcl = ( 148.6022 -16.7434 0.0000 )    u=13 $ Outer bar 56
783 12 -2.3233 #691 #692 #693 #694 #695 #696 #697 #698 #699        $ Concrete
               #700 #701 #702 #703 #704 #705 #706 #707 #708 #709
               #710 #711 #712 #713 #714 #715 #716 #717 #718 #719
               #720 #721 #722 #723 #724 #725 #726 #727 #728 #729
               #730 #731 #732 #733 #734 #735 #736 #737 #738 #739
               #740 #741 #742 #743 #744 #745 #746 #747 #748 #749
               #750 #751 #752 #753 #754 #755 #756 #757 #758 #759
               #760 #761 #762 #763 #764 #765 #766 #767 #768 #769
               #770 #771 #772 #773 #774 #775 #776 #777 #778 #779
               #780 #781 #782       u=13
C Detector Cells - Radial Biasing
799  0  -799  fill=1  $ Cask
800  0  -800  +799  $ Inlet
900  0  -900  +799  +800  $ Inlet+1ft
1000  0  +799  +800  +900  $ Exterior

C Fuel Assembly Surfaces - v1.0
1 RPP -7.1247 7.1247 -7.1247 7.1247 0.0000 261.9502  $ Assy
2 PZ 27.2796       $ Lower Nozzle/Fuel
3 PZ 238.0996       $ Fuel/Upper Plenum
4 PZ 251.1298       $ Upper Plenum/Upper Nozzle
C Surfaces - Standard Fuel Tube v1.0
101 RPP -7.3076 7.3076 -7.3076 7.3076 0.0000 274.4470    $ Tube void
102 RPP -7.4295 7.4295 -7.4295 7.4295 0.0000 249.5550    $ Tube
103 RPP -6.5913 6.5913 7.4295 7.6200 2.0320 245.8720    $ Absorber +Y
104 RPP -6.5913 6.5913 7.6200 7.6657 2.0320 245.8720    $ Cladding +Y
105 RPP 7.4295 7.6200 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
106 RPP 7.6200 7.6657 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
C Surfaces - DFC Fuel Tube v1.0
107 RPP -7.6251 7.6251 -7.6251 7.6251 0.0000 274.4470    $ Tube void
108 RPP -7.7470 7.7470 -7.7470 7.7470 0.0000 249.5550    $ Tube
109 RPP -6.5913 6.5913 7.7470 7.9375 2.0320 245.8720    $ Absorber +Y
110 RPP -6.5913 6.5913 7.9375 7.9832 2.0320 245.8720    $ Cladding +Y
111 RPP 7.7470 7.9375 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
112 RPP 7.9375 7.9832 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
c Surface Cards - Disk Stack  v1.0
201 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.1380 $ Structural disk
202 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.2700 87.7951 $ Heat transfer disk
203 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Weldment disk
c Surface Cards - Basket v1.0
301 RPP -7.7711 7.7711 -7.7711 7.7711 0.0000 274.4470  $ Std opening
302 RPP -8.0899 8.0899 -8.0899 8.0899 0.0000 274.4470  $ DFC opening
303 PY 0.0000       $ Cut plane
304 PX 0.0000       $ Cut plane
C Surfaces - Canister v1.0
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
501 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470 88.4428   $ Cavity
502 CZ 1.3843          $ Bot Cylinder Radius
503 CZ 5.0800          $ Mid Cyclinder Radius
504 CZ 5.7150          $ Top Cylinder Radius
505 PZ 282.8798          $ Port plane bot/mid
506 PZ 289.3822          $ Port plane mid/top
507 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670 89.7128   $ Canister
c Surface Cards - Storage Cask Geometry v4.0
601  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 -58.6740 162.5600 $ Bottom Section Container
602  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 352.5520 162.5600 $ Top Section Container (Not VCC
Lid)
603  CZ 100.3300       $ VCC liner inner
604  CZ 106.6800       $ VCC liner outer
605  RCC 0.0000 0.0000 -5.7150 0.0000 0.0000 5.7150 91.4400 $ Base plate/cover
606  KZ 47.2803 0.1357 -1     $ Baffle weldment bot
607  KZ 45.4435 0.1357 -1     $ Baffle weldment bot void
608  KZ -111.2883 0.1357 1     $ Baffle weldment top
609  KZ -109.4515 0.1357 1     $ Baffle weldment top void
610  PZ -32.0040       $ Baffle middle cut surface
611  PZ -7.8740       $ Baffle top cut surface
612  CZ 63.5000       $ Stand outer
613  CZ 58.4200       $ Stand inner
614 1 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
615 1 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
616 2 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
617 2 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
618  PZ -56.1340       $ Bottom plate height
619  RPP -25.6540 25.6540 -63.5001 63.5001 -25.6540 -5.7150  $ Stand top cut box
620  RCC 0.0000 0.0000 352.5520 0.0000 0.0000 3.8100 116.2050 $ VCC lid
621  RCC 0.0000 0.0000 347.4720 0.0000 0.0000 5.0800 124.3330 $ Top flange cylinder
622  CZ 102.8700       $ Top flange inner cut cylinder
623  RCC 0.0000 0.0000 331.2668 0.0000 0.0000 21.2852 99.0600 $ Lid concrete enclosure
624  RCC 0.0000 0.0000 332.2193 0.0000 0.0000 20.3327 98.1075 $ Lid concrete
625  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 336.8040  $ Box for outlet structure
(outside liner)
626  RPP -54.2290 54.2290 -127.0635 127.0635 315.7220 336.8040  $ Upper portion concrete
627  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 324.7390  $ Lower portion concrete
628  RPP -54.2290 54.2290 -143.2560 143.2560 303.6570 324.7390  $ Lower portion concrete cut
surface
629  RPP -53.2765 53.2765 -138.1760 138.1760 304.6095 335.8515  $ Lower/middle outlet void
630  RPP -53.2765 53.2765 -128.0160 128.0160 314.7695 335.8515  $ Cut box for lower/middle void
631  RPP -53.2765 53.2765 -162.5600 162.5600 325.6915 335.8515  $ Upper void
632  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 336.8040  $ Box for outlet structure
(outside liner)
633  RPP -127.0635 127.0635 -54.2290 54.2290 315.7220 336.8040  $ Upper portion concrete
634  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete
635  RPP -143.2560 143.2560 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete cut
surface
636  RPP -138.1760 138.1760 -53.2765 53.2765 304.6095 335.8515  $ Lower/middle outlet void
637  RPP -128.0160 128.0160 -53.2765 53.2765 314.7695 335.8515  $ Cut box for lower/middle void
638  RPP -162.5600 162.5600 -53.2765 53.2765 325.6915 335.8515  $ Upper void
639  RPP -54.2290 54.2290 -106.6800 106.6800 303.6570 315.7220  $ Outlet cut in liner
640  RPP -53.2765 53.2765 -106.6800 106.6800 304.6095 314.7695  $ Portion of outlet in liner
641  CZ 104.1400       $ Air outlet inner radius
642  RCC 0.0000 0.0000 -158.6740 0.0000 0.0000 100.0000 162.5600 $ Concrete pad
643 1 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 +x+y
644 1 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 +x+y
645 1 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 +x+y
646 1 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 +x+y
647 2 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 -x-y
648 2 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 -x-y
649 2 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 -x-y
650 2 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 -x-y
651 3 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 -x+y
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
652 3 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 -x+y
653 3 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 -x+y
654 3 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 -x+y
655 4 RCC 130.8100 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 1 +x-y
656 4 RCC 110.4900 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 2 +x-y
657 4 RCC 90.1700 -15.2400 -48.5140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 3 +x-y
658 4 RCC 69.8500 -15.2400 -35.8140 0.0000 30.4800 0.0000 5.0800 $ Air inlet pipe 4 +x-y
C VCC Rebar Surfaces - v4.0
659  TZ 0.0000 0.0000 2.2860 113.3475 0.9525 0.9525  $ Inner hoop 1
660  TZ 0.0000 0.0000 22.6060 113.3475 0.9525 0.9525  $ Inner hoop 2
661  TZ 0.0000 0.0000 42.9260 113.3475 0.9525 0.9525  $ Inner hoop 3
662  TZ 0.0000 0.0000 63.2460 113.3475 0.9525 0.9525  $ Inner hoop 4
663  TZ 0.0000 0.0000 83.5660 113.3475 0.9525 0.9525  $ Inner hoop 5
664  TZ 0.0000 0.0000 103.8860 113.3475 0.9525 0.9525  $ Inner hoop 6
665  TZ 0.0000 0.0000 124.2060 113.3475 0.9525 0.9525  $ Inner hoop 7
666  TZ 0.0000 0.0000 144.5260 113.3475 0.9525 0.9525  $ Inner hoop 8
667  TZ 0.0000 0.0000 164.8460 113.3475 0.9525 0.9525  $ Inner hoop 9
668  TZ 0.0000 0.0000 185.1660 113.3475 0.9525 0.9525  $ Inner hoop 10
669  TZ 0.0000 0.0000 205.4860 113.3475 0.9525 0.9525  $ Inner hoop 11
670  TZ 0.0000 0.0000 225.8060 113.3475 0.9525 0.9525  $ Inner hoop 12
671  TZ 0.0000 0.0000 246.1260 113.3475 0.9525 0.9525  $ Inner hoop 13
672  TZ 0.0000 0.0000 266.4460 113.3475 0.9525 0.9525  $ Inner hoop 14
673  TZ 0.0000 0.0000 286.7660 113.3475 0.9525 0.9525  $ Inner hoop 15
674  TZ 0.0000 0.0000 307.0860 113.3475 0.9525 0.9525  $ Inner hoop 16
675  TZ 0.0000 0.0000 327.4060 113.3475 0.9525 0.9525  $ Inner hoop 17
676  TZ 0.0000 0.0000 2.2860 151.4475 0.9525 0.9525  $ Outer hoop 1
677  TZ 0.0000 0.0000 12.4460 151.4475 0.9525 0.9525  $ Outer hoop 2
678  TZ 0.0000 0.0000 22.6060 151.4475 0.9525 0.9525  $ Outer hoop 3
679  TZ 0.0000 0.0000 32.7660 151.4475 0.9525 0.9525  $ Outer hoop 4
680  TZ 0.0000 0.0000 42.9260 151.4475 0.9525 0.9525  $ Outer hoop 5
681  TZ 0.0000 0.0000 53.0860 151.4475 0.9525 0.9525  $ Outer hoop 6
682  TZ 0.0000 0.0000 63.2460 151.4475 0.9525 0.9525  $ Outer hoop 7
683  TZ 0.0000 0.0000 73.4060 151.4475 0.9525 0.9525  $ Outer hoop 8
684  TZ 0.0000 0.0000 83.5660 151.4475 0.9525 0.9525  $ Outer hoop 9
685  TZ 0.0000 0.0000 93.7260 151.4475 0.9525 0.9525  $ Outer hoop 10
686  TZ 0.0000 0.0000 103.8860 151.4475 0.9525 0.9525  $ Outer hoop 11
687  TZ 0.0000 0.0000 114.0460 151.4475 0.9525 0.9525  $ Outer hoop 12
688  TZ 0.0000 0.0000 124.2060 151.4475 0.9525 0.9525  $ Outer hoop 13
689  TZ 0.0000 0.0000 134.3660 151.4475 0.9525 0.9525  $ Outer hoop 14
690  TZ 0.0000 0.0000 144.5260 151.4475 0.9525 0.9525  $ Outer hoop 15
691  TZ 0.0000 0.0000 154.6860 151.4475 0.9525 0.9525  $ Outer hoop 16
692  TZ 0.0000 0.0000 164.8460 151.4475 0.9525 0.9525  $ Outer hoop 17
693  TZ 0.0000 0.0000 175.0060 151.4475 0.9525 0.9525  $ Outer hoop 18
694  TZ 0.0000 0.0000 185.1660 151.4475 0.9525 0.9525  $ Outer hoop 19
695  TZ 0.0000 0.0000 195.3260 151.4475 0.9525 0.9525  $ Outer hoop 20
696  TZ 0.0000 0.0000 205.4860 151.4475 0.9525 0.9525  $ Outer hoop 21
697  TZ 0.0000 0.0000 215.6460 151.4475 0.9525 0.9525  $ Outer hoop 22
698  TZ 0.0000 0.0000 225.8060 151.4475 0.9525 0.9525  $ Outer hoop 23
699  TZ 0.0000 0.0000 235.9660 151.4475 0.9525 0.9525  $ Outer hoop 24
700  TZ 0.0000 0.0000 246.1260 151.4475 0.9525 0.9525  $ Outer hoop 25
701  TZ 0.0000 0.0000 256.2860 151.4475 0.9525 0.9525  $ Outer hoop 26
702  TZ 0.0000 0.0000 266.4460 151.4475 0.9525 0.9525  $ Outer hoop 27
703  TZ 0.0000 0.0000 276.6060 151.4475 0.9525 0.9525  $ Outer hoop 28
704  TZ 0.0000 0.0000 286.7660 151.4475 0.9525 0.9525  $ Outer hoop 29
705  TZ 0.0000 0.0000 296.9260 151.4475 0.9525 0.9525  $ Outer hoop 30
706  TZ 0.0000 0.0000 307.0860 151.4475 0.9525 0.9525  $ Outer hoop 31
707  TZ 0.0000 0.0000 317.2460 151.4475 0.9525 0.9525  $ Outer hoop 32
708  TZ 0.0000 0.0000 327.4060 151.4475 0.9525 0.9525  $ Outer hoop 33
709  TZ 0.0000 0.0000 337.5660 151.4475 0.9525 0.9525  $ Outer hoop 34
710  RCC 0.0000 0.0000 2.2860 0.0000 0.0000 332.7400 0.9525 $ Bar
C Storage Cask & Pad Container
799  RCC  0.0000  0.0000  -158.6740  0.0000  0.0000  515.0360  162.5601
C Radial Detector DIAA (Inlet)
800  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  33.0200  162.6601
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
801      PX  0.0000
802  5   PX  0.0000
803  6   PX  0.0000
804  7   PX  0.0000
805  8   PX  0.0000
806  9   PX  0.0000
807  10   PX  0.0000
808  11   PX  0.0000
809  12   PX  0.0000
810      PY  0.0000
811  13   PX  0.0000
812  14   PX  0.0000
813  15   PX  0.0000
814  16   PX  0.0000
815  17   PX  0.0000
816  18   PX  0.0000
817  19   PX  0.0000
818  20   PX  0.0000
C Radial Detector DIBA (Inlet+1ft)
900  RCC  0.0000  0.0000  -58.6740  0.0000  0.0000  33.0200  193.1401
901      PX  0.0000
902  5   PX  0.0000
903  6   PX  0.0000
904  7   PX  0.0000
905  8   PX  0.0000
906  9   PX  0.0000
907  10   PX  0.0000
908  11   PX  0.0000
909  12   PX  0.0000
910      PY  0.0000
911  13   PX  0.0000
912  14   PX  0.0000
913  15   PX  0.0000
914  16   PX  0.0000
915  17   PX  0.0000
916  18   PX  0.0000
917  19   PX  0.0000
918  20   PX  0.0000

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized UO2 Fuel
m2     24000 -2.9967E-02
       25055 -3.1544E-03
       26000 -1.0961E-01
       28000 -1.4983E-02
       92235 -2.6729E-02
       92238 -7.1574E-01
        8016 -9.9810E-02
C Homogenized Upper Plenum
m3     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized Upper Nozzle
m4     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Water
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
m5     1001 2 8016 1
C Stainless Steel
m6     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m7     26000 -0.99 6012 -0.01
C Neutron Poison
m8     13027 -0.8466  5010 -0.0216  5011 -0.0985
        6012 -0.0333
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11     5010 -9.3127E-04 13027 -2.1420E-01  6012 -2.7627E-01
        5011 -3.7721E-03  1001 -6.0012E-02  7014 -1.9815E-02
        8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
C Vent Port Middle Cylinder
m13    24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Damaged Lower Nozzle
m15    24000 -2.7312E-02
       25055 -2.8750E-03
       26000 -9.9905E-02
       28000 -1.3656E-02
       92235 -2.7172E-02
       92238 -7.2761E-01
       8016 -1.0147E-01
phys:p 100 0 0 0 1     $ Disable Doppler energy broadening
C
C Cell Importances
C
imp:p 1 414r 0
C
C BWR Source Definition - Lower Nozzle - DamagedGam - PrefD
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=799:632:501:d5:6
si1    -7.1247 7.1247
sp1    0 1
si2    -7.1247 7.1247
sp2    0 1
si3    0.0000 27.2796
sp3    0 1
si4    1.000E-02 2.000E-02 5.000E-02 1.000E-01 2.000E-01 3.000E-01
       4.000E-01 6.000E-01 8.000E-01 1.000E+00 1.220E+00 1.440E+00
       1.660E+00 2.000E+00 2.500E+00 3.000E+00 4.000E+00 5.000E+00
       6.500E+00 8.000E+00 1.000E+01 1.200E+01 1.400E+01
sp4    0.0000E+00 3.9346E+13 5.1398E+13 2.4748E+13 1.5283E+13 4.7419E+12
       3.2789E+12 2.3939E+12 1.3546E+14 1.0605E+12 5.0505E+11 8.2048E+11
       7.5368E+10 8.4076E+09 4.2540E+08 2.8405E+07 1.8349E+05 6.1637E+04
       2.4653E+04 4.8213E+03 1.0215E+03 5.2748E+01 0.0000E+00
C Source Information
si5 1                   302  304
               306  308  310  312  314  316
           318        332
           334        348
       350  352        366  368
       370  372        386  388
           390        404
           406        420
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
                422  424  426  428  430  432
                          434  436
C Source Probability
sp5                     0.36 0.36
               0.36 0.36 0.36 0.36 0.36 0.36
          0.36       0.36
          0.36       0.36
      0.36 0.36       0.36 0.36
      0.36 0.36       0.36 0.36
          0.36       0.36
          0.36       0.36
               0.36 0.36 0.36 0.36 0.36 0.36
                        0.36 0.36
mode p
nps 200000000
C
C ANSI/ANS-6.1.1-1977 - Gamma Flux-to-Dose Conversion Factors
C (mrem/hr)/(photons/cm2-sec)
C
de0   0.01 0.03 0.05 0.07 0.1 0.15 0.2
      0.25 0.3 0.35 0.4 0.45 0.5 0.55
      0.6 0.65 0.7 0.8 1 1.4 1.8
      2.2 2.6 2.8 3.25 3.75 4.25 4.75
      5 5.25 5.75 6.25 6.75 7.5 9
      11 13 15
df0   3.96E-03 5.82E-04 2.90E-04 2.58E-04 2.83E-04 3.79E-04 5.01E-04
      6.31E-04 7.59E-04 8.78E-04 9.85E-04 1.08E-03 1.17E-03 1.27E-03
      1.36E-03 1.44E-03 1.52E-03 1.68E-03 1.98E-03 2.51E-03 2.99E-03
      3.42E-03 3.82E-03 4.01E-03 4.41E-03 4.83E-03 5.23E-03 5.60E-03
      5.80E-03 6.01E-03 6.37E-03 6.74E-03 7.11E-03 7.66E-03 8.77E-03
      1.03E-02 1.18E-02 1.33E-02
C
C Weight Window Generation - Air Inlet
C
wwg 2 0 0 0 0
wwp:p 5 3 5 0 -1 0
mesh geom=cyl ref=78 9 4 origin=0.1 0.1 -160
     imesh 88.4 89.7 100.3 106.7 162.6 662.6
     iints 5 1 1 2 4 1
     jmesh 101 104 134 137 154 162 189 400 424 437 454 491 512 516 1016
     jints 1 1 1 1 1 2 2 10 1 1 3 1 2 1 1
     kmesh 0.11 0.14 0.36 0.39 0.61 0.64 0.86 0.89 1.00
     kints 1 1 1 1 1 1 1 1 1
wwge:p 1e-3 1 20
fc2 Radial Inlet Tally Q1 (+x+y)
f2:p +800.1
fm2 3.1267E+15
fs2 -801  -810
     +809  +808  +807  +806  +805  +804
     +803  +802  T
sd2 1.6874E+04  8.4368E+03  9.3742E+02  8r  3.3747E+04
tf2
fc12 Radial Inlet Tally Q2 (-x+y)
f12:p +800.1
fm12 3.1267E+15
fs12 +801  -810
     -818  -817  -816  -815  -814  -813
     -812  -811  T
sd12 1.6874E+04  8.4368E+03  9.3742E+02  8r  3.3747E+04
tf12
fc22 Radial Inlet Tally Q3 (-x-y)
f22:p +800.1
fm22 3.1267E+15
fs22 +801  +810
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
     -809  -808  -807  -806  -805  -804
     -803  -802  T
sd22 1.6874E+04  8.4368E+03  9.3742E+02  8r  3.3747E+04
tf22
fc32 Radial Inlet Tally Q4 (+x-y)
f32:p +800.1
fm32 3.1267E+15
fs32 -801  +810
     +818  +817  +816  +815  +814  +813
     +812  +811  T
sd32 1.6874E+04  8.4368E+03  9.3742E+02  8r  3.3747E+04
tf32
fc42 Radial Inlet+1ft Tally Q1 (+x+y)
f42:p +900.1
fm42 3.1267E+15
fs42 -901  -910
     +909  +908  +907  +906  +905  +904
     +903  +902  T
sd42 2.0035E+04  1.0018E+04  1.1131E+03  8r  4.0071E+04
tf42
fc52 Radial Inlet+1ft Tally Q2 (-x+y)
f52:p +900.1
fm52 3.1267E+15
fs52 +901  -910
     -918  -917  -916  -915  -914  -913
     -912  -911  T
sd52 2.0035E+04  1.0018E+04  1.1131E+03  8r  4.0071E+04
tf52
fc62 Radial Inlet+1ft Tally Q3 (-x-y)
f62:p +900.1
fm62 3.1267E+15
fs62 +901  +910
     -909  -908  -907  -906  -905  -904
     -903  -902  T
sd62 2.0035E+04  1.0018E+04  1.1131E+03  8r  4.0071E+04
tf62
fc72 Radial Inlet+1ft Tally Q4 (+x-y)
f72:p +900.1
fm72 3.1267E+15
fs72 -901  +910
     +918  +917  +916  +915  +914  +913
     +912  +911  T
sd72 2.0035E+04  1.0018E+04  1.1131E+03  8r  4.0071E+04
tf72
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 45 degree rotation around z-axis
*TR1 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0
C 135 degree rotation around z-axis
*TR2 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0
C 225 degree rotation around z-axis
*TR3 0.0 0.0 0.0 225 315 90 135 225 90 90 90 0
C 315 degree rotation around z-axis
```

Figure 5.A.6-6 MPC-LACBWR MCNP Input File for Storage Cask Inlet Biasing – Lower End Fitting Damaged Fuel Gamma Source

```
*TR4 0.0 0.0 0.0 315 405 90 225 315 90 90 90 0
C 10 degree rotation around z-axis
*TR5 0.0 0.0 0.0 10 100 90 -80 10 90 90 90 0
C 20 degree rotation around z-axis
*TR6 0.0 0.0 0.0 20 110 90 -70 20 90 90 90 0
C 30 degree rotation around z-axis
*TR7 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0
C 40 degree rotation around z-axis
*TR8 0.0 0.0 0.0 40 130 90 -50 40 90 90 90 0
C 50 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50 140 90 -40 50 90 90 90 0
C 60 degree rotation around z-axis
*TR10 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0
C 70 degree rotation around z-axis
*TR11 0.0 0.0 0.0 70 160 90 -20 70 90 90 90 0
C 80 degree rotation around z-axis
*TR12 0.0 0.0 0.0 80 170 90 -10 80 90 90 90 0
C 100 degree rotation around z-axis
*TR13 0.0 0.0 0.0 100 190 90 10 100 90 90 90 0
C 110 degree rotation around z-axis
*TR14 0.0 0.0 0.0 110 200 90 20 110 90 90 90 0
C 120 degree rotation around z-axis
*TR15 0.0 0.0 0.0 120 210 90 30 120 90 90 90 0
C 130 degree rotation around z-axis
*TR16 0.0 0.0 0.0 130 220 90 40 130 90 90 90 0
C 140 degree rotation around z-axis
*TR17 0.0 0.0 0.0 140 230 90 50 140 90 90 90 0
C 150 degree rotation around z-axis
*TR18 0.0 0.0 0.0 150 240 90 60 150 90 90 90 0
C 160 degree rotation around z-axis
*TR19 0.0 0.0 0.0 160 250 90 70 160 90 90 90 0
C 170 degree rotation around z-axis
*TR20 0.0 0.0 0.0 170 260 90 80 170 90 90 90 0
C 18 degree rotation around z-axis
*TR21 0.0 0.0 0.0 18 108 90 -72 18 90 90 90 0
C 36 degree rotation around z-axis
*TR22 0.0 0.0 0.0 36 126 90 -54 36 90 90 90 0
C 54 degree rotation around z-axis
*TR23 0.0 0.0 0.0 54 144 90 -36 54 90 90 90 0
C 72 degree rotation around z-axis
*TR24 0.0 0.0 0.0 72 162 90 -18 72 90 90 90 0
C 108 degree rotation around z-axis
*TR25 0.0 0.0 0.0 108 198 90 18 108 90 90 90 0
C 126 degree rotation around z-axis
*TR26 0.0 0.0 0.0 126 216 90 36 126 90 90 90 0
C 144 degree rotation around z-axis
*TR27 0.0 0.0 0.0 144 234 90 54 144 90 90 90 0
C 162 degree rotation around z-axis
*TR28 0.0 0.0 0.0 162 252 90 72 162 90 90 90 0
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
LACBWR Transfer Cask - trfShlDryBotLfn_PrefD
C Bottom Axial Biasing - Lower Nozzle Source
C Fuel Assembly Cells - v1.0
1 1 -1.3734 -1 -2    u=11 $ Lower Nozzle
2 2 -3.7790 -1 +2 -3   u=11 $ Fuel
3 3 -0.9880 -1 +3 -4   u=11 $ Upper Plenum
4 4 -0.6145 -1 +4    u=11 $ Upper Nozzle
5 0         +1     u=11 $ Outside
C Fuel Assembly Cells - v1.0
6 15 -9.5539 -1 -2    u=10 $ Lower Nozzle
7 2 -3.7790 -1 +2 -3   u=10 $ Fuel
8 3 -0.9880 -1 +3 -4   u=10 $ Upper Plenum
9 4 -0.6145 -1 +4    u=10 $ Upper Nozzle
10 0         +1     u=10 $ Outside
C Cells - Standard Fuel Tube  v1.0
101 0         -101       u=5 $ Tube void
102 6 -7.9400 -102 +101      u=5 $ Tube
103 8 -2.6707 -103       u=5 $ Absorber +Y
104 6 -7.9400 -104       u=5 $ Cladding +Y
105 8 -2.6707 -105       u=5 $ Absorber +X
106 6 -7.9400 -106       u=5 $ Cladding +X
107 0         +101 +102 +103 +104 +106 +105  u=5 $ Void
C Cells - DFC Fuel Tube Absorber 2 Sides v1.0
108 0         -107       u=6 $ Tube void
109 6 -7.9400 -108 +107      u=6 $ Tube
110 8 -2.6707 -109       u=6 $ Absorber +Y
111 6 -7.9400 -110       u=6 $ Cladding +Y
112 8 -2.6707 -111       u=6 $ Absorber +X
113 6 -7.9400 -112       u=6 $ Cladding +X
114 0         +107 +108 +109 +110 +112 +111  u=6 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (Y) v1.0
115 0         -107       u=7 $ Tube void
116 6 -7.9400 -108 +107      u=7 $ Tube
117 8 -2.6707 -109       u=7 $ Absorber +Y
118 6 -7.9400 -110       u=7 $ Cladding +Y
119 0         +107 +108 +109 +110    u=7 $ Void
C Cells - DFC Fuel Tube Absorber 1 Side (X) v1.0
120 0         -107       u=8 $ Tube void
121 6 -7.9400 -108 +107      u=8 $ Tube
122 8 -2.6707 -111       u=8 $ Absorber +X
123 6 -7.9400 -112       u=8 $ Cladding +X
124 0         +107 +108 +111 +112    u=8 $ Void
C Cells - DFC Fuel Tube No Absorber v1.0
125 0         -107       u=9 $ Tube void
126 6 -7.9400 -108 +107      u=9 $ Tube
127 0         +107 +108      u=9 $ Void
c Cell Cards - Disk Stack v1.0
201 6 -7.94 -203 trcl = ( 0.0000 0.0000 2.5400 )    u=4 $ Bottom weldment disk
202 6 -7.94 -201 trcl = ( 0.0000 0.0000 15.0368 )    u=4 $ Support disk 1
203 like 202 but   trcl = ( 0.0000 0.0000 24.7650 )    u=4 $ Support disk 2
204 like 202 but   trcl = ( 0.0000 0.0000 34.4932 )    u=4 $ Support disk 3
205 like 202 but   trcl = ( 0.0000 0.0000 44.2214 )    u=4 $ Support disk 4
206 like 202 but   trcl = ( 0.0000 0.0000 53.9496 )    u=4 $ Support disk 5
207 9 -2.70 -202 trcl = ( 0.0000 0.0000 58.9788 )    u=4 $ Heat transfer disk 1
208 like 202 but   trcl = ( 0.0000 0.0000 63.6778 )    u=4 $ Support disk 6
209 like 207 but   trcl = ( 0.0000 0.0000 68.7070 )    u=4 $ Heat transfer disk 2
210 like 202 but   trcl = ( 0.0000 0.0000 73.4060 )    u=4 $ Support disk 7
211 like 207 but   trcl = ( 0.0000 0.0000 78.4352 )    u=4 $ Heat transfer disk 3
212 like 202 but   trcl = ( 0.0000 0.0000 83.1342 )    u=4 $ Support disk 8
213 like 207 but   trcl = ( 0.0000 0.0000 88.1634 )    u=4 $ Heat transfer disk 4
214 like 202 but   trcl = ( 0.0000 0.0000 92.8624 )    u=4 $ Support disk 9
215 like 207 but   trcl = ( 0.0000 0.0000 97.8916 )    u=4 $ Heat transfer disk 5
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
216 like 202 but   trcl = ( 0.0000 0.0000 102.5906 )    u=4 $ Support disk 10
217 like 207 but   trcl = ( 0.0000 0.0000 107.6198 )    u=4 $ Heat transfer disk 6
218 like 202 but   trcl = ( 0.0000 0.0000 112.3188 )    u=4 $ Support disk 11
219 like 207 but   trcl = ( 0.0000 0.0000 117.3480 )    u=4 $ Heat transfer disk 7
220 like 202 but   trcl = ( 0.0000 0.0000 122.0470 )    u=4 $ Support disk 12
221 like 207 but   trcl = ( 0.0000 0.0000 127.0762 )    u=4 $ Heat transfer disk 8
222 like 202 but   trcl = ( 0.0000 0.0000 131.7752 )    u=4 $ Support disk 13
223 like 207 but   trcl = ( 0.0000 0.0000 136.8044 )    u=4 $ Heat transfer disk 9
224 like 202 but   trcl = ( 0.0000 0.0000 141.5034 )    u=4 $ Support disk 14
225 like 207 but   trcl = ( 0.0000 0.0000 146.5326 )    u=4 $ Heat transfer disk 10
226 like 202 but   trcl = ( 0.0000 0.0000 151.2316 )    u=4 $ Support disk 15
227 like 207 but   trcl = ( 0.0000 0.0000 156.2608 )    u=4 $ Heat transfer disk 11
228 like 202 but   trcl = ( 0.0000 0.0000 160.9598 )    u=4 $ Support disk 16
229 like 207 but   trcl = ( 0.0000 0.0000 165.9890 )    u=4 $ Heat transfer disk 12
230 like 202 but   trcl = ( 0.0000 0.0000 170.6880 )    u=4 $ Support disk 17
231 like 207 but   trcl = ( 0.0000 0.0000 175.7172 )    u=4 $ Heat transfer disk 13
232 like 202 but   trcl = ( 0.0000 0.0000 180.4162 )    u=4 $ Support disk 18
233 like 207 but   trcl = ( 0.0000 0.0000 185.4454 )    u=4 $ Heat transfer disk 14
234 like 202 but   trcl = ( 0.0000 0.0000 190.1444 )    u=4 $ Support disk 19
235 like 202 but   trcl = ( 0.0000 0.0000 199.8726 )    u=4 $ Support disk 20
236 like 202 but   trcl = ( 0.0000 0.0000 209.6008 )    u=4 $ Support disk 21
237 like 202 but   trcl = ( 0.0000 0.0000 219.3290 )    u=4 $ Support disk 22
238 like 202 but   trcl = ( 0.0000 0.0000 229.0572 )    u=4 $ Support disk 23
239 like 202 but   trcl = ( 0.0000 0.0000 238.7854 )    u=4 $ Support disk 24
240 like 201 but   trcl = ( 0.0000 0.0000 255.8796 )    u=4 $ Top weldment disk
241 0              $ Outside Disks
      #201 #202 #203 #204 #205 #206 #207 #208 #209 #210
      #211 #212 #213 #214 #215 #216 #217 #218 #219 #220
      #221 #222 #223 #224 #225 #226 #227 #228 #229 #230
      #231 #232 #233 #234 #235 #236 #237 #238 #239
      #240        u=4
c Cell Cards - Basket v1.0
301 0          -302 #302  fill=8 ( -8.8265 77.5233 0.0000 )      $ Tube/Disk 1
           trcl = ( -8.8265 77.5233 0.0000 )     u=3
302 0          -1  fill=10 trcl = ( -8.8265 77.5233 0.0000 )     u=3 $ Assembly 1
303 0          -302 #304  fill=9 ( 8.8265 77.5233 0.0000 )      $ Tube/Disk 2
           trcl = ( 8.8265 77.5233 0.0000 )     u=3
304 like 302 but    fill=10 trcl = ( 8.8265 77.5233 0.0000 )     u=3 $ Assembly 2
305 0          -302 #306  fill=8 ( -44.1274 61.2699 0.0000 )      $ Tube/Disk 3
           trcl = ( -44.1274 61.2699 0.0000 )     u=3
306 like 302 but    fill=10 trcl = ( -44.1274 61.2699 0.0000 )     u=3 $ Assembly 3
307 0          -302 #308  fill=8 ( -26.4770 59.8729 0.0000 )      $ Tube/Disk 4
           trcl = ( -26.4770 59.8729 0.0000 )     u=3
308 like 302 but    fill=10 trcl = ( -26.4770 59.8729 0.0000 )     u=3 $ Assembly 4
309 0          -302 #310  fill=6 ( -8.8265 59.8729 0.0000 )      $ Tube/Disk 5
           trcl = ( -8.8265 59.8729 0.0000 )     u=3
310 like 302 but    fill=10 trcl = ( -8.8265 59.8729 0.0000 )     u=3 $ Assembly 5
311 0          -302 #312  fill=6 ( 8.8265 59.8729 0.0000 )      $ Tube/Disk 6
           trcl = ( 8.8265 59.8729 0.0000 )     u=3
312 like 302 but    fill=10 trcl = ( 8.8265 59.8729 0.0000 )     u=3 $ Assembly 6
313 0          -302 #314  fill=8 ( 26.4770 59.8729 0.0000 )      $ Tube/Disk 7
           trcl = ( 26.4770 59.8729 0.0000 )     u=3
314 like 302 but    fill=10 trcl = ( 26.4770 59.8729 0.0000 )     u=3 $ Assembly 7
315 0          -302 #316  fill=9 ( 44.1274 61.2699 0.0000 )      $ Tube/Disk 8
           trcl = ( 44.1274 61.2699 0.0000 )     u=3
316 like 302 but    fill=10 trcl = ( 44.1274 61.2699 0.0000 )     u=3 $ Assembly 8
317 0          -302 #318  fill=8 ( -61.2699 44.1274 0.0000 )      $ Tube/Disk 9
           trcl = ( -61.2699 44.1274 0.0000 )     u=3
318 like 302 but    fill=10 trcl = ( -61.2699 44.1274 0.0000 )     u=3 $ Assembly 9
319 0          -301 #320  fill=5 ( -42.5399 42.5399 0.0000 )      $ Tube/Disk 10
           trcl = ( -42.5399 42.5399 0.0000 )     u=3
320 like 302 but    fill=11 trcl = ( -42.5399 42.5399 0.0000 )     u=3 $ Assembly 10
321 0          -301 #322  fill=5 ( -25.5245 42.5399 0.0000 )      $ Tube/Disk 11
           trcl = ( -25.5245 42.5399 0.0000 )     u=3
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
322 like 302 but    fill=11 trcl = ( -25.5245 42.5399 0.0000 )     u=3 $ Assembly 11
323 0         -301 #324  fill=5 ( -8.5090 42.5399 0.0000 )      $ Tube/Disk 12
          trcl = ( -8.5090 42.5399 0.0000 )     u=3
324 like 302 but    fill=11 trcl = ( -8.5090 42.5399 0.0000 )     u=3 $ Assembly 12
325 0         -301 #326  fill=5 ( 8.5090 42.5399 0.0000 )      $ Tube/Disk 13
          trcl = ( 8.5090 42.5399 0.0000 )     u=3
326 like 302 but    fill=11 trcl = ( 8.5090 42.5399 0.0000 )     u=3 $ Assembly 13
327 0         -301 #328  fill=5 ( 25.5245 42.5399 0.0000 )      $ Tube/Disk 14
          trcl = ( 25.5245 42.5399 0.0000 )     u=3
328 like 302 but    fill=11 trcl = ( 25.5245 42.5399 0.0000 )     u=3 $ Assembly 14
329 0         -301 #330  fill=5 ( 42.5399 42.5399 0.0000 )      $ Tube/Disk 15
          trcl = ( 42.5399 42.5399 0.0000 )     u=3
330 like 302 but    fill=11 trcl = ( 42.5399 42.5399 0.0000 )     u=3 $ Assembly 15
331 0         -302 #332  fill=9 ( 61.2699 44.1274 0.0000 )      $ Tube/Disk 16
          trcl = ( 61.2699 44.1274 0.0000 )     u=3
332 like 302 but    fill=10 trcl = ( 61.2699 44.1274 0.0000 )     u=3 $ Assembly 16
333 0         -302 #334  fill=6 ( -59.8729 26.4770 0.0000 )      $ Tube/Disk 17
          trcl = ( -59.8729 26.4770 0.0000 )     u=3
334 like 302 but    fill=10 trcl = ( -59.8729 26.4770 0.0000 )     u=3 $ Assembly 17
335 0         -301 #336  fill=5 ( -42.5399 25.5245 0.0000 )      $ Tube/Disk 18
          trcl = ( -42.5399 25.5245 0.0000 )     u=3
336 like 302 but    fill=11 trcl = ( -42.5399 25.5245 0.0000 )     u=3 $ Assembly 18
337 0         -301 #338  fill=5 ( -25.5245 25.5245 0.0000 )      $ Tube/Disk 19
          trcl = ( -25.5245 25.5245 0.0000 )     u=3
338 like 302 but    fill=11 trcl = ( -25.5245 25.5245 0.0000 )     u=3 $ Assembly 19
339 0         -301 #340  fill=5 ( -8.5090 25.5245 0.0000 )      $ Tube/Disk 20
          trcl = ( -8.5090 25.5245 0.0000 )     u=3
340 like 302 but    fill=11 trcl = ( -8.5090 25.5245 0.0000 )     u=3 $ Assembly 20
341 0         -301 #342  fill=5 ( 8.5090 25.5245 0.0000 )      $ Tube/Disk 21
          trcl = ( 8.5090 25.5245 0.0000 )     u=3
342 like 302 but    fill=11 trcl = ( 8.5090 25.5245 0.0000 )     u=3 $ Assembly 21
343 0         -301 #344  fill=5 ( 25.5245 25.5245 0.0000 )      $ Tube/Disk 22
          trcl = ( 25.5245 25.5245 0.0000 )     u=3
344 like 302 but    fill=11 trcl = ( 25.5245 25.5245 0.0000 )     u=3 $ Assembly 22
345 0         -301 #346  fill=5 ( 42.5399 25.5245 0.0000 )      $ Tube/Disk 23
          trcl = ( 42.5399 25.5245 0.0000 )     u=3
346 like 302 but    fill=11 trcl = ( 42.5399 25.5245 0.0000 )     u=3 $ Assembly 23
347 0         -302 #348  fill=7 ( 59.8729 26.4770 0.0000 )      $ Tube/Disk 24
          trcl = ( 59.8729 26.4770 0.0000 )     u=3
348 like 302 but    fill=10 trcl = ( 59.8729 26.4770 0.0000 )     u=3 $ Assembly 24
349 0         -302 #350  fill=8 ( -77.5233 8.8265 0.0000 )      $ Tube/Disk 25
          trcl = ( -77.5233 8.8265 0.0000 )     u=3
350 like 302 but    fill=10 trcl = ( -77.5233 8.8265 0.0000 )     u=3 $ Assembly 25
351 0         -302 #352  fill=6 ( -59.8729 8.8265 0.0000 )      $ Tube/Disk 26
          trcl = ( -59.8729 8.8265 0.0000 )     u=3
352 like 302 but    fill=10 trcl = ( -59.8729 8.8265 0.0000 )     u=3 $ Assembly 26
353 0         -301 #354  fill=5 ( -42.5399 8.5090 0.0000 )      $ Tube/Disk 27
          trcl = ( -42.5399 8.5090 0.0000 )     u=3
354 like 302 but    fill=11 trcl = ( -42.5399 8.5090 0.0000 )     u=3 $ Assembly 27
355 0         -301 #356  fill=5 ( -25.5245 8.5090 0.0000 )      $ Tube/Disk 28
          trcl = ( -25.5245 8.5090 0.0000 )     u=3
356 like 302 but    fill=11 trcl = ( -25.5245 8.5090 0.0000 )     u=3 $ Assembly 28
357 0         -301 #358  fill=5 ( -8.5090 8.5090 0.0000 )      $ Tube/Disk 29
          trcl = ( -8.5090 8.5090 0.0000 )     u=3
358 like 302 but    fill=11 trcl = ( -8.5090 8.5090 0.0000 )     u=3 $ Assembly 29
359 0         -301 #360  fill=5 ( 8.5090 8.5090 0.0000 )      $ Tube/Disk 30
          trcl = ( 8.5090 8.5090 0.0000 )     u=3
360 like 302 but    fill=11 trcl = ( 8.5090 8.5090 0.0000 )     u=3 $ Assembly 30
361 0         -301 #362  fill=5 ( 25.5245 8.5090 0.0000 )      $ Tube/Disk 31
          trcl = ( 25.5245 8.5090 0.0000 )     u=3
362 like 302 but    fill=11 trcl = ( 25.5245 8.5090 0.0000 )     u=3 $ Assembly 31
363 0         -301 #364  fill=5 ( 42.5399 8.5090 0.0000 )      $ Tube/Disk 32
          trcl = ( 42.5399 8.5090 0.0000 )     u=3
364 like 302 but    fill=11 trcl = ( 42.5399 8.5090 0.0000 )     u=3 $ Assembly 32
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
365 0          -302 #366  fill=6 ( 59.8729 8.8265 0.0000 )       $ Tube/Disk 33
           trcl = ( 59.8729 8.8265 0.0000 )      u=3
366 like 302 but    fill=10 trcl = ( 59.8729 8.8265 0.0000 )      u=3 $ Assembly 33
367 0          -302 #368  fill=9 ( 77.5233 8.8265 0.0000 )       $ Tube/Disk 34
           trcl = ( 77.5233 8.8265 0.0000 )      u=3
368 like 302 but    fill=10 trcl = ( 77.5233 8.8265 0.0000 )      u=3 $ Assembly 34
369 0          -302 #370  fill=6 ( -77.5233 -8.8265 0.0000 )      $ Tube/Disk 35
           trcl = ( -77.5233 -8.8265 0.0000 )      u=3
370 like 302 but    fill=10 trcl = ( -77.5233 -8.8265 0.0000 )      u=3 $ Assembly 35
371 0          -302 #372  fill=6 ( -59.8729 -8.8265 0.0000 )      $ Tube/Disk 36
           trcl = ( -59.8729 -8.8265 0.0000 )      u=3
372 like 302 but    fill=10 trcl = ( -59.8729 -8.8265 0.0000 )      u=3 $ Assembly 36
373 0          -301 #374  fill=5 ( -42.5399 -8.5090 0.0000 )      $ Tube/Disk 37
           trcl = ( -42.5399 -8.5090 0.0000 )      u=3
374 like 302 but    fill=11 trcl = ( -42.5399 -8.5090 0.0000 )      u=3 $ Assembly 37
375 0          -301 #376  fill=5 ( -25.5245 -8.5090 0.0000 )      $ Tube/Disk 38
           trcl = ( -25.5245 -8.5090 0.0000 )      u=3
376 like 302 but    fill=11 trcl = ( -25.5245 -8.5090 0.0000 )      u=3 $ Assembly 38
377 0          -301 #378  fill=5 ( -8.5090 -8.5090 0.0000 )      $ Tube/Disk 39
           trcl = ( -8.5090 -8.5090 0.0000 )      u=3
378 like 302 but    fill=11 trcl = ( -8.5090 -8.5090 0.0000 )      u=3 $ Assembly 39
379 0          -301 #380  fill=5 ( 8.5090 -8.5090 0.0000 )      $ Tube/Disk 40
           trcl = ( 8.5090 -8.5090 0.0000 )      u=3
380 like 302 but    fill=11 trcl = ( 8.5090 -8.5090 0.0000 )      u=3 $ Assembly 40
381 0          -301 #382  fill=5 ( 25.5245 -8.5090 0.0000 )      $ Tube/Disk 41
           trcl = ( 25.5245 -8.5090 0.0000 )      u=3
382 like 302 but    fill=11 trcl = ( 25.5245 -8.5090 0.0000 )      u=3 $ Assembly 41
383 0          -301 #384  fill=5 ( 42.5399 -8.5090 0.0000 )      $ Tube/Disk 42
           trcl = ( 42.5399 -8.5090 0.0000 )      u=3
384 like 302 but    fill=11 trcl = ( 42.5399 -8.5090 0.0000 )      u=3 $ Assembly 42
385 0          -302 #386  fill=6 ( 59.8729 -8.8265 0.0000 )      $ Tube/Disk 43
           trcl = ( 59.8729 -8.8265 0.0000 )      u=3
386 like 302 but    fill=10 trcl = ( 59.8729 -8.8265 0.0000 )      u=3 $ Assembly 43
387 0          -302 #388  fill=7 ( 77.5233 -8.8265 0.0000 )      $ Tube/Disk 44
           trcl = ( 77.5233 -8.8265 0.0000 )      u=3
388 like 302 but    fill=10 trcl = ( 77.5233 -8.8265 0.0000 )      u=3 $ Assembly 44
389 0          -302 #390  fill=6 ( -59.8729 -26.4770 0.0000 )      $ Tube/Disk 45
           trcl = ( -59.8729 -26.4770 0.0000 )      u=3
390 like 302 but    fill=10 trcl = ( -59.8729 -26.4770 0.0000 )      u=3 $ Assembly 45
391 0          -301 #392  fill=5 ( -42.5399 -25.5245 0.0000 )      $ Tube/Disk 46
           trcl = ( -42.5399 -25.5245 0.0000 )      u=3
392 like 302 but    fill=11 trcl = ( -42.5399 -25.5245 0.0000 )      u=3 $ Assembly 46
393 0          -301 #394  fill=5 ( -25.5245 -25.5245 0.0000 )      $ Tube/Disk 47
           trcl = ( -25.5245 -25.5245 0.0000 )      u=3
394 like 302 but    fill=11 trcl = ( -25.5245 -25.5245 0.0000 )      u=3 $ Assembly 47
395 0          -301 #396  fill=5 ( -8.5090 -25.5245 0.0000 )      $ Tube/Disk 48
           trcl = ( -8.5090 -25.5245 0.0000 )      u=3
396 like 302 but    fill=11 trcl = ( -8.5090 -25.5245 0.0000 )      u=3 $ Assembly 48
397 0          -301 #398  fill=5 ( 8.5090 -25.5245 0.0000 )      $ Tube/Disk 49
           trcl = ( 8.5090 -25.5245 0.0000 )      u=3
398 like 302 but    fill=11 trcl = ( 8.5090 -25.5245 0.0000 )      u=3 $ Assembly 49
399 0          -301 #400  fill=5 ( 25.5245 -25.5245 0.0000 )      $ Tube/Disk 50
           trcl = ( 25.5245 -25.5245 0.0000 )      u=3
400 like 302 but    fill=11 trcl = ( 25.5245 -25.5245 0.0000 )      u=3 $ Assembly 50
401 0          -301 #402  fill=5 ( 42.5399 -25.5245 0.0000 )      $ Tube/Disk 51
           trcl = ( 42.5399 -25.5245 0.0000 )      u=3
402 like 302 but    fill=11 trcl = ( 42.5399 -25.5245 0.0000 )      u=3 $ Assembly 51
403 0          -302 #404  fill=7 ( 59.8729 -26.4770 0.0000 )      $ Tube/Disk 52
           trcl = ( 59.8729 -26.4770 0.0000 )      u=3
404 like 302 but    fill=10 trcl = ( 59.8729 -26.4770 0.0000 )      u=3 $ Assembly 52
405 0          -302 #406  fill=6 ( -61.2699 -44.1274 0.0000 )      $ Tube/Disk 53
           trcl = ( -61.2699 -44.1274 0.0000 )      u=3
406 like 302 but    fill=10 trcl = ( -61.2699 -44.1274 0.0000 )      u=3 $ Assembly 53
407 0          -301 #408  fill=5 ( -42.5399 -42.5399 0.0000 )      $ Tube/Disk 54
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
          trcl = ( -42.5399 -42.5399 0.0000 )      u=3
408 like 302 but    fill=11 trcl = ( -42.5399 -42.5399 0.0000 )      u=3 $ Assembly 54
409 0         -301 #410  fill=5 ( -25.5245 -42.5399 0.0000 )       $ Tube/Disk 55
          trcl = ( -25.5245 -42.5399 0.0000 )      u=3
410 like 302 but    fill=11 trcl = ( -25.5245 -42.5399 0.0000 )      u=3 $ Assembly 55
411 0         -301 #412  fill=5 ( -8.5090 -42.5399 0.0000 )       $ Tube/Disk 56
          trcl = ( -8.5090 -42.5399 0.0000 )      u=3
412 like 302 but    fill=11 trcl = ( -8.5090 -42.5399 0.0000 )      u=3 $ Assembly 56
413 0         -301 #414  fill=5 ( 8.5090 -42.5399 0.0000 )       $ Tube/Disk 57
          trcl = ( 8.5090 -42.5399 0.0000 )      u=3
414 like 302 but    fill=11 trcl = ( 8.5090 -42.5399 0.0000 )      u=3 $ Assembly 57
415 0         -301 #416  fill=5 ( 25.5245 -42.5399 0.0000 )       $ Tube/Disk 58
          trcl = ( 25.5245 -42.5399 0.0000 )      u=3
416 like 302 but    fill=11 trcl = ( 25.5245 -42.5399 0.0000 )      u=3 $ Assembly 58
417 0         -301 #418  fill=5 ( 42.5399 -42.5399 0.0000 )       $ Tube/Disk 59
          trcl = ( 42.5399 -42.5399 0.0000 )      u=3
418 like 302 but    fill=11 trcl = ( 42.5399 -42.5399 0.0000 )      u=3 $ Assembly 59
419 0         -302 #420  fill=7 ( 61.2699 -44.1274 0.0000 )       $ Tube/Disk 60
          trcl = ( 61.2699 -44.1274 0.0000 )      u=3
420 like 302 but    fill=10 trcl = ( 61.2699 -44.1274 0.0000 )      u=3 $ Assembly 60
421 0         -302 #422  fill=6 ( -44.1274 -61.2699 0.0000 )       $ Tube/Disk 61
          trcl = ( -44.1274 -61.2699 0.0000 )      u=3
422 like 302 but    fill=10 trcl = ( -44.1274 -61.2699 0.0000 )      u=3 $ Assembly 61
423 0         -302 #424  fill=6 ( -26.4770 -59.8729 0.0000 )       $ Tube/Disk 62
          trcl = ( -26.4770 -59.8729 0.0000 )      u=3
424 like 302 but    fill=10 trcl = ( -26.4770 -59.8729 0.0000 )      u=3 $ Assembly 62
425 0         -302 #426  fill=6 ( -8.8265 -59.8729 0.0000 )       $ Tube/Disk 63
          trcl = ( -8.8265 -59.8729 0.0000 )      u=3
426 like 302 but    fill=10 trcl = ( -8.8265 -59.8729 0.0000 )      u=3 $ Assembly 63
427 0         -302 #428  fill=6 ( 8.8265 -59.8729 0.0000 )       $ Tube/Disk 64
          trcl = ( 8.8265 -59.8729 0.0000 )      u=3
428 like 302 but    fill=10 trcl = ( 8.8265 -59.8729 0.0000 )      u=3 $ Assembly 64
429 0         -302 #430  fill=6 ( 26.4770 -59.8729 0.0000 )       $ Tube/Disk 65
          trcl = ( 26.4770 -59.8729 0.0000 )      u=3
430 like 302 but    fill=10 trcl = ( 26.4770 -59.8729 0.0000 )      u=3 $ Assembly 65
431 0         -302 #432  fill=7 ( 44.1274 -61.2699 0.0000 )       $ Tube/Disk 66
          trcl = ( 44.1274 -61.2699 0.0000 )      u=3
432 like 302 but    fill=10 trcl = ( 44.1274 -61.2699 0.0000 )      u=3 $ Assembly 66
433 0         -302 #434  fill=7 ( -8.8265 -77.5233 0.0000 )       $ Tube/Disk 67
          trcl = ( -8.8265 -77.5233 0.0000 )      u=3
434 like 302 but    fill=10 trcl = ( -8.8265 -77.5233 0.0000 )      u=3 $ Assembly 67
435 0         -302 #436  fill=7 ( 8.8265 -77.5233 0.0000 )       $ Tube/Disk 68
          trcl = ( 8.8265 -77.5233 0.0000 )      u=3
436 like 302 but    fill=10 trcl = ( 8.8265 -77.5233 0.0000 )      u=3 $ Assembly 68
437 0         +303 +304         $ Canister Cavity Q1
      #303 #311 #313 #315 #325 #327 #329 #331 #341
      #304 #312 #314 #316 #326 #328 #330 #332 #342
      #343 #345 #347 #359 #361 #363 #365 #367
      #344 #346 #348 #360 #362 #364 #366 #368
          fill=4      u=3
438 0         +303 -304         $ Canister Cavity Q2
      #301 #305 #307 #309 #317 #319 #321 #323 #333
      #302 #306 #308 #310 #318 #320 #322 #324 #334
      #335 #337 #339 #349 #351 #353 #355 #357
      #336 #338 #340 #350 #352 #354 #356 #358
          fill=4      u=3
439 0         -303 -304         $ Canister Cavity Q3
      #369 #371 #373 #375 #377 #389 #391 #393 #395
      #370 #372 #374 #376 #378 #390 #392 #394 #396
      #405 #407 #409 #411 #421 #423 #425 #433
      #406 #408 #410 #412 #422 #424 #426 #434
          fill=4      u=3
440 0         -303 +304         $ Canister Cavity Q4
      #379 #381 #383 #385 #387 #397 #399 #401 #403
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
      #380 #382 #384 #386 #388 #398 #400 #402 #404
      #413 #415 #417 #419 #427 #429 #431 #435
      #414 #416 #418 #420 #428 #430 #432 #436
          fill=4      u=3
C Cells - Canister v1.0
501 0          -501 fill=3      u=2 $ Cavity
502 6 -7.9400 -507 +501.3      u=2 $ Canister Bottom
503 0          -502 +501.2 -505 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Bottom Drain Port
504 0          -503 +505 -506 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Middle Drain Port
505 6 -7.9400 -504 +506 -507.2 trcl = ( 72.8704 22.2787 0.0000 )    u=2 $ Top Drain Port
506 like 503 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Bottom Vent Port
507 like 504 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Middle Vent Port
508 like 505 but   trcl = ( -72.8704 -22.2787 0.0000 )    u=2 $ Top Vent Port
509 6 -7.9400 -507 -501.3 +501.1     u=2 $ Canister Shell
510 6 -7.9400 -507 -501.1 +501.2 #503 #504 #505 #506 #507 #508     u=2 $ Lid
511 0          +507       u=2 $ Outside
C Transfer Cask Cells - v4.0
601 0          -601 -602  fill=2 ( 0.0000 0.0000 2.5400 )   u=1 $ Cavity
602 7 -7.8212 -601 +602 -606    u=1 $ Bottom forging
603 7 -7.8212 -603 +602 +606 -607 +613  u=1 $ Inner shell
604 10 -11.344 -604 +603 +606 -607 +613  u=1 $ Lead shell
605 11 -1.6316 -605 +604 +606 -607 +613  u=1 $ NS-4-FR
606 7 -7.8212 -601 +605 +606 -607 +613  u=1 $ Outer shell
607 7 -7.8212 -601 +602 +607    u=1 $ Top forging
608 7 -7.8212 -601 +602 -613    u=1 $ Trunnion
609 7 -7.8212 (-608 +609 -615) : (-608 -610 -615)      u=1 $ Door rail
610 7 -7.8212 -614 -611 +612 -615   u=1 $ Door steel
611 0          +601 #609  #610     u=1 $ Void
C Detector Cells - Axial Biasing
700  0  -700  fill=1  $ Surface
800  0  -800  +700  $ 1ft
900  0  -900  +700  +800  $ 1m
1000  0  -1000  +700  +800  +900  $ 2m
1100  0  -1100  +700  +800  +900  +1000  $ 4m
1200  0  +700  +800  +900  +1000  +1100  $ Exterior

C Fuel Assembly Surfaces - v1.0
1 RPP -7.1247 7.1247 -7.1247 7.1247 0.0000 261.9502  $ Assy
2 PZ 27.2796       $ Lower Nozzle/Fuel
3 PZ 238.0996       $ Fuel/Upper Plenum
4 PZ 251.1298       $ Upper Plenum/Upper Nozzle
C Surfaces - Standard Fuel Tube v1.0
101 RPP -7.3076 7.3076 -7.3076 7.3076 0.0000 274.4470    $ Tube void
102 RPP -7.4295 7.4295 -7.4295 7.4295 0.0000 249.5550    $ Tube
103 RPP -6.5913 6.5913 7.4295 7.6200 2.0320 245.8720    $ Absorber +Y
104 RPP -6.5913 6.5913 7.6200 7.6657 2.0320 245.8720    $ Cladding +Y
105 RPP 7.4295 7.6200 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
106 RPP 7.6200 7.6657 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
C Surfaces - DFC Fuel Tube v1.0
107 RPP -7.6251 7.6251 -7.6251 7.6251 0.0000 274.4470    $ Tube void
108 RPP -7.7470 7.7470 -7.7470 7.7470 0.0000 249.5550    $ Tube
109 RPP -6.5913 6.5913 7.7470 7.9375 2.0320 245.8720    $ Absorber +Y
110 RPP -6.5913 6.5913 7.9375 7.9832 2.0320 245.8720    $ Cladding +Y
111 RPP 7.7470 7.9375 -6.5913 6.5913 2.0320 245.8720    $ Absorber +X
112 RPP 7.9375 7.9832 -6.5913 6.5913 2.0320 245.8720    $ Cladding +X
c Surface Cards - Disk Stack  v1.0
201 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.1380 $ Structural disk
202 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.2700 87.7951 $ Heat transfer disk
203 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Weldment disk
c Surface Cards - Basket v1.0
301 RPP -7.7711 7.7711 -7.7711 7.7711 0.0000 274.4470  $ Std opening
302 RPP -8.0899 8.0899 -8.0899 8.0899 0.0000 274.4470  $ DFC opening
303 PY 0.0000       $ Cut plane
304 PX 0.0000       $ Cut plane
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
C Surfaces - Canister v1.0
501 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470 88.4428   $ Cavity
502 CZ 1.3843          $ Bot Cylinder Radius
503 CZ 5.0800          $ Mid Cyclinder Radius
504 CZ 5.7150          $ Top Cylinder Radius
505 PZ 282.8798          $ Port plane bot/mid
506 PZ 289.3822          $ Port plane mid/top
507 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670 89.7128   $ Canister
C Transfer Cask Surfaces - v4.0
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 313.6900 109.8550  $ Cask
602 CZ 90.8050         $ Cavity
603 CZ 92.7100         $ Inner shell OR
604 CZ 101.6000         $ Lead shell OR
605 CZ 106.6800         $ Outer shell IR
606 PZ 2.5400         $ Bottom forging
607 PZ 308.6100         $ Top forging
608 RPP -110.1852 110.1852 -107.3150 107.3150 -24.1300 0.0000   $ Door container
609 PY 95.8850         $ Inside rail +y
610 PY -95.8850         $ Inside rail -y
611 PY 95.4024         $ Door +y
612 PY -95.4024         $ Door -y
613 RCC -109.8550 0.0000 275.5900 219.7100 0.0000 0.0000 12.7000  $ Trunnion
614 RHP 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300   $ Door prism
        109.6679 0.0000 0.0000 87.5826 -66.1670 0.0000
        -87.5826 -66.1670 0.0000
615 RCC 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300 109.8550  $ Door container
C Axial Detector DBA (Surface)
700  RCC  0.0000  0.0000  -24.2300  0.0000  0.0000  338.0200  109.9550
701  CZ  10.9955
702  CZ  21.9910
703  CZ  32.9865
704  CZ  43.9820
705  CZ  54.9775
706  CZ  65.9730
707  CZ  76.9685
708  CZ  87.9640
709  CZ  98.9595
C Axial Detector DBB (1ft)
800  RCC  0.0000  0.0000  -54.7100  0.0000  0.0000  368.5000  140.4350
801  CZ  14.0435
802  CZ  28.0870
803  CZ  42.1305
804  CZ  56.1740
805  CZ  70.2175
806  CZ  84.2610
807  CZ  98.3045
808  CZ  112.3480
809  CZ  126.3915
C Axial Detector DBC (1m)
900  RCC  0.0000  0.0000  -124.2300  0.0000  0.0000  438.0200  209.9550
901  CZ  20.9955
902  CZ  41.9910
903  CZ  62.9865
904  CZ  83.9820
905  CZ  104.9775
906  CZ  125.9730
907  CZ  146.9685
908  CZ  167.9640
909  CZ  188.9595
C Axial Detector DBD (2m)
1000  RCC  0.0000  0.0000  -224.2300  0.0000  0.0000  538.0200  309.9550
1001  CZ  30.9955
1002  CZ  61.9910
1003  CZ  92.9865
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
1004  CZ  123.9820
1005  CZ  154.9775
1006  CZ  185.9730
1007  CZ  216.9685
1008  CZ  247.9640
1009  CZ  278.9595
C Axial Detector DBE (4m)
1100  RCC  0.0000  0.0000  -424.2300  0.0000  0.0000  738.0200  509.9550
1101  CZ  50.9955
1102  CZ  101.9910
1103  CZ  152.9865
1104  CZ  203.9820
1105  CZ  254.9775
1106  CZ  305.9730
1107  CZ  356.9685
1108  CZ  407.9640
1109  CZ  458.9595

C
C Materials List - Common Materials - v1.0
C
C Homogenized Lower Nozzle
m1     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized UO2 Fuel
m2     24000 -2.9967E-02
       25055 -3.1544E-03
       26000 -1.0961E-01
       28000 -1.4983E-02
       92235 -2.6729E-02
       92238 -7.1574E-01
        8016 -9.9810E-02
C Homogenized Upper Plenum
m3     24000 -1.9000E-01
       25055 -2.0000E-02
       26000 -6.9500E-01
       28000 -9.5000E-02
C Homogenized Upper Nozzle
m4     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Water
m5     1001 2 8016 1
C Stainless Steel
m6     24000 -0.190 25055 -0.020 26000 -0.695
       28000 -0.095
C Carbon Steel
m7     26000 -0.99 6012 -0.01
C Neutron Poison
m8     13027 -0.8466  5010 -0.0216  5011 -0.0985
        6012 -0.0333
C Aluminum
m9     13027 -1.0
C Lead
m10    82000 -1.0
C NS-4-FR
m11     5010 -9.3127E-04 13027 -2.1420E-01  6012 -2.7627E-01
        5011 -3.7721E-03  1001 -6.0012E-02  7014 -1.9815E-02
        8016 -4.2500E-01
C Concrete
m12    26000 -0.014 20000 -0.044 14000 -0.337
        1001 -0.010  8016 -0.532 11023 -0.029
       13027 -0.034
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
C Vent Port Middle Cylinder
m13   24000 -0.190 25055 -0.020 26000 -0.695
      28000 -0.095
C Damaged Lower Nozzle
m15   24000 -2.7312E-02
      25055 -2.8750E-03
      26000 -9.9905E-02
      28000 -1.3656E-02
      92235 -2.7172E-02
      92238 -7.2761E-01
      8016 -1.0147E-01
nonu                  $ Disable subcritical multiplication
C
C Cell Importances
C
imp:n 1 244r 0
C
C BWR Source Definition - Lower Nozzle - DamagedNut - PrefD
C
sdef x=d1 y=d2 z=d3 erg=d4 cell=700:601:501:d5:6
si1   -7.1247 7.1247
sp1   0 1
si2   -7.1247 7.1247
sp2   0 1
si3   0.0000 27.2796
sp3   0 1
si4   1.000E-11 7.090E-08 5.500E-07 1.500E-06 4.000E-06 1.600E-05
      4.810E-05 1.660E-04 3.540E-04 9.610E-04 2.950E-03 9.120E-03
      2.480E-02 6.740E-02 1.100E-01 3.900E-01 6.400E-01 1.740E+00
      2.870E+00 3.680E+00 4.720E+00 6.070E+00 7.000E+00 8.250E+00
      1.000E+01 1.125E+01 1.250E+01 1.360E+01 1.460E+01
sp4   0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
      0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00 0.0000E+00
      0.0000E+00 0.0000E+00 2.4850E+01 6.1350E+04 1.7620E+05 7.3960E+05
      6.2630E+05 2.6030E+05 1.4660E+05 7.8130E+04 2.3350E+04 1.3530E+04
      5.0380E+03 1.6060E+03 4.8350E+02 1.1600E+02 0.0000E+00
C Source Information
si5 l                  302  304
              306  308  310  312  314  316
          318        332
          334        348
      350  352        366  368
      370  372        386  388
          390        404
          406        420
              422  424  426  428  430  432
                     434  436
C Source Probability
sp5                   0.36 0.36
             0.36 0.36 0.36 0.36 0.36 0.36
         0.36       0.36
         0.36       0.36
     0.36 0.36       0.36 0.36
     0.36 0.36       0.36 0.36
         0.36       0.36
         0.36       0.36
             0.36 0.36 0.36 0.36 0.36 0.36
                      0.36 0.36
mode n
nps 9100000
C
C ANSI/ANS-6.1.1-1977 - Neutron Flux-to-Dose Conversion Factors
C (mrem/hr)/(neutrons/cm2-sec)
C
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
de0   2.5E-08 1E-07 1E-06 0.00001 0.0001 0.001 0.01
      0.1 0.5 1 2.5 5 7 10
      14 20
df0   3.67E-03 3.67E-03 4.46E-03 4.54E-03 4.18E-03 3.76E-03 3.56E-03
      2.17E-02 9.26E-02 1.32E-01 1.25E-01 1.56E-01 1.47E-01 1.47E-01
      2.08E-01 2.27E-01
C
C Weight Window Generation - Bottom Axial
C
wwg 2 0 0 0 0
wwp:n 5 3 5 0 -1 0
mesh geom=cyl ref=9 9 4 origin=0.1 0.1 -524
     imesh 88.4 89.7 90.8 92.7 101.6 106.7 109.9 609.9
     iints 5 1 1 1 1 1 1 1
     jmesh 500 524 527 554 765 778 789 801 819 1319
     jints 1 1 1 1 10 1 1 1 2 1
     kmesh 1
     kints 1
wwge:n  1e-5 1e-3 1 20
fc2 Axial Surface Tally
f2:n +700.3
fm2 7.2567E+07
fs2  -701  -702  -703  -704  -705  -706
     -707  -708  -709  T
tf2
fc12 Axial 1ft Tally
f12:n +800.3
fm12 7.2567E+07
fs12  -801  -802  -803  -804  -805  -806
     -807  -808  -809  T
tf12
fc22 Axial 1m Tally
f22:n +900.3
fm22 7.2567E+07
fs22  -901  -902  -903  -904  -905  -906
     -907  -908  -909  T
tf22
fc32 Axial 2m Tally
f32:n +1000.3
fm32 7.2567E+07
fs32  -1001  -1002  -1003  -1004  -1005  -1006
     -1007  -1008  -1009  T
tf32
fc42 Axial 4m Tally
f42:n +1100.3
fm42 7.2567E+07
fs42  -1101  -1102  -1103  -1104  -1105  -1106
     -1107  -1108  -1109  T
tf42
C
C
C Print Control
C
prdmp -30 -60 1 2
print
C
C Random Number Generator
C
rand gen=2 seed=19073486328125 stride=152917 hist=1
C
C Rotation Matrix
C
C 5.625 degree rotation around z-axis
*TR1 0.0 0.0 0.0 5.625 95.625 90 -84.375 5.625 90 90 90 0
```

Figure 5.A.6-7 MPC-LACBWR MCNP Input File for Transfer Cask Dry Canister Bottom Axial Biasing – Lower End Fitting Damaged Fuel Neutron Source

```
C 11.25 degree rotation around z-axis
*TR2 0.0 0.0 0.0 11.250 101.250 90 -78.750 11.250 90 90 90 0
C 16.875 degree rotation around z-axis
*TR3 0.0 0.0 0.0 16.875 106.875 90 -73.125 16.875 90 90 90 0
C 22.5 degree rotation around z-axis
*TR4 0.0 0.0 0.0 22.500 112.500 90 -67.500 22.500 90 90 90 0
C 28.125 degree rotation around z-axis
*TR5 0.0 0.0 0.0 28.125 118.125 90 -61.875 28.125 90 90 90 0
C 33.75 degree rotation around z-axis
*TR6 0.0 0.0 0.0 33.750 123.750 90 -56.250 33.750 90 90 90 0
C 39.375 degree rotation around z-axis
*TR7 0.0 0.0 0.0 39.375 129.375 90 -50.625 39.375 90 90 90 0
C 45 degree rotation around z-axis
*TR8 0.0 0.0 0.0 45.000 135.000 90 -45.000 45.000 90 90 90 0
C 50.625 degree rotation around z-axis
*TR9 0.0 0.0 0.0 50.625 140.625 90 -39.375 50.625 90 90 90 0
C 56.25 degree rotation around z-axis
*TR10 0.0 0.0 0.0 56.250 146.250 90 -33.750 56.250 90 90 90 0
C 61.875 degree rotation around z-axis
*TR11 0.0 0.0 0.0 61.875 151.875 90 -28.125 61.875 90 90 90 0
C 67.5 degree rotation around z-axis
*TR12 0.0 0.0 0.0 67.500 157.500 90 -22.500 67.500 90 90 90 0
C 73.125 degree rotation around z-axis
*TR13 0.0 0.0 0.0 73.125 163.125 90 -16.875 73.125 90 90 90 0
C 78.75 degree rotation around z-axis
*TR14 0.0 0.0 0.0 78.750 168.750 90 -11.250 78.750 90 90 90 0
C 84.375 degree rotation around z-axis
*TR15 0.0 0.0 0.0 84.375 174.375 90 -5.625 84.375 90 90 90 0
C 95.625 degree rotation around z-axis
*TR16 0.0 0.0 0.0 95.625 185.625 90 5.625 95.625 90 90 90 0
C 101.25 degree rotation around z-axis
*TR17 0.0 0.0 0.0 101.250 191.250 90 11.250 101.250 90 90 90 0
C 106.875 degree rotation around z-axis
*TR18 0.0 0.0 0.0 106.875 196.875 90 16.875 106.875 90 90 90 0
C 112.5 degree rotation around z-axis
*TR19 0.0 0.0 0.0 112.500 202.500 90 22.500 112.500 90 90 90 0
C 118.125 degree rotation around z-axis
*TR20 0.0 0.0 0.0 118.125 208.125 90 28.125 118.125 90 90 90 0
C 123.75 degree rotation around z-axis
*TR21 0.0 0.0 0.0 123.750 213.750 90 33.750 123.750 90 90 90 0
C 129.375 degree rotation around z-axis
*TR22 0.0 0.0 0.0 129.375 219.375 90 39.375 129.375 90 90 90 0
C 135 degree rotation around z-axis
*TR23 0.0 0.0 0.0 135.000 225.000 90 45.000 135.000 90 90 90 0
C 140.625 degree rotation around z-axis
*TR24 0.0 0.0 0.0 140.625 230.625 90 50.625 140.625 90 90 90 0
C 146.25 degree rotation around z-axis
*TR25 0.0 0.0 0.0 146.250 236.250 90 56.250 146.250 90 90 90 0
C 151.875 degree rotation around z-axis
*TR26 0.0 0.0 0.0 151.875 241.875 90 61.875 151.875 90 90 90 0
C 157.5 degree rotation around z-axis
*TR27 0.0 0.0 0.0 157.500 247.500 90 67.500 157.500 90 90 90 0
C 163.125 degree rotation around z-axis
*TR28 0.0 0.0 0.0 163.125 253.125 90 73.125 163.125 90 90 90 0
C 168.75 degree rotation around z-axis
*TR29 0.0 0.0 0.0 168.750 258.750 90 78.750 168.750 90 90 90 0
C 174.375 degree rotation around z-axis
*TR30 0.0 0.0 0.0 174.375 264.375 90 84.375 174.375 90 90 90 0
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6.0 CRITICALITY EVALUATION

This chapter provides the criticality evaluation of the NAC-MPC storage system and demonstrates that the NAC-MPC storage system is subcritical in accordance with the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG-1536. The evaluations show that the effective neutron multiplication factor of the NAC-MPC system is less than 0.95, including biases and uncertainties under normal, off-normal and accident conditions.

The NAC-MPC storage system is comprised of a transportable storage canister (canister), a transfer cask and a vertical concrete cask (storage cask). The canister comprises a stainless steel canister and a basket. The basket comprises fuel tubes held in place with stainless steel support disks and tie rods. The transfer cask containing the canister and basket is loaded underwater in the spent fuel pool. Once loaded with fuel, the canister is drained, dried, inerted, and welded shut. The transfer cask is then used to transfer the canister to the storage cask where it is stored until transported off-site.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, the moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Assuming the most reactive mechanical basket configuration, moderator intrusion into the canister and moderator intrusion into the fuel cladding (100% fuel failure), bounds all normal, off-normal and accident conditions.

Under normal storage conditions, moderator is not present in the canister. However, access to the environment is possible via the air inlets in the storage cask and the convective heat transfer annulus between the canister and the storage cask steel liner. This provides paths for moderator intrusion during a flood. Under off-normal conditions, moderator intrusion into the convective heat transfer annulus is evaluated. Under accident conditions of the cask loaded with intact fuel, it is hypothetically assumed that the canister confinement fails, and moderator intrusion into the canister and into the fuel cladding (100% fuel failure) is evaluated. This is a highly conservative assumption, since, as shown in Chapters 3 and 11, there are no design basis normal, off-normal or accident conditions that result in the failure of the canister confinement boundary that would allow the intrusion of water.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 Yankee Class spent fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee (CY) spent fuel assemblies and is referred to as the CY-MPC. The third, MPC-LACBWR, is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor(LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans. The transportable storage canister (canister) configurations differ primarily in fuel basket design, but also differ in overall length and weight. There are corresponding differences in the principal dimensions and weights of the transfer cask and vertical concrete casks used with each of these NAC-MPC storage systems.

6.1 Discussion and Results

A description of the Yankee Class fuel and a summary of the results of the Yankee-MPC criticality evaluation are presented in Section 6.1.1. The description of the Connecticut Yankee fuel and a summary of the CY-MPC criticality results are presented in Section 6.1.2. The description of the LACBWR fuel and a summary of the MPC-LACBWR criticality results are presented in Appendix 6.A.

The Yankee-MPC criticality evaluation is performed using the SCALE 4.3 Criticality Safety Analysis Sequence (CSAS). This sequence uses KENO-Va Monte Carlo analysis to determine the effective neutron multiplication factor, k_{eff}. The CY-MPC configurations are evaluated using the MONK8A Monte Carlo Program. Consequently, these configurations are evaluated using different modeling and analysis techniques, but similar fuel and system assumptions are conservatively established. These conservative assumptions include:

1. No fuel burnup (fresh fuel assumption).
2. No fission product build up as a poison.
3. Fuel assemblies of the most reactive type.
4. UO_2 fuel density at 95% of theoretical.
5. No dissolved boron in the spent fuel pool water (water temperature 293°K).
6. Infinite cask array.
7. Moderator intrusion into the intact fuel rod clad/pellet gap under accident conditions.
8. A most reactive mechanical configuration.

In addition, consistent with Section 6, Part IV of NUREG-1536, 75% of the specified minimum ^{10}B loading in the BORAL plates is assumed.

The evaluation of the two NAC-MPC storage systems, the spent fuel stored in these two systems, and the criticality evaluation methods used are described separately in the appropriate sections and/or appendix of this chapter.

6.1.1 Yankee-MPC System Criticality Discussion and Results

The criticality evaluation of the Yankee-MPC is performed with the SCALE 4.3 (ORNL) Criticality Safety Analysis Sequence (CSAS)(Landers). This sequence includes KENO-Va (Petrie) Monte Carlo analysis to determine the effective neutron multiplication factor (k_{eff}). The 27-group ENDF/B-IV neutron library (Jordan) is used in all calculations. CSAS with the 27-group library is benchmarked by comparison to 63 critical experiments relevant to Light Water Reactor fuel in storage and transport casks.

Criticality control in the Yankee-MPC canister basket is achieved using a flux trap principle. The flux trap principle controls the reactivity in the interior of each of the three basket configurations. In the first of the configurations, all fuel tubes are separated by a flux trap that is formed by surrounding the tube with stainless steel support disks and four 0.01g $^{10}B/cm^2$ (minimum) areal density BORAL sheets, which are held in place by stainless steel covers. In the second configuration, the size of the four fuel tubes (one outer tube in each quadrant of the basket, as shown in Figure 6.3.1-4) is increased by removing the BORAL sheets from the outside of the tubes. The remainder of the tubes have BORAL sheets on each of the four sides. In the third configuration, the four enlarged fuel tubes, which do not have BORAL sheets, are replaced with screened damaged fuel cans. The remainder of the fuel tubes have BORAL sheets on all four sides. The spacing of the fuel tubes is maintained by the stainless steel support disks. These disks provide water gap spacings between tubes of 0.875, 0.810, or 0.750 inches, depending on the position of the fuel tube in the basket. When the canister is flooded with water, fast neutrons leaking from the fuel assemblies are thermalized in the water gaps and are absorbed in the BORAL sheets before causing a fission in an adjacent fuel assembly. The Yankee-MPC basket can accommodate up to 36 Yankee Class Zircaloy-clad assemblies with a nominal initial enrichment of 4.0 wt % ^{235}U or 36 Yankee Class stainless steel-clad assemblies with a nominal initial enrichment of 4.94 wt % ^{235}U.

Criticality evaluations are performed for both the transfer and storage casks under normal, off-normal and accident conditions applying the conservative conditions and assumptions described in Section 6.1. As specified, these consider the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The maximum effective neutron multiplication factor with bias and uncertainties for the transfer cask is 0.9021. The maximum multiplication factor with bias and uncertainties for the storage cask is 0.4503 under normal dry storage conditions and 0.9018 under the hypothetical accident conditions involving full moderator intrusion. The maximum bias and uncertainty adjusted reactivities for the basket containing the four enlarged fuel tubes are slightly higher at 0.9175 for transfer conditions and 0.9182 for a hypothetical storage accident condition involving full moderator intrusion.

Analysis of simultaneous moderator density variation inside and outside either the transfer or storage casks shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density condition bounds any off-normal or accident situation. Analysis of moderator intrusion into the storage cask heat transfer annulus with the canister dry shows a slight decrease in reactivity from the completely dry condition.

6.1.2 CY-MPC System Criticality Discussion and Results

The criticality evaluation of the CY-MPC is performed with the MONK8A (AEA Technology) Monte Carlo Program for Nuclear Criticality Safety Analysis. 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 6.5.2. The NUREG/CR-6361 method-based verification performed for MONK8A has established an upper subcritical limit as a function of system parameters. For the CY-MPC system, the upper subcritical limit is 0.9425 (Section 6.5.2).

Criticality control in the Yankee-MPC canister basket is achieved using geometric control of the fuel assemblies in the basket along with the flux trap principle. Each of the fuel tubes in the canister basket is surrounded by four BORAL sheets with a core areal density of 0.02g $^{10}B/cm^2$ (minimum), which are held in place by stainless steel cladding. The center-to-center spacing of the fuel tubes is maintained by the stainless steel support disks. When the canister is flooded with water, neutrons are thermalized in the water gaps between the fuel tubes and are absorbed in the BORAL sheets, reducing the number of neutrons available to cause a fission event in an adjacent fuel assembly.

Two configurations of the CY-MPC basket are available for loading at Connecticut Yankee: the standard 26-assembly basket configuration, and a 24-assembly basket configuration where two basket openings are blocked. The 26-assembly basket configuration is analyzed for Zircaloy-clad assemblies with an initial enrichment of up to 3.93 wt % ^{235}U and stainless steel clad assemblies with an initial enrichment of up to 4.03 wt % ^{235}U. The 24-assembly basket configuration allows the loading of Zircaloy-clad assemblies with an initial enrichment of up to 4.61 wt % ^{235}U and the same stainless steel clad fuel assemblies as the 26-assembly configuration. The 24-assembly design is used for the 53 Westinghouse Vantage 5H fuel assemblies in the Connecticut Yankee spent fuel inventory. Using this reduced capacity only for the Vantage 5H fuel allows the higher uranium enrichments to be accommodated without penalizing the capacity of the system as a whole.

As demonstrated in the Yankee-MPC evaluation, the most reactive configuration is independent of shield geometry for an MPC-sized system. Therefore, the reactivity of the transfer cask loaded

with fuel is assumed to accurately represent the reactivity of the storage cask. While the transfer cask and canister are flooded in normal use, there are no credible normal, off-normal or accident condition events that would cause the canister to become flooded while in the concrete cask.

Criticality evaluations of the CY-MPC basket are performed within the transfer cask under normal, off-normal and accident conditions, applying the conservative conditions and assumptions described in Section 6.1. As specified, these consider the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The most reactive CY-MPC fuel loading occurs with the 24-assembly basket configuration fully loaded with Zircaloy-clad fuel assemblies with a maximum enrichment of 4.61 wt % ^{235}U. The 24-assembly basket configuration loaded with the most reactive fuel bounds the most reactive 26-assembly basket configuration loading.

The maximum effective neutron multiplication factor from this loading is 0.3715 under dry conditions and 0.9327 under the postulated accident conditions involving full moderator intrusion. Including two standard deviations establishes a system reactivity threshold, $k_{eff} + 2\sigma$, of 0.9343, which is less than the subcritical limit of 0.9425. Consequently, the most reactive configuration of the CY-MPC, containing the most reactive fuel assemblies in the most reactive configuration, is well below the regulatory criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

6.2 Package Fuel Loading

This section presents the physical descriptions of the fuel types to be loaded into the NAC-MPC storage system and describes the loading configurations of the fuel that are considered in the criticality safety evaluations.

For the CY-MPC, the package loading description limits loading of the Westinghouse Vantage 5H fuel assemblies to the 24-assembly basket configuration. Other package loading limits apply to containers of individual rods, fuel debris, damaged fuel assemblies or individual damaged fuel rods. Specifically, the cross-sectional dimensions of the damaged fuel cans and the CY-MPC reconfigured fuel assembly are designed so that they may only be loaded into the four oversized corner locations in the CY-MPC basket.

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6.2.1 Yankee-MPC Fuel Loading

The Yankee-MPC storage system can safely transfer and store 36 Yankee Class fuel assemblies. As shown in Figures 6.3.1-2 and 6.3.1-3, there are 37 fuel tube positions in the support and heat transfer disks that form the canister basket. Loading of fuel in the center tube position is prevented by the design of the top weldment, which blocks this position (Drawing 455-892). The various Yankee Class assemblies to be transferred and stored in the Yankee-MPC are presented in Table 6.2.1-1. Five vendor categories, each with two fuel rod configurations (types), are available within the Yankee Class. These are: Combustion Engineering (CE) 16 × 16 Type A and Type B, two categories of Exxon 16 × 16 Type A and Type B, United Nuclear 16 × 16 Type A and Type B, and Westinghouse 18 × 18 stainless steel clad Type A and Type B. See Figures 6.2.1-1, 6.2.1-2 and 6.2.1-3 for the fuel array configurations. The Combustion Engineering manufactured fuel has the same fuel rod arrays for Types A and B as the Exxon fuel. The Type A and Type B fuel array configurations allow a cruciform control rod to be inserted between assemblies during core operation. The most reactive Yankee Class fuel assembly is the United Nuclear, Type A, 16 × 16 fuel assembly with 4.0 wt % ^{235}U initial enrichment. This fuel assembly type bounds all of the Yankee Class fuel assemblies, including the Westinghouse stainless steel clad fuel with a 4.94 wt % ^{235}U initial enrichment. The United Nuclear Type A fuel assembly with 4.0 wt % ^{235}U initial enrichment is the design basis fuel assembly used in Yankee-MPC storage system criticality evaluations. As described in Section 6.4.1 and Table 6.2.1-1, certain fuel assemblies have enrichments nominally greater than the maximum enrichments considered in the design basis analysis. These nominally higher enrichments are considered in Section 6.4.1 and are shown not to be significant. To preclude any potential increase in reactivity due to empty fuel rod positions in the spent fuel assembly, any fuel rods removed from the assembly lattice must be replaced with solid filler rods fabricated from Zircaloy or Type 304 stainless steel.

A canister may contain one or more reconfigured fuel assemblies. The reconfigured fuel assembly is designed to confine the Yankee Class spent fuel rods, or portions thereof, which are classified as failed fuel and to maintain the geometric configuration of those fuel rods. This assembly can accept up to 64 full length spent fuel rods in an eight by eight array of tubes.

The reconfigured fuel assembly consists of a shell (square tube with end fittings), a basket assembly and 64 fuel tubes. Reconfigured fuel assembly parameters are presented in Table 6.2.1-2. The external dimensions of the shell are the same as those of a standard Yankee Class fuel assembly and all materials are stainless steel. It is designed such that it can be handled in the same manner as a standard Yankee Class fuel assembly. The spent fuel is confined in the

fuel tubes. The tubes are supported by a basket assembly within the shell and have end plugs with drilled holes to permit draining, drying and inerting with helium. The shell has holes in the top and bottom fittings to permit draining, drying and inerting of the assembly.

The total number of full length rods that can be placed in the reconfigured fuel assembly is less than the number that are in the Yankee Class fuel assemblies (maximum of 64 versus 237 rods). Consequently, the reactivity of the reconfigured fuel assembly, even with the most reactive fuel rods, is less than the design basis fuel assembly used in criticality evaluations.

A comparison of the reactivity of the reconfigured fuel assembly to intact assemblies is made in conjunction with the most reactive assembly evaluation in Section 6.4.1.2.1.

Alternatively, a canister may contain four damaged fuel cans. The damaged fuel can is designed to confine an entire Yankee-Class spent fuel assembly that has up to 20 fuel rod positions that may either hold fuel rods classified as damaged or be empty. Each Yankee Class fuel assembly listed in Table 6.2.1-1 is allowed to be loaded into a damaged fuel can.

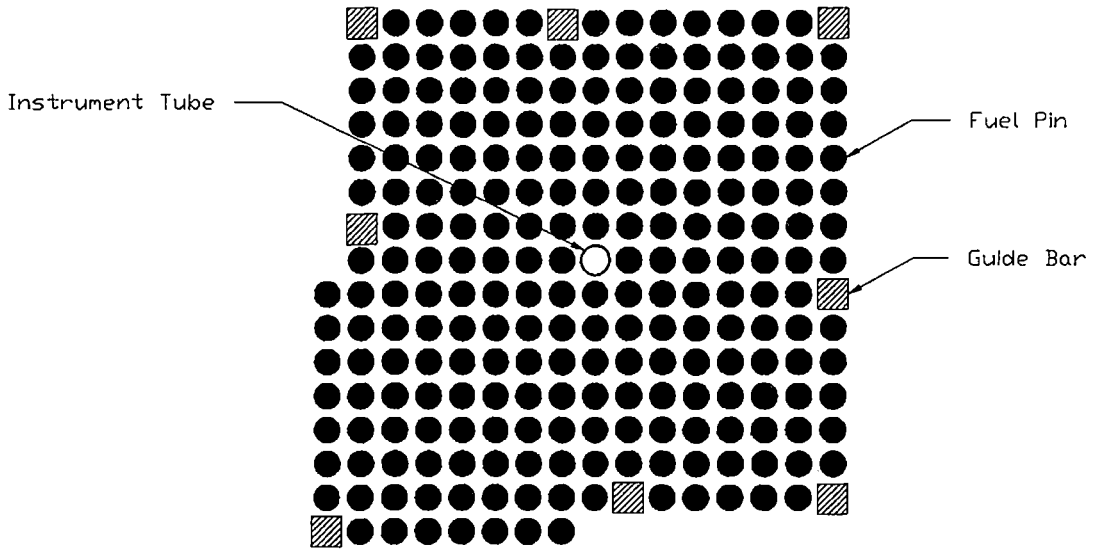
The determination of the maximum reactivity of a canister containing damaged fuel cans is documented in Section 6.4.1.7.

The Yankee-MPC may also hold a recaged fuel assembly in any fuel loading position. A recaged fuel assembly consists of United Nuclear Yankee Class fuel rods placed in a Combustion Engineering fuel assembly lattice (skeleton). The impact effect on system reactivity of the recaged fuel assembly is documented in Section 6.4.1.2.1.

A limited number of Yankee Class fuel assemblies have fuel rods replaced with filler rods. The filler rods may be solid Zircaloy or stainless steel rods or may consist of hollow zirconium tubes holding either Zircaloy or stainless steel slugs. The reactivity evaluation of fuel assemblies with these filler rods is presented in Section 6.4.1.6.

Figure 6.2.1-1 Yankee-MPC Class Type A and Type B Exxon and CE Fuel Assembly Arrays

Type A



Type B

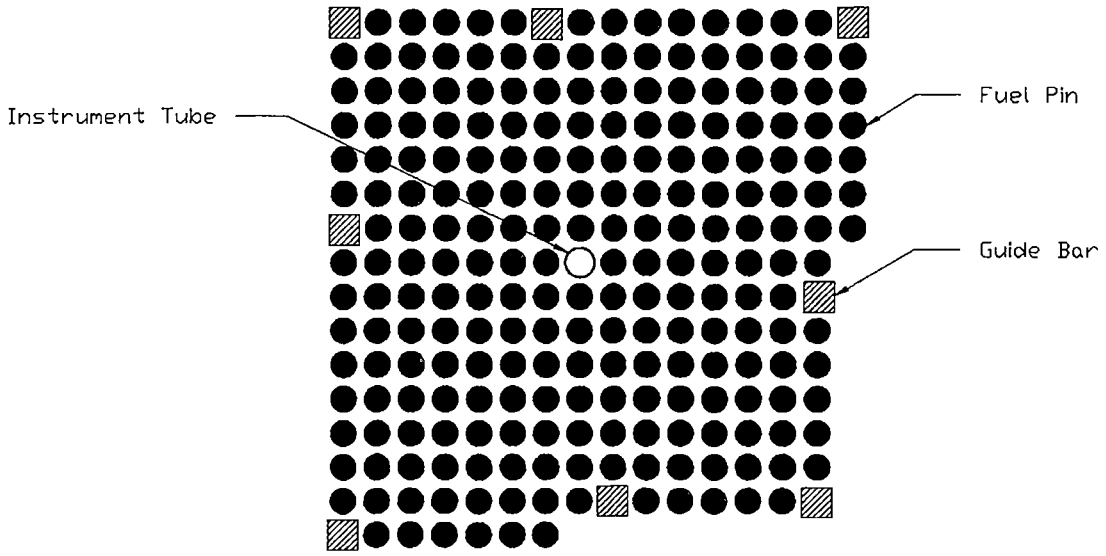
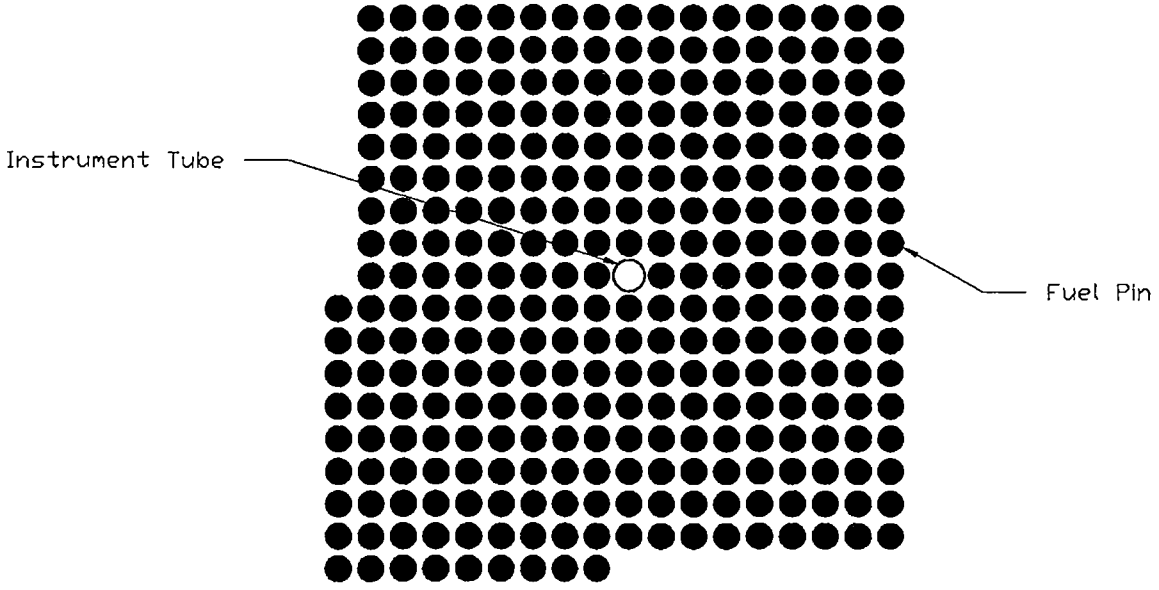


Figure 6.2.1-2 Yankee-MPC Class Type A and Type B Westinghouse Fuel Assembly Arrays

Type A



Type B

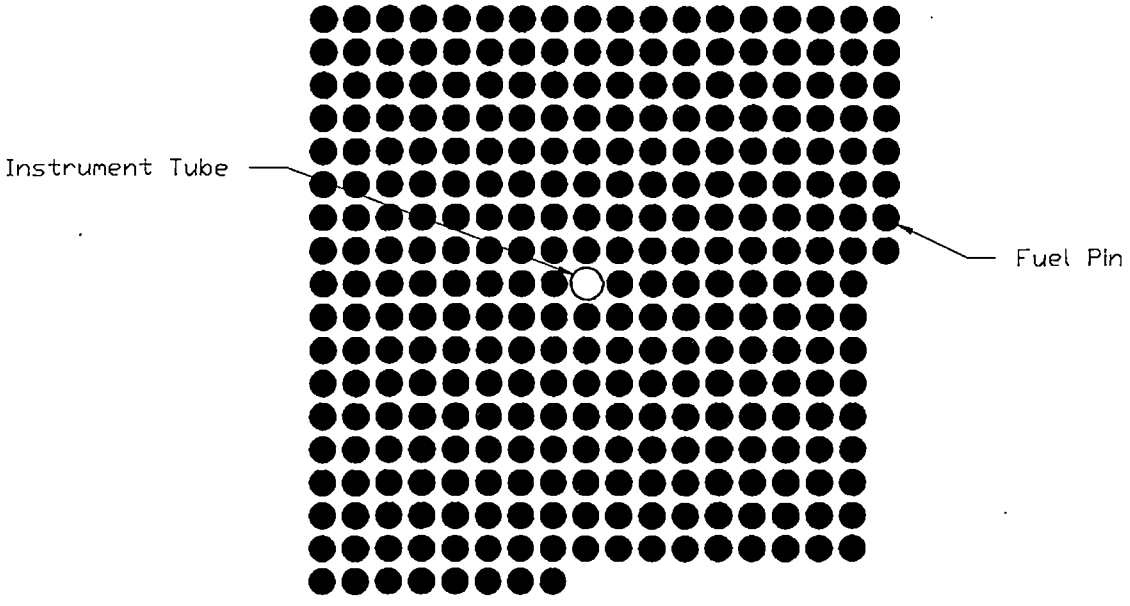
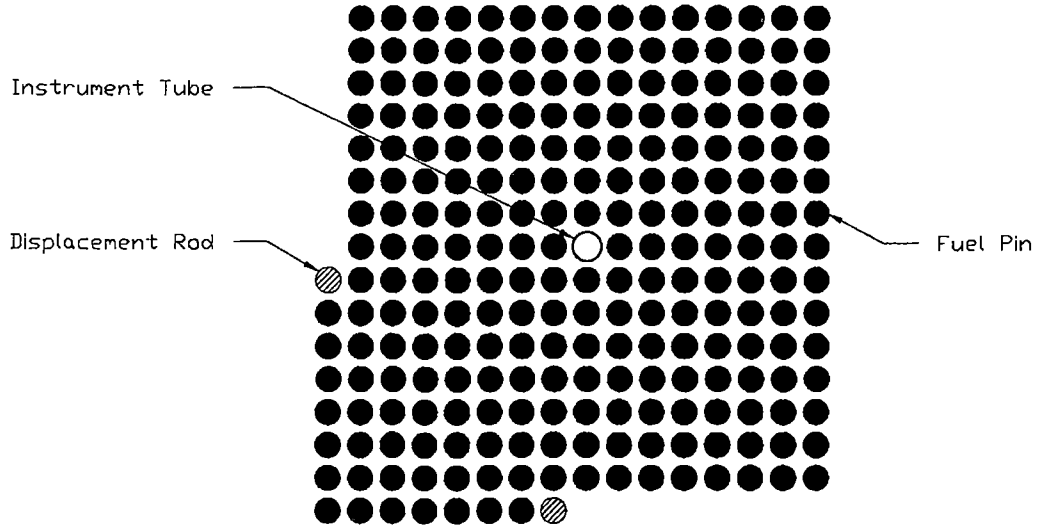


Figure 6.2.1-3 Yankee-MPC Class Type A and Type B United Nuclear Fuel Assembly Arrays

Type A



Type B

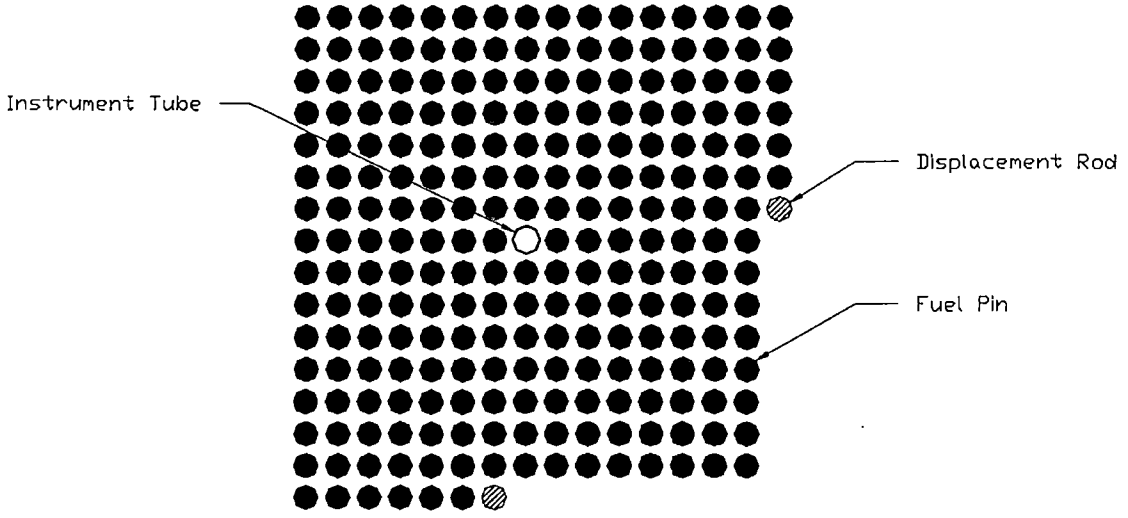


Table 6.2.1-1 Yankee-MPC Class Fuel Assembly Parameters

Parameter	CE Type A	CE Type B	Exxon Type A	Exxon Type B	Exxon Type A	Exxon Type B	West. Type A	West. Type B	United Nuclear Type A	United Nuclear Type B
Assembly Configuration	-	-	-	-	-	-	-	-	-	-
Assembly Array	16 × 16	16 × 16	16 × 16	16 × 16	16 × 16	16 × 16	18 × 18	18 × 18	16 × 16	16 × 16
Max. Enrichment (wt % ^{235}U)[1]	3.90	3.90	4.00	4.00	3.70	3.70	4.94	4.94	4.00	4.00
Max. MTU[2]	0.2394	0.2384	0.2394	0.2384	0.2394	0.2384	0.2869	0.2860	0.2456	0.2446
Fuel Rod Configuration	-	-	-	-	-	-	-	-	-	-
Fuel Rod Pitch (cm)	1.1989	1.1989	1.1989	1.1989	1.1989	1.1989	1.0719	1.0719	1.1887	1.1887
Active Fuel Length (cm)	231.1400	231.1400	231.1400	231.1400	231.1400	231.1400	233.9975	233.9975	231.1400	231.1400
Rod OD (cm)	0.9271	0.9271	0.9271	0.9271	0.9271	0.9271	0.8636	0.8636	0.9271	0.9271
Clad ID (cm)	0.8052	0.8052	0.8052	0.8052	0.8052	0.8052	0.7569	0.7569	0.8052	0.8052
Pellet OD (cm)	0.7887	0.7887	0.7887	0.7887	0.7887	0.7887	0.7468	0.7468	0.7887	0.7887
Diametral Gap (cm)	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0102	0.0102	0.0165	0.0165
Rods per Assembly	231	230	231	230	231	230	305	304	237	236
Fuel Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Clad Material	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	SS 348	SS 348	Zircaloy	Zircaloy
Displacement Rod Configuration	-	-	-	-	-	-	-	-	-	-
Displacement Rod Material	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Zircaloy - 4	Zircaloy - 4
Displacement Rod Diameter (cm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.9271	0.9271
Number Per Assembly	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	2
Guide Bar Configuration	-	-	-	-	-	-	-	-	-	-
Guide Bar Material	Zircaloy - 4	Zircaloy - 4	SS 304L	SS 304L	Zircaloy	Zircaloy	N/A	N/A	N/A	N/A
Guide Bar Width (cm)	1.0973	1.0973	1.0566	1.0566	1.0566	1.0566	N/A	N/A	N/A	N/A
Guide Bar Shape (cm)	Square	Square	Square	Square	Square	Square	N/A	N/A	N/A	N/A
Number Per Assembly	8	8	8	8	8	8	N/A	N/A	N/A	N/A
Instrument Tube Configuration	-	-	-	-	-	-	-	-	-	-
Instrument Tube ID (cm)	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970	0.9995	0.9995	0.9995	0.9995
Instrument Tube OD (cm)	1.1481	1.1481	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884
Number Per Assembly	1	1	1	1	1	1	1	1	1	1
Instrument Tube Material	Zircaloy - 4	Zircaloy - 4	SS 304	SS 304	Zircaloy	Zircaloy	SS 304	SS 304	SS 304	SS 304

1. Certain fuel assemblies of the type specified may have a maximum enrichment up to 0.03 wt % ^{235}U higher than the value shown.
2. Maximum MTU based on 95% of UO_2 theoretical density for the fuel pellet stack density.

Table 6.2.1-2 Yankee-MPC Class Reconfigured Fuel Assembly Parameters

Parameter	CE Type A/B	Exxon Type A/B	Exxon Type A/B	West. Type A/B	United Nuclear Type A/B
ASSEMBLY CONFIGURATION					
Assembly Array	8x8	8x8	8x8	8x8	8x8
Max. Enrichment (wt % ^{235}U)	3.90	4.00	3.70	4.94	4.00
Max. kgU*	66.33	66.33	66.33	60.21	66.33
FUEL ROD CONFIGURATION (EACH ROD PLACED WITHIN ENCAPSULATING ROD)					
Rod Pitch (cm)	1.905	1.905	1.905	1.905	1.905
Active Fuel Length (cm)	231.1400	231.1400	231.1400	233.9975	231.1400
Rod OD (cm)	0.9271	0.9271	0.9271	0.8636	0.9271
Clad ID (cm)	0.8052	0.8052	0.8052	0.7569	0.8052
Pellet OD (cm)	0.7887	0.7887	0.7887	0.7468	0.7887
Diametrical Gap (cm)	0.0165	0.0165	0.0165	0.0102	0.0165
Max Rods per Assembly	64	64	64	64	64
Fuel Material	UO_2	UO_2	UO_2	UO_2	UO_2
Clad Material	Zircaloy	Zircaloy	Zircaloy	SS 348	Zircaloy
ENCAPSULATING ROD					
Rod OD (cm)	1.27	1.27	1.27	1.27	1.27
Rod ID (cm)	1.1278	1.1278	1.1278	1.1278	1.1278
Rod Material	SS 304	SS 304	SS 304	SS 304	SS 304

* Maximum kgU based on 95% of UO_2 theoretical density for the fuel pellet stack density.

6.2.2 CY-MPC Fuel Loading

The CY-MPC storage system can safely transfer and store up to 26 Connecticut Yankee fuel assemblies. As shown in Figure 6.3.2-1, there are 26 fuel tube locations in the standard 26-assembly basket configuration. In the 24-assembly basket configuration, loading of fuel into two positions (Fuel positions 12 and 15 of Figure 6.3.2-1) is prevented by the design of the top weldment, which blocks those positions. Physical characteristics of the various Connecticut Yankee fuel assemblies to be accommodated are presented in Tables 2.1-3 and 6.2.2-1. Connecticut Yankee employed both Zircaloy and stainless steel clad 15 × 15 fuel assemblies. Stainless steel clad fuel assemblies were originally utilized, and were produced by Westinghouse Electric Co. (Westinghouse), Babcock & Wilcox (B&W) Fuel Co., Gulf General Atomic (GGA), Gulf Nuclear Fuel Co. (GNFC) and Nuclear Materials and Equipment Corporation (NUMEC). Gulf General Atomic (GGA), Nuclear Materials and Equipment Corporation (NUMEC) and Babcock & Wilcox (B&W) Fuel Co. also produced the Zircaloy-clad fuel assembly types. The general array configuration of the 15 × 15 fuel assemblies, including the positioning of the fuel rods and guide tubes, are shown in Figure 6.2.2-1. As demonstrated in Section 6.4.2, the most reactive Connecticut Yankee fuel assembly is the Westinghouse Vantage 5H 15 × 15 Zircaloy-clad fuel assembly, with a maximum initial enrichment of 4.61 wt % ^{235}U.

Either basket configuration may contain CY-MPC reconfigured fuel assemblies. The reconfigured fuel assembly is designed to confine and maintain geometric configuration of individual spent fuel rods, or portions thereof, or fuel pellets, which may be classified as damaged fuel or fuel debris. The total equivalent fuel mass in each tube is restricted to that of one spent fuel rod. The CY-MPC reconfigured fuel assembly contains a 10 × 10 array of tubes, as shown in Figure 6.2.2-2, and can accept up to 100 spent fuel rods. The individual tubes are supported/positioned by tie plates in the upper and lower end fittings. These tie plates have drain holes to permit draining, drying and inerting with helium, and are covered with 250 micron screens to contain small particulate material. The CY-MPC reconfigured fuel assembly parameters are presented in Table 6.2.2-2. The external dimensions of the CY-MPC reconfigured fuel assembly are larger than the opening of the standard size fuel tube. Consequently, loading the CY-MPC reconfigured fuel assembly is physically restricted to the oversized fuel tubes in the four corner positions.

The total number of full length fuel rods that can be placed in the CY-MPC reconfigured fuel assembly is significantly less than the number that are in the intact fuel assemblies (maximum of 100 versus 204 rods). Consequently, the reactivity of the CY-MPC reconfigured fuel assembly, even with the most reactive fuel rods, is less than the design basis fuel assembly used in criticality evaluations.

Either CY-MPC basket configuration may also contain damaged fuel cans. The damaged fuel can may hold a complete Connecticut Yankee fuel assembly, a lattice or a failed rod storage canister. The outer dimensions of these cans also require them to be loaded in one of the four corner positions. The damaged fuel can is designed such that it can be handled in the same manner as a fuel assembly.

Figure 6.2.2-1 Connecticut Yankee 15 × 15 Fuel Assembly Array

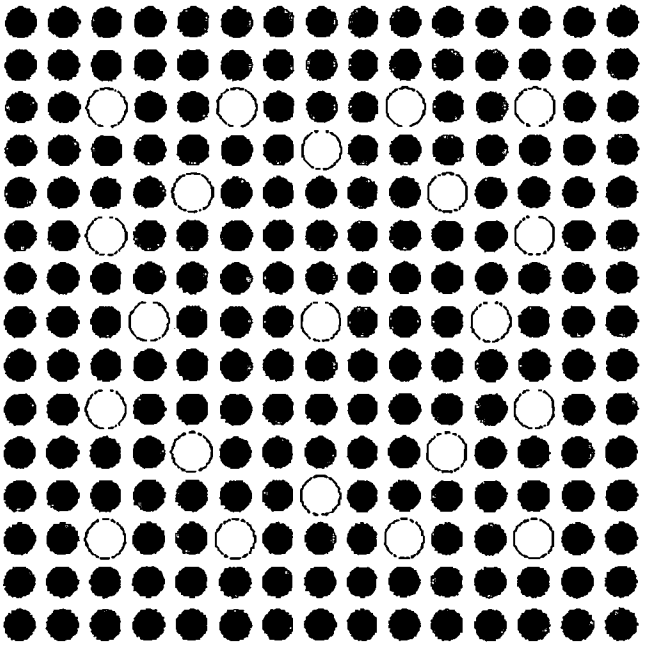


Figure 6.2.2-2 CY-MPC Reconfigured Fuel Assembly Array

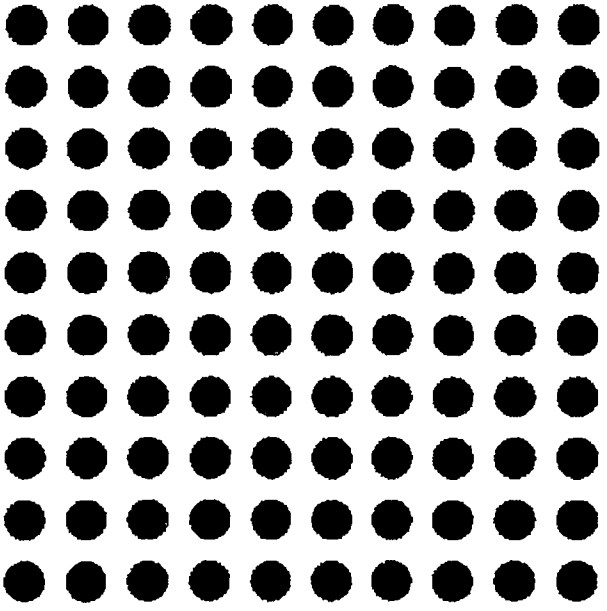


Table 6.2.2-1 Connecticut Yankee Design Basis Fuel Assembly Parameters

Vendor	WE	B&W	B&W, GGA, NUMEC	B&W (GUNF), GGA, NUMEC, WE
Array	15 × 15	15 × 15	15 × 15	15 × 15
Clad Material	Zircaloy	Zircaloy	Zircaloy	Stainless Steel
Maximum wt % ^{235}U	4.61	3.93	3.42	4.03
Maximum MTU[1]	0.3900	0.3742	0.3971	0.4337
Maximum Number of Fuel Rods	204	204	204	204
Maximum Pitch (in)	0.568	0.568	0.568	0.5702
Minimum Rod Diameter (in)	0.42	0.4194[2]	0.42	0.4175
Minimum Clad Thick (in)	0.0223	0.025	0.022	0.01375
Maximum Pellet Diameter (in)	0.3664	0.3615	0.3685	0.384
Maximum Active Length (in)	120.55	118.825	121.35	122.05
Minimum Guide Tube Thick (in)	0.013	0.008	0.008	0.008
Number Guide/Instrument Tubes	21	21	21	21
Guide/Instrument Tube Material	Zircaloy	Stainless Steel	Stainless Steel	Stainless Steel

1. Based on 95% of UO_2 theoretical density.
2. Results are reported for a rod diameter of 0.42 in. in Section 6.4.2. Sensitivity analyses were performed to show that this rod diameter produced no statistically significant variation in the k_{eff} results.

Table 6.2.2-2 CY-MPC Reconfigured Fuel Assembly Parameters

Parameter	Value
Array	10 × 10
Maximum Number of Fuel Rods	100
Maximum Enrichment (wt % ^{235}U)	4.61
Maximum kg U[1]	212
Maximum Tube Pitch (in)	0.81
Maximum Tube OD (in)	0.5675
Minimum Tube Thickness (in)	0.0315
Tube Material	SS 304

1. Based on 95% of UO_2 theoretical density.

6.3 Criticality Model Specification

This section describes models used in the criticality evaluation of the Yankee-MPC and CY-MPC. As described in Section 6.3.1, KENO-Va models are used in the criticality evaluation of the Yankee-MPC. The geometric representation of the design basis fuel assembly, the NAC-MPC basket and the associated transfer and storage cask shield regions are described. The material densities and nuclide concentrations are also specified. The CY-MPC evaluation is performed using the MONK8A criticality code. The MONK8A criticality model is described in Section 6.3.2.

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6.3.1 Description of the Yankee-MPC Calculational Models

Three models are used in the Yankee-MPC storage system criticality evaluations: a fuel/basket model, a transfer cask model and a storage cask model. The fuel/basket model is a single Yankee-MPC basket cell containing a fuel assembly. This model is used to determine the most reactive fuel assembly type and to evaluate mechanical perturbations of the fuel and basket. The transfer cask model is an explicit representation of the Yankee-MPC basket and canister containing 36 design basis fuel assemblies surrounded by the transfer cask radial shields. This model is used to evaluate the transfer cask reactivity during loading, draining and drying operations. The storage cask model is an explicit representation of the Yankee-MPC basket and canister containing up to 36-design basis fuel assemblies, surrounded by the storage cask radial shields. This model is used to evaluate the storage cask during normal, off-normal and accident storage situations.

The fuel/basket model comprises a single basket cell with periodic axial and reflective radial boundary conditions. This simulates an infinite array of fuel/basket cells. The model geometry is divided into four vertical layers: an aluminum heat transfer layer; a flux trap water layer; a steel support disk layer; and a top flux trap water layer. In each of these layers, the fuel assembly array, fuel tube, BORAL sheets, flux trap water gap, steel, or aluminum disk web are modeled. Figure 6.3.1-1 shows a sketch of the Yankee-MPC fuel/basket model.

Both of the storage and transfer cask criticality models are derived from a radial slice of the basket at the central (heat transfer) region. This section is the most reactive region, due to the number of steel support disks and aluminum heat transfer disks displacing water in the flux trap gap. Each model is a stack of four slices containing one aluminum disk, two identical water regions and one steel support disk region (stacked aluminum, water, steel, water). The basket is modeled in each slice and contains a design basis fuel assembly in each of the 36 basket tubes with BORAL sheets. Both cask models explicitly arrange the fuel assemblies and basket tubes in the most reactive configuration consistent with the mechanical tolerances specified by the design drawings. In all models, the fuel assemblies, fuel tubes, BORAL sheets and water gaps are explicitly represented. There are no homogenizations. Each cask slice includes the cask radial shield regions surrounded by an outer CUBOID. The four slices are stacked into the KENO-Va GLOBAL UNIT.

Periodic boundary conditions are imposed on the top and bottom of the GLOBAL UNIT to simulate infinite axial extent. Reflecting boundary conditions are imposed on the sides of the

GLOBAL UNIT simulating an infinite number of casks in the X-Y plane. Moderator density is varied both in the cask cavity regions normally filled with water and in the exterior CUBOID. Figures 6.3.1-2 and 6.3.1-3 show the transfer cask and storage cask criticality models, respectively.

Figure 6.3.1-4 depicts the location of the four fuel tubes without BORAL sheet coverage. The enlarged fuel tubes are modeled as simple square stainless steel boxes with an opening width of 7.99 inches and a wall thickness of 0.048 inches.

An axially finite basket model is required for the damaged fuel can evaluation in which loose fuel may be located outside the neutron absorber sheet elevations. Details on the axially finite basket model are included in Section 6.4.1.7.

Figure 6.3.1-5 depicts the location of the four loading positions for damaged fuel cans that also do not have BORAL sheets attached. These fuel cans are also modeled as simple square stainless steel boxes with an opening width of 7.99 inches and a wall thickness of 0.048 inches.

6.3.1.1 Yankee-MPC Package Regional Densities

The SCALE 4.3 standard composition library (Petrie) default densities and isotopic distributions are used unless otherwise indicated. The densities used in the KENO-Va criticality analyses are:

Material	Density (g/cc)
UO_2 at 95% TD	10.412
Zircaloy	6.56
Type 348 Stainless Steel	7.92 (non-standard, Westinghouse fuel clad)
H_2O	0.9982
Type 304 Stainless Steel	7.92
Lead	11.344
Aluminum	2.702
BORAL (core)	2.623 (non-standard)
NS-4-FR	1.629 (non-standard)
Concrete	2.243 (based on 140 lb/ft^3 design spec. minimum)
Carbon Steel	7.821

6.3.1.2 Fuel Region Densities for Yankee Class Fuel

Fuel densities are:

Material	Element	Density (atoms/barn-cm)
UO_2 (at 3.9 wt %)	^{235}U	9.271×10^{-4}
	^{238}U	2.231×10^{-2}
	O	4.646×10^{-2}
UO_2 (at 4.0 wt %)	^{235}U	9.406×10^{-4}
	^{238}U	2.229×10^{-2}
	O	4.646×10^{-2}
UO_2 (at 4.9 wt %)	^{235}U	1.162×10^{-4}
	^{238}U	2.207×10^{-2}
	O	4.646×10^{-2}
Zircaloy	Zr	4.331×10^{-2}
Stainless Steel 348	Fe	5.529×10^{-2}
	Cr	1.743×10^{-2}
	Ni	1.057×10^{-2}
	C	3.180×10^{-4}
	Mn	1.736×10^{-3}
	Si	1.698×10^{-3}
	P	6.159×10^{-5}
	S	4.463×10^{-5}

6.3.1.3 Yankee-MPC Cask Materials

Cask materials include those used in the canister, fuel basket, fuel tubes, transfer cask and storage cask. The densities used are:

Material	Element	Density (atoms/barn-cm)
Boral Core	^{10}B	7.098×10^{-3} *
	^{11}B	3.925×10^{-2}
	C	1.220×10^{-2}
	Al	3.358×10^{-2}
Aluminum	Al	6.03×10^{-2}
Stainless Steel 304	Cr	1.743×10^{-2}
	Fe	5.936×10^{-2}
	Ni	7.721×10^{-3}
	Mn	1.736×10^{-3}
Lead	Pb	3.297×10^{-2}
NS-4-FR	H	5.841×10^{-2}
	O	2.607×10^{-2}
	C	2.265×10^{-2}
	N	1.401×10^{-3}
	Al	7.781×10^{-3}
	^{11}B	3.565×10^{-4}
	^{10}B	9.798×10^{-5}
Concrete	O	4.494×10^{-2}
	Si	1.621×10^{-2}
	H	1.340×10^{-2}
	Na	1.704×10^{-3}
	Ca	1.483×10^{-3}
	Fe	3.386×10^{-4}
	Al	1.702×10^{-3}
Carbon Steel	Fe	8.350×10^{-2}
	C	3.925×10^{-3}

* This value represents 75% poison credit.

6.3.1.4 Water Reflector Densities for the Yankee-MPC

The material densities for the water inside and outside the storage cask under normal conditions are:

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

Water density is varied using the volume fraction (VF) parameter on the SCALE 4.3 material information processor card. This parameter acts as a simple multiplier on these densities.

Figure 6.3.1-1 Yankee-MPC KENO-Va Fuel/Basket Model

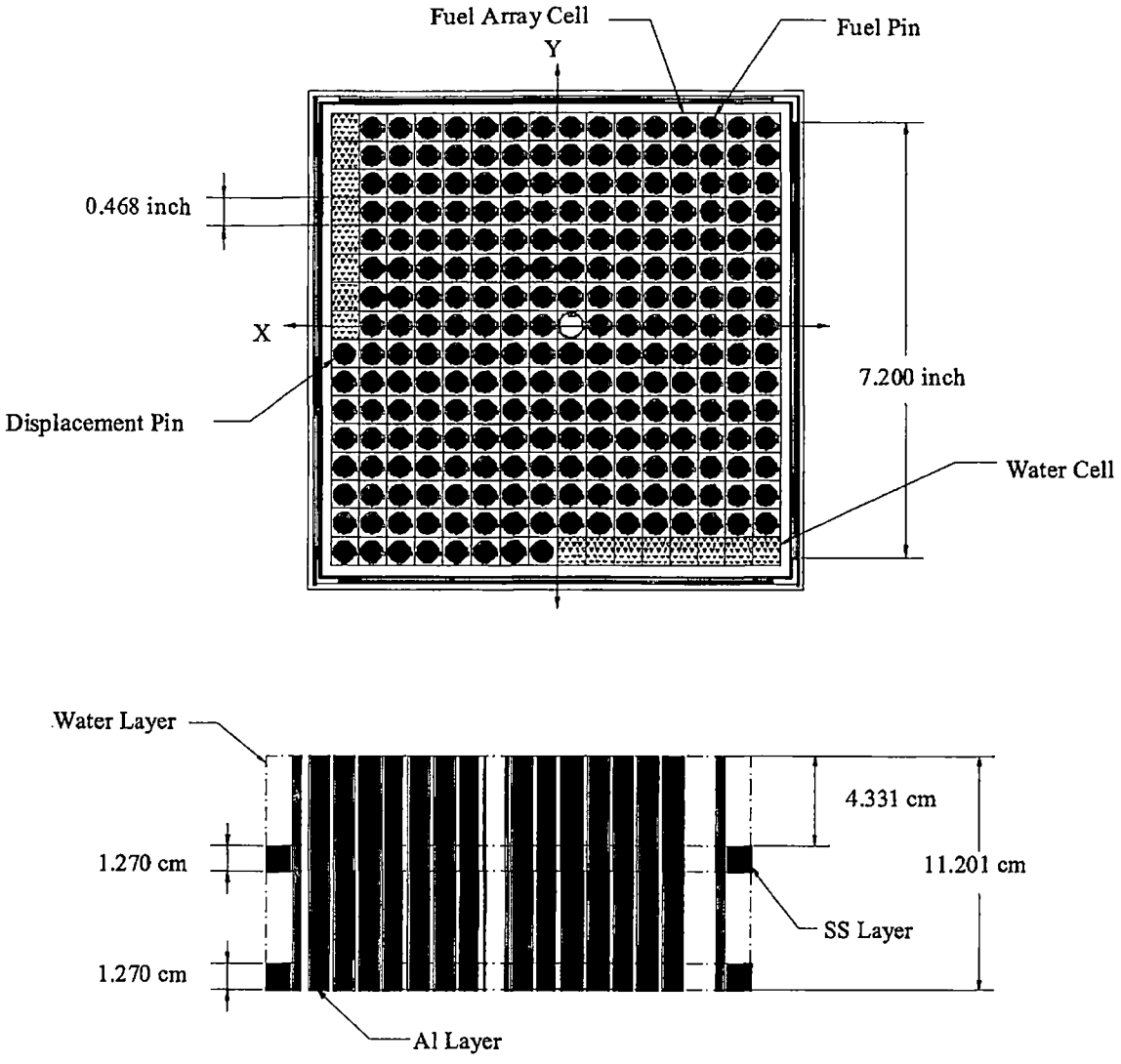
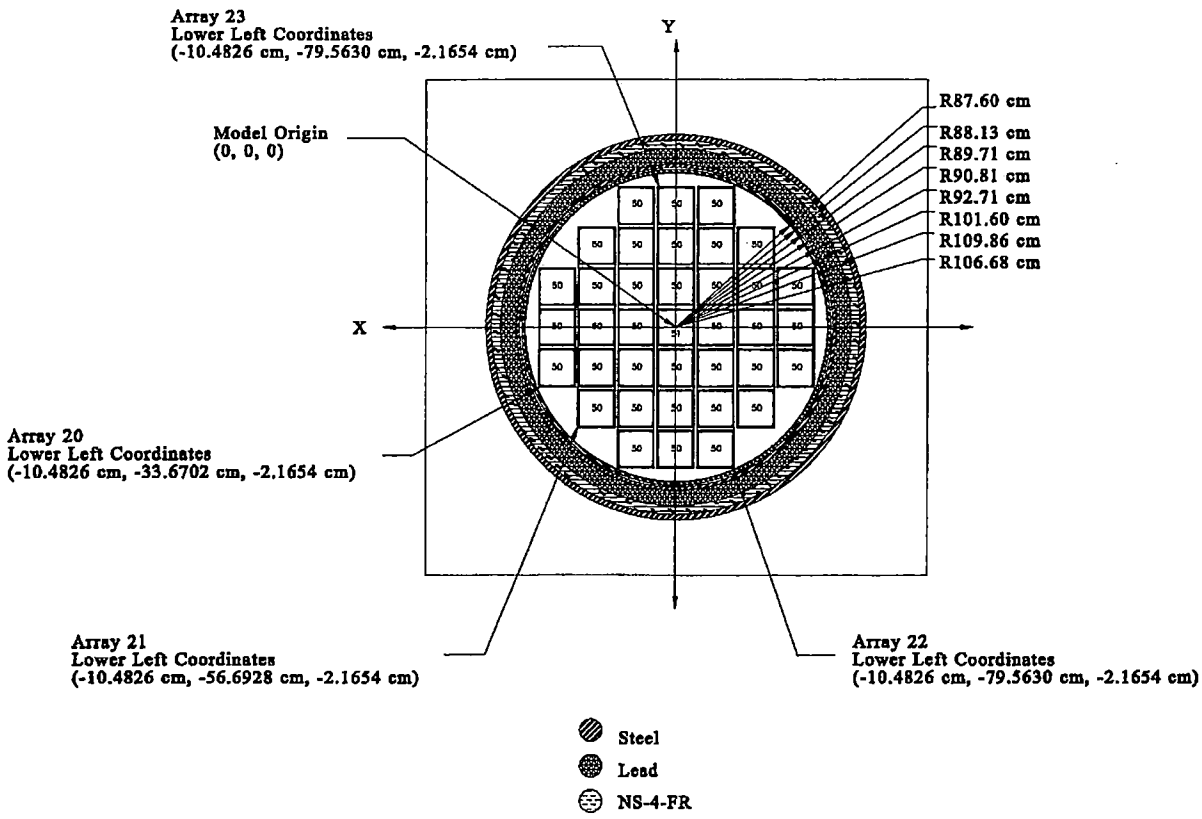
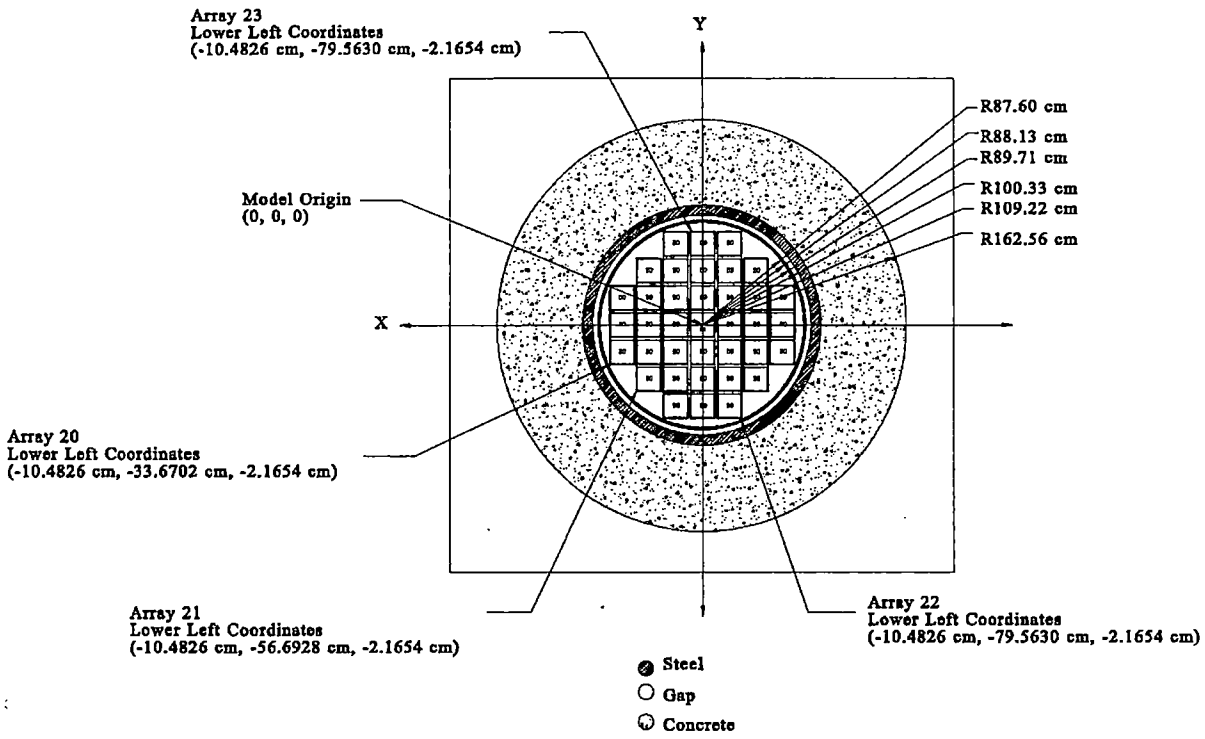


Figure 6.3.1-2 Yankee-MPC KENO-Va Transfer Cask Model



Note: This model represents a slice between a support disk and a heat transfer disk. The center fuel tube position is filled with unit 51. This unit cell describes the vacant fuel tube. As previously stated, the criticality analysis considers 36 Yankee Class fuel assemblies, assuming the center tube is empty.

Figure 6.3.1-3 Yankee-MPC KENO-Va Storage Cask Model



Note: This model represents a slice between a support disk and a heat transfer disk. The center fuel tube position is filled with unit 51. This unit cell describes the vacant fuel tube. As previously stated, the criticality analysis considers 36 Yankee Class fuel assemblies, assuming the center tube is empty.

Figure 6.3.1-4 Yankee-MPC Enlarged Fuel Tube Locations

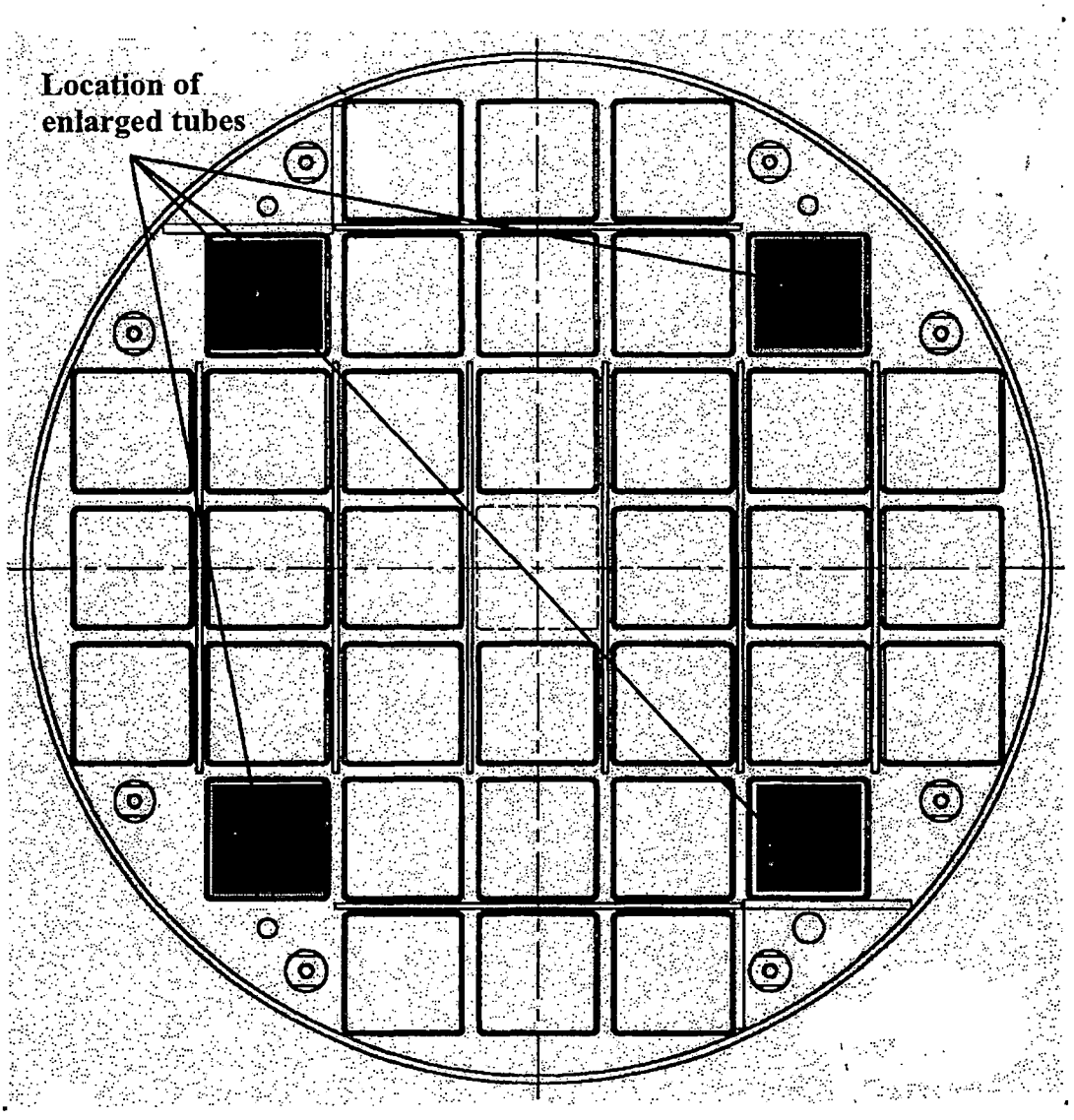
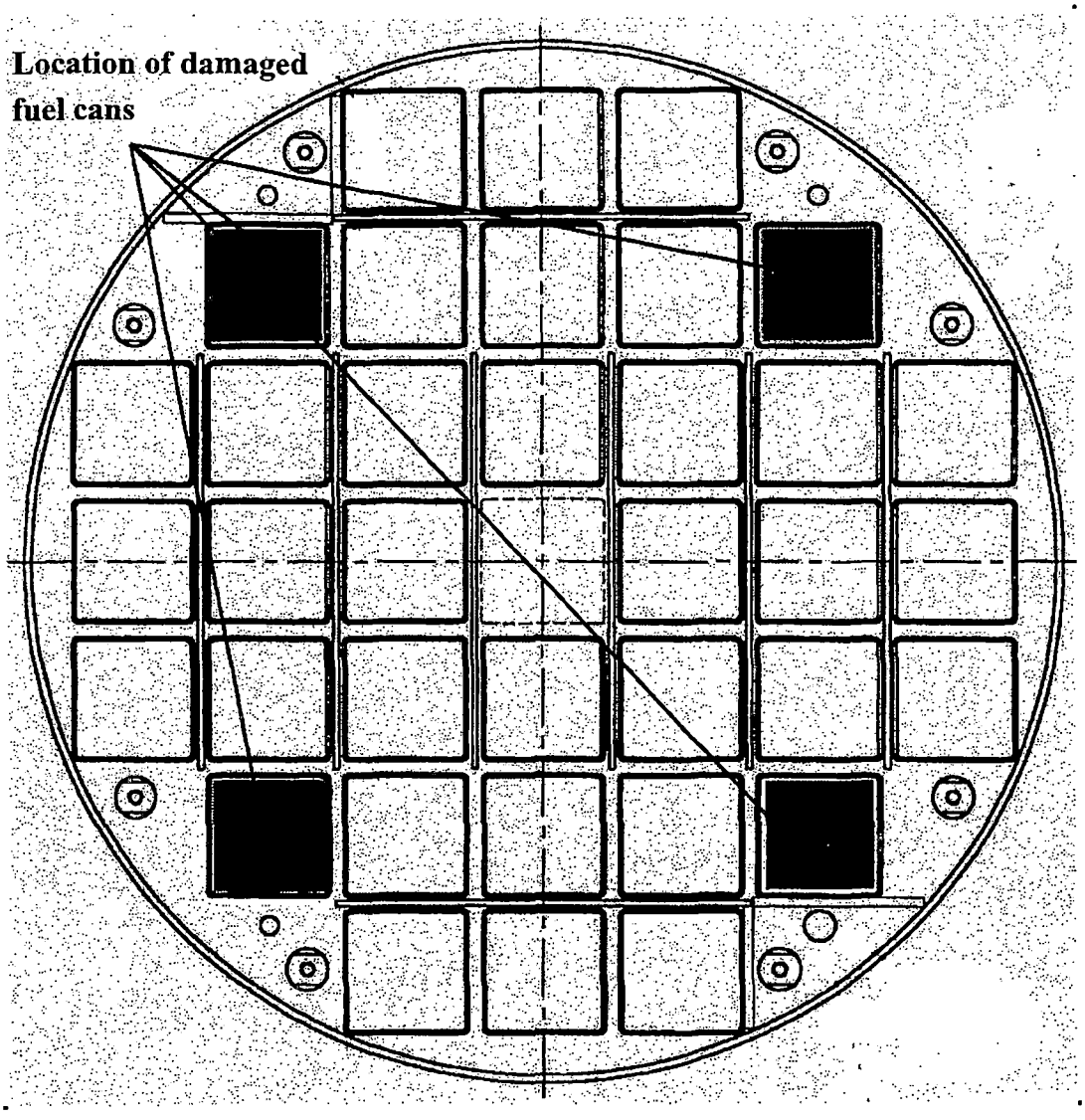


Figure 6.3.1-5 Yankee-MPC Damaged Fuel Can Locations



6.3.2 Description of the CY-MPC Calculational Models

The CY-MPC system criticality evaluations are performed using the transfer cask geometry. The transfer cask model includes the canister and fuel basket containing up to 26 fuel assemblies surrounded by the transfer cask radial and axial shields. This model is used to determine the most reactive fuel assembly type and reactivity impacts of mechanical perturbations and tolerances of the fuel and/or basket under fully flooded conditions. The maximum reactivity configuration, including mechanical perturbations, is then used to evaluate the reactivity of the system during loading, draining and drying operations of the transfer cask.

The CY-MPC transfer cask is constructed as a finite model that accurately represents the geometry of the canister, fuel basket and transfer cask. The MONK8A criticality code employed in the evaluation 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 represent the nominal basket/cask condition, and is modified for each of the perturbations described in Section 6.4.2. Figure 6.3.2-1 shows the cross-section of the support disk that maintains separation of the fuel tubes in the cask. Also shown in the figure is a detail of the fuel tube that surrounds the fuel assembly and fits into the basket fuel position opening. The detail shown is for a standard fuel tube. The cross-section of the oversize fuel tubes is 0.4 inch wider. The support disks are axially separated by two 1.795 inch spacers and a 0.5 inch aluminum heat transfer disk. As discussed in Section 6.4.2, the fuel assemblies and fuel basket components are analyzed in the most reactive configuration consistent with the mechanical tolerances specified by the design drawings.

In all models, the fuel assemblies, basket tubes, BORAL sheets and water gaps are explicitly represented. With exception of the fuel assembly end fittings, there are no homogenizations employed in the analysis. The exterior of the transfer cask is modeled with periodic axial and reflective radial boundary conditions (Figure 6.3.2-2). This simulates an infinite array of casks. As previously discussed, the model of an infinite array of transfer casks is considered to bound any configuration of concrete casks. The hydrogenous content of the concrete cask body serves to neutronically isolate the contents of each individual concrete cask. Additionally, there are no postulated events that would result in a flooded canister while it is in the concrete cask.

6.3.2.1 CY-MPC Package Regional Densities

The MONK8A standard composition library densities and isotopic distributions are used, except for BORAL and NS-4-FR. BORAL and NS-4-FR are not in the MONK8A standard composition library. Consequently, the calculated densities used for these materials are labeled as "non-standard." The material densities used in the criticality analyses are:

Material	Density (g/cc)
UO_2 at 95% TD	10.412
Zircaloy	6.5
Type 304 L Stainless Steel	7.93
Water (H_2O)	0.9982
Lead (Pb)	11.04
Aluminum	2.7
BORAL (core)	2.623(non-standard)
NS-4-FR	1.629 (non-standard)

6.3.2.2 Fuel Region Densities for Connecticut Yankee Fuel

The fuel rod material compositions used in the analysis are:

Material	Element	Density (atoms/barn-cm)
UO_2 (3.42 wt % ^{235}U)	^{235}U	8.043×10^{-4}
	^{238}U	2.242×10^{-2}
	O	4.647×10^{-2}
UO_2 (3.93 wt % ^{235}U)	^{235}U	9.241×10^{-4}
	^{238}U	2.230×10^{-2}
	O	4.647×10^{-2}
UO_2 (4.03 wt % ^{235}U)	^{235}U	9.476×10^{-4}
	^{238}U	2.228×10^{-2}
	O	4.647×10^{-2}
UO_2 (4.61 wt % ^{235}U)	^{235}U	1.084×10^{-3}
	^{238}U	2.215×10^{-2}
	O	4.648×10^{-2}
Zircaloy	Zr	4.291×10^{-2}
Stainless Steel	^{54}Fe	3.733×10^{-3}
	^{56}Fe	5.804×10^{-2}
	^{57}Fe	1.329×10^{-3}
	^{58}Fe	1.772×10^{-4}
	^{50}Cr	7.183×10^{-4}
	^{52}Cr	1.385×10^{-2}
	^{53}Cr	1.571×10^{-3}
	^{54}Cr	3.910×10^{-4}
	^{58}Ni	4.431×10^{-3}
	^{60}Ni	1.707×10^{-3}
	^{61}Ni	7.420×10^{-5}
	^{62}Ni	2.365×10^{-4}
	^{64}Ni	6.027×10^{-5}

6.3.2.3 CY-MPC Cask Materials

The parameters utilized for the cask materials, including those used in the canister, fuel basket, fuel tubes, and transfer cask, are:

Material	Element	Atom Density (atoms/barn-cm)
BORAL (core)	Al	3.359×10^{-2}
	^{10}B	7.099×10^{-3} *
	^{11}B	3.924×10^{-2}
	C	1.218×10^{-2}
Aluminum	Al	6.026×10^{-2}
Lead	Pb	3.209×10^{-2}
Stainless Steel	^{54}Fe	3.733×10^{-3}
	^{56}Fe	5.804×10^{-2}
	^{57}Fe	1.329×10^{-3}
	^{58}Fe	1.772×10^{-4}
	^{50}Cr	7.183×10^{-4}
	^{52}Cr	1.385×10^{-2}
	^{53}Cr	1.571×10^{-3}
	^{54}Cr	3.910×10^{-4}
	^{58}Ni	4.431×10^{-3}
	^{60}Ni	1.707×10^{-3}
	^{61}Ni	7.420×10^{-5}
	^{62}Ni	2.365×10^{-4}
	^{64}Ni	6.027×10^{-5}
NS-4-FR	H	5.854×10^{-2}
	O	2.609×10^{-2}
	C	2.264×10^{-2}
	N	1.394×10^{-3}
	Al	7.796×10^{-3}
	^{11}B	3.422×10^{-4}
	^{10}B	8.553×10^{-5}

* This value represents 75% poison credit.

6.3.2.4 Water Reflector Densities for the CY-MPC

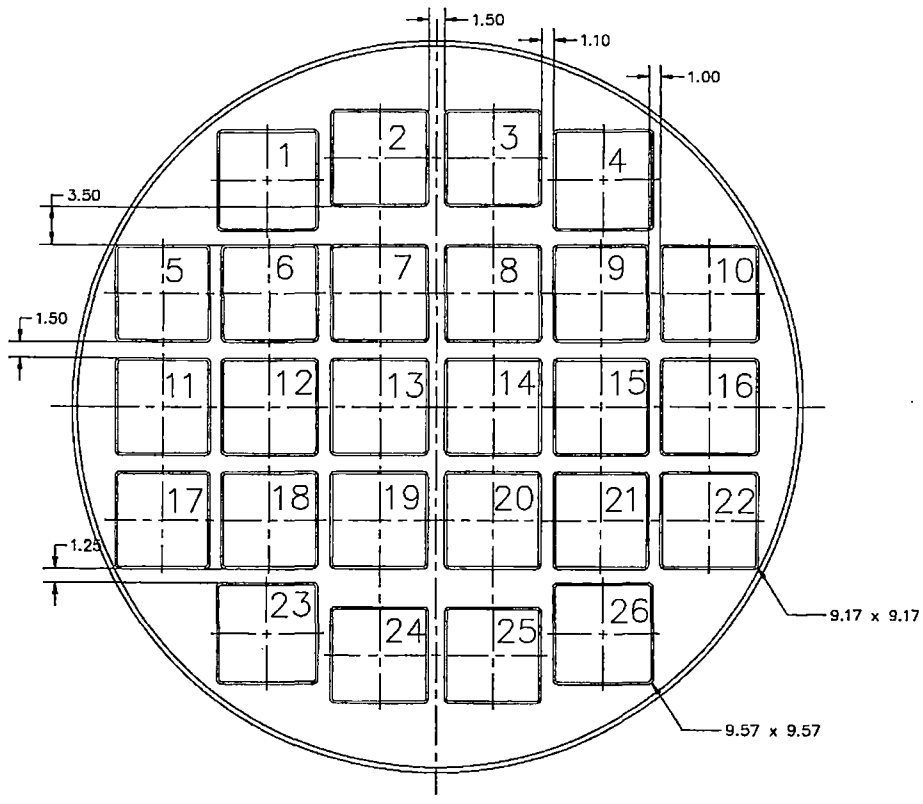
The material composition utilized for the water flooding the cask is:

Material	Element	Density (atoms/barn-cm)
Water	H	6.675×10^{-2}
	O	3.338×10^{-2}

The water composition is defined by first constructing a mixture made of 2 hydrogen and 1 oxygen atom. In the material cards a density is assigned the mixture. This enables simple moderator density variation.

Figure 6.3.2-1 CY-MPC Support Disk and Fuel Tube Criticality Analysis Models

(Dimensions in Inches)



Note: In the 24-assembly configuration, fuel positions numbered 12 and 15 are blocked.

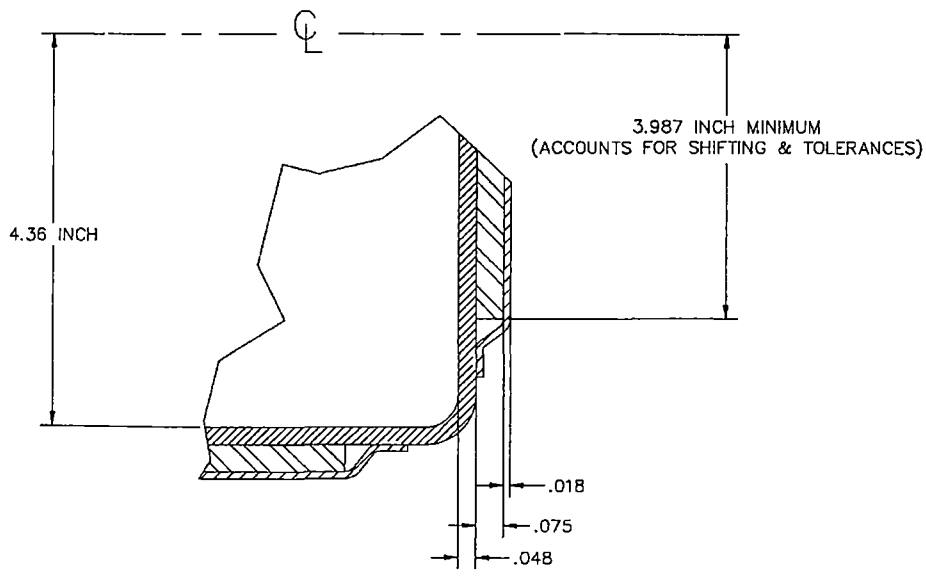
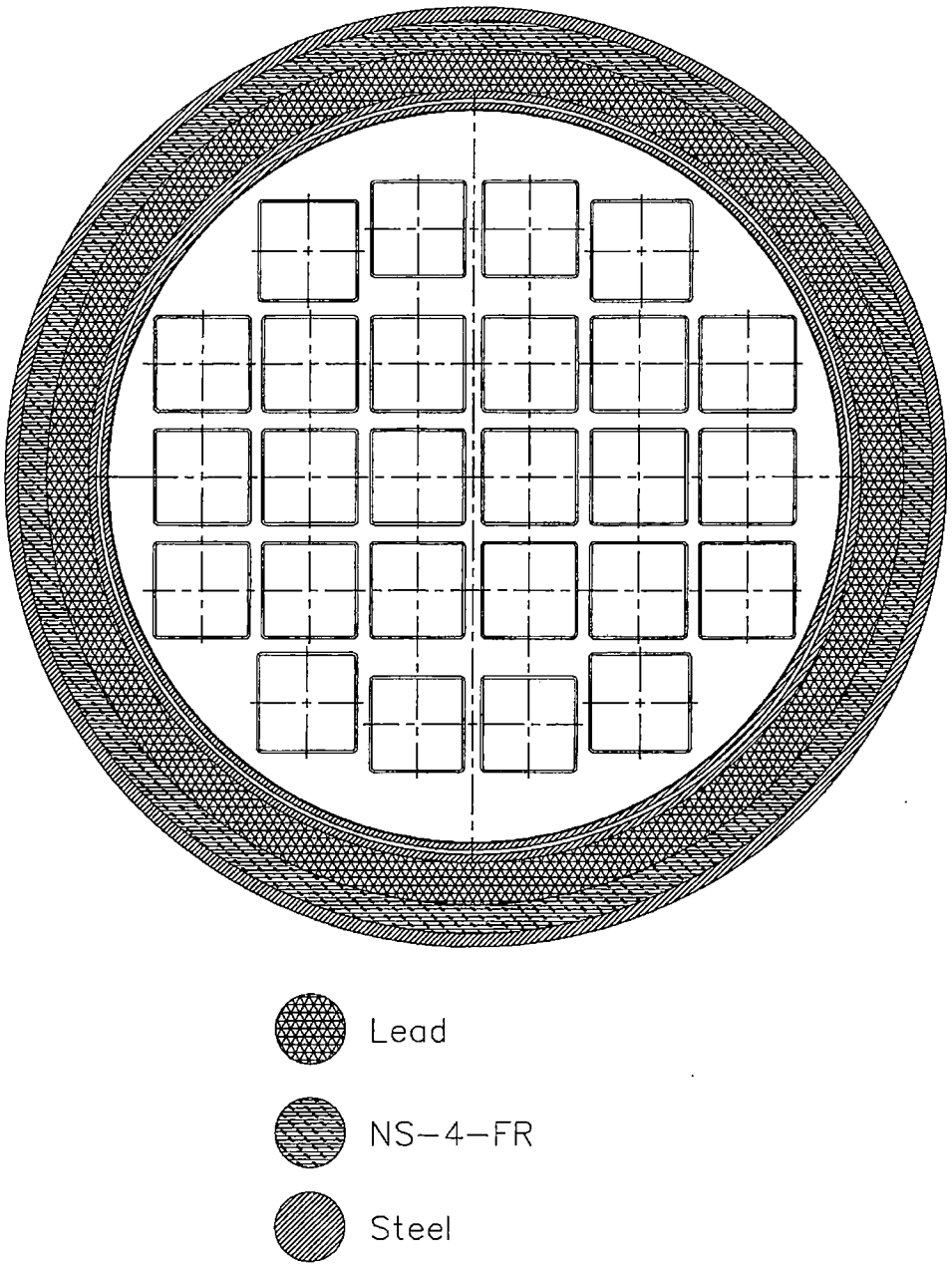


Figure 6.3.2-2 CY-MPC Transfer Cask Model



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6.4 NAC-MPC Storage System Criticality Calculation

This section demonstrates that the criticality analysis of the NAC-MPC, in either the Yankee-MPC or CY-MPC configuration, is sufficient to satisfy the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG-1536. The calculation method is described in the following sections. Criticality calculations are performed to determine: the most reactive fuel assembly type and basket loading; the most reactive mechanical configuration in the fuel basket; and the most reactive moderator density under normal, off-normal and accident conditions.

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6.4.1 Yankee-MPC Calculational Method

The criticality evaluation of the Yankee-MPC is performed with the SCALE 4.3 (ORNL) Criticality Safety Analysis Sequence (CSAS) (Landers) for the PC. CSAS includes: the SCALE Material Information Processor (Bucholz), BONAMI (Greene), NITAWL-II (Westfall), and KENO-Va (Petrie). 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 and NITAWL-II codes are used to prepare a resonance-corrected cross section library in AMPX working format. The KENO-Va code calculates the model k_{eff} using Monte Carlo techniques. The 27-group ENDF/B-IV neutron cross section library (Jordan) is used in this calculation. The Yankee-MPC KENO-Va models are described in further detail below.

6.4.1.1 Yankee Class Fuel Loading Optimization

The fuel loading is optimized in the Yankee-MPC cask criticality models by using: 1) fresh fuel, 2) the most reactive Yankee Class 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 36 design basis fuel assemblies. The models use reflecting 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.

6.4.1.2 Yankee Class Fuel Criticality Results

This section establishes the most reactive Yankee Class fuel and the most reactive configuration of the fuel within the canister basket. These results are used to calculate the effective neutron multiplication factor for the transfer cask and storage cask assuming full moderation. Sections 6.4.1.3 and 6.4.1.4 contain the results for the basket in transfer and storage configurations (respectively) without enlarged fuel tubes, while Section 6.4.1.5 extends the evaluation results to the basket with four enlarged fuel tubes. Section 6.4.1.6 documents the evaluation of replacement rods that are not solid. Section 6.4.1.7 documents the evaluation of replacing the four enlarged fuel tubes with screened YR-MPC damaged fuel cans and loading these damaged fuel cans with assemblies that may contain up to 20 damaged fuel rods. Section 6.4.1.8 documents the evaluation of a preferential flooding scenario and a hypothetical uneven drain down scenario for a canister containing YR-MPC damaged fuel cans. Section 6.4.1.9 provides a summary of the most reactive Yankee NAC-MPC loading configuration.

6.4.1.2.1 Yankee Class Fuel Most Reactive Assembly

Using the fuel/basket model of the Yankee-MPC basket, each of the Yankee Class fuel assembly vendor categories shown in Table 6.2.1-1 is evaluated. Each particular fuel rod array is explicitly modeled. This includes the Westinghouse 18 × 18 Types A and B at 4.94 wt % ^{235}U, United Nuclear 16 × 16 Types A and B at 4.0 wt % ^{235}U, Exxon 16 × 16 Types A and B with steel guide bars and instrument tube at 4.0 wt % ^{235}U, and CE Type A and B at 3.90 wt % ^{235}U, as well as the reconfigured fuel assembly with the most reactive fuel rods. Note, the Exxon 16 × 16 Types A and B with Zircaloy guide bars and instrument tube is identical to the CE configuration. In order to standardize the comparison, each assembly is evaluated with the fuel UO_2 at 95% theoretical density.

Table 6.4.1-1 shows the multiplication factor for each Yankee Class fuel type in the Yankee-MPC basket. This table shows that the United Nuclear Type A or Type B has the highest multiplication factor of the Yankee Class fuel assembly vendor categories. Table 6.4.1-1 also shows that it is difficult to resolve the difference between Type A and Type B fuel assemblies. There is only one fuel rod difference in loading. However, since the United Nuclear Type A has the highest UO_2 mass, this fuel rod array is chosen as the most reactive design basis fuel assembly for the Yankee-MPC. This design basis fuel assembly is used in all subsequent transfer and storage cask evaluations.

Additional analyses were performed to account for certain United Nuclear, Combustion Engineering, and Exxon and Westinghouse Type A and Type B fuel assemblies having nominally higher maximum enrichment than that considered in the design basis. The base case unit cell models of the United Nuclear, Combustion Engineering, and Exxon and Westinghouse fuel were modified to increase the enrichment of the fuel to 4.03 wt % ^{235}U, 3.93 wt % ^{235}U, and 4.03 wt % ^{235}U and 4.97 wt % ^{235}U, respectively. These nominal increases were evaluated to encompass the actual enrichment of the fuel as supplied by the manufacturer.

The calculated differences in reactivity for these fuel assemblies show that the increased enrichments do not result in a statistically significant increase in reactivity for all fuel types, except the Westinghouse Type A fuel. However, the reactivity of the Westinghouse Type A fuel with increased enrichment is significantly less than the United Nuclear Type A or B fuel at the nominal enrichment. No statistically significant differences in reactivity exists between the United Nuclear Type A or Type B fuels at 4.00 or 4.03 wt % ^{235}U. Therefore, the design basis analysis, which uses United Nuclear Type A fuel at 4.00 wt % ^{235}U, is adequate to demonstrate the criticality safety of the Yankee-MPC system.

An evaluation of the recaged fuel assembly, containing United Nuclear fuel rods in a CE lattice, did not result in a statistically different reactivity than the United Nuclear Type A or B assembly. Moving the higher enrichment United Nuclear rods into the CE lattice increased reactivity in the recaged assembly Type B cage to a k_{eff} of 0.8983 from a base assembly reactivity of 0.8939.

6.4.1.2.2 Yankee Class Fuel Most Reactive Mechanical Configuration

Using the fuel/basket model with the design basis fuel assembly, an evaluation of the effect of different Yankee-MPC basket perturbations is made. This criticality analysis determines the most reactive basket mechanical configuration by altering the nominal fuel/basket model with the design basis assembly and comparing the perturbed k_{eff} to the nominal result. If Δk_{eff} ($k_{perturbed}$ - $k_{nominal}$) is positive, the tolerance causes an increase in reactivity. Conversely, if Δk_{eff} is negative, the tolerance causes a decrease in reactivity. Two sets of perturbations are assessed in this evaluation of the criticality control: fabrication tolerances and component movement within the basket.

Four major fabrication tolerances are evaluated: the fuel tube opening, the disk opening, the disk thickness and the disk opening placement. Modifications to the nominal fuel/basket model dimensions are made based on the basket and fuel tube tolerances given on the Yankee-MPC drawings provided in Chapter 1.0. The tolerance analysis results are shown in Table 6.4.1-2. Table 6.4.1-2 shows that the most reactive set of basket tolerances are maximum fuel tube opening, minimum disk opening, maximum disk thickness and minimum (close packed) disk opening placement.

Increasing the fuel tube opening brings more moderator into the gap between the assembly and the tube lowering the efficiency of the BORAL sheets, hence increasing the reactivity of the system. Minimizing the disk opening and maximizing the disk thickness removes water from the flux trap, consequently increasing k_{eff}. Finally, decreasing the web thickness, decreases the flux trap size and also moves assemblies closer together producing an increase in k_{eff}. With respect to fabrication tolerances, this is the most reactive configuration.

Two major component movements within the basket are evaluated: the assembly within the tube and the tube within the basket. Unique to this package is the Yankee Class diagonally symmetric fuel assembly. Consequently, movement toward the three corners must be evaluated as opposed to one corner for a fully symmetric assembly. This assembly produces five movement perturbations: fuel tube movement to the upper right corner, the upper left corner, the lower left

corner and side to side. Table 6.4.1-3 shows the assembly movement analysis results. These results show that the most reactive assembly position is centered within the basket tube. This centering provides the most optimum moderating water gap within the tube.

Similar to the fuel assembly movement analysis, five possible fuel tube movements are evaluated: the upper right corner, the upper left corner, the lower left corner and side to side. Mirror and periodic boundary conditions on the sides of the model are evaluated. Table 6.4.1-4 shows the tube movement evaluations. These results indicate that the most reactive fuel tube location is shifted to the right side of the tube with mirrored boundary conditions. This result is reasonable given the orientation of the assembly. Shifting the tube to the right side with mirrored boundary conditions moves a complete fuel pin row of two assemblies closer together, hence pushing the largest amount of fuel together and minimizing the flux trap gap between tubes. In general, these results show that moving the tubes towards each other with the fuel assembly centered in the tube is the most reactive component configuration.

Thus, the following most reactive mechanical configuration is imposed on the Yankee-MPC basket model: assemblies centered in the tubes, fuel tubes moved toward the center of the basket, maximum fuel tube opening, minimum disk opening, maximum disk thickness and close packed disk opening locations. The reactivity penalty associated with this configuration versus the nominal dimension configuration is discussed in the transfer cask and storage cask criticality evaluations that follow.

The fuel/basket model clusters the fuel in groups of four (mirrored boundary), or shifts the fuel to one side of the tube (periodic boundary) and, therefore, does not represent the closest fuel material approach feasible in a model with fuel moved radially inward. To document the maximum reactivity configuration, both tube and assembly movement analyses are repeated in the full cask model. The k_{eff} of these analyses are compared to the nominal dimension cask model. Based on the storage cask and transfer cask reactivity evaluation, the shield configuration of the transport cask does not impact k_{eff} significantly. Therefore, the results of the transport cask analysis, shown below, are applicable to the storage and transfer cask results.

Position	k_{eff}	σ	Δk_{eff}
Nominal	0.8637	0.0007	---
Fuel Tubes Moved Toward the Basket Center	0.8689	0.0008	0.0052
Fuel Tubes Moved Toward the Basket Shell	0.8596	0.0008	-0.0041
Assemblies Moved Toward the Basket Center	0.8677	0.0007	0.0040
Assemblies Moved Toward the Basket Shell	0.8590	0.0008	-0.0047

Based on the cask analysis of the basket model without enlarged fuel tubes, the assembly moved towards the cask center configuration adds a Δk_{eff} of 0.004 to the reactivity of the nominal dimension configuration. The model, documented as worst case mechanical configuration in the fuel/basket evaluation, and employed in optimum moderator and enlarged fuel tube studies, is not adjusted from its assembly centered configuration. The Δk_{eff} associated with the assembly movement is accounted for by adding the Δk_{eff} of 0.004 to the KENO-Va neutron multiplication factor (k_{eff}) during k_s calculations.

To verify that the criticality axial models represent the most reactive configuration, the transfer cask accident condition, with full density water, is evaluated assuming that the aluminum heat transfer disk is replaced with water. The results show a decrease in reactivity (Δk_{eff} = - 0.014) for the water replacement condition. Consequently, the axial model incorporating the aluminum heat transfer disk is conservative.

6.4.1.3 Yankee-MPC Transfer Cask Criticality Evaluation

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes an evaluation of the reactivity effects of moderator density variation inside the cask. Off-normal and accident conditions are bounded by assuming the most reactive mechanical basket configuration as well as moderator intrusion into the fuel cladding (100% fuel failure).

Using the transfer cask criticality model, an evaluation of the assumption of 75% of ^{10}B in BORAL, the cumulative effect of worst case mechanical perturbations and the effect of moderator density variation is made. Table 6.4.1-5 shows transfer cask multiplication factors at various conditions. Table 6.4.1-5 shows that the assumption of 75% of the BORAL ^{10}B loading results in a reactivity penalty (Δk_{eff}) of 0.015 and the cumulative effect of the worst case mechanical configuration results in an additional 1% reactivity penalty from the nominal

dimension configuration. Table 6.4.1-5 also shows that reactivity decreases monotonically with decreasing moderator density, and the optimum moderator density is at 1 g/cc. Under normal conditions involving loading, draining and drying, the maximum k_{eff} including bias and uncertainties is 0.8929. The CSAS output file (including an input listing) is shown in Figure 6.7.1-1. In the off-normal or accident situation involving fuel failure and moderator intrusion, the maximum k_{eff}, including biases and uncertainties, is 0.9021. The CSAS output file (including an output listing) is shown in Figure 6.7.1-2. Thus, the Yankee-MPC transfer cask containing 36 Yankee Class fuel assemblies of the most reactive type in the most reactive configuration is well below the 0.95 NRC criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

6.4.1.4 Yankee-MPC Storage Cask Criticality Evaluation

Under normal conditions, moderator is not present in the storage cask. However, access to the environment is possible via air inlets and the convective heat transfer annulus between the canister and the storage cask steel liner. This access provides paths for moderator intrusion during a flood. Off-normal conditions evaluate moderator intrusion into the convective heat transfer annulus. Under accident conditions, it is assumed that the canister confinement fails and moderator intrudes into the canister and fuel cladding (100% failure) is evaluated along with moderator density variation. The accident condition analyses also examine the effect of interior/exterior moderator density variations.

Using the storage cask criticality model, an evaluation is performed of moderator intrusion into the heat transfer annulus under off-normal conditions and into the canister under accident conditions. Table 6.4.1-6 shows the storage cask multiplication factors at various conditions. Under normal dry conditions, maximum k_{eff}, including biases and uncertainty, is 0.4503, which is well subcritical. The CSAS output file (including an input listing) is shown in Figure 6.7.1-3. Under off-normal conditions involving flooding of the heat transfer annulus, the k_{eff} of the cask is even less. Under accident conditions involving full moderator intrusion into the canister and fuel clad gap, the maximum k_{eff} of the cask is 0.9018. The CSAS output file (including an input listing) is shown in Figure 6.7.1-4. Similar to the transfer cask analysis, the storage cask accident condition moderator density study evaluates a monotonic decrease in reactivity with moderator density inside and outside the cask. Thus, the Yankee-MPC storage cask containing 36 fuel assemblies of the most reactive Yankee Class type in the most reactive configuration is well below the 0.95 NRC criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

Based on the results of the criticality analysis for the transfer cask and the storage cask presented in Tables 6.4.1-5 and 6.4.1-6, respectively, there is no significant impact on system reactivity when changing reflector dimensions and material composition.

6.4.1.5 Storage and Transfer Cask Evaluation for a Yankee-MPC Basket Containing Enlarged Fuel Tubes

The maximum reactivity, fully moderated, cask models documented in Section 6.4.1.3 and 6.4.1.4 are evaluated with four enlarged fuel tubes replacing standard fuel tubes (BORAL sheets on four sides) on the basket periphery. As expected, the reactivity of these systems increases slightly due to the increased neutron interaction between fuel tubes in those locations where BORAL sheets were removed. Adjusting for the 0.004 Δk_{eff} associated with the assembly movement in the tubes results in a maximum bias and uncertainty adjusted k_{eff} (k_s) of 0.9175 for transfer conditions and 0.9182 for a hypothetical storage accident condition involving full moderator intrusion. Both storage and transfer maximum reactivities for the enlarged fuel tube basket are, therefore, well below the 0.95 criticality safety limit.

6.4.1.6 Evaluation of Non-solid Replacement Rods in Yankee Class Fuel

The Yankee Class spent fuel inventory contains a limited number of fuel assemblies with replacement rods. These replacement rods include displacement rods and filler rods. Any assembly that contains filler rods that displace at least the same amount of moderator (in the fully flooded condition, including the fuel-clad gap) as the nominal fuel rods is allowed to be loaded into the Yankee-MPC. This is permissible because the modified assembly would be less reactive than its original configuration due to a lower fissile mass.

Some Yankee Class fuel assemblies have fuel rods replaced with filler rods, some of which may not be solid filler rods. The subject assemblies may have hollow Zirconium clad filler rods that contain stainless steel slugs or Zircaloy slugs. Fully flooded unit cell analyses are performed to evaluate these assemblies. The first unit cell analysis models the most reactive United Nuclear Type A assembly with no filler rods and floods the fuel-clad gap of all fuel rods to establish a base case reactivity. The second set of analyses models two geometries of a United Nuclear Type A assembly with 12 filler rods that contain stainless steel slugs. The gap between the cladding and the slug or pellets in all rods is flooded. The diameter of the stainless steel slugs ranges from 0.265 to 0.275 inch. However, stainless steel slug diameters of up to 0.308 inch are evaluated. The results of the analyses, documented in Table 6.4.1-7, show that replacing up to 12 fuel rods

with filler rods that contain` stainless steel slugs with a minimum diameter of 0.265 inch decreases the system reactivity significantly.

The third set of analyses models multiple geometries of a United Nuclear Type A assembly with 12 filler rods that contain Zircaloy slugs. These models also flood the gap between the cladding and the slug or pellets of all rods. The diameter of the Zircaloy slugs ranges from 0.290 to 0.308 inch. The change in reactivity between these models and the base case, documented in Table 6.4.1-8, demonstrates that replacing up to 12 fuel rods with filler rods that contain Zircaloy slugs with a minimum diameter of 0.290 inch does not have a statistically significant impact on system reactivity. Therefore, Yankee Class fuel assemblies having up to 12 fuel rods replaced with non-solid filler rods that contain stainless steel slugs with a minimum diameter of 0.265 inch, or Zircaloy slugs with a minimum diameter of 0.290 inch, are allowed contents.

Six United Nuclear Type B assemblies in the Yankee Rowe Class inventory have two displacement rods that vary in geometry from the displacement rod dimensions listed in Table 6.2.1-1. To analyze these assemblies, the unit cell model of the United Nuclear Type B assembly referred to in Section 6.4.1.2.1, is modified to model the subject displacement rods as empty rod positions. The change in reactivity due to this configuration, Δk_{eff} = 0.00021, is within the statistical uncertainty of the code. Based on this evaluation, the United Nuclear Type B assemblies displacement rod dimension has no noticeable impact on system reactivity, and any displacement rod dimension is permissible for loading.

6.4.1.7 Storage and Transfer Cask Evaluation for a Basket Containing Damaged Fuel Cans

To provide flexibility and to allow loading of damaged fuel rods without placement of the damaged rods into the Yankee Class RFA, a damaged fuel can basket configuration is evaluated. To accommodate damaged fuel assemblies, the four enlarged fuel tubes referred to in Section 6.4.1.5 have been modified into damaged fuel cans. The damaged fuel can is designed to preclude the release of pellets and gross particulate into the canister cavity. The evaluation of a canister loaded with four (4) damaged fuel cans considers each damaged fuel can to contain a Yankee Class assembly with up to 20 damaged or missing fuel rods and considers 100% dispersal of the fuel from these rods within the damaged fuel can.

All of the spent fuel assemblies containing fuel rods that are classified as damaged shall be stored in a damaged fuel can. The damaged fuel cans are located in the four corner locations of the basket, as shown in Figure 6.3.1-5.

The analysis of a canister containing four damaged fuel cans is performed in multiple steps. Damaged fuel is evaluated in a missing rod configuration followed by a loose fuel evaluation. The loose fuel evaluation considers the fissile material to be located within the fuel rod lattice or above and below the active fuel region, but within the fuel can. The evaluation is performed within the transport cask radial overpack and considers the storage and transfer cask conditions. The most reactive canister configuration is independent of shield geometry.

Missing Rod Geometry

Initially, the most reactive missing rod geometry is determined for each Yankee Class fuel type. Assuming that a damaged fuel rod is a missing or empty fuel rod location is conservative as this increases the H/U ratio of the under moderated assembly. Evaluating up to 20 missing rods in various configurations establishes an increased H/U ratio within the assembly and thus the most reactive (20) missing rod or damaged rod geometry. The determination of the most reactive missing rod geometry is conducted using the fuel tube unit cell models employed in Section 6.4.1.7. The results of this evaluation, which are documented in Tables 6.4.1-9 through 6.4.1-16, show that the most reactive missing rod geometry occurs with United Nuclear Type A fuel assemblies that have all 20 damaged rods modeled as missing rods. This missing rod geometry is shown in Figure 6.4.1-1.

The most reactive missing rod geometry is then modeled in the damaged fuel can in each of the four corner locations of the basket to provide an initial accident condition reactivity. In the mechanical configuration documented in Section 6.4.1.2, this loading configuration increases the reactivity of the system, $\Delta k_{eff} = 0.00435$, over that containing intact fuel in the enlarged fuel tubes. Therefore, a detailed study is performed to determine the reactivity of the system resulting from maximizing interaction between the intact assemblies in the basket and the contents of the damaged fuel cans. Maximum interaction occurs when the orientation of each assembly is modified such that the two sides of the intact assemblies that have a complete row of fuel rods face the two complete fuel rod rows of the fuel assemblies in damaged fuel cans. In addition, fuel assemblies and fuel tubes are shifted toward the damaged fuel can location. This configuration, damaged fuel cans containing assemblies with missing rods combined with a basket geometry that maximizes interaction between all contents of the basket, increases reactivity, Δk_{eff}, by 0.02461. This loading configuration, which results in a system reactivity ($k_{eff} \pm \sigma$) of 0.92480 ± 0.00073, is shown in Figure 6.4.1-2. The input/output file for this case is provided in Figure 6.7.1-6.

Dispersed Fuel Evaluation

To determine the effect on reactivity due to the dispersed damaged fuel occupying the void regions within each damaged fuel can, all dispersed fuel in each analysis is modeled as a homogeneous mixture of UO_2 and water. The volume fractions of the fuel versus the water are varied from 0%-100%. By varying the fuel fraction up to 100%, this evaluation addresses UO_2 masses significantly larger than what is available from 20 damaged Yankee Class fuel rods.

In the first dispersed fuel evaluation, the loose fuel is evaluated between the remaining rods of the most reactive missing rod geometry. The results of this analysis, provided in Table 6.4.1-17, show that this scenario decreases the reactivity of the system compared to just placing the most reactive missing rod array within each can. This is because adding fuel to the bounding missing rod array, with an increased moderator to fuel ratio, reduces the reactivity of the system as this effectively returns the system to an under moderated state.

Loose fuel is also considered above and below the active fuel region of the most reactive missing rod array. Locating fuel outside the fuel rod active fuel region may also place fissile material outside the neutron absorber sheet axial extends. Previous criticality evaluations were based on an infinite height, repeating stack of aluminum and steel disks separated by spacers, which would not adequately account for this material. This analysis is, therefore, performed within a finite height cask model that represents the canister cavity in two regions: the region of the basket between the top and bottom support disks, and the regions within the transportable storage canister cavity that are above and below the top and bottom support disks. This model conservatively extends the active fuel height of all assemblies to match the disk elevations and conservatively truncates neutron absorber sheet elevation to the same height. A mirror boundary is placed in the middle of the region between the ends of the truncated neutron absorber and the extent of the canister cavity. This conservatively models an infinite height, alternating stacks of active fuel with neutron absorber sheet coverage and the regions without coverage. For simplicity, the height of the region below the neutron poison is modeled with the same height as the region above the neutron poison. Figure 6.4.1-3 provides a graphical representation of the various axial regions of the model.

This height is modeled first at 7.5 cm to conservatively encompass half the minimum height of the region between the actual neutron absorber and the canister bottom (~16.5 cm). By placing a mirror boundary condition at the end of each 7.5 cm region, an effective 15 cm of fuel debris is uncovered. This model conservatively replaces the lids with active fuel and effectively

eliminates axial leakage. The 7.5 cm inch height is then increased to 15 cm to encompass half the maximum height of the region between the neutron absorber and the shield lid (~28 cm).

The results of these studies, provided in Tables 6.4.1-18 and 6.4.1-19, show the possible mixture of fuel and water above and below the neutron poison sheet coverage; therefore, mixtures above and below the active fuel region will not increase the reactivity of the system beyond that of the infinite height model of each damaged fuel can containing an assembly with the most reactive (20) missing rod array, $k_{eff} \pm \sigma = 0.92480 \pm 0.00073$.

6.4.1.8 Evaluation of a Preferential Flooding and a Hypothetical Uneven Drain Down

Preferential flooding of the canister cavity and the damaged fuel can cavity is also considered. The model utilized—an infinite height, repeating stack of aluminum and steel disks separated by spacers—considers the most reactive fuel assemblies and the most reactive damaged fuel can contents as documented in Section 6.4.1.7. The density of the moderator filling the canister cavity is initially set to zero to model a dry canister cavity, while the void regions in each damaged fuel can are filled with full density moderator. The density of the moderator filling the canister cavity is then incrementally increased to full density. A study is also performed with a fully flooded canister cavity, while the density of the moderator occupying the void regions in each damaged fuel can is initially set to zero and then incrementally increased to full density. The results of these moderator density variations, provided in Table 6.4.1-20, demonstrate that the most reactive configuration for both the canister cavity and the damaged fuel cans occurs with full density water.

A case modeling a partially flooded canister loaded with four fully flooded damaged fuel cans in a hypothetical uneven drain down condition is also evaluated. The geometry of this case is taken from the axially finite basket model with 7.5 cm regions above and below the active fuel; and, thus, above and below the neutron absorber. The canister cavity is modeled with full density moderator along the entire axial extent of the active fuel. The four damaged fuel cans are hypothetically assumed to remain fully flooded along the entire axial extent of each can. The material occupying the 7.5 cm regions above and below the active fuel in each damaged fuel can is taken to be 10% UO_2 and 90% water. As shown in Table 6.4.1-18, this damaged fuel can content results in the maximum increase in reactivity compared to the same geometry with no loose damaged fuel. The UO_2 volume fraction of the loose damaged fuel mixture is closer to what would be expected from only 20 rods than the UO_2 mixture volume fractions employed in the other cases. The resulting geometry, shown in Figure 6.4.1-4, bounds a hypothetical uneven drain down of a canister containing damaged fuel cans. The calculated reactivity of this

configuration, $k_{eff} \pm \sigma = 0.92004 \pm 0.00074$, is within the statistical uncertainty band of the fully flooded condition of the same geometry.

6.4.1.9 Summary of Most Reactive Fuel Loading

All the criticality safety analyses result in a system reactivity that is bounded by the infinite height model of a fully flooded canister loaded with 32 intact United Nuclear Type A assemblies and four YR-MPC damaged fuel cans, each containing a United Nuclear Type A assembly with a maximum of 20 damaged or missing fuel rods. As documented in Section 6.4.1.7, this configuration results in a system reactivity ($k_{eff} \pm \sigma_{mc}$) of 0.92480 ± 0.00073. The maximum system reactivity for this configuration, $k_{eff} + 2\sigma_{mc} = 0.92625$, is less than the USL of 0.9361. The maximum system reactivity including the code bias and the bias uncertainty, $k_s = k_{eff}+0.0052+(0.0087^2+(2\sigma_{mc})^2)^{(1/2)}$, is calculated to be 0.93883, which is below 0.95. Thus, assemblies with up to 20 damaged or missing rods are allowed contents in a damaged fuel can.

Figure 6.4.1-1 Yankee-MPC Most Reactive Missing Rod Geometry

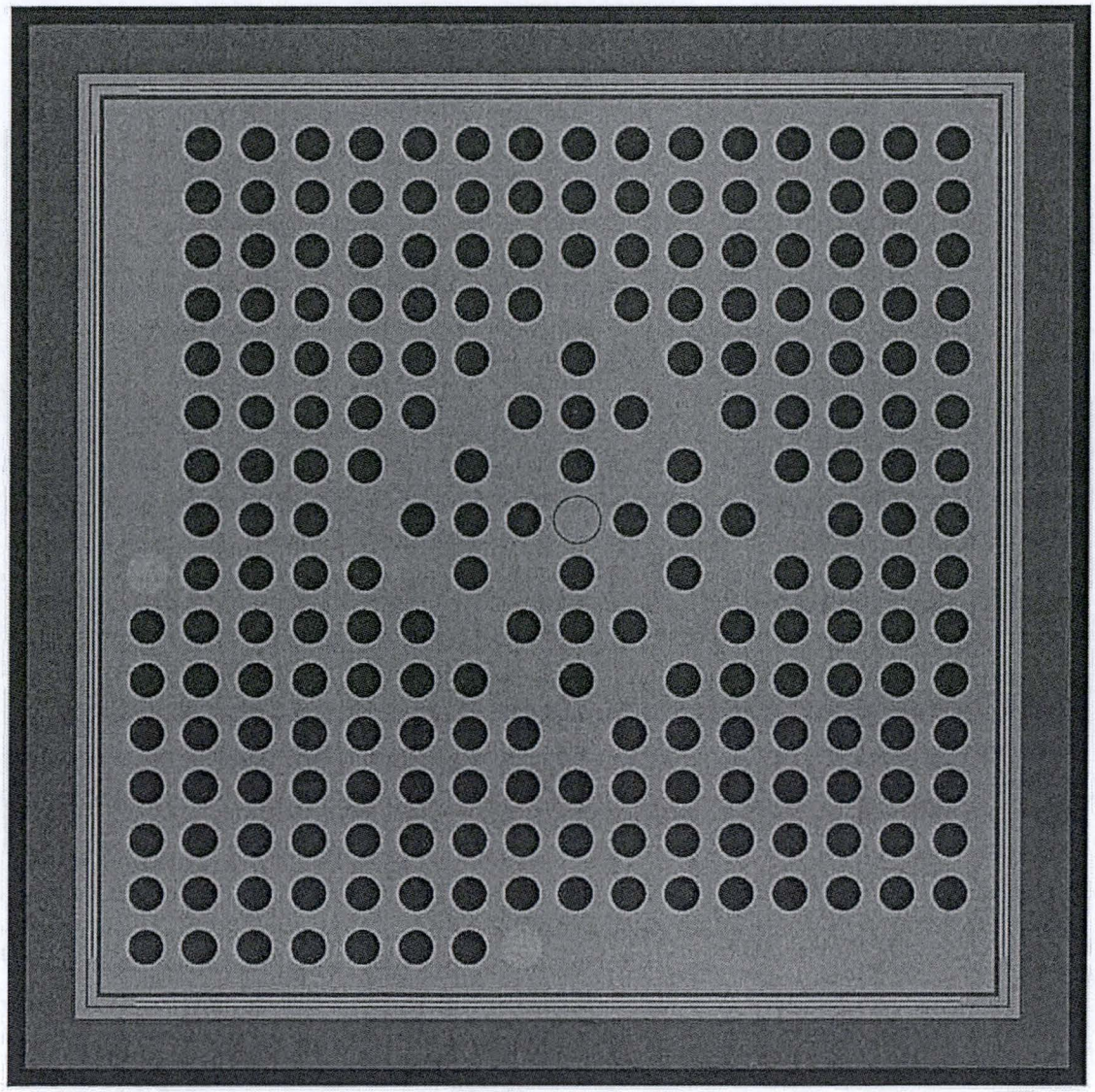


Figure 6.4.1-2 Yankee-MPC Most Reactive Missing Rod Array in the Damaged Fuel Can

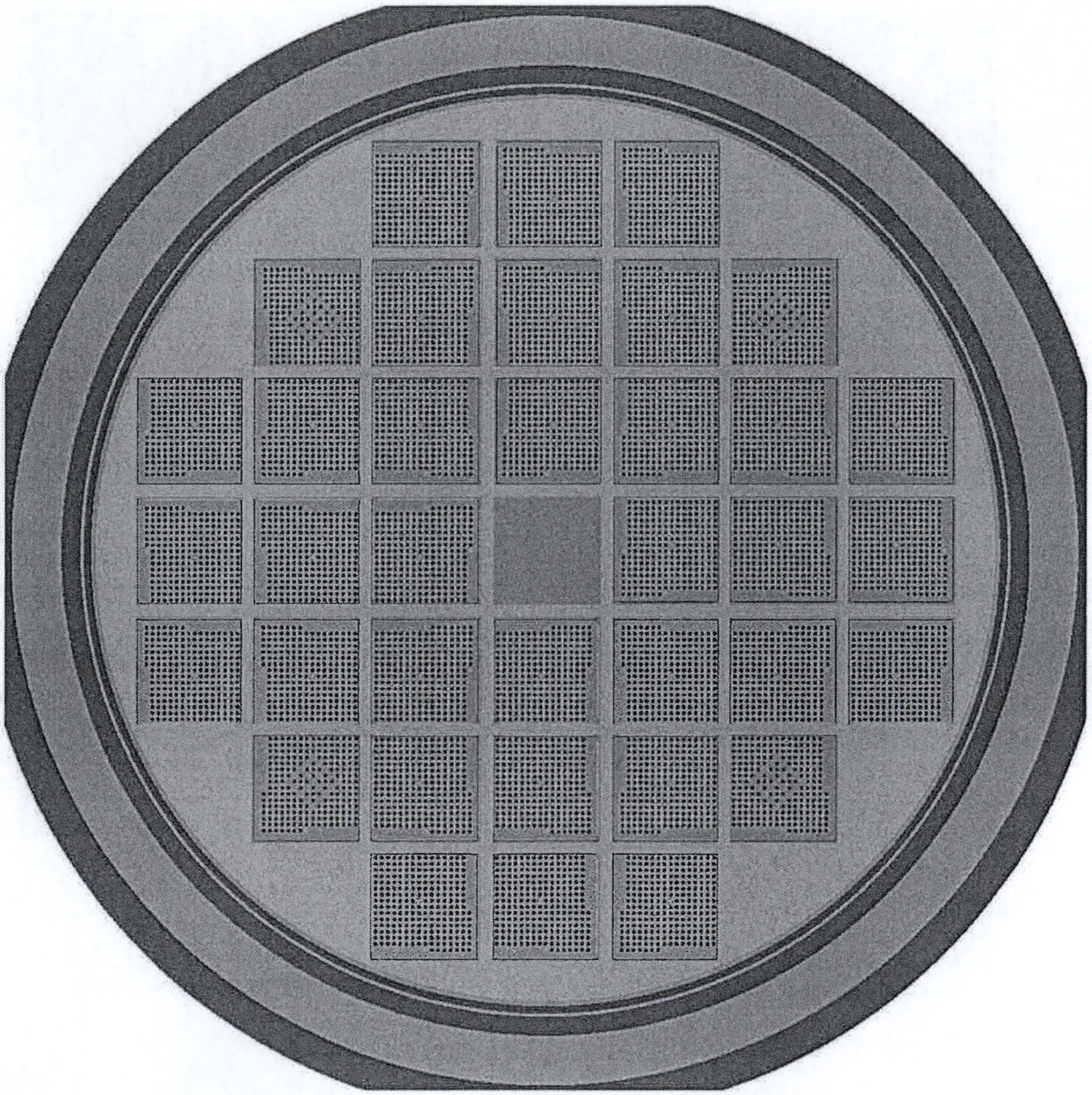


Figure 6.4.1-3 Yankee-MPC Damaged Fuel Can – 7.5 cm Regions without Neutron Absorber Coverage

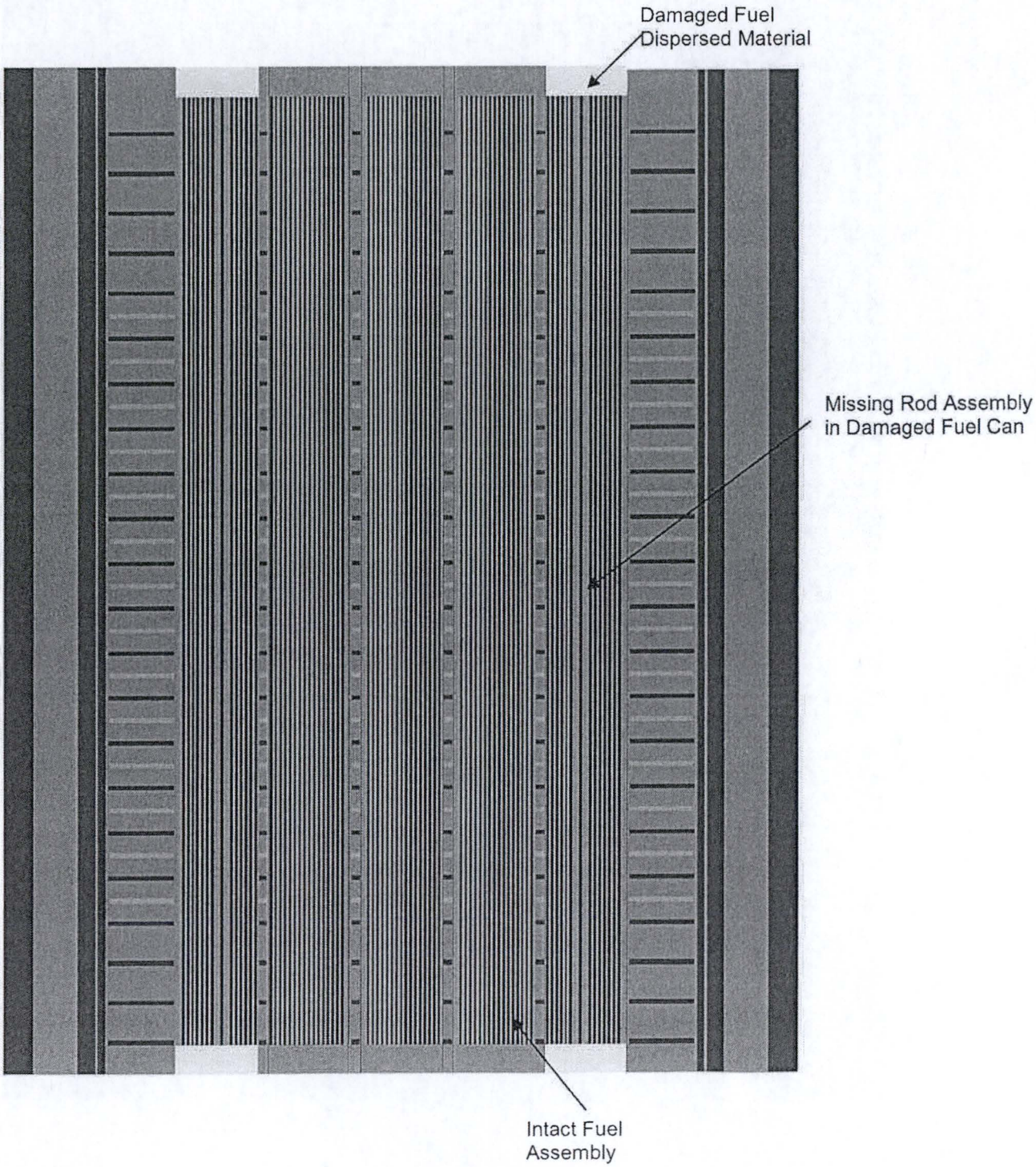


Figure 6.4.1-4 Yankee-MPC Hypothetical Uneven Drain Down Model

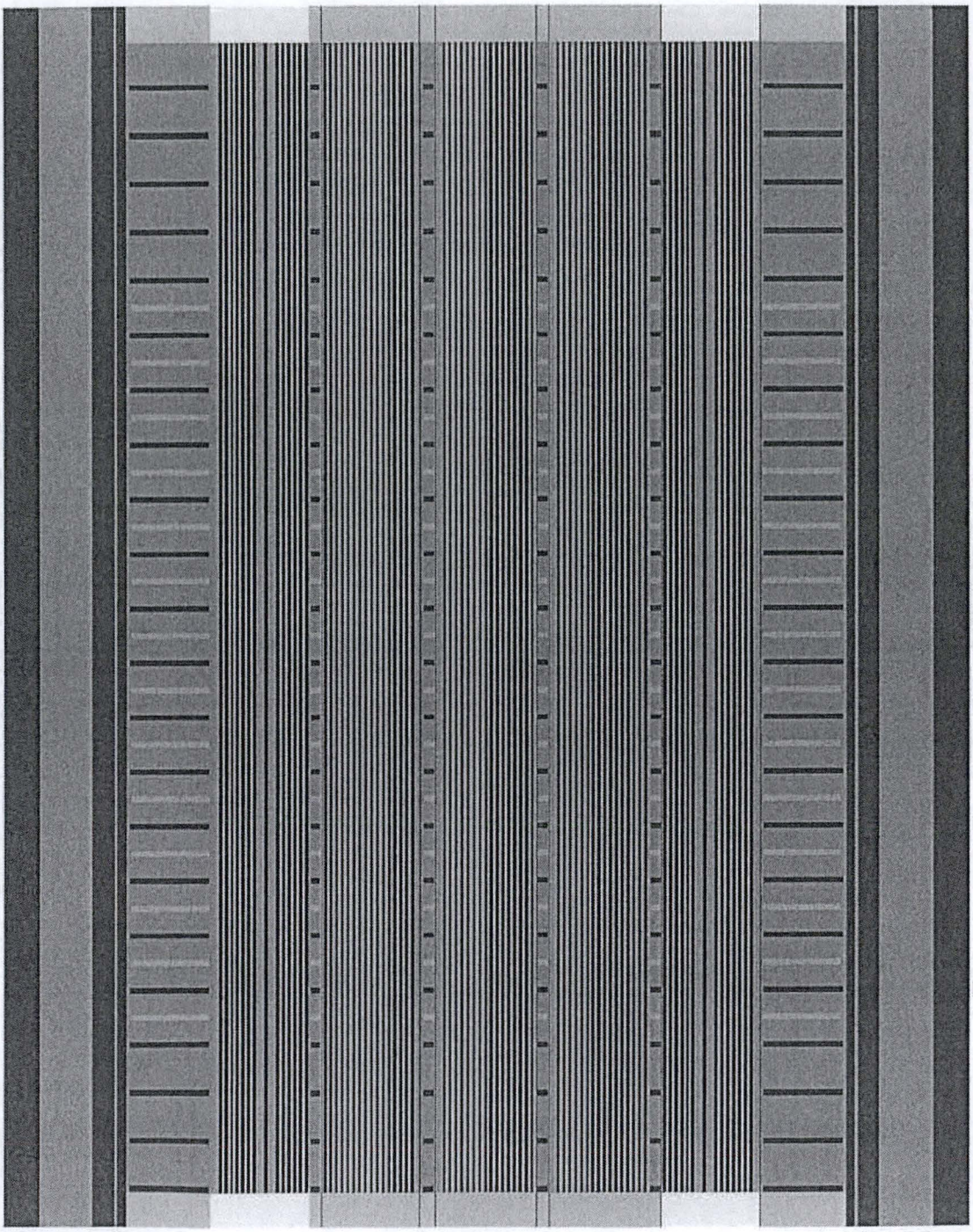


Table 6.4.1-1 Yankee Class Fuel Assembly Reactivity by Fuel Type

Assembly	Initial Enrichment (wt % ^{235}U)	In Basket k_{eff}	σ
Westinghouse Type A	4.94	0.8642	0.00105
Westinghouse Type B	4.94	0.8664	0.00102
United Nuclear Type A	4.00	0.8974	0.00087
United Nuclear Type B	4.00	0.8974	0.00106
Exxon Type A	4.00	0.8870	0.00111
Exxon Type B	4.00	0.8877	0.00111
Combustion Engineering Type A	3.90	0.8943	0.00060
Combustion Engineering Type B	3.90	0.8939	0.00163
Reconfigured Fuel Assembly	4.00	0.6280	0.0007

Table 6.4.1-2 Yankee-MPC Basket Tolerance Reactivity Evaluations

Analysis	k_{eff}	σ	Δk_{eff}
Nominal Dimension	0.8981	0.0007	-
Fuel Tube Maximum Opening	0.9018	0.0007	0.0037
Fuel Tube Minimum Opening	0.8916	0.0007	-0.0065
Disk Maximum Opening	0.8972	0.0007	-0.0009
Disk Minimum Opening	0.8991	0.0008	0.0010
Disk Maximum Thickness	0.8987	0.0008	0.0006
Disk Minimum Thickness	0.8972	0.0008	-0.0009
Loose Packed Disk Opening	0.8974	0.0008	-0.0007
Close Packed Disk Opening	0.8993	0.0007	0.0012

Table 6.4.1-3 Yankee-MPC Fuel Movement Reactivity Evaluations

Assembly Movement	Boundary Conditions	k_{eff}	σ	Δk_{eff}
Nominal Dimension	Reflective	0.8981	0.0007	-
Upper Right Corner	Mirrored	0.8954	0.0007	-0.0027
Upper Right Corner	Periodic	0.8943	0.0007	-0.0038
Lower Left Corner	Mirrored	0.8977	0.0007	-0.0004
Lower Left Corner	Periodic	0.8978	0.0008	-0.0003
Upper Left Corner	Mirrored	0.8963	0.0007	-0.0018
Upper Left Corner	Periodic	0.8961	0.0008	-0.0020
Right Side	Mirrored	0.8949	0.0007	-0.0032
Right Side	Periodic	0.8951	0.0007	-0.0030
Left Side	Mirrored	0.8978	0.0007	-0.0003
Left Side	Periodic	0.8972	0.0007	-0.0009

Table 6.4.1-4 Yankee-MPC Fuel Tube Movement Reactivity Evaluations

Tube Movement	Boundary Conditions	k_{eff}	σ	Δk_{eff}
Nominal Dimension	Reflective	0.8981	0.0007	-
Upper Right Corner	Mirrored	0.8999	0.0007	0.0018
Upper Right Corner	Periodic	0.8979	0.0007	-0.0002
Lower Left Corner	Mirrored	0.8984	0.0008	0.0003
Lower Left Corner	Periodic	0.8962	0.0007	-0.0019
Upper Left Corner	Mirrored	0.8991	0.0008	0.0010
Upper Left Corner	Periodic	0.8959	0.0007	-0.0022
Right Side	Mirrored	0.9005	0.0008	0.0024
Right Side	Periodic	0.8966	0.0007	-0.0015
Left Side	Mirrored	0.8968	0.0007	-0.0013
Left Side	Periodic	0.8976	0.0007	-0.0005

Table 6.4.1-5 Criticality Results for Yankee-MPC Transfer Cask

Cask Pitch (cm)	Basket Configuration	H_2O Inside (density g/cc)	H_2O Outside (density g/cc)	^{10}B in BORAL	k_{eff}	σ	k_s [1]
319.71	Nominal Dimension	1.0	1.0	100%	0.85035	0.00076	0.8684
319.71	Nominal Dimension	1.0	1.0	75%	0.86504	0.00070	0.8831
319.71	Worst Case	1.0	1.0	75%	0.87422	0.00076	0.8923
319.71	Worst Case	1.0	0.0001	75%	0.87488	0.00076	0.8929
319.71	Worst Case	0.8	0.0001	75%	0.82355	0.00074	0.8416
319.71	Worst Case	0.6	0.0001	75%	0.76550	0.00069	0.7835
319.71	Worst Case	0.4	0.0001	75%	0.69378	0.00064	0.7118
319.71	Worst Case	0.2	0.0001	75%	0.60267	0.00051	0.6206
319.71	Worst Case	0.1	0.0001	75%	0.55065	0.00042	0.5686
319.71	Worst Case	0.05	0.0001	75%	0.51859	0.00034	0.5365
319.71	Worst Case	0.01	0.0001	75%	0.46634	0.00032	0.4843
319.71	Worst Case + Water in Gap	1.0	1.0	75%	0.88403	0.00074	0.9021

1. Includes a Δk of 0.004 due to radial movement of fuel assembly toward basket center.

Table 6.4.1-6 Criticality Results for Yankee-MPC Storage Cask

Cask Pitch (cm)	Basket Configuration	H_2O Inside (density g/cc)	H_2O[1] Outside (density g/cc)	^{10}B	k	σ	k_s[2]
457.2	Nominal Dimension	0.0001	0.0001	75%	0.43088	0.00029	0.4488
457.2	Worst Case	0.0001	1.0	75%	0.39800	0.00030	0.4159
457.2	"	0.0001	0.8	75%	0.39906	0.00031	0.4170
457.2	"	0.0001	0.6	75%	0.39869	0.00032	0.4166
457.2	"	0.0001	0.4	75%	0.40071	0.00031	0.4186
457.2	"	0.0001	0.2	75%	0.40963	0.00031	0.4276
457.2	"	0.0001	0.1	75%	0.42134	0.00031	0.4393
457.2	"	0.0001	0.05	75%	0.42924	0.00031	0.4472
457.2	"	0.0001	0.01	75%	0.43241	0.00030	0.4503
457.2	Worst Case + water in gap	1.0	1.0	75%	0.88376	0.00072	0.9018
457.2	"	0.8	0.8	75%	0.83228	0.00072	0.8503
457.2	"	0.6	0.6	75%	0.77378	0.00068	0.7918
457.2	"	0.4	0.4	75%	0.69781	0.00062	0.7158
457.2	"	0.2	0.2	75%	0.59996	0.00053	0.6179
457.2	"	0.1	0.1	75%	0.54264	0.00042	0.5606
457.2	"	0.05	0.05	75%	0.51048	0.00036	0.5284
457.2	"	0.01	0.01	75%	0.46246	0.00031	0.4804

1. Includes heat transfer annulus region.
2. Includes a Δk of 0.004 due to radial movement of fuel assembly toward basket center.

Table 6.4.1-7 Yankee-MPC Most Reactive Fuel Containing Non-Solid Filler Rods with Stainless Steel Slugs

Pattern	Slug Diam (in)	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
------	------	0.90565	0.00074	-----	-----
a	0.265	0.89351	0.00073	-0.01214	-16.4
a	0.270	0.89382	0.00072	-0.01183	-16.0
a	0.275	0.89284	0.00073	-0.01281	-17.3
a	0.280	0.89099	0.00073	-0.01466	-19.8
a	0.285	0.89071	0.00073	-0.01494	-20.2
a	0.290	0.89009	0.00074	-0.01556	-21.0
a	0.295	0.88806	0.00074	-0.01759	-23.8
a	0.300	0.88741	0.00073	-0.01824	-24.6
a	0.305	0.88796	0.00071	-0.01769	-23.9
a	0.308	0.88555	0.00072	-0.02010	-27.2
b	0.265	0.89278	0.00073	-0.01287	-17.4
b	0.270	0.89141	0.00073	-0.01424	-19.2
b	0.275	0.89197	0.00075	-0.01368	-18.5
b	0.280	0.88887	0.00074	-0.01678	-22.7
b	0.285	0.88824	0.00074	-0.01741	-23.5
b	0.290	0.88790	0.00072	-0.01775	-24.0
b	0.295	0.88712	0.00073	-0.01853	-25.0
b	0.300	0.88452	0.00074	-0.02113	-28.6
b	0.305	0.88358	0.00073	-0.02207	-29.8
b	0.308	0.88588	0.00072	-0.01977	-26.7

Table 6.4.1-8 Yankee-MPC Most Reactive Fuel Containing Non-Solid Filler Rods with Zircaloy Alloy Slugs

Pattern	Slug Diam (in)	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
------	------	0.90565	0.00074	-----	-----
a	0.290	0.90708	0.00071	0.00143	1.9
a	0.295	0.90692	0.00033	0.00127	1.7
a	0.300	0.90684	0.00074	0.00119	1.6
a	0.305	0.90576	0.00072	0.00011	0.1
a	0.308	0.90542	0.00073	-0.00023	-0.3
b	0.290	0.90662	0.00071	0.00097	1.3
b	0.295	0.90566	0.00076	0.00001	0.0
b	0.300	0.90684	0.00025	0.00119	1.6
b	0.305	0.90524	0.00073	-0.00041	-0.6
b	0.308	0.90455	0.00074	-0.00110	-1.5
c	0.290	0.90646	0.00073	0.00081	1.1
c	0.295	0.90528	0.00033	-0.00037	-0.5
c	0.300	0.90456	0.00077	-0.00109	-1.5
c	0.305	0.90657	0.00072	0.00092	1.2
c	0.308	0.90539	0.00073	-0.00026	-0.4
d	0.290	0.90562	0.00072	-0.00003	0.0
d	0.295	0.90685	0.00033	0.00120	1.6
d	0.300	0.90606	0.00076	0.00041	0.6
d	0.305	0.90493	0.00077	-0.00072	-1.0
d	0.308	0.90522	0.00074	-0.00043	-0.6
e	0.290	0.90711	0.00018	0.00146	1.97
e	0.295	0.90648	0.00033	0.00083	1.1
e	0.300	0.90606	0.00076	0.00041	0.6
e	0.305	0.90493	0.00077	-0.00072	-1.0
e	0.308	0.90522	0.00074	-0.00043	-0.6

Table 6.4.1-9 Yankee-MPC United Nuclear Type A Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff} / \sigma$
01	0.90152	0.00123	-0.02747	-23.5
01	0.90069	0.00106	-0.02830	-24.2
02	0.89986	0.00121	-0.02913	-24.9
02	0.89967	0.00115	-0.02932	-25.1
04	0.90466	0.00123	-0.02433	-20.8
04	0.90459	0.00113	-0.02440	-20.9
08	0.91344	0.00119	-0.01555	-13.3
08	0.91342	0.00121	-0.01557	-13.3
12	0.91483	0.00108	-0.01416	-12.1
12	0.91930	0.00117	-0.00969	-8.3
16	0.92239	0.00116	-0.00660	-5.6
16	0.91899	0.00113	-0.01000	-8.5
20	0.92612	0.00111	-0.00287	-2.5
20	0.92833	0.00116	-0.00066	-0.6
20	0.92899	0.00117	-----	-----
20	0.92666	0.00109	-0.00233	-2.0

Table 6.4.1-10 Yankee-MPC United Nuclear Type B Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
01	0.90235	0.00121	-0.02593	-20.9
01	0.89816	0.00114	-0.03012	-24.3
02	0.90229	0.00108	-0.02599	-21.0
02	0.90113	0.00113	-0.02715	-21.9
04	0.90507	0.00111	-0.02321	-18.7
04	0.90569	0.00115	-0.02259	-18.2
08	0.91027	0.00118	-0.01801	-14.5
08	0.91210	0.00113	-0.01618	-13.0
12	0.91777	0.00121	-0.01051	-8.5
12	0.91751	0.00125	-0.01077	-8.7
16	0.92272	0.00120	-0.00556	-4.5
16	0.91744	0.00115	-0.01084	-8.7
20	0.92800	0.00118	-0.00028	-0.2
20	0.92603	0.00119	-0.00225	-1.8
20	0.92626	0.00115	-0.00202	-1.6
20	0.92828	0.00124	-----	-----

Table 6.4.1-11 Yankee-MPC Combustion Engineering Type A Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff} / \sigma$
01	0.89413	0.00114	-0.02906	-24.6
01	0.89648	0.00109	-0.02671	-22.6
02	0.89594	0.00115	-0.02725	-23.1
02	0.89507	0.00117	-0.02812	-23.8
04	0.90229	0.00109	-0.02090	-17.7
04	0.90108	0.00113	-0.02211	-18.7
08	0.90533	0.00116	-0.01786	-15.1
08	0.90612	0.00108	-0.01707	-14.5
12	0.90941	0.00114	-0.01378	-11.7
12	0.91232	0.00118	-0.01087	-9.2
16	0.91807	0.00114	-0.00512	-4.3
16	0.91282	0.00115	-0.01037	-8.8
20	0.92263	0.00117	-0.00056	-0.5
20	0.92042	0.00114	-0.00277	-2.3
20	0.92212	0.0012	-0.00107	-0.9
20	0.92319	0.00118	-----	-----

Table 6.4.1-12 Yankee-MPC Combustion Engineering Type B Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff} / \sigma$
01	0.89397	0.00114	-0.02997	-25.8
01	0.89481	0.00118	-0.02913	-25.1
02	0.89584	0.00119	-0.02810	-24.2
02	0.89697	0.00122	-0.02697	-23.2
04	0.90213	0.00120	-0.02181	-18.8
04	0.90048	0.00115	-0.02346	-20.2
08	0.90822	0.00114	-0.01572	-13.6
08	0.90661	0.00121	-0.01733	-14.9
12	0.90993	0.00113	-0.01401	-12.1
12	0.91239	0.00122	-0.01155	-10.0
16	0.9178	0.00116	-0.00614	-5.3
16	0.91421	0.00112	-0.00973	-8.4
20	0.92254	0.00114	-0.00140	-1.2
20	0.91982	0.00119	-0.00412	-3.6
20	0.92394	0.00116	-----	-----
20	0.9221	0.00116	-0.00184	-1.6

Table 6.4.1-13 Yankee-MPC Exxon Type A Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff} / \sigma$
01	0.89171	0.00118	-0.02705	-23.9
01	0.88843	0.00119	-0.03033	-26.8
02	0.88992	0.00107	-0.02884	-25.5
02	0.89274	0.00108	-0.02602	-23.0
04	0.89287	0.00115	-0.02589	-22.9
04	0.89416	0.00112	-0.02460	-21.8
08	0.90302	0.00116	-0.01574	-13.9
08	0.89969	0.00116	-0.01907	-16.9
12	0.90492	0.00123	-0.01384	-12.2
12	0.90812	0.00102	-0.01064	-9.4
16	0.91225	0.00125	-0.00651	-5.8
16	0.90747	0.00112	-0.01129	-10.0
20	0.91876	0.00113	-----	-----
20	0.91425	0.00114	-0.00451	-4.0
20	0.91498	0.00116	-0.00378	-3.3
20	0.91687	0.00115	-0.00189	-1.7

Table 6.4.1-14 Yankee-MPC Exxon Type B Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
01	0.89017	0.00113	-0.02604	-24.8
01	0.89000	0.00112	-0.02621	-25.0
02	0.89067	0.00109	-0.02554	-24.3
02	0.88884	0.00111	-0.02737	-26.1
04	0.89334	0.00119	-0.02287	-21.8
04	0.89293	0.00114	-0.02328	-22.2
08	0.89925	0.00115	-0.01696	-16.2
08	0.90053	0.00110	-0.01568	-14.9
12	0.90562	0.00115	-0.01059	-10.1
12	0.90544	0.00120	-0.01077	-10.3
16	0.90952	0.00121	-0.00669	-6.4
16	0.90679	0.00121	-0.00942	-9.0
20	0.91433	0.00116	-0.00188	-1.8
20	0.91254	0.00115	-0.00367	-3.5
20	0.91183	0.00118	-0.00438	-4.2
20	0.91621	0.00105	-----	-----

Table 6.4.1-15 Yankee-MPC Westinghouse Type A Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff} / \sigma$
01	0.86696	0.00109	-0.02844	-26.8
01	0.86502	0.00112	-0.03038	-28.7
02	0.86736	0.00102	-0.02804	-26.5
02	0.86715	0.00107	-0.02825	-26.7
04	0.87038	0.00105	-0.02502	-23.6
04	0.87110	0.00109	-0.02430	-22.9
08	0.87648	0.00105	-0.01892	-17.8
08	0.87746	0.00107	-0.01794	-16.9
12	0.88039	0.00108	-0.01501	-14.2
12	0.88512	0.00104	-0.01028	-9.7
16	0.88957	0.00113	-0.00583	-5.5
16	0.88917	0.00107	-0.00623	-5.9
20	0.89458	0.00113	-0.00082	-0.8
20	0.89429	0.00109	-0.00111	-1.0
20	0.89540	0.00106	-----	-----
20	0.89514	0.00108	-0.00026	-0.2

Table 6.4.1-16 Yankee-MPC Westinghouse Type B Removed Rod Results

# of Removed Rods	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
01	0.86772	0.00108	-0.02809	-26.8
01	0.86720	0.00108	-0.02861	-27.2
02	0.86832	0.00105	-0.02749	-26.2
02	0.87009	0.00110	-0.02572	-24.5
04	0.87128	0.00107	-0.02453	-23.4
04	0.87058	0.00109	-0.02523	-24.0
08	0.87938	0.00110	-0.01643	-15.6
08	0.87817	0.00109	-0.01764	-16.8
12	0.88366	0.00110	-0.01215	-11.6
12	0.88429	0.00106	-0.01152	-11.0
16	0.88829	0.00099	-0.00752	-7.2
16	0.88933	0.00109	-0.00648	-6.2
20	0.89565	0.00108	-0.00016	-0.2
20	0.89233	0.00106	-0.00348	-3.3
20	0.89581	0.00105	-----	-----
20	0.89384	0.00109	-0.00197	-1.9

Table 6.4.1-17 Yankee-MPC Damaged Fuel Can Results of Fuel-Water Mixture Between Rods

Volume Fraction of UO_2 in Water	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
0.0	0.92480	0.00073	-----	-----
0.1	0.91083	0.00072	-0.01397	-19.1
0.2	0.90715	0.00074	-0.01765	-24.2
0.3	0.90313	0.00073	-0.02167	-29.7
0.4	0.89873	0.00074	-0.02607	-35.7
0.5	0.89733	0.00076	-0.02747	-37.6
0.6	0.89611	0.00073	-0.02869	-39.3
0.7	0.89504	0.00073	-0.02976	-40.8
0.8	0.89374	0.00071	-0.03106	-42.5
0.9	0.89411	0.00074	-0.03069	-42.0
1.0	0.89292	0.00074	-0.03188	-43.7

Table 6.4.1-18 Yankee-MPC Damaged Fuel Can Analysis Results of Fuel-Water Mixture Outside Neutron Absorber Coverage – 30 cm Exposed

Height of Top & Bottom Exposed Regions (cm)	Volume Fraction of UO_2 in Water	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
30	0.0	0.91886[1]	0.00074	-----	-----
30	0.1	0.91710	0.00074	-0.00171	-2.4
30	0.2	0.91872	0.00074	-0.00009	-0.1
30	0.3	0.91753	0.00071	-0.00128	-1.8
30	0.4	0.91921	0.00073	0.00040	0.6
30	0.5	0.91811	0.00076	-0.00070	-1.0
30	0.6	0.91826	0.00077	-0.00055	-0.8
30	0.7	0.91984	0.00074	0.00103	1.5
30	0.8	0.91807	0.00074	-0.00074	-1.0
30	0.9	0.91827	0.00074	-0.00054	-0.8
30	1.0	0.91874	0.00076	-0.00007	-0.1

Notes:
1. Lower in reactivity than the 0% volume fraction case in Table 6.4.1-17 due to axial leakage from finite basket height model.

Table 6.4.1-19 Yankee-MPC Damaged Fuel Can Analysis Results of Fuel-Water Mixture Outside Neutron Absorber Coverage – 15 cm Exposed

Height of Top & Bottom Exposed Regions (cm)	Volume Fraction of UO_2 in Water	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
15	0.0	0.91763[1]	0.00073	-----	-----
15	0.1	0.91966	0.00073	0.00203	2.8
15	0.2	0.91791	0.00076	0.00028	0.4
15	0.3	0.91946	0.00073	0.00183	2.5
15	0.4	0.91846	0.00076	0.00083	1.1
15	0.5	0.91828	0.00074	0.00065	0.9
15	0.6	0.91770	0.00072	0.00007	0.1
15	0.7	0.91746	0.00071	-0.00017	-0.2
15	0.8	0.91753	0.00075	-0.00010	-0.1
15	0.9	0.91948	0.00074	0.00185	2.5
15	1.0	0.91881	0.00071	0.00118	1.6

Notes:
1. Lower in reactivity than the 0% volume fraction case in Table 6.4.1-17 due to axial leakage from finite basket height model.

Table 6.4.1-20 Yankee-MPC Damaged Fuel Can Preferential Flooding Analysis

Moderator Density					
TSC	Fuel Can	k_{eff}	σ	Δk_{eff}	$\Delta k_{eff}/\sigma$
1.0	1.0	0.92480[1]	0.00073	-----	-----
0.0	1.0	0.89988	0.00076	-0.02492	-34.1
0.1	1.0	0.85082	0.00064	-0.07398	-101.3
0.2	1.0	0.84184	0.00071	-0.08296	-113.6
0.3	1.0	0.84192	0.00068	-0.08288	-113.5
0.4	1.0	0.84910	0.00073	-0.07570	-103.7
0.5	1.0	0.85830	0.00072	-0.06650	-91.1
0.6	1.0	0.86870	0.00072	-0.05610	-76.8
0.7	1.0	0.88328	0.00073	-0.04152	-56.9
0.8	1.0	0.89573	0.00074	-0.02907	-39.8
0.9	1.0	0.90964	0.00075	-0.01516	-20.8
1.0	0.0	0.88624	0.00071	-0.03856	-52.8
1.0	0.1	0.88708	0.00076	-0.03772	-51.7
1.0	0.2	0.88879	0.00073	-0.03601	-49.3
1.0	0.3	0.89028	0.00070	-0.03452	-47.3
1.0	0.4	0.89134	0.00074	-0.03346	-45.8
1.0	0.5	0.89500	0.00076	-0.02980	-40.8
1.0	0.6	0.89672	0.00075	-0.02808	-38.5
1.0	0.7	0.90249	0.00076	-0.02231	-30.6
1.0	0.8	0.90933	0.00073	-0.01547	-21.2
1.0	0.9	0.91511	0.00074	-0.00969	-13.3

1. Base case from Table 6.4.1-17 with 0.0 UO_2 in H_2O.

6.4.2 CY-MPC Calculational Method

The criticality evaluation of the CY-MPC is performed using the MONK8A (AEA Technology) Monte Carlo Program for Nuclear Criticality Safety Analysis. The code employs JEF 2.2 point energy neutron cross-section libraries. Calculations are performed for the normal operating and accident conditions (contingencies), which includes optimum moderation. The evaluation considers the CY-MPC transfer cask loaded with intact fuel assemblies, assemblies with Reactor Control Cluster Assemblies or Flow Mixers, fuel debris within CY-MPC reconfigured fuel assemblies and damaged fuel cans containing fuel assemblies with damaged cladding. Bounding fuel assembly dimensions, conservative basket dimensions, radial shifting of the fuel and the fuel basket, partial flooding of the canister and optimum moderation are also considered.

The individual MONK calculations execute until the standard deviation of the final result is less than or equal to 0.0008 for each of the configurations analyzed. Upon completion of each set of analyses, a reactivity comparison is made to determine the most reactive configuration.

6.4.2.1 Connecticut Yankee Fuel Loading Optimization

The 26-assembly basket configuration represents a canister/cask fully loaded with 26 design basis fuel assemblies, except the Westinghouse Vantage 5H fuel assemblies. The 24-assembly basket configuration represents a canister/cask loaded with 24 design basis Vantage 5H fuel assemblies. The two baskets are identical, except that 2 loading positions of the 26-assembly basket are blocked to create the 24-assembly basket. The blocked fuel positions cannot be loaded. The models use a reflecting boundary condition on the radial surface of the transfer cask and periodic boundary conditions on the top and bottom. These conditions bound an infinite three-dimensional array of casks.

6.4.2.2 Connecticut Yankee Fuel Criticality Results

This section establishes the most reactive CY-MPC contents and the most reactive loading for each basket configuration. These results are used to calculate the effective neutron multiplication factor for the transfer cask assuming full moderation.

6.4.2.2.1 Connecticut Yankee Fuel Most Reactive Assembly

Each of the Connecticut Yankee fuel assembly design groupings shown in Table 6.2.2-1 is evaluated in the fully flooded 26-assembly basket configuration. The basket is configured assuming centered basket components with nominal dimensions. For each design grouping, the

bounding fuel assembly dimensions that serve to increase moderation within the active fuel region are considered. To maximize moderation, the fuel pellet/clad gap is assumed to be flooded, and the maximum fuel rod pitch is used in conjunction with the minimum clad outer diameter and cladding thickness. To maximize the fuel volume, the maximum active fuel length is used for each design grouping. Fuel pellet diameter studies are also performed. Maximizing the fuel pellet diameter is not necessarily conservative, since the increased fuel volume displaces moderator in the flooded pellet/clad gap. In order to standardize the comparison, each assembly is evaluated with the UO_2 at 95% theoretical density.

Table 6.4.2-1 presents the results for each of the fuel assembly design groupings at three different pellet outer diameters. The pellet diameters are labeled minimum, middle and maximum and were established based on the variations of the pellet diameters within each of the design groups. The results of the evaluation demonstrates that the reactivity of the Westinghouse Vantage 5H fuel assemblies at a maximum initial enrichment of 4.61 wt % ^{235}U in the 26-assembly basket configuration is 0.9460, which exceeds the upper subcritical limit of 0.9425 (Section 6.5.2), even though significant subcritical margin remains. As a result, Zircaloy-clad fuel enriched over 3.93 wt % ^{235}U may be loaded only in the 24-assembly basket configuration. Disk openings 12 and 15 in Figure 6.3.2-1 are blocked in the 24-assembly basket configuration because removing the fuel assemblies from these locations results in a maximum separation of fuel assemblies and provides the largest reactivity savings. The k_{eff} of the 4.61 wt % Zircaloy-clad Westinghouse Vantage 5H fuel assemblies centered in the 24-assembly basket configuration is 0.9197, compared to 0.9460 in the 26-assembly basket.

For the 26-assembly basket configuration, the Zircaloy-clad fuel enriched to 3.93 wt % ^{235}U bounds all stainless steel-clad fuel and the lower enrichment Zircaloy-clad fuel. The remaining analyses are, therefore, performed with either the 24-assembly basket configuration containing 4.61 wt % ^{235}U Zircaloy-clad fuel assemblies, or the 26-assembly basket configuration containing 3.93 wt % ^{235}U Zircaloy-clad fuel assemblies. As shown in Table 6.4.2-1, no statistically significant differences in reactivity (i.e., greater than 2σ or 0.0016 Δk_{eff}) result from the pellet diameter variations. Therefore, further analyses will use the largest pellet diameter, as this maximizes the fuel within the system.

The CY-MPC reconfigured fuel assembly with the most reactive fuel rods is also explicitly modeled in the 26-assembly basket configuration. As shown in Section 6.4.2.2.6, detailed studies are performed demonstrating that the CY-MPC reconfigured fuel assembly containing fuel material enriched to 4.61 wt % ^{235}U is lower in reactivity than intact fuel assemblies.

6.4.2.2.2 Connecticut Yankee Fuel Most Reactive Mechanical Configuration

Evaluations of the effect of basket dimensional perturbations are made using the 26-assembly and 24-assembly basket configurations, along with the design basis 3.93 and 4.61 wt % ^{235}U Zircaloy-clad fuel assemblies, respectively. These criticality analyses determine the most reactive basket mechanical configurations by altering the nominal model dimensional parameters and comparing the perturbed k_{eff} to the nominal result. If Δk_{eff} ($k_{perturbed}$ - $k_{nominal}$) is positive, the tolerance causes an increase in reactivity. Conversely, if Δk_{eff} is negative, the tolerance causes a decrease in reactivity. Two types of perturbations are assessed in these evaluations: fabrication tolerances and component movement within the basket.

Fabrication Tolerances

Five major fabrication tolerances are evaluated: the fuel tube opening size (± 0.03 inch), the disk opening size (± 0.015 inch) and center location within 0.015 inch, and the neutron poison sheet length and width (± 0.06 inch). The tolerances associated with each component are independently analyzed with assemblies centered in the fuel tubes and with the fuel tubes centered in the disk openings. A 26-assembly basket configuration with the design basis Zircaloy-clad fuel enriched to 4.61 wt % ^{235}U is used in these analyses. This fuel assembly was conservatively used, since the most reactive loading will be more sensitive to variations in component dimensions than a less reactive loading. The modeled width of the BORAL sheet is decreased to 7.974 inches, from a minimum tolerance width of 8.17 inches, to account for shifting of the BORAL sheet or off-center placement on the side of the fuel tube. This dimension was calculated by determining the minimum width remaining on half the tube face due to shifting to the opposite side of the tube, then conservatively applying this distance to the entire BORAL sheet width. The modeled size of the tube is 8.75 inches, which is the maximum opening size.

Table 6.4.2-2 indicates that the most reactive set of basket tolerances are: maximum fuel tube opening and minimum neutron poison material. Increasing the fuel tube opening brings more moderator into the gap between the assembly and the tube, lowering the efficiency of the BORAL sheets and increasing the reactivity of the system.

Mechanical Perturbations

In addition to these basket tolerances, possible mechanical perturbations of the system are evaluated. Radial component shifting is analyzed to ensure that the system remains subcritical under shifted conditions. Axial shifting of components is not evaluated, since no design basis

storage or transfer conditions postulate the canister in a non-vertical configuration. However, to ensure that the active fuel is within the portion of the fuel tube covered by BORAL, a minimum distance to the fuel region from the base of the canister is specified as 3.8 inches in Table B2-3 of the Certificate of Compliance. Tolerances on the disk opening size are applied during the mechanical perturbation evaluation since an increased disk opening would provide additional movement space. The disk opening center location variance is applied since shifting the disk opening centers will allow increased interaction for the shifted tube and/or assembly. Disk opening center tolerances are applied in the same direction as the component shift studied.

Shifting analyses are performed for the 26-assembly basket configuration loaded with design basis Zircaloy-clad fuel enriched to 3.93 wt % ^{235}U, and for the 24-assembly basket configuration loaded with design basis Zircaloy-clad fuel enriched to 4.61 wt % ^{235}U. The results of these analyses are provided in Table 6.4.2-3 and Table 6.4.2-4 with the most reactive shifting patterns listed following the base case. The shifting patterns considered were evaluated toward various areas of the basket. The shifting patterns that produce the maximum reactivity for the 26-assembly and 24-assembly basket configurations are shown in Figure 6.4.2-1 and Figure 6.4.2-2, respectively. It should be noted that each fuel assembly, tube and disk opening are shifted in the direction indicated by the arrow.

Most Reactive Configuration Summary

Combining the worst-case fabrication tolerances with the worst-case shifting pattern produces the maximum reactivity systems for the 26-assembly and 24-assembly basket configurations. The k_{eff} values calculated for these worst-case scenarios are 0.9219 for the 26-assembly basket configuration and 0.9313 for the 24-assembly basket configuration. It should be noted that these combinations of fabrication tolerances and mechanical perturbations are highly unrealistic, and unlikely to occur during actual operations. However, by combining conservative assumptions, the most reactive credible configuration is bounded.

6.4.2.2.3 Connecticut Yankee Fuel Assemblies with Missing Fuel Rods

Some of the Connecticut Yankee fuel assemblies are missing individual fuel rods. The exact number and location of these missing rods differs from assembly to assembly. To determine a bounding reactivity for these assemblies, an analysis varying the number of rods removed from the 15 × 15 array is performed. This analysis uses the most reactive 24-assembly basket configuration loaded with Zircaloy-clad fuel assemblies enriched to 4.61 wt % ^{235}U. The

maximum reactivity resulting from loading assemblies with missing rods in this configuration bounds the maximum reactivity resulting from loading assemblies with the same missing rod geometry into other less reactive configurations such as the 26-assembly basket. Tolerances on basket components, as well as the most reactive shifting pattern for the 24-assembly basket configuration, are considered. For each case, all 24 assemblies have the same number and location of missing fuel rods. The results presented in Table 6.4.2-5 show that 24 rods missing from the array represents the bounding number of missing fuel rods for the CY fuel assemblies. Figure 6.4.2-3 shows the locations of the 24 fuel rods that were removed. In effect, this study has optimized the H/U ratio within all 24 undermoderated fuel assemblies and has resulted in a substantial increase in system reactivity. Hence, loading of assemblies with missing rods will be restricted to the four corner fuel tube locations (openings 1, 4, 23 and 26 as seen in Figure 6.3.2-1). This configuration results in a system reactivity of 0.9327 and corresponds to change in reactivity, Δk_{eff} = +0.0014, which is within the statistics of the code. Therefore, loading of assemblies with missing fuel rods into the four corner fuel tube locations does not significantly affect the overall reactivity of the CY-MPC system.

6.4.2.2.4 Connecticut Yankee Non-Fuel Hardware

The inventory of the Connecticut Yankee spent fuel pool contains both Reactor Control Cluster Assemblies and Flow Mixers. Either of these components may be placed within a fuel assembly for transfer and storage in the CY-MPC. Adding a Reactor Control Cluster Assembly into a fuel assembly displaces moderator in the guide tubes and slightly modifies the reflection material outside the top of the fuel region. As shown in Section 6.4.2.3, the Connecticut Yankee fuel assemblies are undermoderated. Therefore, removing moderator from the lattice decreases reactivity. The partial flooding evaluation in Section 6.4.2.3 demonstrates that removing the moderator above the active fuel region has no significant impact on cask reactivity. Therefore, replacing the water in the guide tubes above the active fuel region and a small portion of water above the upper end fitting with stainless steel from the Reactor Control Cluster Assembly or Flow Mixer would also not have a significant effect on the reactivity of the system.

6.4.2.2.5 Damaged Fuel Assembly Can Evaluation

A number of the fuel assemblies in the Connecticut Yankee spent fuel pool inventory may be classified as damaged, i.e., cladding damage greater than pinhole leaks or hairline cracks. These damaged fuel assemblies must be placed in a damaged fuel can prior to being loaded in the canister. This can has a screened opening in the base-plate and the top plate to permit drainage,

vacuum drying, and inerting of the can without releasing fissile material from the can. Prior to loading the assemblies with damaged fuel rods into the damaged fuel assembly can, all fuel must be within the confines of the fuel rod cladding. Damaged fuel assembly cans are physically restricted to the four oversized fuel tubes in the basket. Assemblies with damaged rods may be placed into a damaged fuel assembly can prior to being loaded into a basket. However, if the damaged fuel assembly cans are first installed in the basket, the damaged fuel should be loaded before loading the remaining (intact) fuel assemblies. This ensures that no fuel material is accidentally dispersed into other regions of the basket that contain fuel.

The evaluation of the CY-MPC 24-assembly basket loaded with 20 of the most reactive fuel assemblies and with 4 damaged fuel assembly cans is performed within the transfer cask. Connecticut Yankee 15 × 15 assemblies that have up to 204 damaged fuel rods are analyzed within the damaged fuel assembly can, considering 100% dispersal of the fuel from the rods. All loose fuel in each analysis is modeled as a homogeneous mixture of fuel and water in which the volume fractions of the fuel versus the water are varied from 0-1.0 and vice versa. The clad material of the damaged rods is conservatively ignored. The bottom of the can is assumed to be in contact with the canister floor. The top of the can lid assembly support ring is assumed to be in contact with canister lid. Thus, the can cavity height is conservatively extended. Figures 6.4.2-4 through Figure 6.4.2-7 show the damaged fuel assembly can model. The base case used for reactivity comparisons of these analyses is that of loading the can with an assembly in the most reactive missing rod array containing no damaged or loose fuel. This base case configuration results in a system reactivity, k_{eff}, of 0.9330 with a standard deviation of 0.0008.

First, loose fuel from the damaged fuel rods is distributed between the remaining rods of the assembly in each can. These remaining rods are conservatively assumed to be in the most reactive missing rod array. The results of this analysis, provided in Table 6.4.2-6, show that this scenario slightly decreases the reactivity of the system compared to just placing the most reactive missing rod array within each can. This due to the fact that adding fuel to the already optimized H/U ratio of the bounding missing rod array reduces the reactivity of the system as this effectively returns the system to an undermoderated state. Second, loose fuel is considered above and below the active fuel region of the most reactive missing rod array within each can. The results of this study, provided in Table 6.4.2-7, show that any possible mixture combination of fuel and water above and below the active fuel region will not significantly increase the reactivity of the system beyond that of the most reactive missing rod array within the can. Loose fuel is also considered to replace all contents of the CY damaged fuel assembly can in each oversized fuel tube location. The results of this study, provided in Table 6.4.2-8, show that any mixture of

fuel and water within the damaged fuel assembly can cavity will not significantly increase the reactivity of the system beyond that of placing an assembly in the most reactive missing rod array within each can.

The most reactive damaged fuel configuration occurs when the fully flooded 24-assembly basket configuration is loaded with 4 damaged fuel assembly cans, with each fully flooded can containing an assembly in the most reactive missing rod array. This configuration results in a system reactivity of 0.9330. This corresponds to a change in reactivity, $\Delta k_{eff} = -0.0017$, which is considered to be within the statistics of the code when compared to loading the 24-assembly basket configuration with 24 Westinghouse Vantage 5H assemblies. Loading the 26-assembly basket with 4 damaged fuel cans containing Zircaloy-clad fuel assemblies enriched up to 3.93 wt % ^{235}U or stainless steel clad fuel assemblies, either type with up 204 damaged fuel rods, would behave similarly. Therefore, loading the basket with damaged fuel assembly cans containing assemblies with up to 204 damaged rods does not affect the overall reactivity of the CY-MPC system as long as the enrichment of the fuel within each can is limited to that of the basket configuration in which it is loaded.

6.4.2.2.6 CY-MPC Reconfigured Fuel Assembly Evaluation

The Connecticut Yankee spent fuel pool inventory includes a number of individual fuel rods that have been removed from their host fuel assemblies and may be intact or damaged. The CY-MPC reconfigured fuel assembly is designed to accommodate these individual fuel rods, or other fuel debris. The key physical dimensions and limits on the fuel material to be stored are listed in Table 6.2.2-2. The CY-MPC reconfigured fuel assembly restricts the fuel rods to a 10 × 10 array of tubes that are captured between top and bottom tie-plates. The tie-plates have a smaller drain line at each tube. There is a screened drain reservoir below the bottom tie-plate. The analysis of the CY-MPC reconfigured fuel assembly assumes that the fuel rods contain fuel with an initial enrichment of 4.61 wt % ^{235}U. For conservatism, the fuel rod cladding is not modeled within each individual tube. The CY-MPC reconfigured fuel assembly is designed to be physically restricted to the four corner fuel tube locations. However, the analysis conservatively evaluated the assemblies in all 26 basket locations in order to demonstrate that the CY-MPC reconfigured fuel assembly design has a lower reactivity than either of the design basis intact fuel assembly configurations.

Four individual studies are performed to demonstrate that the CY-MPC reconfigured fuel assembly is bounded by the design basis intact fuel evaluation. The first study evaluates the

reactivity of the CY-MPC reconfigured fuel assembly as a function of the fuel pellet diameter within the tubes as shown in Table 6.4.2-9. The fuel pellet diameter inside each tube is decreased from the 1.2814 cm maximum. The reported variation in reactivity between diameters of 1.2814 cm and 1.27 cm is statistically insignificant. Therefore, the largest diameter is assumed to be the most reactive, as this maximizes the amount of fissile material in the system. The second study considers variations in water moderator density within the flooded canister, including within the CY-MPC reconfigured fuel assembly. Results for this moderator density study are shown in Table 6.4.2-10 and demonstrate that the effective full density moderator condition is the most reactive, and that the reactivity of the CY-MPC reconfigured fuel assembly is well below that of the design basis intact fuel assembly. The third study considers a homogeneous volume fraction study of a fuel-water mixture within each reconfigured fuel assembly tube. Results for this evaluation are shown in Table 6.4.2-11. Excluding the statistically insignificant variations in reactivity that occur for water volume fractions below 10%, the most reactive configuration is for the individual tubes completely filled with fuel material. The fourth study considers the reactivity impact of fuel debris in the drain lines and drain reservoir in the bottom end fitting, as depicted in Figure 6.4.2-8. In this figure, the drain lines in the bottom tie-plate are conservatively considered to be the same size as the tube. The results of this case, $k_{eff} = 0.9079$, shows that conservatively modeling the drain tubes beneath each of the tubes in the 10 × 10 array and the drain reservoir with solid fuel material surrounded by water results in the most reactive CY-MPC reconfigured fuel assembly configuration.

Comparison of the most reactive CY-MPC reconfigured fuel assembly case to either of the design basis intact fuel assembly payload cases demonstrates that the reactivity of the CY-MPC reconfigured fuel assembly is bounded by that of the design basis fuel assemblies. As an additional conservative margin, CY-MPC reconfigured fuel assemblies can be loaded only into the four corner locations in the fuel basket.

6.4.2.3 CY-MPC Transfer Cask Criticality Evaluation

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes an evaluation of the reactivity effects of moderator density variation inside the cask. The transfer cask model utilized combines the selection of the most reactive fuel assemblies, fabrication tolerances, and mechanical perturbations as described in Section 6.4.2.2.2. This conservative configuration is bounding for all postulated normal, off-normal and accident condition events,

and also conservatively considers intrusion of water moderator into the pellet/clad gap resulting from cladding failure. The results of the moderator density variation study in the transfer cask are shown in Table 6.4.2-12. The moderator density variations demonstrate that the most reactive configurations for both the 26-assembly and 24-assembly baskets occurs with full density water.

Preferential flooding of the canister cavity and the damaged fuel assembly can cavity are also considered. The transfer cask model utilized here combines the selection of the most reactive fuel assemblies, the most reactive damaged fuel assembly can contents, fabrication tolerances, and mechanical perturbations as described in Section 6.4.2.2.2 and 6.4.2.2.5. The results of this moderator density variation study within the transfer cask are shown in Table 6.4.2-12. The moderator density variations demonstrate that the most reactive configurations for both basket and the damaged fuel assembly cans occur with full density water.

When flooding or draining the canister, the water level inside the canister varies as a function of time. It is not instantaneously drained or filled with water. An additional analysis is performed to evaluate the reactivity effect on the system for the canister cavity flooded only to the top of the active fuel region. This scenario is analyzed to consider the potential increased neutron scattering in the top end of the canister that may result when water is not present in this region. This scenario is evaluated with the 26-assembly basket configuration, containing the 3.93 wt % ^{235}U, Zircaloy-clad fuel assemblies. A graphical illustration of the partially flooded basket is shown in Figure 6.4.2-9. This case produces a k_{eff} value of 0.9210, and the change in reactivity from the base case (Δk_{eff} = 0.0009), is statistically insignificant. Similar results would be expected from the 24-assembly basket configuration.

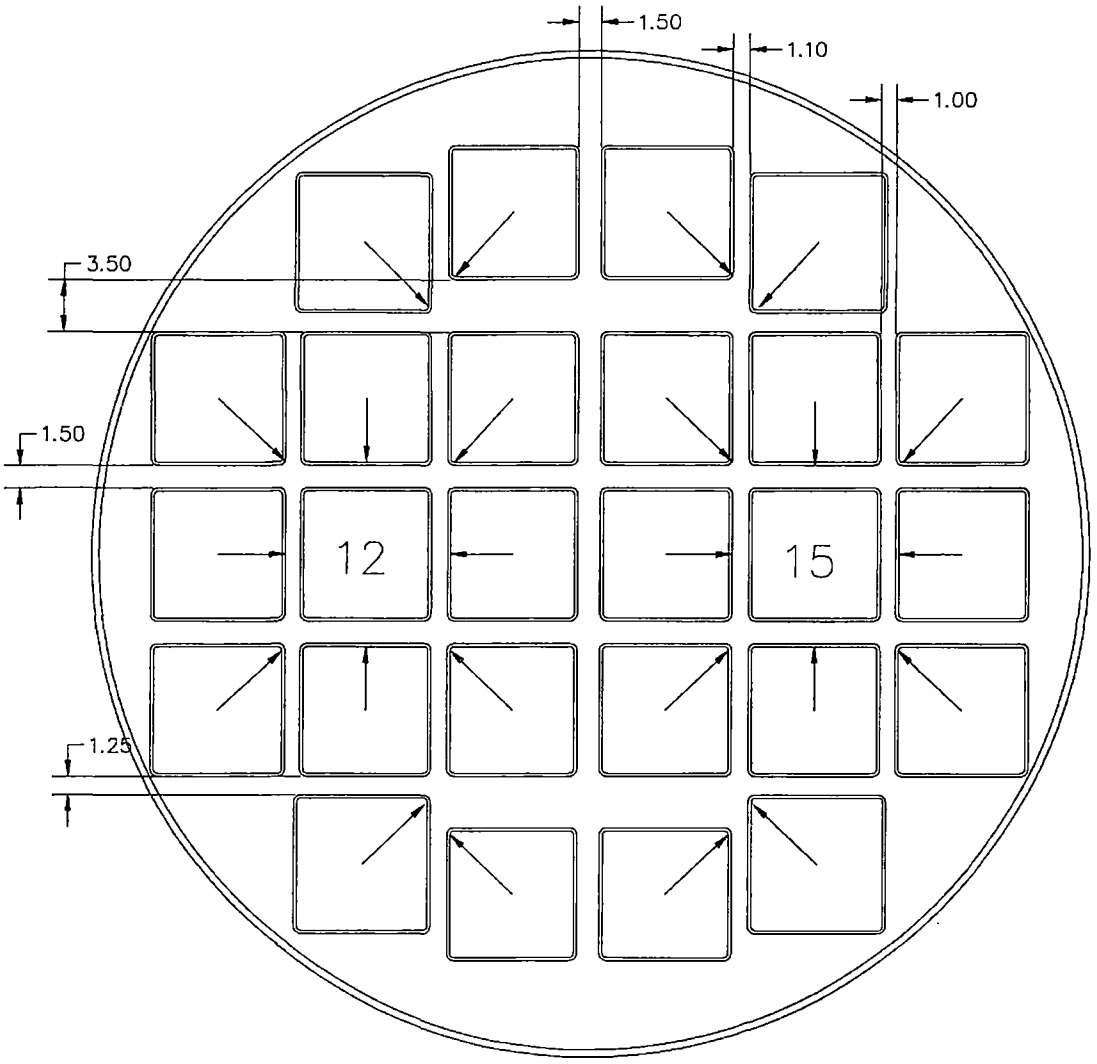
A case discretely modeling an uneven drain down condition is also evaluated. The geometry of this case is identical to the most reactive damaged fuel can configuration documented in Section 6.4.2.2.5 with the following exception. The canister cavity is modeled with full density moderator to a height approximately equal to the middle of the active fuel. The four damaged fuel cans are hypothetically assumed to remain fully flooded along the entire axial extent of each can. This represents the postulated uneven drain down condition for a canister containing damaged fuel cans. The calculated reactivity of this configuration, $k_{eff} \pm 2\sigma = 0.9259 \pm 0.0008$, is less than that of the fully flooded condition, demonstrating that the full canister flooding scenario is bounding. Similar results would be expected from the 26-assembly basket configuration.

As described in Section 6.4.2.2.1, the most reactive system configuration is the 24-assembly basket configuration loaded with the Westinghouse Vantage 5H Zircaloy-clad fuel assemblies with a maximum initial enrichment of 4.61 wt % ^{235}U. This configuration is evaluated against the subcritical upper safety limit of 0.9425. This produces a k_{eff} value of 0.9313. Including two standard deviations, this establishes a maximum reactivity ($k_{eff} + 2\sigma$) of 0.9329, which is less than the subcritical limit of 0.9425. The reduced MONK8A output file for this most reactive case is shown in Figure 6.7.2-1.

6.4.2.4 CY-MPC Storage Cask Criticality Evaluation

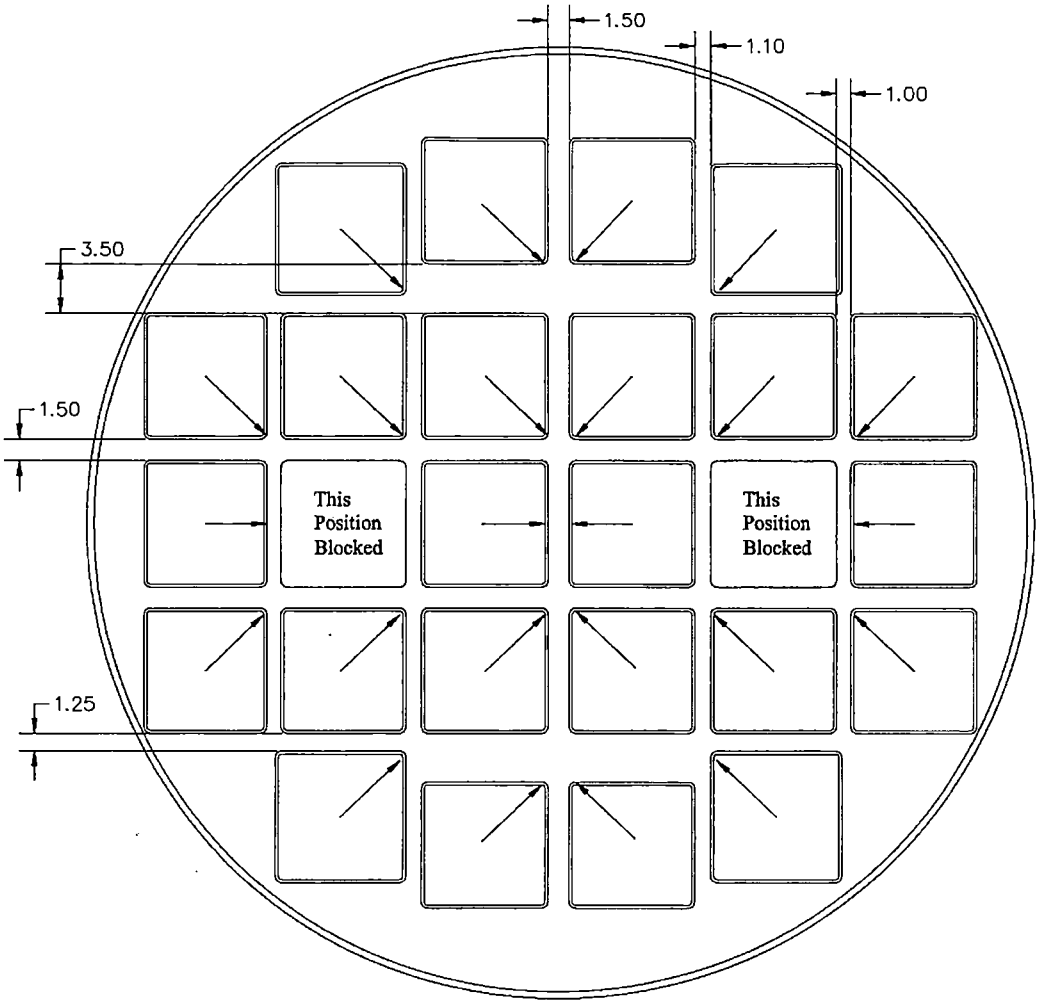
While in the storage cask, the canister maintains its confinement during all normal and accident conditions. This precludes any possible moderator intrusion into the canister while in the storage cask. As shown in the Yankee-MPC evaluation presented in Section 6.4.1, the reactivities of the fully flooded transfer cask and storage casks are identical within statistical uncertainty. For conservatism, the reactivities of the transfer cask calculation may, therefore, be applied to the concrete cask under the assumption of a hypothetical failure of the confinement boundary and flooding of the canister.

Figure 6.4.2-1 CY-MPC Maximum Reactivity Shifting Pattern – 26 Assembly Basket



(Units = inches, Not drawn to scale)

Figure 6.4.2-2 CY-MPC Maximum Reactivity Shifting Pattern – 24 Assembly Basket



(Units = inches, Not drawn to scale)

Figure 6.4.2-3 CY-MPC Most Reactive Missing Fuel Rod Geometry

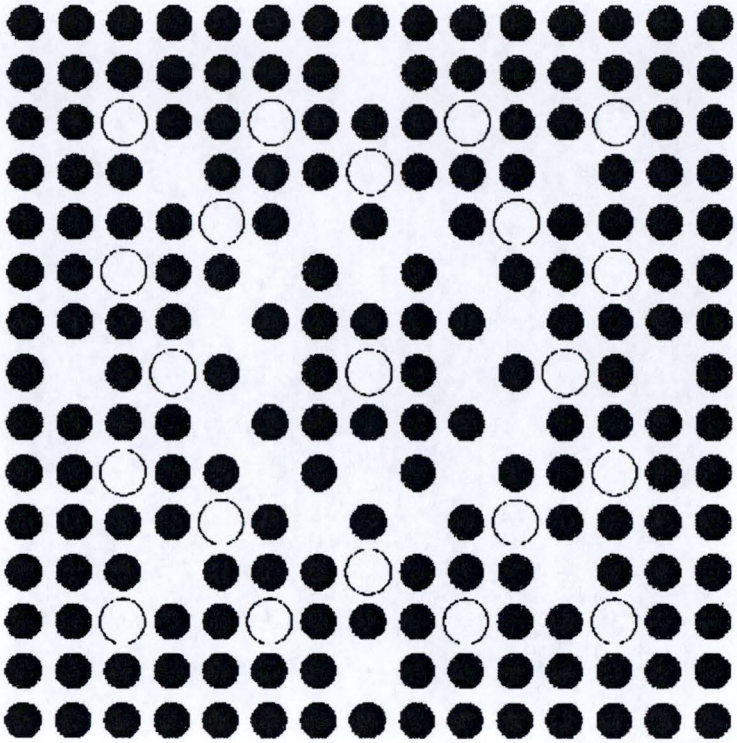


Figure 6.4.2-4 CY-MPC Shifted Can and Most Reactive Missing Rod Array

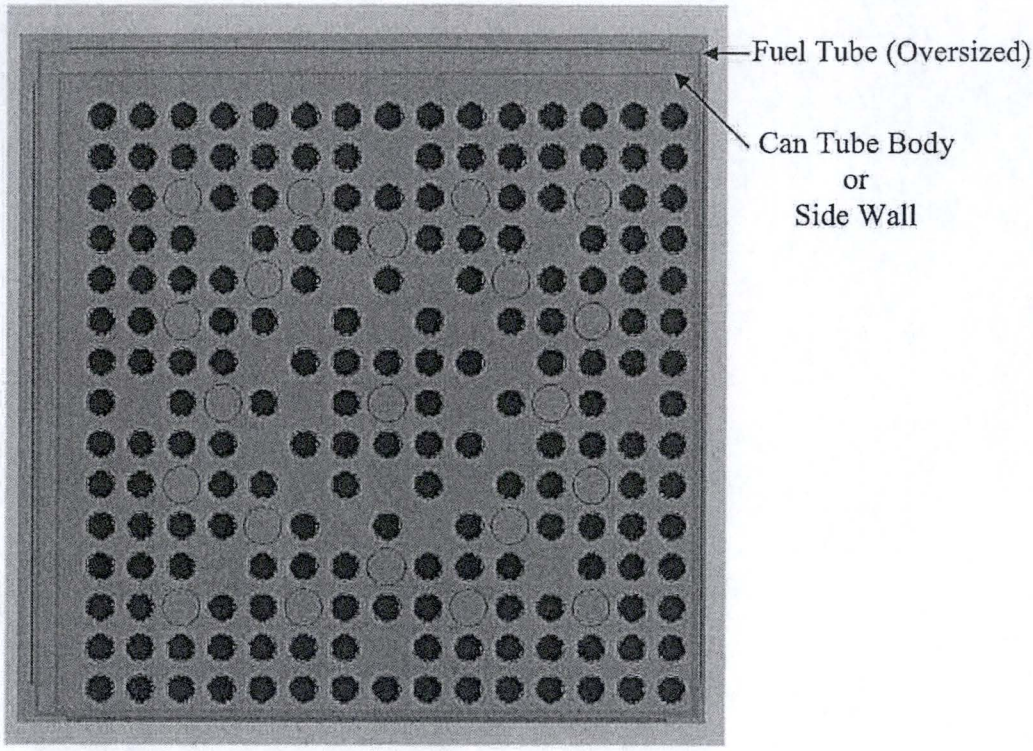


Figure 6.4.2-5 CY-MPC Model Geometry Below Active Fuel

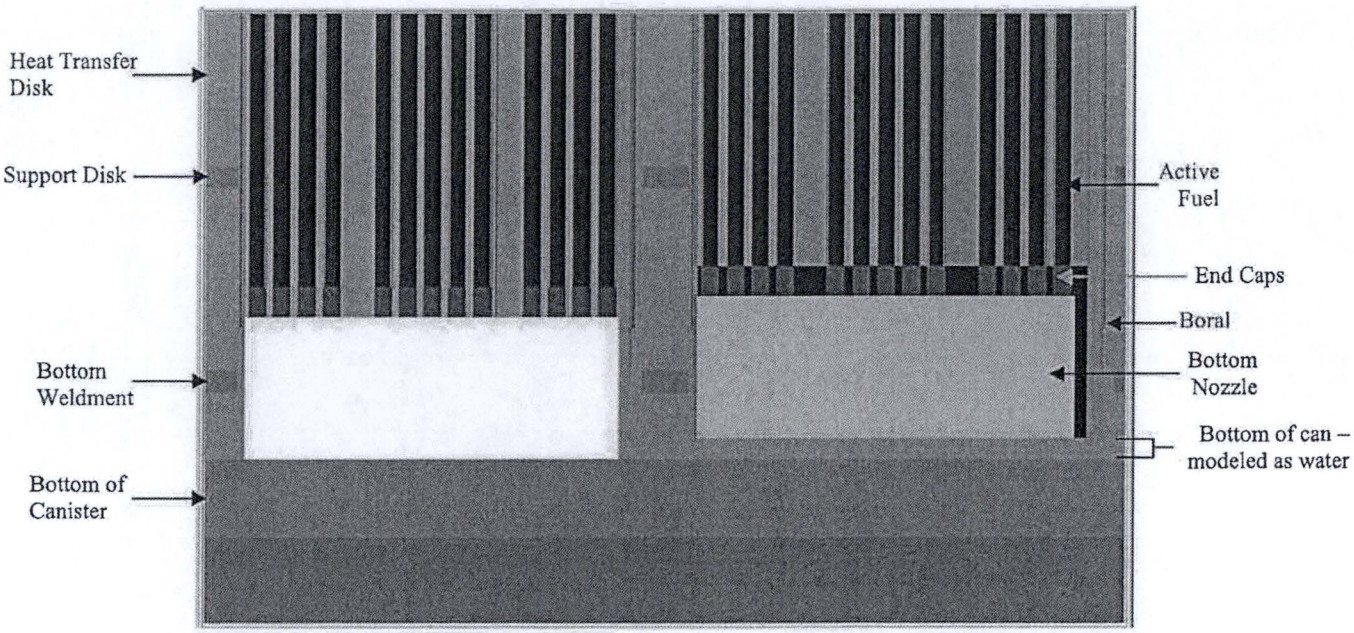


Figure 6.4.2-6 CY-MPC Model Geometry Above Active Fuel

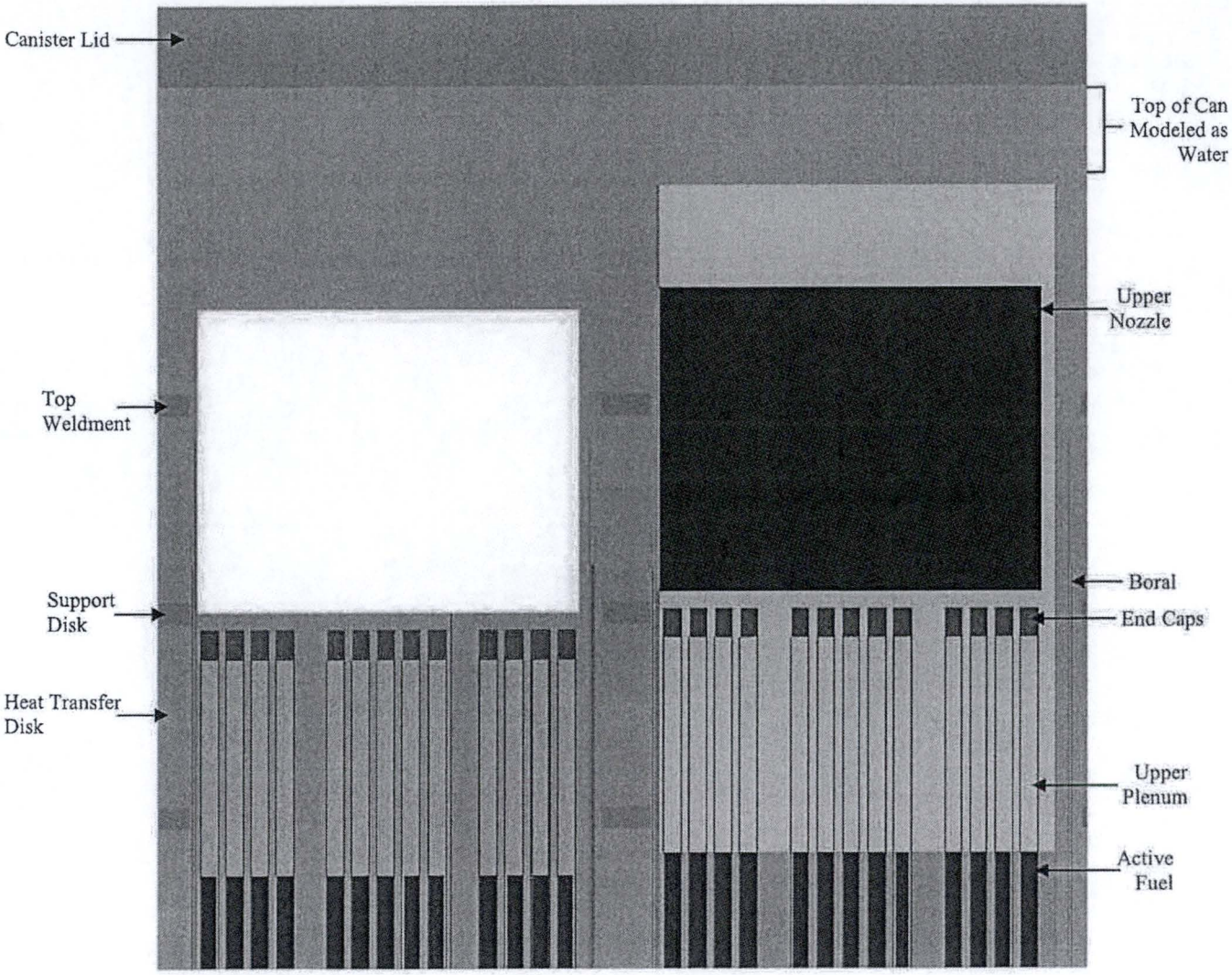


Figure 6.4.2-7 CY-MPC Model Slice of Two Corner Tubes with Cans and Two Middle Tubes

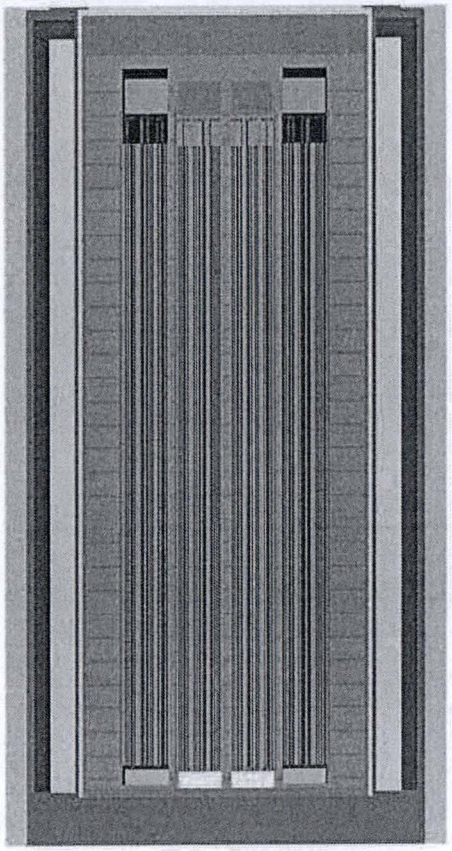


Figure 6.4.2-8 CY-MPC Reconfigured Fuel Assembly - Axial Model Configuration with Fuel in Drain Reservoir

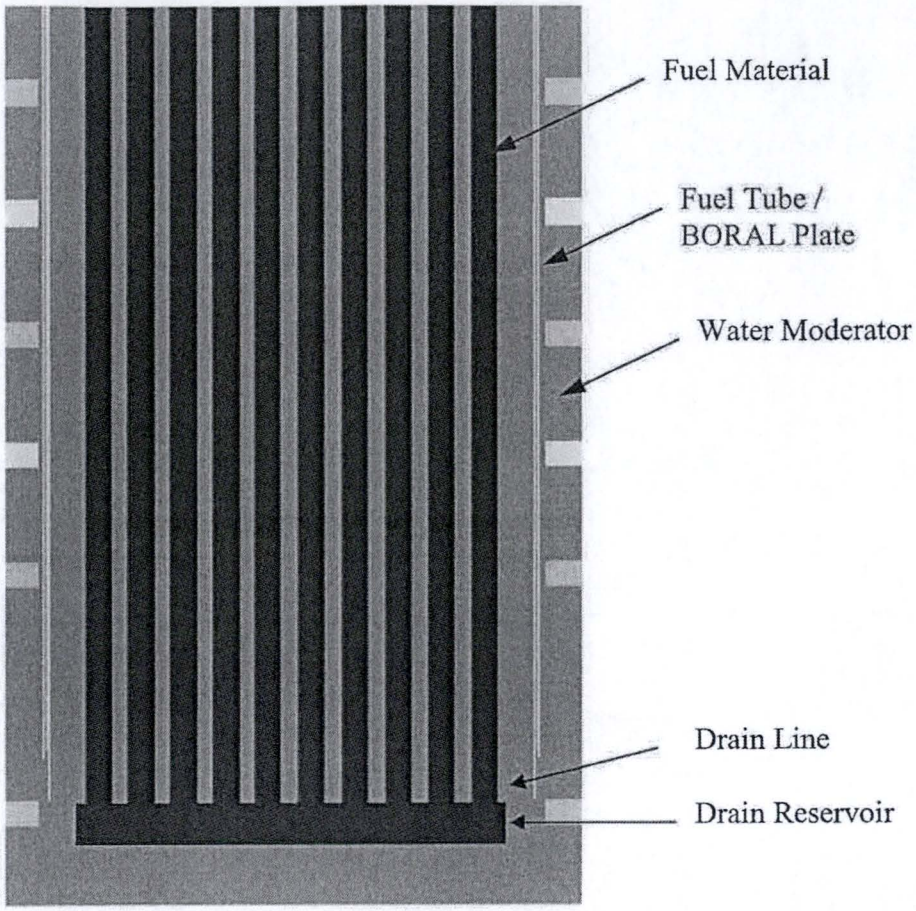


Figure 6.4.2-9 CY-MPC Partial Flooding Model – Top of Active Fuel Region Detail

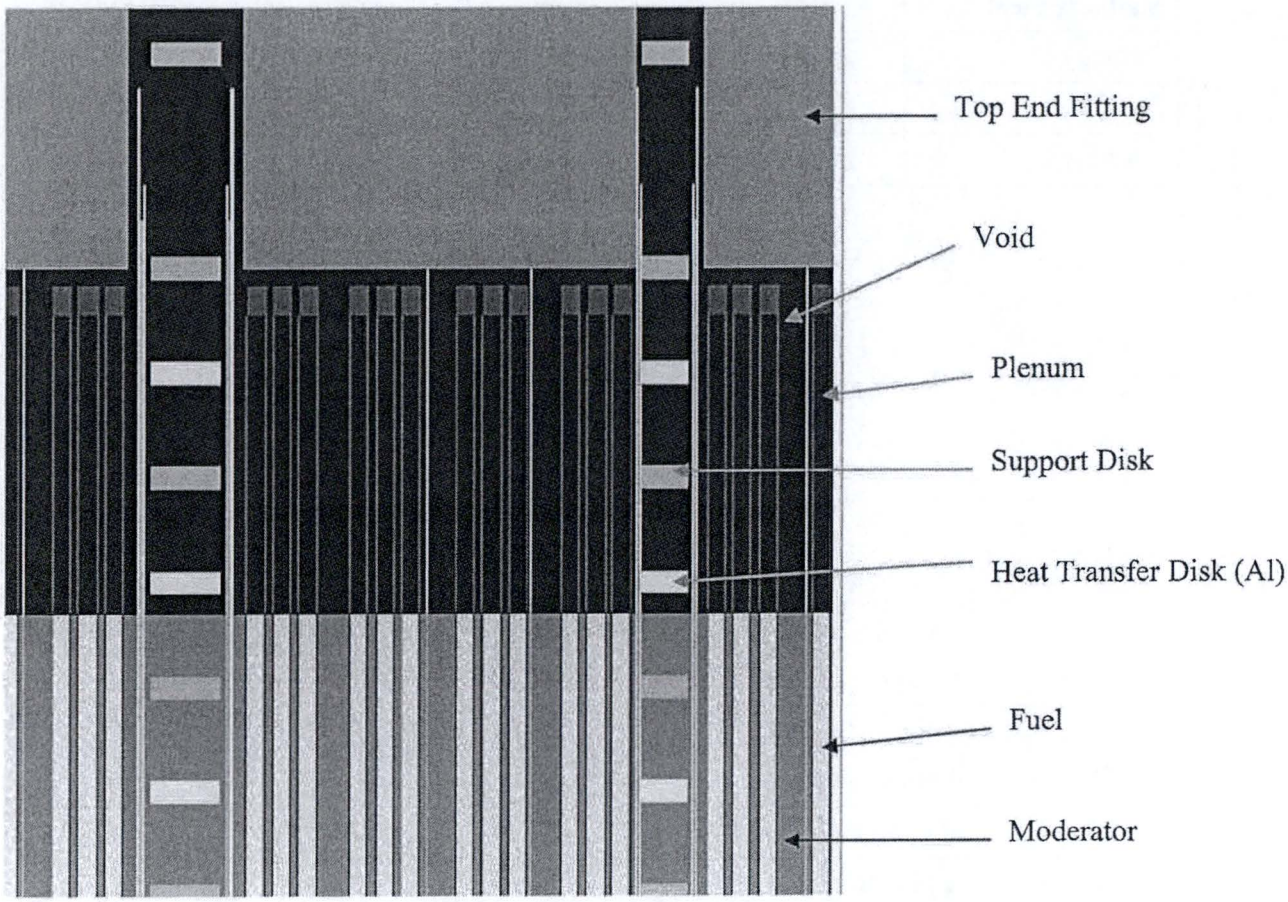


Table 6.4.2-1 Connecticut Yankee Most Reactive Fuel Assembly Evaluation

	Enrichment	k_{eff} - Flooded Gap		
		Min Pellet OD	Mid Pellet OD	Max Pellet OD
Stainless Steel	4.03	0.8898	0.8903	0.8904
Zircaloy	3.42	0.8840	0.8834	0.8824
Zircaloy	3.93	0.9073	0.9077	0.9064
Zircaloy	4.61	0.9454	0.9445	0.9460

Table 6.4.2-2 CY-MPC Fabrication Tolerance Evaluation

Model	k_{eff}	Δk_{eff}
Base Case	0.9460	N/A
BORAL sheet minus tolerances	0.9479	0.0019
Disk opening center minus tolerance	0.9456	-0.0004
Disk opening center plus tolerance	0.9454	-0.0006
Disk opening minus tolerance	0.9457	-0.0003
Disk opening plus tolerance	0.9434	-0.0026
Tube opening minus tolerance	0.9413	-0.0047
Tube opening plus tolerance	0.9500	0.0040
Combined BORAL sheet and tube opening tolerances	0.9494	0.0034

Note: The Base Case is 26 Zircaloy clad fuel assemblies with 4.61 wt % ^{235}U, maximum pellet diameter, centered in the tube openings.

Table 6.4.2-3 CY-MPC Mechanical Perturbation Evaluation – 26 Assembly Basket

Configuration	k_{eff}	Δk_{eff}
Base Case – No shift	0.9064	NA
Toward Openings 12 and 15	0.9153	0.0089
Toward Openings 13 and 14	0.9136	0.0072
9, 10, 15, 16 towards each other; 11, 12, 17, 18 towards each other; remaining openings towards 13 and 14	0.9129	0.0065
6, 12, 18 towards 11; 9, 15, 21 towards 16; remaining openings towards 13 and 14	0.9120	0.0056
2, 6, 12, 18, 24 towards 11; 3, 9, 15, 21, 25 towards 16; remaining openings towards 13 and 14	0.9119	0.0055
4 peripheral clusters targeting 1.1 inch gaps center row also targeting 1.1 inch gaps	0.9096	0.0032
6 peripheral clusters targeting 1.0 inch gaps; remaining openings (which are adjacent to 1.5 inch gap) towards 13 and 14	0.9089	0.0025
4 peripheral clusters targeting 1.1 inch gaps 3 clusters in center row	0.9081	0.0017

Note: The Base Case is 26 Zircaloy clad fuel assemblies with 3.93 wt % ^{235}U, maximum pellet diameter, maximum disk opening size, with the fuel, tubes and disk openings shifted as specified. Fuel position numbers are as shown in Figure 6.3.2-1.

Table 6.4.2-4 CY-MPC Mechanical Perturbation Evaluation – 24 Assembly Basket

Configuration	k_{eff}	Δk_{eff}
Base case - No shift	0.9197	NA
Toward Openings 13 and 14	0.9275	0.0078
4 peripheral clusters targeting 1.1 inch gaps; remaining openings towards 13 and 14	0.9261	0.0064
4 peripheral clusters targeting 1.1 inch gaps; remaining openings towards 1.5 inch gap	0.9260	0.0063
4 peripheral clusters targeting 1.0 inch gaps; remaining openings towards 13 and 14	0.9257	0.0060
Openings surrounding 12 or 15 towards 12 or 15, respectively; remaining openings towards 13 and 14	0.9226	0.0029
Openings surrounding 12 or 15 towards 12 or 15, respectively, remaining openings in 4 clusters targeting 1.1 inch gaps	0.9219	0.0022

Note: The Base Case is 24 Zircaloy clad fuel assemblies with 4.61 wt % ^{235}U, maximum pellet diameter, maximum disk opening size, with the fuel, tubes and disk openings shifted as specified. Fuel position numbers are as shown in Figure 6.3.2-1.

Table 6.4.2-5 CY-MPC Missing Fuel Rod Evaluation Results

Number of Missing Rods	k_{eff}	Δk_{eff}
0 (Base Case)	0.9313	NA
4	0.9396	0.0083
8	0.9376	0.0063
12	0.9401	0.0088
16	0.9413	0.0100
20	0.9441	0.0128
24	0.9464	0.0151
28	0.9444	0.0131
32	0.9439	0.0126
36	0.9463	0.0150
40	0.9453	0.0140
44	0.9399	0.0086
48	0.9396	0.0083
56	0.9384	0.0071

Note: The base case is 24 Zircaloy clad fuel assemblies with 4.61 wt % ^{235}U, maximum tube opening, minimum BORAL width, maximum pellet diameter, maximum disk opening size, with the fuel, tubes and disk openings 13 and 14.

Table 6.4.2-6 CY-MPC Mixture of Damaged Fuel and Water Within Active Fuel Region of Intact Rods in Each Can

V_f of UO_2	k_{eff}	Δk_{eff}
0.00	0.9330	NA
0.20	0.9300	-0.0030
0.40	0.9276	-0.0054
0.60	0.9257	-0.0073
0.80	0.9284	-0.0046
1.00	0.9263	-0.0067

Table 6.4.2-7 CY-MPC Mixture of Damaged Fuel and Water Outside Active Fuel Region of Intact Rods in Each Can

V_f of UO_2	k_{eff}	Δk_{eff}
0.00	0.9330	NA
0.20	0.9337	0.0007
0.40	0.9333	0.0003
0.60	0.9320	-0.0010
0.80	0.9310	-0.0020
1.00	0.9328	-0.0002

Table 6.4.2-8 CY-MPC Mixture of Damaged Fuel and Water Replacing Contents of Each Can

V_f of UO_2	k_{eff}	Δk_{eff}
NA	0.9330	NA
0.00	0.9258	-0.0072
0.20	0.9336	0.0006
0.40	0.9281	-0.0049
0.60	0.9288	-0.0042
0.80	0.9268	-0.0062
1.00	0.9266	-0.0064

Table 6.4.2-9 CY-MPC Reconfigured Fuel Assembly – Reactivity as a Function of Fuel Pellet Diameter

Fuel Diameter (cm)	k_{eff}
1.2814	0.9057
1.270	0.9059
1.250	0.9045
1.245	0.9049
1.240	0.9019
1.235	0.9023
1.230	0.9036
1.225	0.9009
1.200	0.8994
1.100	0.8812
1.000	0.8569

Table 6.4.2-10 CY-MPC Reconfigured Fuel Assembly – Reactivity as a Function of Moderator Density Variations

Moderator Density (g/cc)	k_{eff}
0.9982	0.9057
0.975	0.8990
0.95	0.8949
0.90	0.8800
0.85	0.8699
0.80	0.8587
0.60	0.8022
0.40	0.7245
0.20	0.5979
0.000001 (dry cask)	0.3756

Table 6.4.2-11 CY-MPC Reconfigured Fuel Assembly – Reactivity as a Function of Variations in Fuel/Water Homogeneous Mixture Volume Fractions

Water Volume Fraction	k_{eff}
0.00	0.9057
0.05	0.9032
0.06	0.9047
0.07	0.9059
0.08	0.9020
0.09	0.9020
0.10	0.9032
0.15	0.8986
0.20	0.8962
0.25	0.8931
0.30	0.8873
0.35	0.8831
0.40	0.8695
0.45	0.8618
0.50	0.8466
0.55	0.8305
0.60	0.8119
0.65	0.7846
0.70	0.7513
0.75	0.7095

Table 6.4.2-12 CY-MPC Transfer Cask Analyses – Reactivity as a Function of Moderator Density Variations

Water Density	26-Assembly Basket Configuration	24-Assembly Basket Configuration
(g/cc)	k_{eff}	k_{eff}
0.9982	0.9219	0.9313
0.95	0.9067	0.9173
0.90	0.8930	0.9006
0.85	0.8769	0.8818
0.80	0.8595	0.8622
0.60	0.7818	0.7767
0.40	0.6832	0.6729
0.20	0.5520	0.5500
0.000001 ~ 0.0	0.3555	0.3715

Table 6.4.2-13 CY-MPC Damaged Fuel Assembly Analyses – Reactivity as a Function of Moderator Density Variations

Moderator Density			
Canister	Can	k_{eff}	Δk_{eff}
1.00	1.00	0.9313	NA
1.00	0.00	0.9253	-0.0060
1.00	0.20	0.9263	-0.0050
1.00	0.40	0.9271	-0.0042
1.00	0.60	0.9264	-0.0049
1.00	0.80	0.9282	-0.0031
0.00	1.00	0.9149	-0.0164
0.20	1.00	0.8744	-0.0569
0.40	1.00	0.8692	-0.0621
0.60	1.00	0.8765	-0.0548
0.80	1.00	0.8892	-0.0421

6.5 Critical Benchmark Experiments

This section provides the validation of the computer codes used in the criticality evaluation of the Yankee-MPC and CY-MPC configurations of the NAC-MPC storage system. This validation is required by the criticality safety standards ANSI/ANS-8.1.

Section 6.5.1 describes the methodology, computer program and cross section libraries used, the experimental data, the areas of applicability and the bias and margins of safety applied in the SCALE 4.3 analysis package used in the evaluation of the Yankee-MPC. Section 6.5.2 describes the MONK8A code applied in the analysis of the CY-MPC.

ANSI/ANS-8.17 prescribes the criteria to establish sub-criticality safety margins. This criteria is:

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

where:

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

k_c = the mean k_{eff} that results from the calculation of the benchmark criticality experiments using a particular calculational method. If the calculated k_{eff} for the criticality experiments exhibit a trend with a parameter, then k_c shall be determined by extrapolation on the basis of a best fit to the calculated values. The 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 = an allowance for:

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

Δk_c = a margin for uncertainty in k_c, which includes allowance for:

(a) uncertainties in the critical experiments,

(b) statistical or convergence uncertainties, or both, in the computation of k_c,

(c) uncertainties due to extrapolation of k_c outside the range of experimental data, and

(d) uncertainties due to limitations in the geometrical or material representations used in the computational method.

Δk_m = an arbitrary margin to ensure the subcriticality of k_s.

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

The above equation 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 above equation 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, 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 criterion often used in the DOE criticality safety community.

Alternatively, this equation 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.

Both β and $\Delta\beta$ are evaluated in Section 6.5.1 for the Yankee-MPC and in Section 6.5.2 for the CY-MPC.

6.5.1 Benchmark Experiments and Applicability for Yankee Class Fuel

The criticality safety method is CSAS25 embedded in SCALE version 4.3 for the PC. CSAS25 includes: the SCALE Material Information Processor, BONAMI, NITAWL-II, 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 and NITAWL-II codes are used to prepare a resonance-corrected cross section library in AMPX working format. The KENO-Va code calculates the model k_{eff} using Monte Carlo techniques. The 27-group ENDF/B-IV neutron cross section library is used in this validation.

6.5.1.1 Description of Experiments

Sixty-three critical experiments were selected; nine Babcock and Wilcox (B&W) 2.46 wt % ^{235}U fuel storage (Baldwin), 10 Pacific Northwest Laboratory (PNL) 4.31 wt % ^{235}U lattice (Bierman, 1980), 21 PNL 2.35 and 4.31 wt % ^{235}U with metal reflectors (Bierman, 1979 & 1981), twelve PNL flux trap (Bierman 1980 and 1988) and 11 Valduc Critical Mass Laboratory (VCML) 4.74 wt % ^{235}U experiments, some involving moderator density variations (Manaranche). 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.

The experiments are evaluated using three-dimensional models, as close to the actual experiment as possible, to achieve accurate results. Stochastic Monte Carlo error is kept within ±0.1 percent 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, including Yankee Class, 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 diameters from 0.78 to 1.2 cm, rod outside diameters from 0.95 to 1.88 cm and pitches 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 are within the range of PWR fuel assemblies (1.6 to 2.32) and BWR fuel assemblies (1.6 to 1.9).

For Yankee Class fuel, the majority of the Zircaloy-clad fuel is enriched below 4.03 wt % ^{235}U. For the stainless steel-clad fuel, the maximum enrichment is 4.97 wt % ^{235}U, which is just outside the benchmark experimental range. However, the stainless steel-clad fuel is much less reactive than the Zircaloy-clad and is not limiting. Also, in the case of the Yankee Class fuel, the pellet diameter varies from 0.747 to 0.789 cm, the rod outside diameter varies from 0.864 to 0.927 cm and the pitch varies from 1.07 to 1.20 cm, and the resultant H/U volume ratio varies from 1.28 to 1.57. These fuel parameters are all slightly outside of the range of experiments, but given the lack of statistically significant trends as demonstrated in Figures 6.5.1-2 through 6.5.1-7, confidence in criticality prediction by extrapolation to the Yankee fuel parameters is high.

Experiments covered the geometry and neutron absorber sheet arrangements typical of NAC basket designs. This included flux trap gap spacings of 3.81 cm such as in the NAC-STC basket and gap spacing as low as 1.91 cm as in the Yankee-MPC. The ^{10}B neutron absorber loadings are also typical of NAC basket designs (0.005 to 0.025). The experiments covered the influence of water and metal reflector regions, including steel and lead, which are present in storage and transport cask shielding.

Confidence in predicting criticality, including bias and uncertainty, has been demonstrated for LWR fuel with enrichments up to 4.74 wt % ^{235}U and, based on the lack of significant trend with enrichment, confidence in extrapolating up to 4.97 wt % ^{235}U is high. Confidence in predicting criticality has been demonstrated for storage and transport arrays using flux trap or single neutron absorber sheet or simple spacing criticality control. Confidence in predicting criticality has been demonstrated for LWR fuel storage and transport arrays next to water and metal reflector regions.

6.5.1.3 Results of Benchmark Calculations

The k-effective results for the experiments are shown in Table 6.5.1-1, and a frequency distribution plot is provided in Figure 6.5.1-1. 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.

The overall average and standard deviation of the sixty-three cases is 0.9948 ± 0.0044. The average Monte Carlo error (statistical convergence) is ±0.0012 for the sixty-three cases. This uncertainty component is statistically subtracted from the uncertainties because it is previously included in the above standard deviation. The KENO-Va models are three-dimensional, fully explicit representations (no homogenization) of the experimental geometry. Therefore, the uncertainty due to 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 there are no extrapolations necessary outside of the range of data, and the uncertainty due to this is also taken to be 0.0. Based on 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 critical is β=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). This results in a 95/95 one-sided uncertainty in the bias of $\Delta\beta$=2.012x0.0043=0.0087. Equation 4 now becomes:

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

where Δk_s becomes the uncertainty in k_s due to Monte Carlo error, mechanical and material tolerances and geometric or material representations. If the nominal configuration of the system is evaluated for k_s, then the mechanical and material perturbation 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 in the calculations of k_s (e.g., the most reactive positioning of fuel or basket components and 75% of the specified minimum boron loading), then Δk_s becomes 0.0 and the Monte Carlo error, σ_{mc}, can be combined statistically, since it is independent, with the uncertainty in the bias as:

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

6.5.1.4 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 6.5.1-2 through 6.5.1-7. Included in these scatter plots are linear regression lines with a corresponding

correlation coefficient. This 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). Based on 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 Yankee-MPC basket.

6.5.1.5 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 is 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 6.5.1, 6.5.1.1 and 6.5.1.2.

NAC has performed an extensive LWR critical benchmarking as documented in Sections 6.5.1.1 and 6.5.1.2. 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:

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

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

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

where:

$$USL \equiv 1 - \Delta k_m - \beta - \Delta\beta \quad (5)$$

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

In the analyses presented in Section 6.5.1.1 and 6.5.1.2, the bias and uncertainties are applied directly to the estimate of the system k_{eff}. Noting that the NRC requires a 5% subcriticality margin ($\Delta k_m = 0.05$), Equation 3 can be rewritten applying the bias and uncertainty in the bias to the k_{eff} of the system being analyzed as:

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

In Equation 6, the method bias and all uncertainties are added to k_s. This is the maximum k_{eff} criterion defined in Section 6.5.1.2.

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 principal 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 Yankee-MPC 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 NAC evaluation found no strong correlation. This is based on the observation that the correlation coefficients are all much less than $\pm$ 1. Thus a constant bias with a 95/95 confidence factor is applied to the system k_{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 the USLSTATS computer code from NUREG/CR-6361, which is compared to the constant NAC bias and bias uncertainty used in Section 6.5.1.2.

To evaluate the relative importance of the trend analysis to the upper safety limits, correlation coefficients are required for all independent parameters. Table 6.5.1-2 contains the correlation coefficient, R, for each linear fit of k_{eff} versus experimental parameter (data is extracted from Figure 6.5.1-2 through Figure 6.5.1-7 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 6.5.1-8.

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 Yankee-MPC systems are calculated at enrichments well above this level, the existing bias bounds the NUREG calculated USL. The parameters of the most reactive fuel element analysis are presented in Table 6.5.1-3.

Figure 6.5.1-1 KENO-Va Validation - #27-Group Library Results Frequency Distribution of k_{eff} Values for Yankee Class Fuel

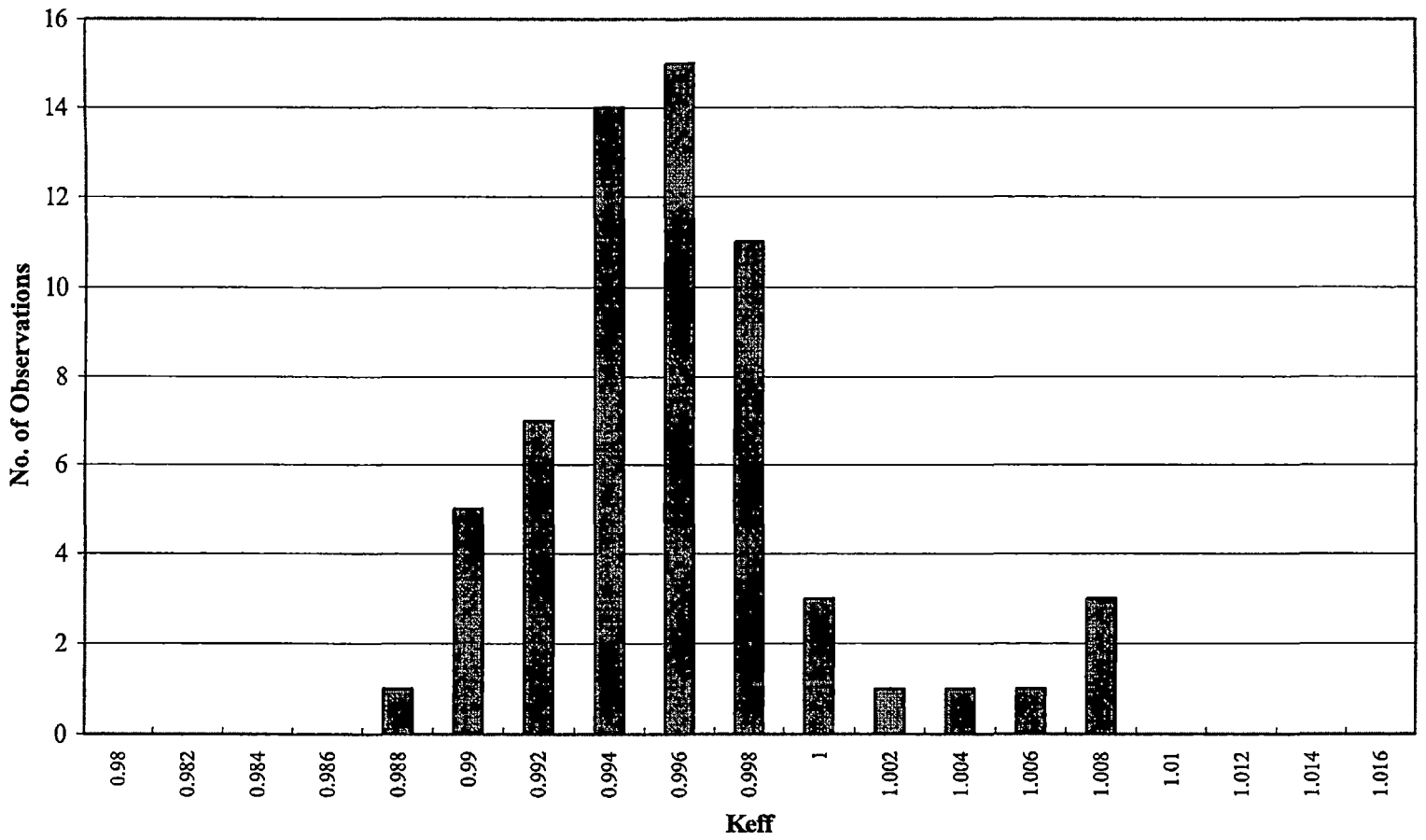


Figure 6.5.1-2 KENO-Va Validation - #27-Group Library k_{eff} Versus Enrichment for Yankee Class Fuel

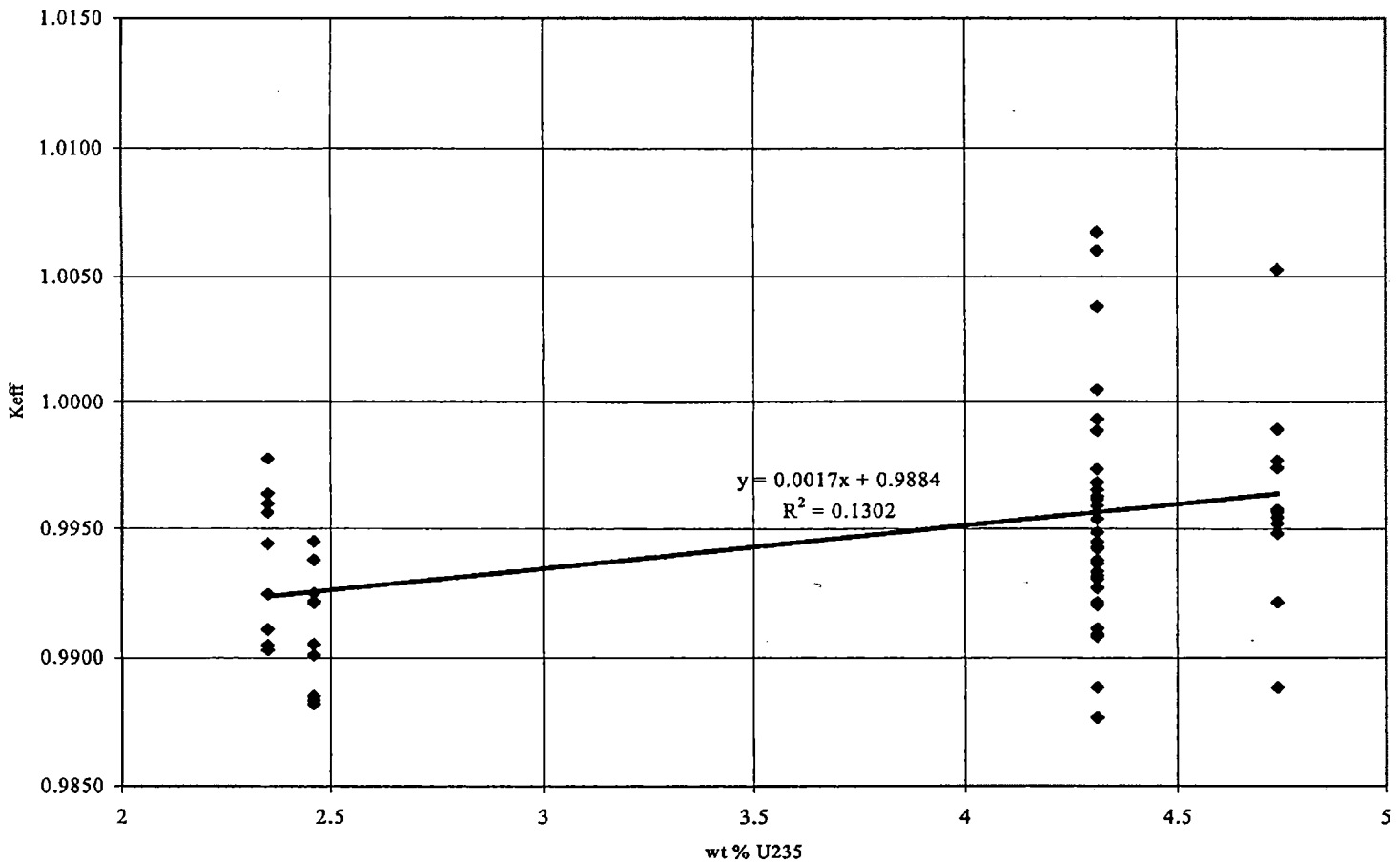


Figure 6.5.1-3 KENO-Va Validation - #27-Group Library k_{eff} Versus Rod Pitch for Yankee Class Fuel

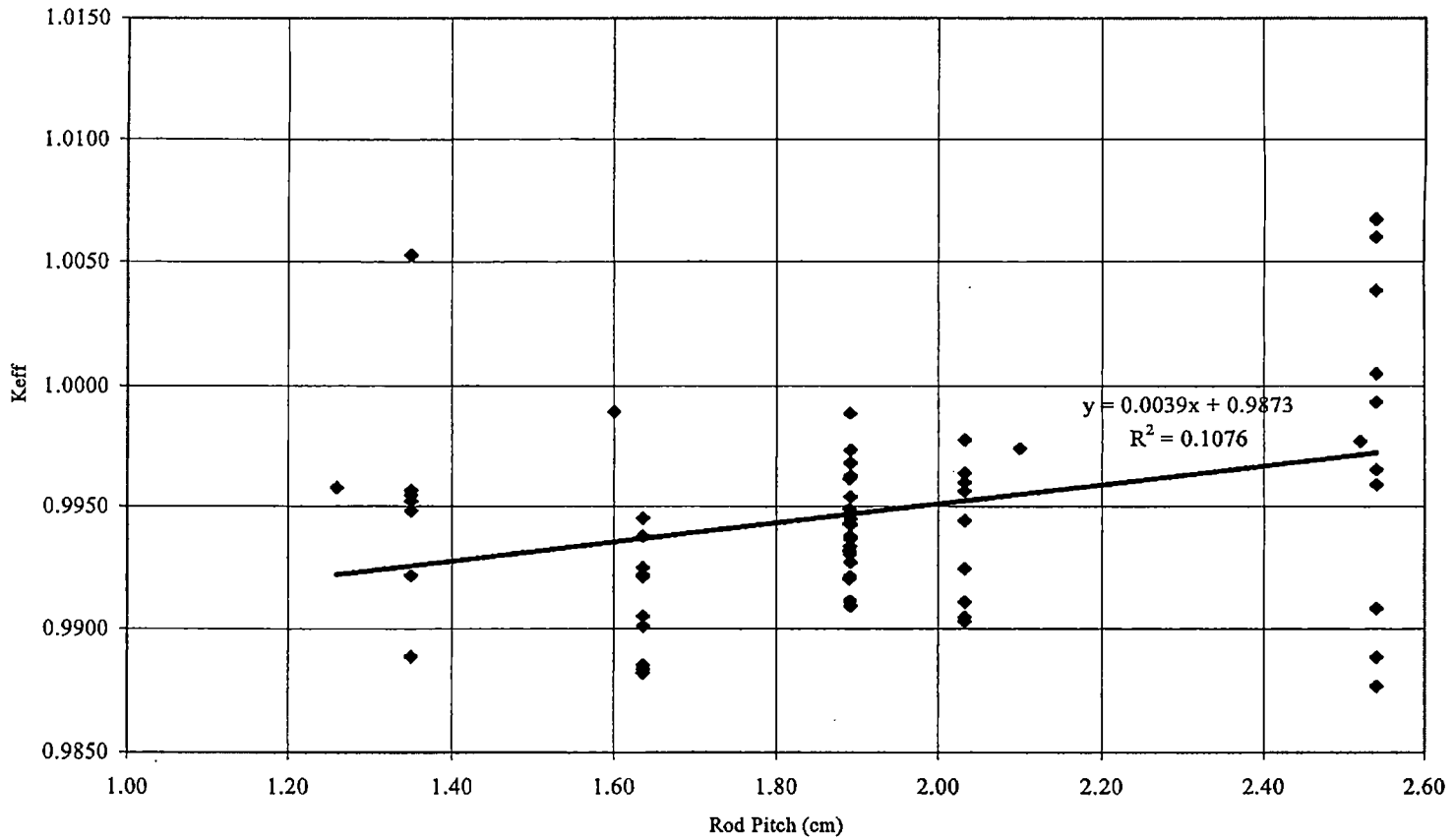


Figure 6.5.1-4 KENO-Va Validation - #27-Group Library k_{eff} Versus H/U Volume Ratio for Yankee Class Fuel

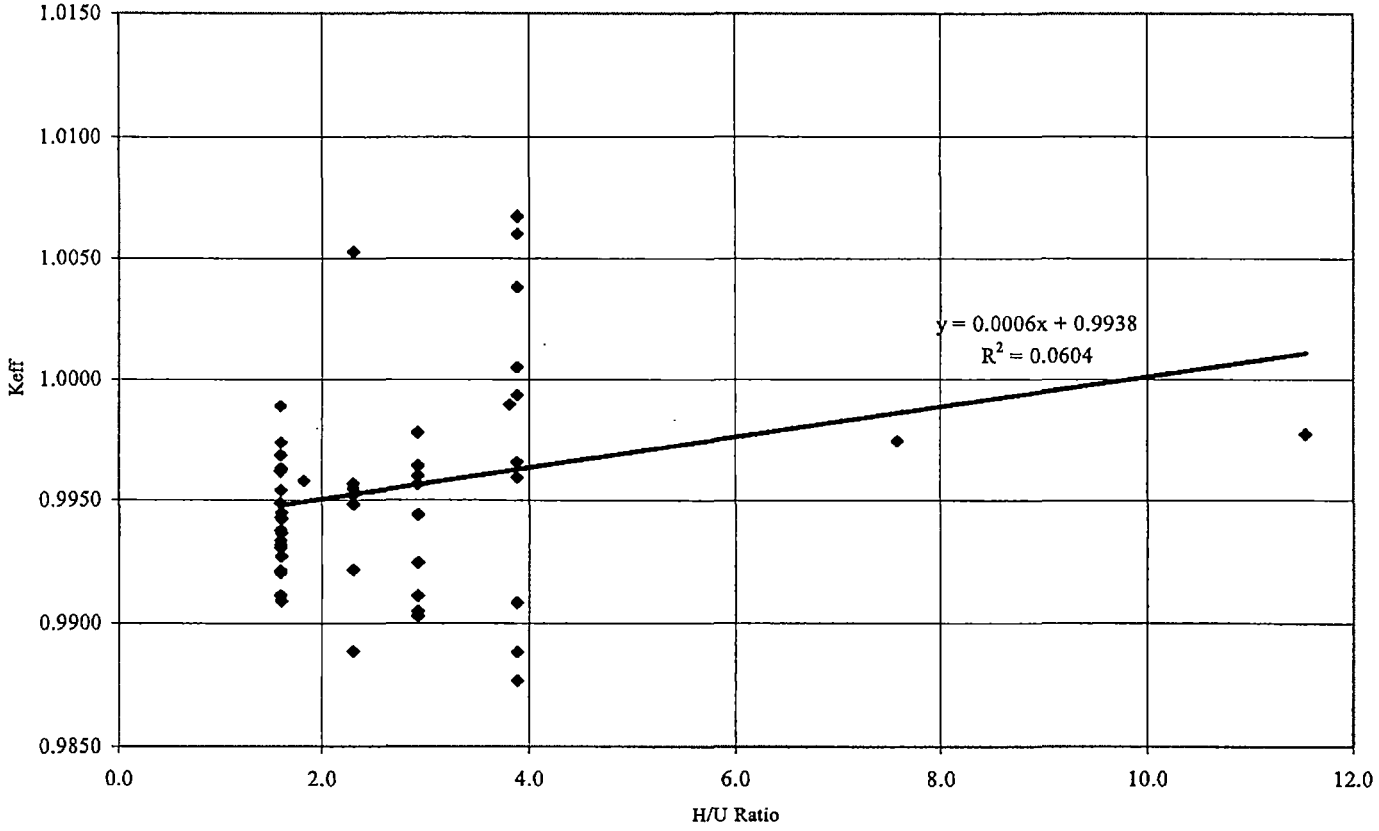


Figure 6.5.1-5 KENO-Va Validation - #27-Group Library k_{eff} Versus Average Group of Fission for Yankee Class Fuel

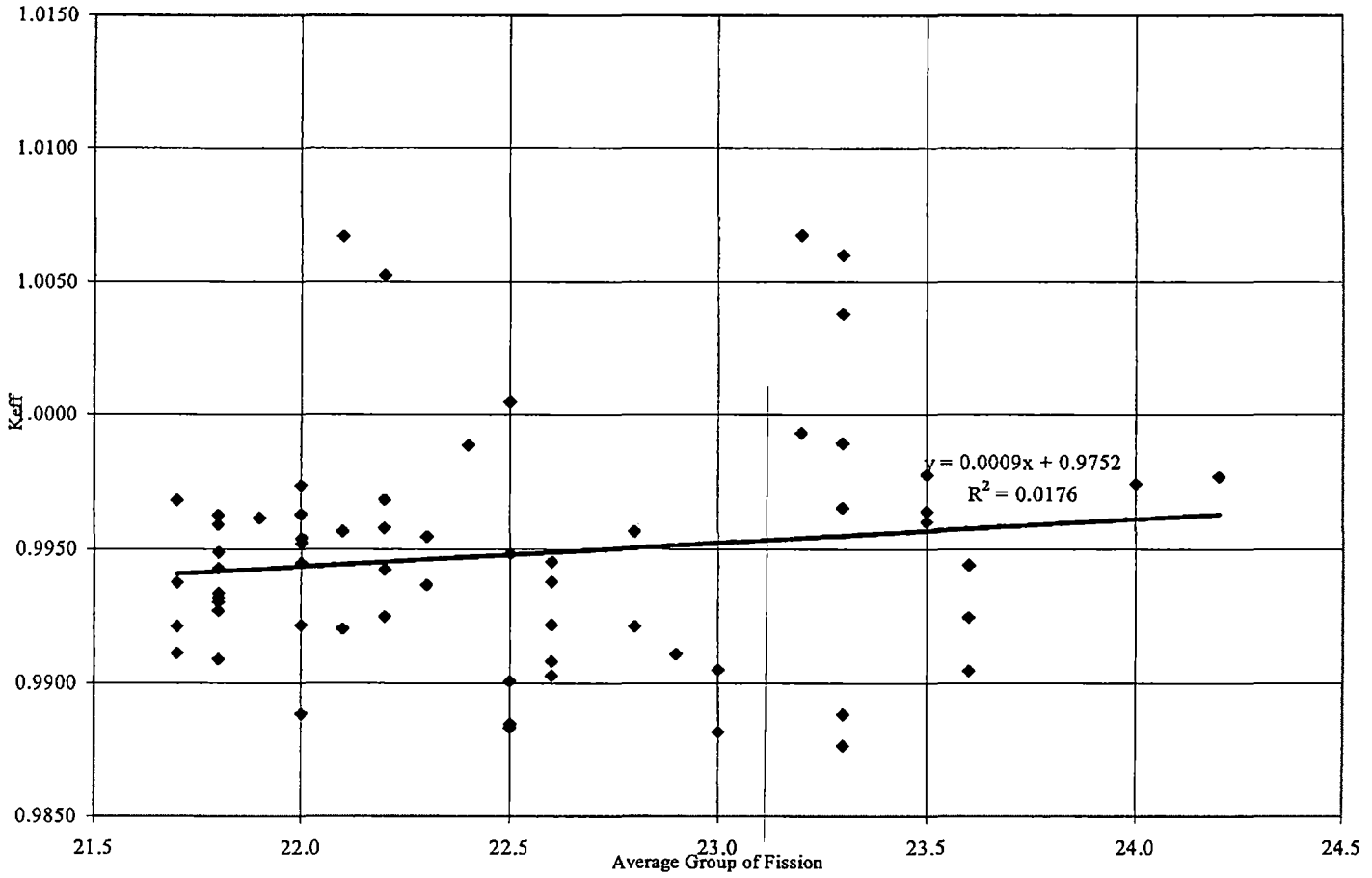


Figure 6.5.1-6 KENO-Va Validation - #27-Group Library k_{eff} Versus ^{10}B Loading For Flux Trap Criticals for Yankee Class Fuel

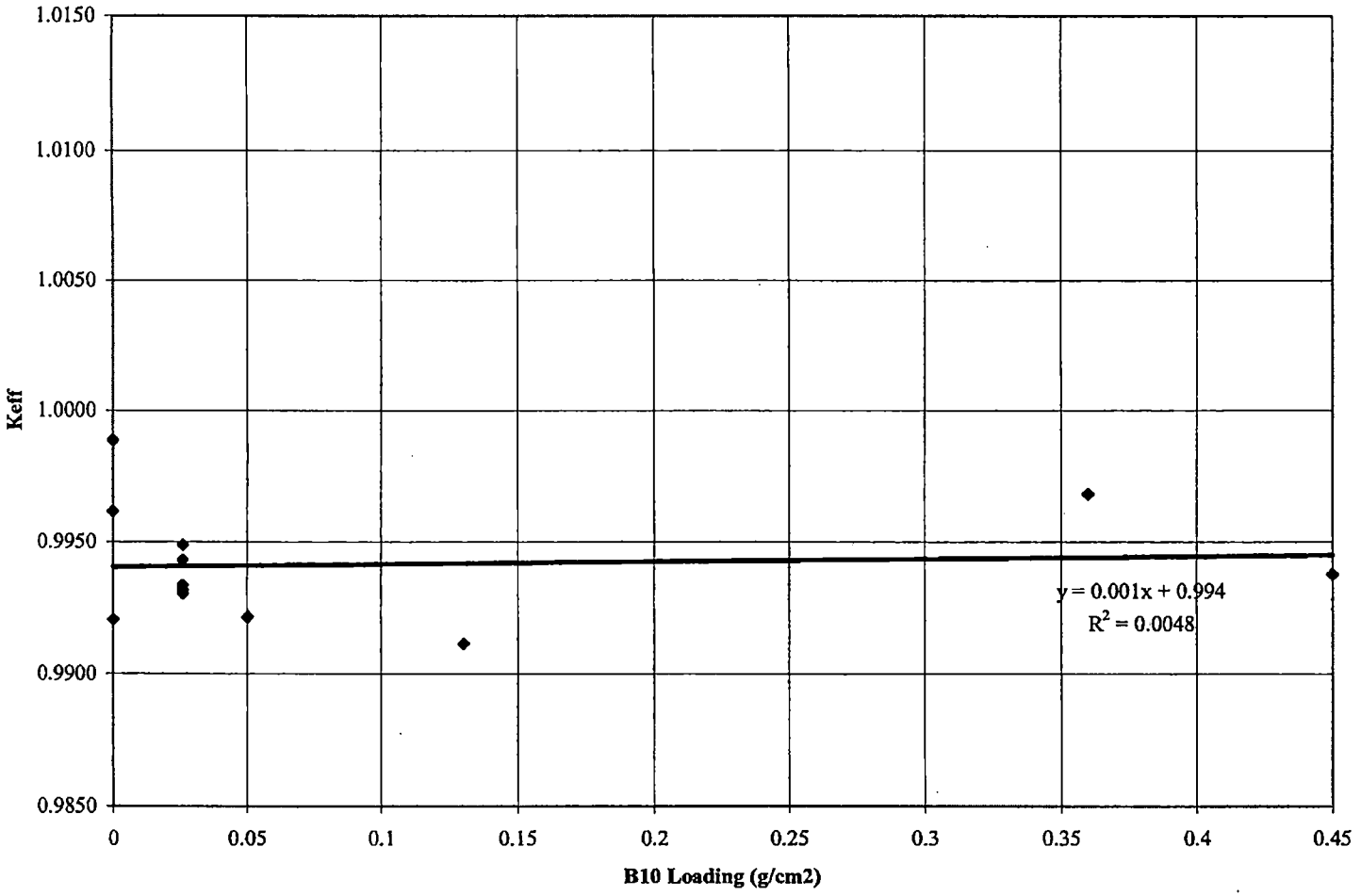


Figure 6.5.1-7 KENO-Va Validation - #27-Group Library Results k_{eff} Versus Flux Trap Critical Gap Thickness for Yankee Class Fuel

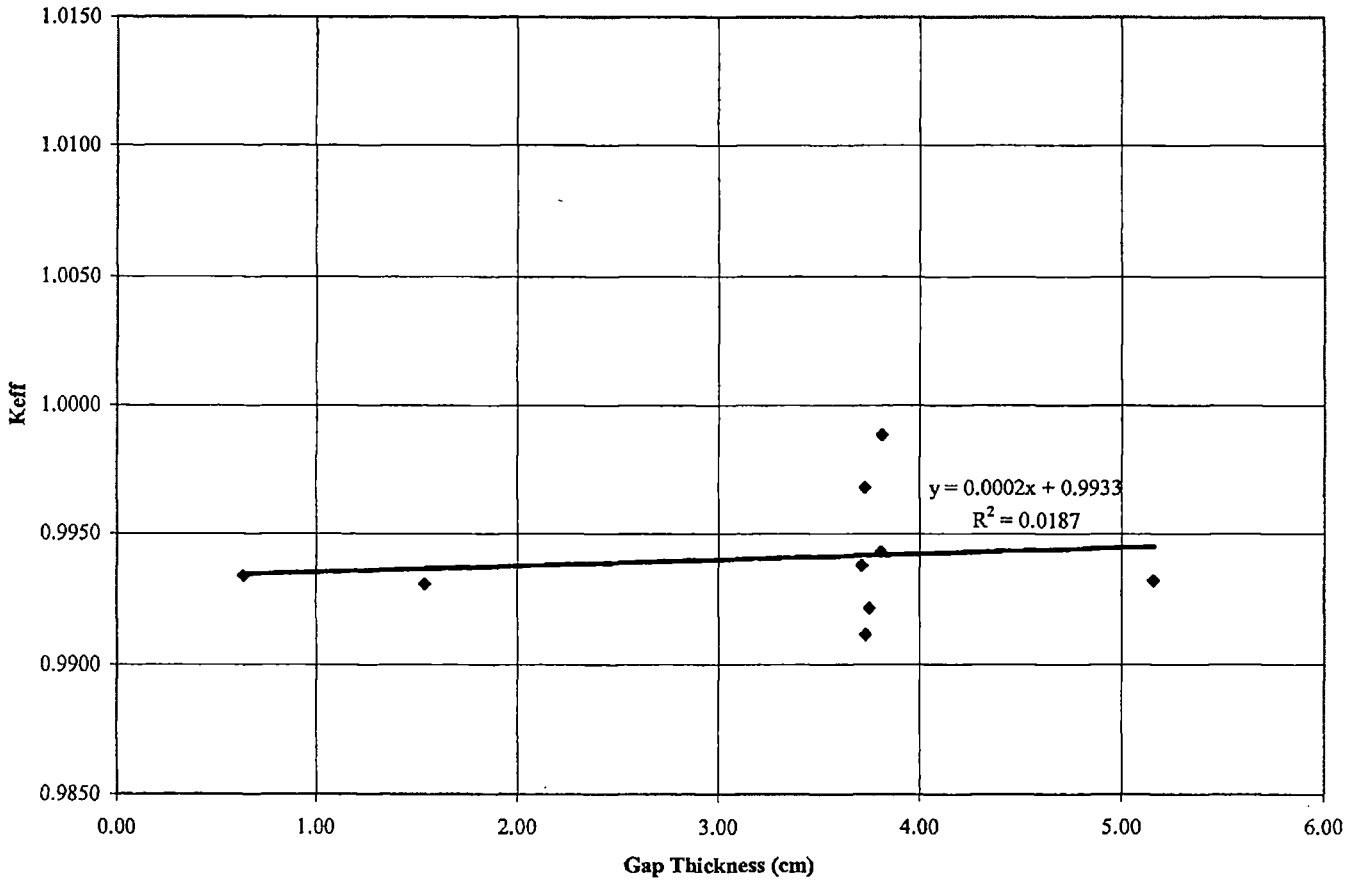


Figure 6.5.1-8 USLSTATS Output for Fuel Enrichment Study for Yankee Class Fuel

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


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
```

Figure 6.5.1-8 USLSTATS Output for Fuel Enrichment Study for Yankee Class Fuel (Continued)

```
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

tudent-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.
```

Table 6.5.1-1 KENO-Va and 27-Group Library Validation Statistics for Yankee Class Fuel

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	k_{eff}	σ
Set 1														
B&W-I	Cylindrical	2.46	1.636	1.206	1.03	1.6	0	NA	NA	0		22.8	0.9921	0.0011
B&W-II	3X3-14X14	2.46	1.636	1.206	1.03	1.6	1,037	NA	NA	0		22.2	0.9925	0.0009
B&W-III	3X3-14X14	2.46	1.636	1.206	1.03	1.6	764	NA	NA	1.636		22.6	0.9938	0.0009
B&W-IX	3X3-14X14	2.46	1.636	1.206	1.03	1.6	0	NA	NA	6.543		23	0.9905	0.0010
B&W-X	3X3-14X14	2.46	1.636	1.206	1.03	1.6	143	NA	NA	4.907		23	0.9882	0.0010
B&W-XI	3X3-14X14	2.46	1.636	1.206	1.03	1.6	514	Steel	0	1.636		22.6	0.9945	0.0010
B&W-XIII	3X3-14X14	2.46	1.636	1.206	1.03	1.6	15	B-Al	0.0052	1.636		22.6	0.9922	0.0010
B&W-XIV	3X3-14X14	2.46	1.636	1.206	1.03	1.6	92	B-Al	0.0040	1.636		22.5	0.9885	0.0010
B&W-XVII	3X3-14X14	2.46	1.636	1.206	1.03	1.6	487	B-Al	0.0008	1.636		22.5	0.9884	0.0010
B&W-XIX	3X3-14X14	2.46	1.636	1.206	1.03	1.6	634	B-Al	0.0003	1.636		22.5	0.9901	0.0009
												Average	0.9911	0.0023
Set 2														
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 6.5.1-1 KENO-Va and 27-Group Library Validation Statistics for Yankee Class Fuel (continued)

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	k_{eff}	σ
Set 3										Cluster	Wall/Cluster			
PNL-STA	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	10.65	0.00	23.5	0.9964	0.0010
PNL-STB	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.20	1.32	23.6	0.9944	0.0010
PNL-STC	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	10.36	2.62	23.6	0.9905	0.0010
PNL-PBA	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.84	0.00	23.5	0.9960	0.0011
PNL-PBB	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.72	0.66	23.5	0.9978	0.0010
PNL_PBC	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.25	2.62	23.6	0.9925	0.0010
PNL-DUA	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.83	0.00	22.6	0.9903	0.0009
PNL-DUB	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	14.11	1.96	22.8	0.9957	0.0010
PNL-DUC	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.70	2.62	22.9	0.9911	0.0010
PNL-H20	3X1 H2O Refl	4.31	2.54	1.415	1.265	3.9	0	NA	NA	8.24	inf	23.3	0.9877	0.0023
PNL-ST0	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	12.89	0	23.2	0.9993	0.0012
PNL-ST1	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	14.12	1.32	23.3	1.0060	0.0022
PNL-ST26	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	12.44	2.62	23.3	0.9965	0.0011
PNL-PB0	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	20.62	0	23.2	1.0068	0.0021
PNL-PB13	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	19.04	1.32	23.3	1.0038	0.0012
PNL-PB5	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	10.3	5.41	23.3	0.9889	0.0011
PNL-DU0	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	15.38	0	21.8	0.9959	0.0011
PNL-DU13	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	19.04	1.32	22.1	1.0067	0.0010
PNL-DU39	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	18.05	3.91	22.5	1.0005	0.0011
PNL-DU54	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	13.49	5.41	22.6	0.9908	0.0011
												Average	0.9964	0.0060

Table 6.5.1-1 KENO-Va and 27-Group Library Validation Statistics for Yankee Class Fuel (continued)

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	k_{eff}	σ
Set 4														
PNL-229	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	Aluminum	0	3.81	0.9982	22.4	0.9989	0.0012
PNL-230	2x2 Flux Trap	4.31	1.89	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	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	1.415	1.265	1.6	0	Steel	0	INF	0.9982	21.9	0.9962	0.0010
												Average	0.9941	0.0022
Set 5														
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0	22.0	0.9922	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.0323	22.0	0.9889	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.2879	22.1	0.9957	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.5540	22.2	1.0053	0.0011
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	2.50	0.9982	22.3	0.9955	0.0012
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	5.00	0.9982	22.5	0.9948	0.0013
VCML	Square Lattice	4.74	1.26	0.94	0.79	1.8	0	NA	NA	NA	NA	22.2	0.9958	0.0012
VCML	Square Lattice	4.74	1.35	0.94	0.79	2.3	0	NA	NA	NA	NA	22.0	0.9952	0.0012
VCML	Square Lattice	4.74	1.60	0.94	0.79	3.8	0	NA	NA	NA	NA	23.3	0.9989	0.0013
VCML	Square Lattice	4.74	2.10	0.94	0.79	7.6	0	NA	NA	NA	NA	24.0	0.9974	0.0012
VCML	Square Lattice	4.74	2.52	0.94	0.79	11.5	0	NA	NA	NA	NA	24.2	0.9977	0.0011
												Average	0.9961	0.0041

Table 6.5.1-2 Correlation Coefficient for Linear Curve-Fit of Critical Benchmarks for Yankee Class Fuel

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 6.5.1-3 Yankee-MPC Most Reactive Configuration Parameters

Parameters	YR-MPC Configuration		
	Std.	4 Enlarged Fuel Tubes	4 Damaged Fuel Cans
Average group causing fission	21.6(1)	21.7	21.8
H/U volume ratio	1.52	1.52	2.1(1)
Enrichment (wt % ^{235}U)	4.0(2)		
Rod pitch (cm)	1.1887		
^{10}B loading (g/cm^2)	0.01 (75% = 0.0075)		
Flux gap thickness (cm)	1.9 to 2.25		

(1) UN Type A assembly with 20 damaged rods modeled as 20 empty locations.
(2) Nominal value stated (fuel fabrication tolerances not included).

6.5.2 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 Yankee-MPC. Section 6.5.2 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 6.5.2-3. The range of the parameters to be benchmarked is summarized in Table 6.5.2-1. 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 presented in Table 6.5.2-3 is plotted in Figures 6.5.2-1 through 6.5.2-8.

To evaluate the relative importance of the trend analysis to the upper safety limits, correlation coefficients are required for all independent parameters. Table 6.5.2-2 contains the correlation coefficient, R, for each linear fit of k_{eff} versus experimental parameter (data is extracted from Figure 6.5.2-1 through Figure 6.5.2-8 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 6.5.2-9.

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 6.5.2-1.

Figure 6.5.2-1 MONK8A – JEF 2.2 Library Validation Statistics – k_{eff} versus Fuel Enrichment

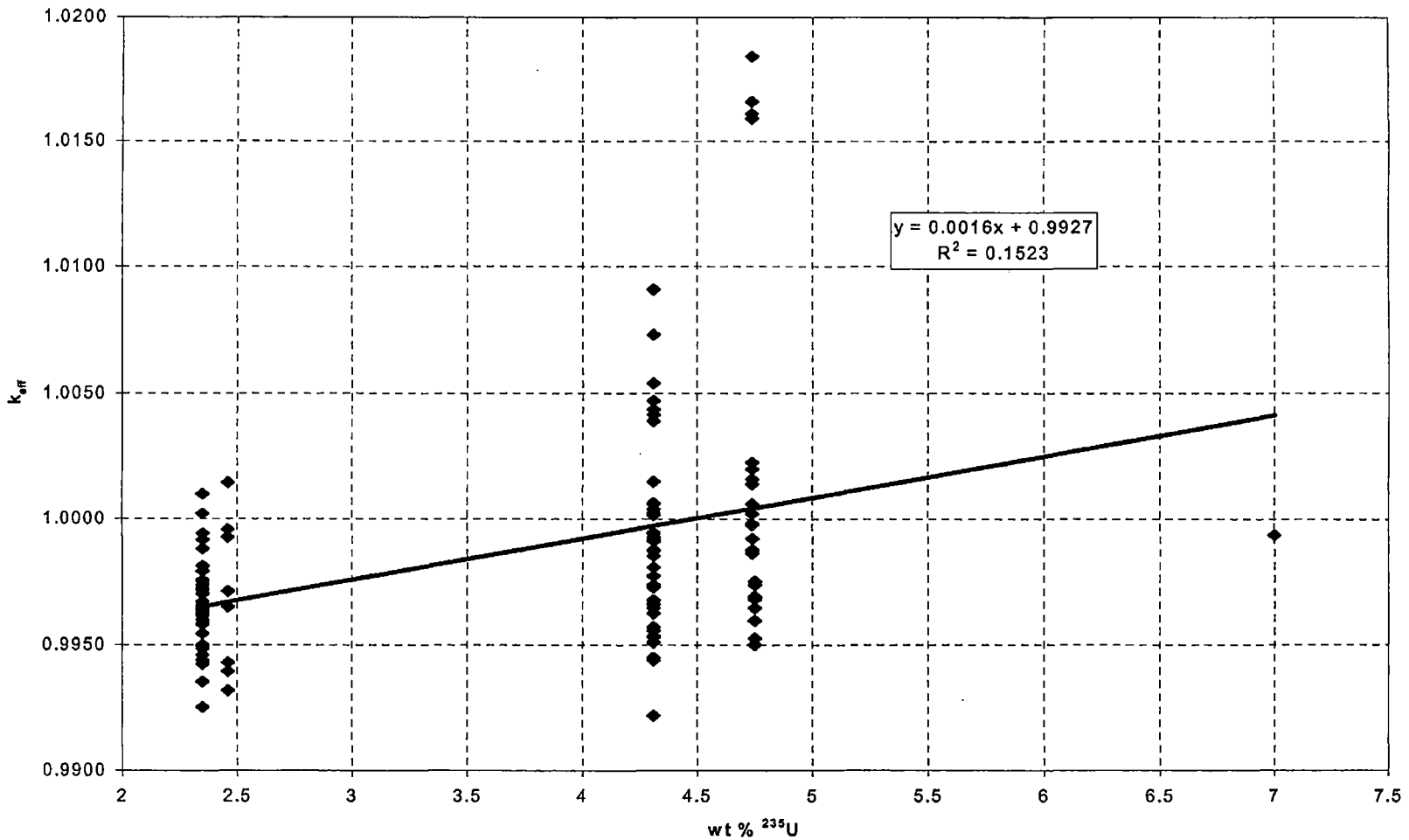


Figure 6.5.2-2 MONK8A – JEF 2.2 Library – k_{eff} versus Rod Pitch

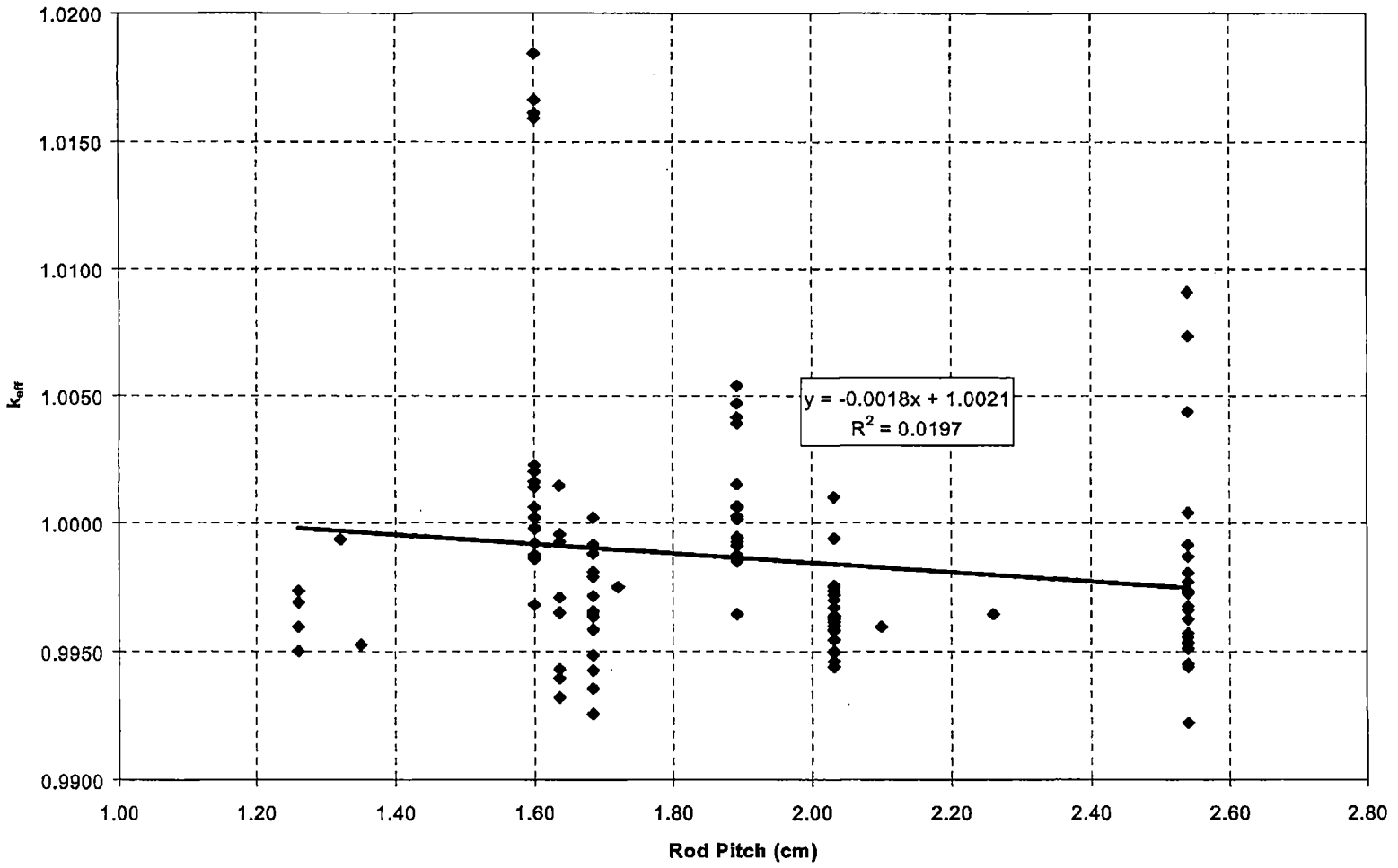


Figure 6.5.2-3 MONK8A – JEF 2.2 Library - k_{eff} versus H/U (fissile) Atom Ratio

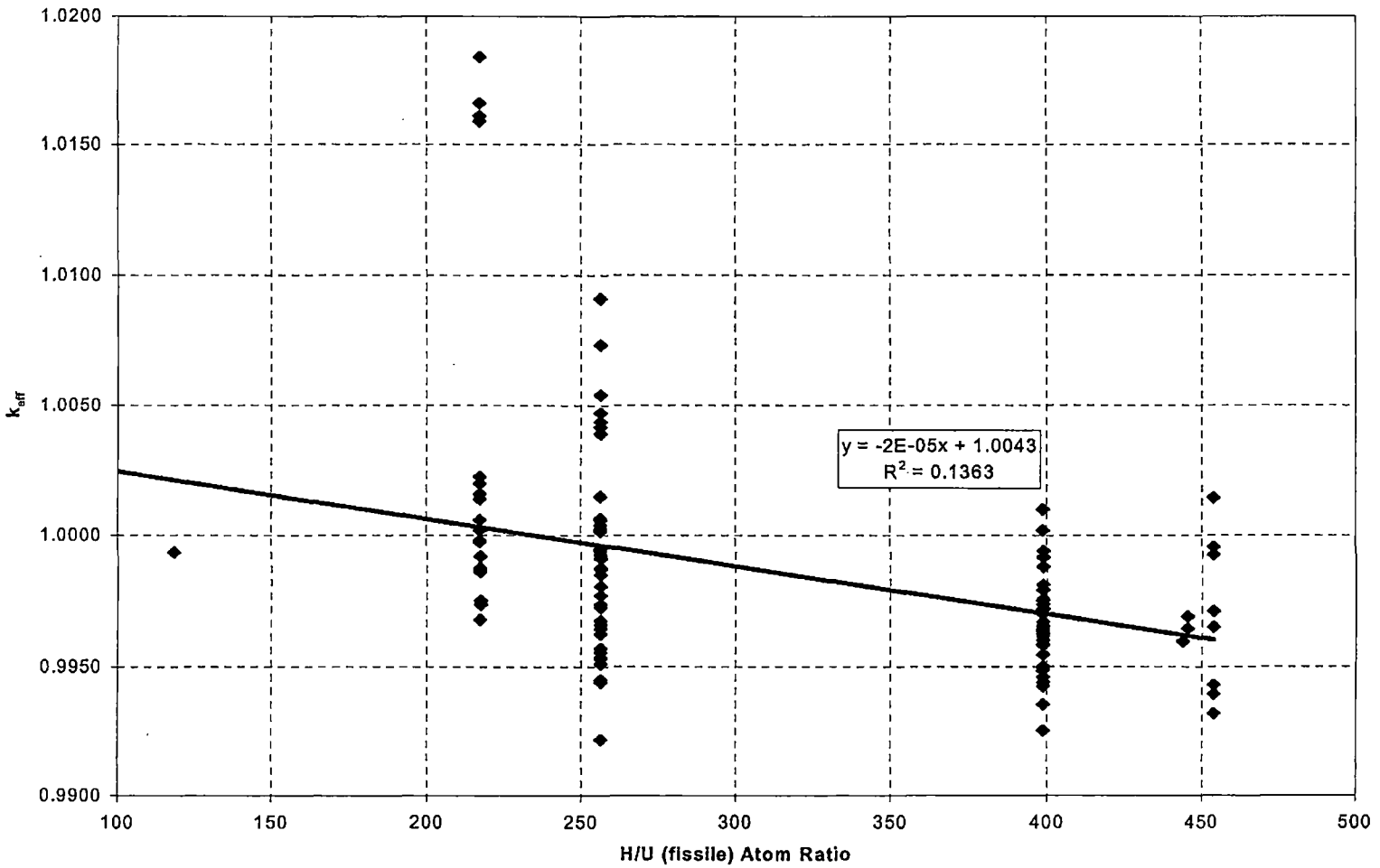


Figure 6.5.2-4 MONK8A – JEF 2.2 Library - k_{eff} versus ^{10}B Loading

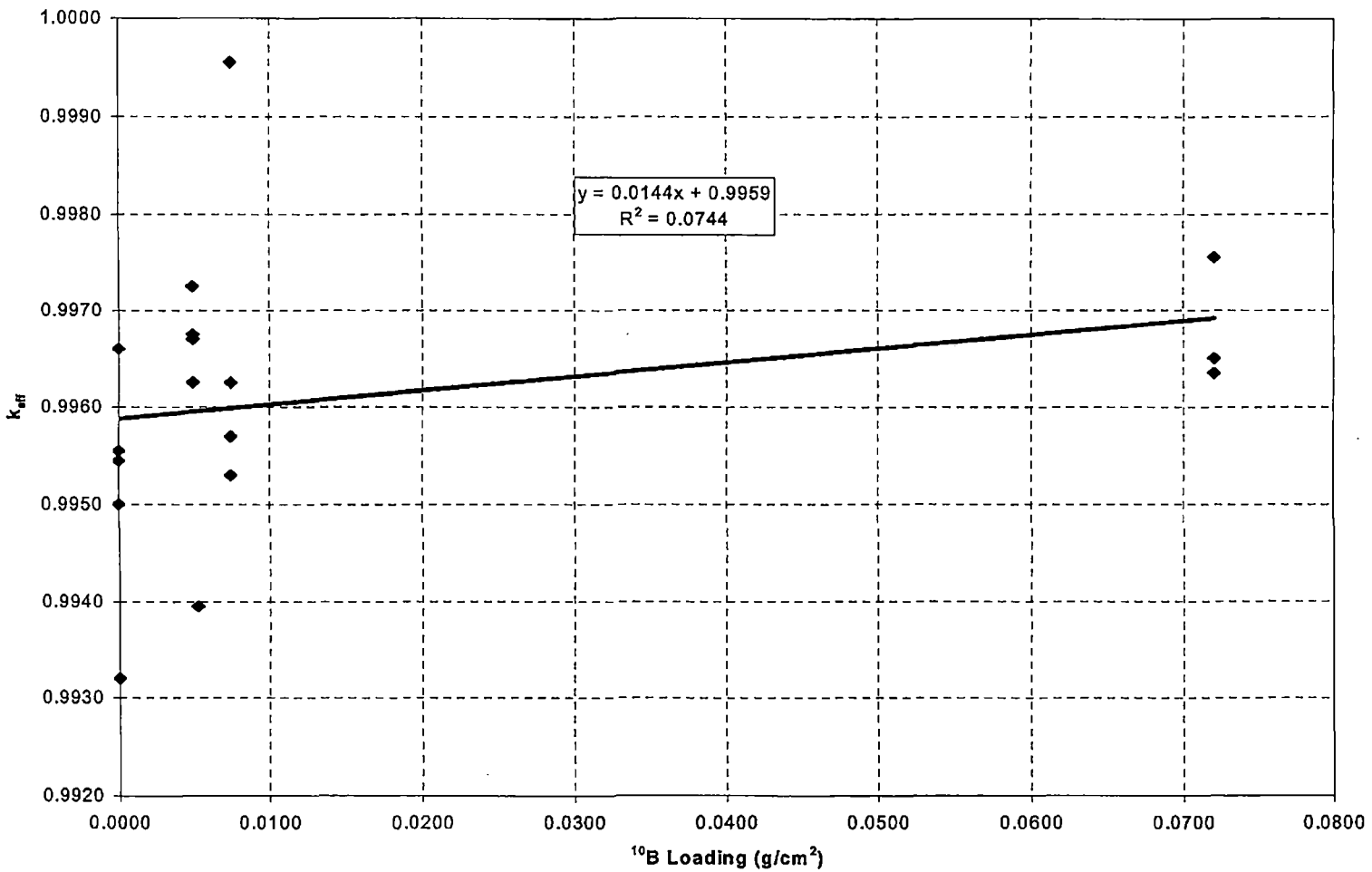


Figure 6.5.2-5 MONK8A – JEF 2.2 Library - k_{eff} versus Mean Neutron Log(E) Causing Fission

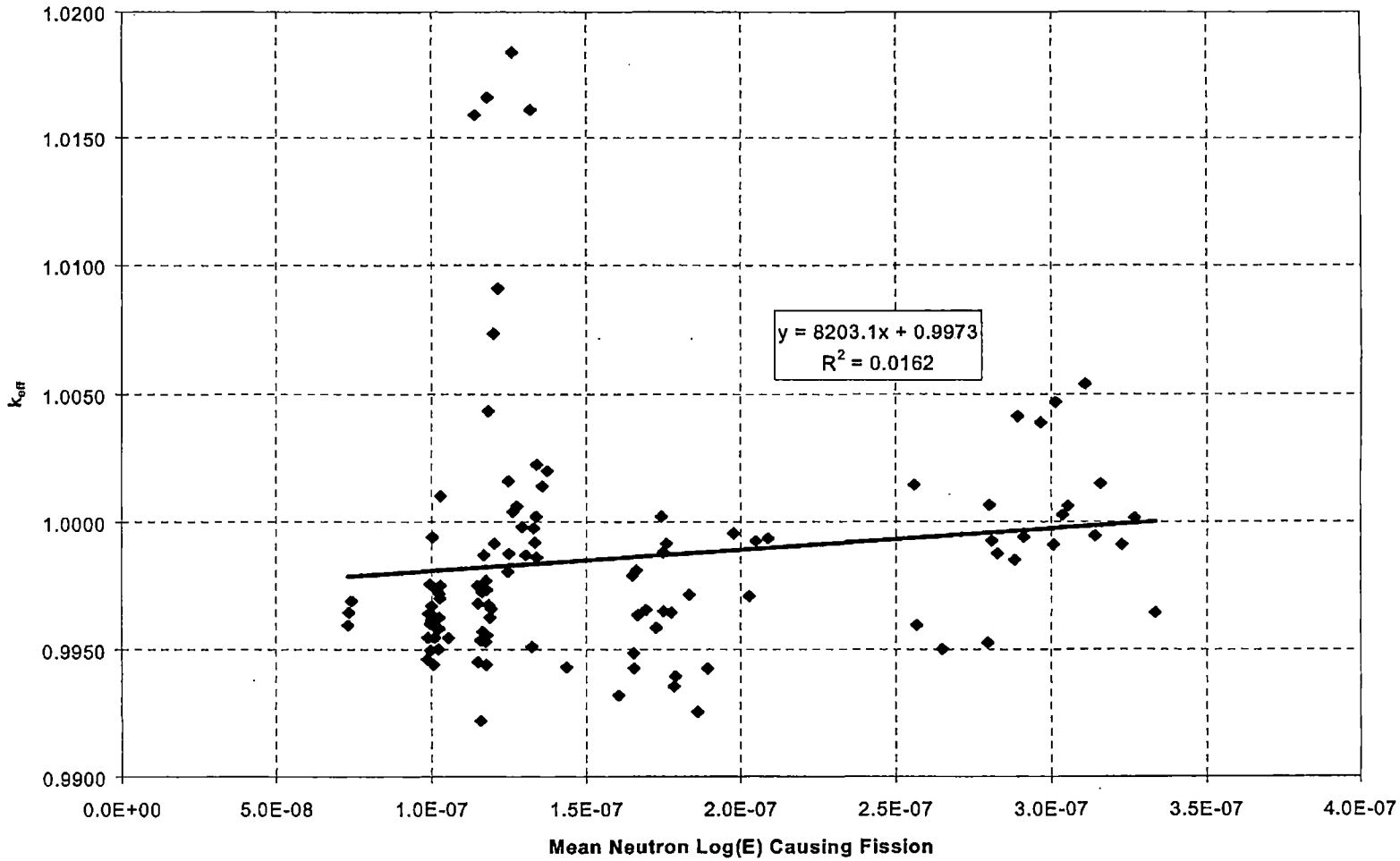


Figure 6.5.2-6 MONK8A – JEF 2.2 Library - k_{eff} versus Cluster Gap Thickness

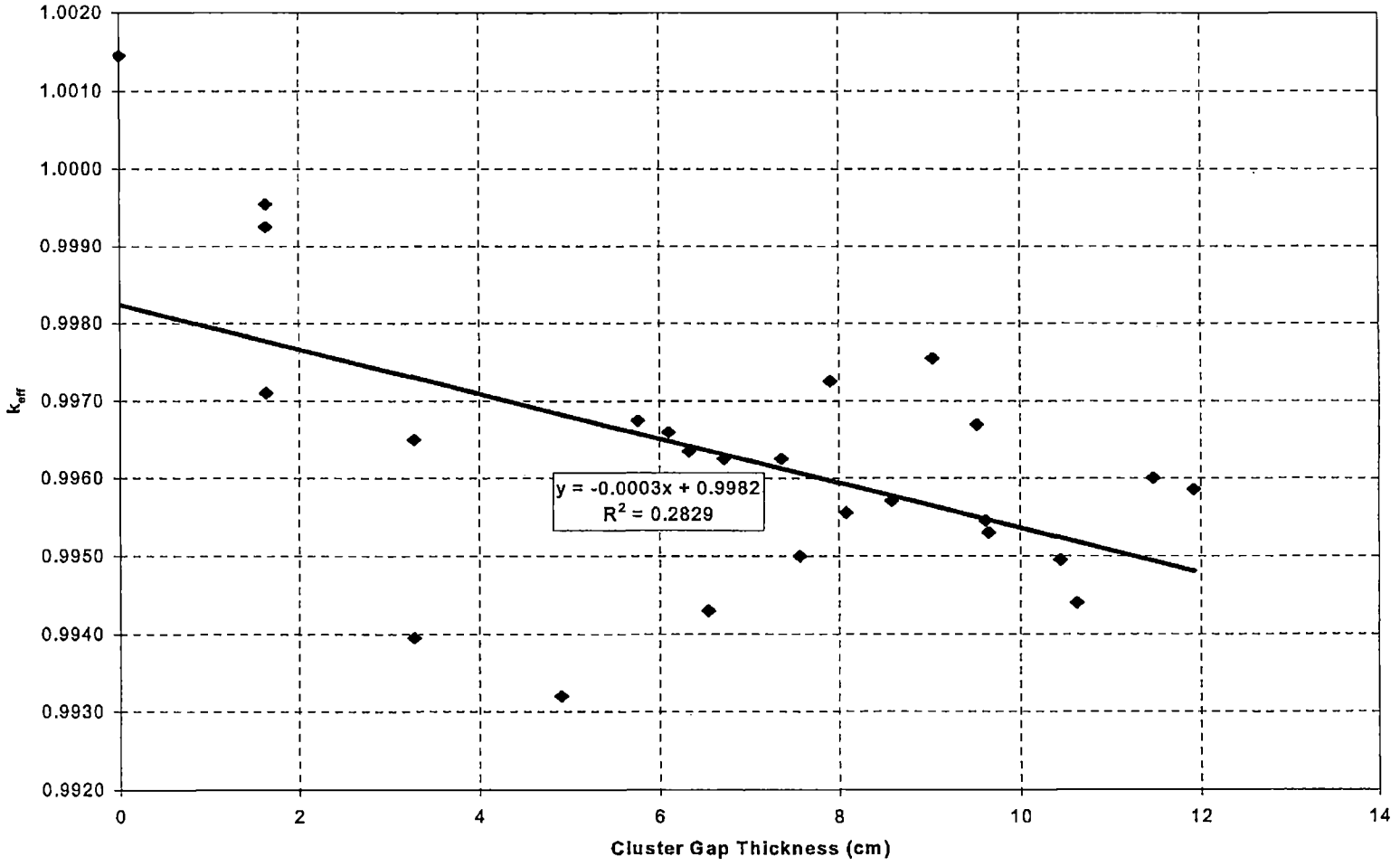


Figure 6.5.2-7 MONK8A – JEF 2.2 Library - k_{eff} versus Fuel Pellet Outside Diameter

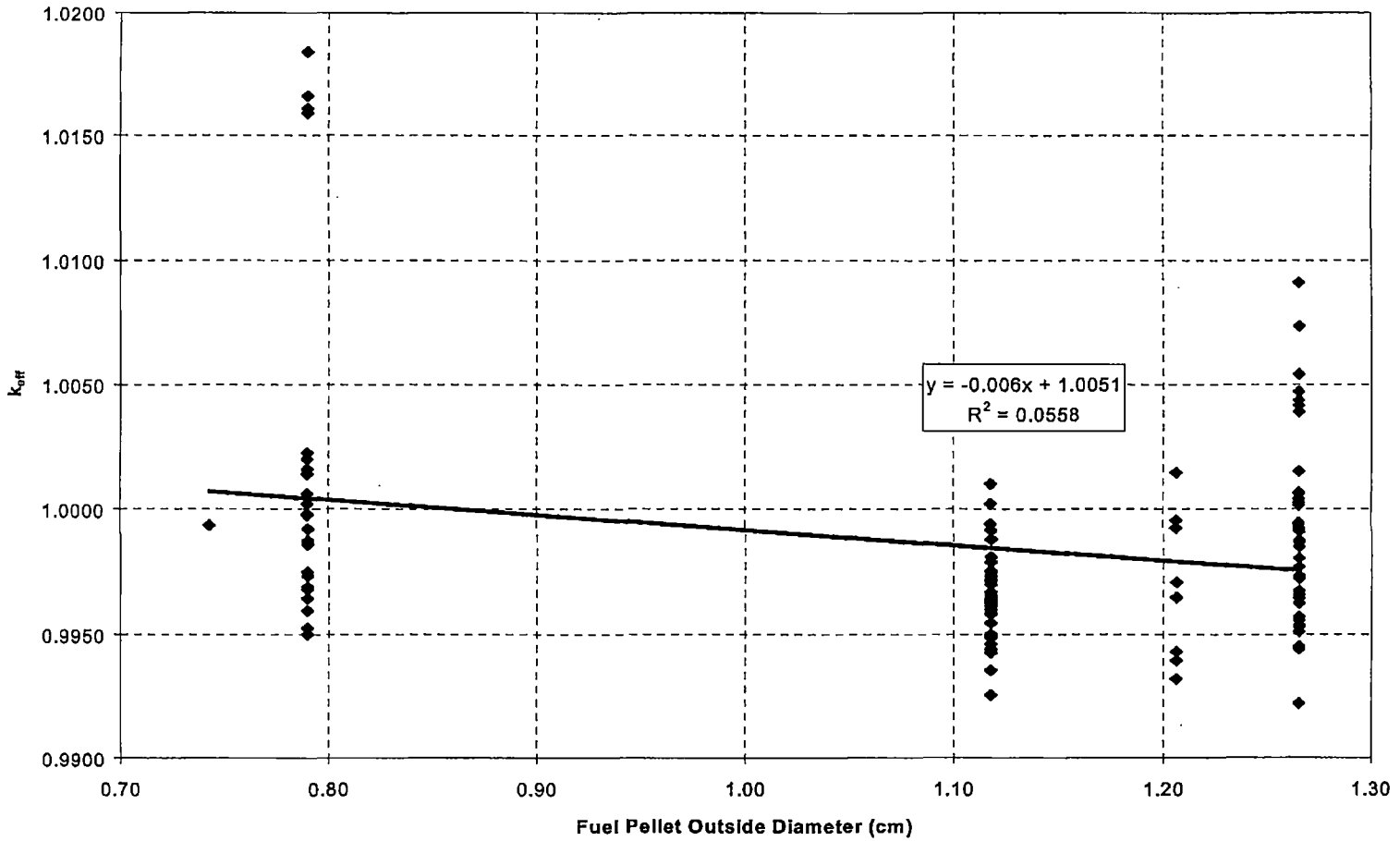


Figure 6.5.2-8 MONK8A – JEF 2.2 Library - k_{eff} versus Fuel Rod Outside Diameter

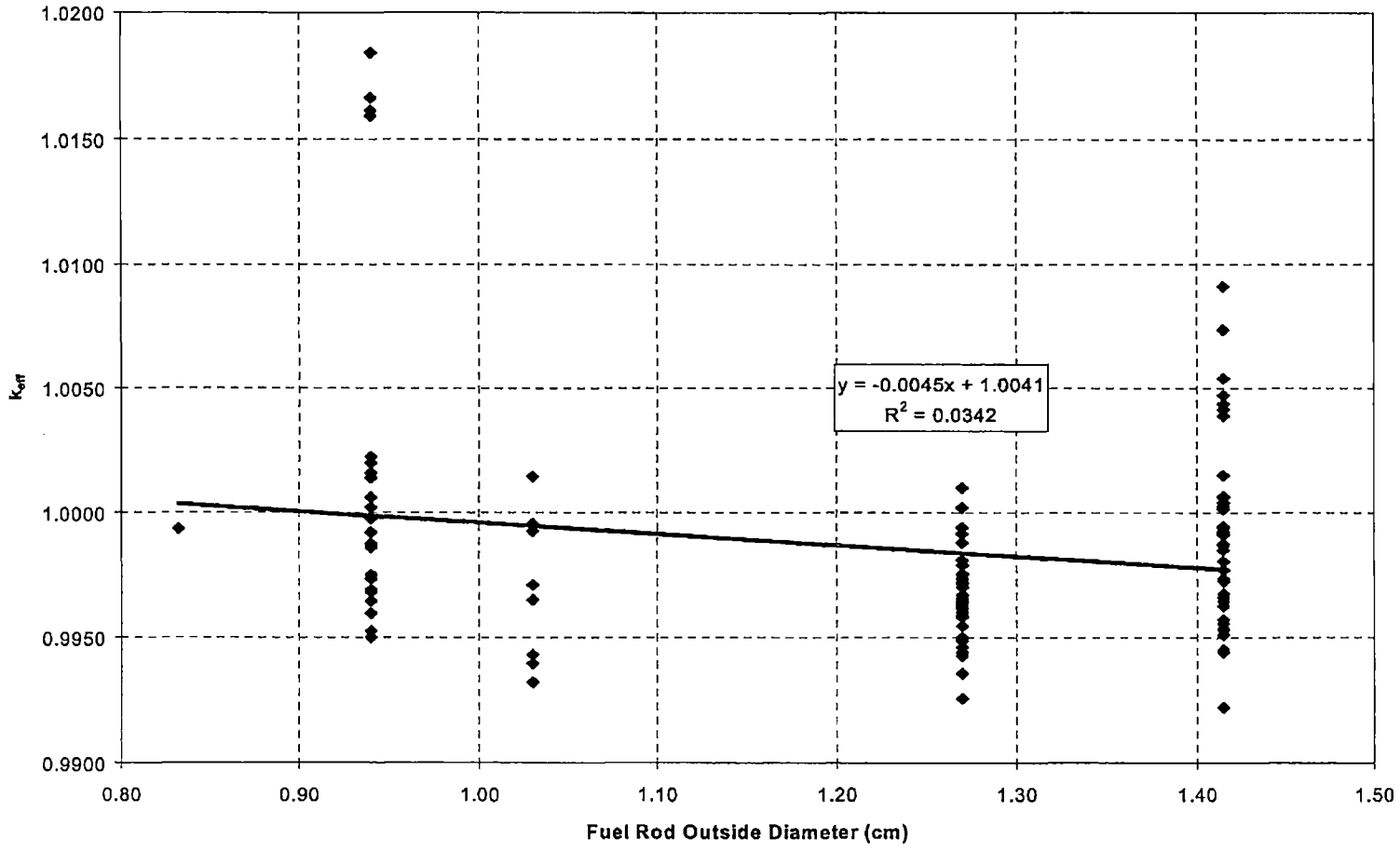


Figure 6.5.2-9 USLSTATS Output - k_{eff} versus Gap Thickness

```
 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 variable - x	dependent variable - y	deviation in y	independent variable - x	dependent variable - y	deviation 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 6.5.2-9 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
-------------------------------------------------------

*****************************************************************************
Thus spake USLSTATS
Finis.
```

Table 6.5.2-1 Range of Correlated Parameters for Connecticut Yankee Fuel

Parameter	Benchmark Minimum Value	Benchmark Maximum Value	CY-MPC
Enrichment (wt % ^{235}U)	2.35	7.00	4.61
Rod pitch (cm)	1.26	2.54	1.429
H/U (fissile) atomic ratio	97.08	453.84	130.17
^{10}B loading (g/cm^2)	0.000	0.072	0.02
Log energy causing fission	7.31E-08	3.33E-07	2.88E-07
Cluster gap thickness (cm)	0.0	11.92	2.54 to 8.89
Fuel diameter (cm)	0.743	1.265	0.975
Clad diameter (cm)	0.8324	1.4150	1.076

Table 6.5.2-2 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 6.5.2-3 MONKA – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel

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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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
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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
2.07	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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
3.08	3 clusters; 8x15 rods	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 rods	2.46	1.6358	1.206	1.03	Al	453.84	1037	None	Na	0	Inf	Water	2.56E-07	1.0015	0.0010

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
7.02	3x3 clusters; 14x14 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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
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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
32.04	14x14 array	4.74	1.60	0.79	0.94	Al		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
17.01	3 clusters; 16x19 rods	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 rods	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 rods	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 rods	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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
17.05	3 clusters; 16x19 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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
17.13	3 clusters; 16x19 rods	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 rods	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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
17.18	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
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 rods	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 rods	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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
10.03	3 clusters; 8x13 rods	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 rods	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 rods	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 rods	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 rods	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
10.08	3 clusters; 8x13 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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

Table 6.5.2-3 MONK8A – JEF 2.2 Library Validation Statistics for Connecticut Yankee Fuel (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
10.17	3 clusters; 12x16 rods	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 rods	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 rods	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
10.20	3 clusters; 12x16 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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 rods	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

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6.7 Supplemental Data

This section presents the input/output files for the computer codes used in the NAC-MPC criticality safety evaluation.

Section 6.7.1 presents the CSAS25 input/output for the criticality analysis of the Yankee-MPC transfer and storage casks under normal and 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. Figures 6.7.1-1 through 6.7.1-4 represent the Yankee-MPC basket without enlarged fuel tubes. The maximum reactivity storage cask output, with enlarged fuel tubes, under the hypothetical accident conditions of full moderation is shown in Figure 6.7.1-5. The maximum reactivity configuration of the canister loaded with four damaged fuel cans containing assemblies with up to 20 damaged fuel rods, including the hypothetical accident conditions of full moderation, is shown in Figure 6.7.1-6.

Section 6.7.2 presents the maximum reactivity output file for the CY-MPC MONK8A evaluation. The code input listing is included in the output file (Figure 6.7.2-1).

6.7.1 Supplemental Data for Yankee Class Fuel

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
  '
  '       File tfn-1000.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE TRANSFER CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '       INTERIOR MODERATOR (MATERIAL  3) VOLUME FRACTION = 1.000
  '       EXTERIOR MODERATOR (MATERIAL 10) VOLUME FRACTION = 0.0001
  '
  27GROUPNDF4 LATTICECELL
  UO2         1              0.95    293.0 92235 4.0 92238 96.0 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
  B-10        6  DEN=2.6226 0.0450  293.0                      END
  B-11        6  DEN=2.6226 0.2736  293.0                      END
  C           6  DEN=2.6226 0.0927  293.0                      END
  AL          6  DEN=2.6226 0.5737  293.0                      END
  PB          7              1.0     293.0                      END
  H           8  DEN=1.6291 0.060   293.0                      END
  O           8  DEN=1.6291 0.425   293.0                      END
  C           8  DEN=1.6291 0.277   293.0                      END
  N           8  DEN=1.6291 0.020   293.0                      END
  AL          8  DEN=1.6291 0.214   293.0                      END
  B-10        8  DEN=1.6291 0.001   293.0                      END
  B-11        8  DEN=1.6291 0.004   293.0                      END
  CARBONSTEEL 9              1.0     293.0                      END
  H2O        10              0.0001  293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 0 END
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
  READ PARAM RUN=yes PLT=NO  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER  0 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER  0 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
  CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0      10.1615  0.0
HOLE  14   0.0      -10.1615 0.0
HOLE  15   10.1615  0.0      0.0
HOLE  15   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                         2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      -0.1584      0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      0.1584       0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.0          0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.0          0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.1584       0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.1584       0.0
UNIT 57
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   0.1584   -0.1584       0.0
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   -0.1584   -0.1584       0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                                2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0      10.1615  0.0
HOLE  16   0.0      -10.1615 0.0
HOLE  17   10.1615  0.0      0.0
HOLE  17   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                                2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.0      -0.1584      0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.0      0.1584       0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   0.0          0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   0.0          0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   0.1584       0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   0.1584       0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   -0.1584       0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   -0.1584       0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0      10.1615  0.0
HOLE  16   0.0      -10.1615 0.0
HOLE  17   10.1615  0.0      0.0
HOLE  17   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                                2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.0      -0.1584      0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.0      0.1584       0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   -0.1584   0.0          0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.1584   0.0          0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.1584   0.1584       0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   -0.1584   0.1584       0.0
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   -0.1584       0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN TRANSFER CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253     2P2.1400
HOLE 80     -69.0614 0.0 0.0
HOLE 82     -46.1912 0.0 0.0
HOLE 81      69.0614 0.0 0.0
HOLE 83      46.1912 0.0 0.0
CYLINDER  5 1  89.7128    2P2.1400
CYLINDER  0 1  90.805     2P2.1400
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
CYLINDER  9 1  92.71       2P2.1400
CYLINDER  7 1 101.6        2P2.1400
CYLINDER  8 1 106.68       2P2.1400
CYLINDER  9 1 109.855      2P2.1400
CUBOID   10 1 4P159.855    2P2.1400
UNIT 111
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046       2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
HOLE 93       46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
UNIT 112
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249        2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -159.855 -159.855 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 1 3 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
53
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
74
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

END DATA
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (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

    11             11                    //     11        7777777777777              //   99999999999    666666666666
   111            111                    //    111        777777777777               //  9999999999999  6666666666666
  1111           1111                    //   1111        77        77               //  99         99  66
    11             11                   //     11                77                //  99         99  66
    11             11                  //      11               77                 //  99         99  66
    11             11                 //       11              77                  //  9999999999999  666666666666
    11             11                //        11              77                   //  999999999999   6666666666666
    11             11               //         11             77                    //             99  66         66
    11             11              //          11             77                   //             99  66         66
    11             11             //           11            77                    //             99  66         66
 11111111       11111111         //           11111111        77                   //  9999999999999  6666666666666
 11111111       11111111         //           11111111        77                   //  999999999999    66666666666

    11        666666666666                    33333333333   5555555555555                    11        33333333333
   111       6666666666666                   3333333333333  5555555555555                   111       3333333333333
  1111       66                    :::       33         33  55                    :::      1111       33         33
    11       66                    :::                33  55                    :::        11                   33
    11       66                    :::                33  55                    :::        11                   33
    11       666666666666                             333  555555555555                    11                 333
    11       6666666666666                            333  5555555555555                   11                 333
    11       66         66         :::                33                55   :::        11                    33
    11       66         66         :::                33                55   :::        11                    33
    11       66         66         :::       33       33  55         55   :::        11        33          33
 11111111    6666666666666                   3333333333333  5555555555555                11111111    3333333333333
 11111111     66666666666                     33333333333    55555555555                 11111111     33333333333
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (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  LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP             CCCCCCCCCCCCC
 SSSSSSSSSSS    CCCCCCCCCCC    AA         AA  LLLLLLLLLLLL  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:  11/17/96                                    *****
*****                                                                   *****
*****   TIME OF EXECUTION:  16:35:13                                    *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

    **** 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     4.000 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  B-10         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.0450 VOLUME FRACTION
    ROTH      2.6226 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        0.2736 VOLUME FRACTION
    ROTH      2.6226 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
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
MX            6 MIXTURE NO.
VF       0.0927 VOLUME FRACTION
ROTH     2.6226 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
           6012      1.00 ATOM/MOLECULE
END

SC  AL          STANDARD COMPOSITION
MX            6 MIXTURE NO.
VF       0.5737 VOLUME FRACTION
ROTH     2.6226 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
          13027      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  H           STANDARD COMPOSITION
MX            8 MIXTURE NO.
VF       0.0600 VOLUME FRACTION
ROTH     1.6291 SPECIFIED 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.
VF       0.4250 VOLUME FRACTION
ROTH     1.6291 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
           8016      1.00 ATOM/MOLECULE
END

SC  C           STANDARD COMPOSITION
MX            8 MIXTURE NO.
VF       0.2770 VOLUME FRACTION
ROTH     1.6291 SPECIFIED 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.
VF       0.0200 VOLUME FRACTION
ROTH     1.6291 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
           7014      1.00 ATOM/MOLECULE
END

SC  AL          STANDARD COMPOSITION
MX            8 MIXTURE NO.
VF       0.2140 VOLUME FRACTION
ROTH     1.6291 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            8 MIXTURE NO.
VF       0.0010 VOLUME FRACTION
ROTH     1.6291 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            8 MIXTURE NO.
VF       0.0040 VOLUME FRACTION
ROTH     1.6291 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
            5011      1.00 ATOM/MOLECULE
END

SC  CARBONSTEEL  STANDARD COMPOSITION
MX             9 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  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     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 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 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                          TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                          ********** 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:\svv\yankee\wrr5402\tfn-1000\FT11F001                  SHORT CROSS SECTION LIBRARY   ***
***                                                                                               ***
***         90     C:\svv\yankee\wrr5402\tfn-1000\FT90F001                  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                                    ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

CONTROL MODULE CSAS25   IS COMPLETE.
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
KK          KK  EEEEEEEEEEEEE  NN          NN   OOOOOOOOOOOO                    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   OOOOOOOOOOOO                           V

SSSSSSSSSSS   CCCCCCCCCCC    AAAAAAAAA   LL          EEEEEEEEEEEEE                PPPPPPPPPPPPP   CCCCCCCCCCC
SSSSSSSSSSSSS CCCCCCCCCCCCC  AAAAAAAAAAA LL          EEEEEEEEEEEEE                PPPPPPPPPPPPPP  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    -------------   PPPPPPPPPPPPPP  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 CCCCCCCCCCCCCC AA       AA  LLLLLLLLLLLL EEEEEEEEEEEEE                PP              CCCCCCCCCCCCC
 SSSSSSSSSSS   CCCCCCCCCCC   AA       AA  LLLLLLLLLLLL EEEEEEEEEEEEE                PP               CCCCCCCCCCC

   11          11                //    11        7777777777777            //   99999999999    666666666666
  111         111               //    111        777777777777            //   9999999999999  6666666666666
 1111        1111              //    1111       77        77            //   99         99  66
   11         11             //       11                77          //   99         99  66
   11         11            //        11               77          //   99         99  66
   11         11           //         11              77          //   9999999999999  666666666666
   11         11          //          11             77          //    999999999999  6666666666666
   11         11         //           11            77          //                99  66        66
   11         11        //            11           77          //                99  66        66
   11         11       //             11          77          //                99  66        66
11111111   11111111  //              11111111     77          //   9999999999999  6666666666666
11111111   11111111 //               11111111     77          //   999999999999   66666666666

   11       666666666666                33333333333   5555555555555                22222222222    99999999999
  111       6666666666666               3333333333333 5555555555555               2222222222222  9999999999999
 1111       66                  :::     33        33  55                   :::   22         22  99         99
   11       66                  :::                33  55                   :::               22  99         99
   11       66                  :::                33  55                   :::               22  99         99
   11       666666666666                         333   555555555555                     22     9999999999999
   11       6666666666666                        333   5555555555555                 22         999999999999
   11       66         66       :::                33              55       :::     22                    99
   11       66         66       :::                33              55       :::   22                      99
   11       66         66       :::     33         33  55         55       :::  22                        99
11111111    6666666666666               3333333333333 5555555555555               2222222222222  9999999999999
11111111     66666666666                 33333333333   55555555555               2222222222222  999999999999
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL            EEEEEEEEEEEEE                  PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA  LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP              CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC     AA         AA  LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP               CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                 PROGRAM VERIFICATION INFORMATION                  *****
*****                                                                   *****
*****                 CODE SYSTEM:  SCALE-PC VERSION:  4.3              *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                                                                   *****
*****              PROGRAM:  000009                                     *****
*****                                                                   *****
*****        CREATION DATE:  03-08-96                                   *****
*****                                                                   *****
*****              VOLUME:   ENG                                        *****
*****                                                                   *****
*****              LIBRARY:  G:\scale43\exe                             *****
*****                                                                   *****
*****                                                                   *****
*****      PRODUCTION CODE:  KENOVA                                     *****
*****                                                                   *****
*****              VERSION:  3.1                                        *****
*****                                                                   *****
*****              JOBNAME:  SCALE-PC                                   *****
*****                                                                   *****
*****    DATE OF EXECUTION:  11/17/96                                   *****
*****                                                                   *****
*****    TIME OF EXECUTION:  16:35:29                                   *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                               ***
*****************************************************************************************************
***                          ******        NUMERIC PARAMETERS        ******                       ***
***                                                                                               ***
***                                                                                               ***
***          TME     MAXIMUM PROBLEM TIME (MIN)                          500.00                   ***
***                                                                                               ***
***          TBA     TIME PER GENERATION (MIN)                             0.50                   ***
***                                                                                               ***
***          GEN     NUMBER OF GENERATIONS                                 1003                   ***
***                                                                                               ***
***          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 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
*****************************************************************************************************
***                                                                                                 ***
***                          TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                                 ***
*****************************************************************************************************
***                                  ******      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 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                          TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***        UNIT                                                VOLUME                                 ***
***       NUMBER              DATA SET NAME                     NAME        UNIT FUNCTION           ***
***       ------              -------------                     ----        -------------           ***
***                                                                                               ***
***    XSC  14     C:\svv\yankee\wrr5402\tfn-1000\FT14F001                   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:\svv\yankee\wrr5402\tfn-1000\FT95F001                   BINARY INPUT DATA       ***
***                                                                                               ***
***    RST  95     C:\svv\yankee\wrr5402\tfn-1000\FT95F001                   READ RESTART DATA       ***
***                                                                                               ***
***    LIB   4     C:\svv\yankee\wrr5402\tfn-1000\FT04F001                   INPUT AMPX WORKING LIBRARY***
***                                                                                               ***
***           8     C:\svv\yankee\wrr5402\tfn-1000\FT08F001                   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 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
                                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) =  2.5833
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   6005010  7.09799E-03  4.56855E-02   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                       UPDATED
08/12/94
   6005011  3.92499E-02  2.77771E-01   5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   6006012  1.22006E-02  9.41116E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   6013027  3.35812E-02  5.82432E-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) =  1.6307
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   8001001  5.84084E-02  5.99323E-02   1001     1.0077     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   8005010  9.79802E-05  9.99025E-04   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                       UPDATED
08/12/94
   8005011  3.56450E-04  3.99615E-03   5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   8006012  2.26463E-02  2.76729E-01   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   8007014  1.40121E-03  1.99805E-02   7014    14.0033     NITROGEN-14    ENDF/B-IV MAT 1275                    UPDATED
08/12/94
   8008016  2.60749E-02  4.24574E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
   8013027  7.78110E-03  2.13789E-01  13027    26.9818    AL-27 1193 218 GP 040375(5)                            UPDATED
08/12/94

MIXTURE =     9          DENSITY(G/CC) =  7.8212
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   9006012  3.92503E-03  1.00001E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   9026000  8.34982E-02  9.90000E-01  26000    55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =    10          DENSITY(G/CC) = 0.99817E-04
   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
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************
***                                                                                   ***
***          TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M   ***
***                                                                                   ***
*****************************************************************************************
*****************************************************************************************
***                                                                                   ***
***                              ****** ADDITIONAL INFORMATION ******                 ***
***                                                                                   ***
***  NUMBER OF ENERGY GROUPS                27      USE LATTICE GEOMETRY                YES  ***
***                                                                                   ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP    1      GLOBAL ARRAY NUMBER                  60  ***
***                                                                                   ***
***  NO. OF SCATTERING ANGLES IN XSECS       2      NUMBER OF UNITS IN THE GLOBAL X DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK    33      NUMBER OF UNITS IN THE GLOBAL Y DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE FISSION BANK    26      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                      48  ***
***                                                                                   ***
***  TOTAL INPUT GEOMETRY REGIONS          133      MAXIMUM HOLE NESTING LEVEL            3  ***
***                                                                                   ***
***  NUMBER OF GEOMETRY REGIONS USED       133      USE NESTED ARRAYS                   YES  ***
***                                                                                   ***
***  LARGEST GEOMETRY UNIT NUMBER          120      NUMBER OF ARRAYS USED                27  ***
***                                                                                   ***
***  LARGEST ARRAY NUMBER                   60      MAXIMUM ARRAY NESTING LEVEL           4  ***
***                                                                                   ***
***                                                                                   ***
***  +X BOUNDARY CONDITION             REFLECT      -X BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Y BOUNDARY CONDITION             REFLECT      -Y BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Z BOUNDARY CONDITION                 PER      -Z BOUNDARY CONDITION                PER  ***
***                                                                                   ***
*****************************************************************************************
```

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	948 INDEPENDENT FISSION POINTS WERE GENERATED			
1	8.37406E-01	1.12667E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	963 INDEPENDENT FISSION POINTS WERE GENERATED			
2	8.81055E-01	1.54667E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	948 INDEPENDENT FISSION POINTS WERE GENERATED			
3	8.74792E-01	1.98667E-01	8.74792E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.50188E-01	2.40833E-01	8.62490E-01	1.23022E-02	0.00000E+00	0.00000E+00
5	8.77478E-01	2.85667E-01	8.67486E-01	8.68389E-03	0.00000E+00	0.00000E+00
6	8.70684E-01	3.29500E-01	8.68285E-01	6.19227E-03	0.00000E+00	0.00000E+00
7	8.43849E-01	3.69000E-01	8.63398E-01	6.84774E-03	0.00000E+00	0.00000E+00
8	8.65031E-01	4.10167E-01	8.63670E-01	5.59777E-03	0.00000E+00	0.00000E+00
9	8.84015E-01	4.50333E-01	8.66577E-01	5.55243E-03	0.00000E+00	0.00000E+00
10	8.94879E-01	4.89833E-01	8.70115E-01	5.96979E-03	0.00000E+00	0.00000E+00
11	8.78442E-01	5.30000E-01	8.71040E-01	5.34555E-03	0.00000E+00	0.00000E+00
12	8.71619E-01	5.70333E-01	8.71098E-01	4.78155E-03	0.00000E+00	0.00000E+00
13	8.55536E-01	6.10667E-01	8.69683E-01	4.55058E-03	0.00000E+00	0.00000E+00
14	8.82806E-01	6.50000E-01	8.70777E-01	4.29561E-03	0.00000E+00	0.00000E+00
15	9.06408E-01	6.89333E-01	8.73518E-01	4.80895E-03	0.00000E+00	0.00000E+00
16	8.76440E-01	7.29667E-01	8.73726E-01	4.45711E-03	0.00000E+00	0.00000E+00
17	8.88423E-01	7.69833E-01	8.74706E-01	4.26345E-03	0.00000E+00	0.00000E+00
18	8.69526E-01	8.08333E-01	8.74382E-01	4.00121E-03	0.00000E+00	0.00000E+00
19	8.96770E-01	8.48667E-01	8.75699E-01	3.98252E-03	0.00000E+00	0.00000E+00
20	9.28071E-01	8.87000E-01	8.78609E-01	4.75012E-03	0.00000E+00	0.00000E+00
21	8.62794E-01	9.27333E-01	8.77776E-01	4.56961E-03	0.00000E+00	0.00000E+00
22	8.55005E-01	9.66667E-01	8.76638E-01	4.48213E-03	0.00000E+00	0.00000E+00
23	9.00226E-01	1.00517E+00	8.77761E-01	4.40885E-03	0.00000E+00	0.00000E+00
24	9.05733E-01	1.04450E+00	8.79033E-01	4.39174E-03	0.00000E+00	0.00000E+00
25	8.73779E-01	1.08667E+00	8.78804E-01	4.20267E-03	0.00000E+00	0.00000E+00
26	8.52265E-01	1.12783E+00	8.77698E-01	4.17293E-03	0.00000E+00	0.00000E+00
27	8.85402E-01	1.16717E+00	8.78006E-01	4.01438E-03	0.00000E+00	0.00000E+00
28	8.91452E-01	1.20750E+00	8.78524E-01	3.89141E-03	0.00000E+00	0.00000E+00
29	9.02320E-01	1.24767E+00	8.79405E-01	3.84683E-03	0.00000E+00	0.00000E+00
30	9.03355E-01	1.28617E+00	8.80260E-01	3.80430E-03	0.00000E+00	0.00000E+00
31	9.06389E-01	1.32550E+00	8.81161E-01	3.77974E-03	0.00000E+00	0.00000E+00
32	8.66698E-01	1.36583E+00	8.80679E-01	3.68326E-03	0.00000E+00	0.00000E+00
33	8.65915E-01	1.40517E+00	8.80203E-01	3.59416E-03	0.00000E+00	0.00000E+00
34	8.79578E-01	1.44550E+00	8.80183E-01	3.48008E-03	0.00000E+00	0.00000E+00
35	8.44839E-01	1.48483E+00	8.79112E-01	3.53894E-03	0.00000E+00	0.00000E+00
36	8.69605E-01	1.52417E+00	8.78833E-01	3.44465E-03	0.00000E+00	0.00000E+00
37	8.92265E-01	1.56267E+00	8.79216E-01	3.36672E-03	0.00000E+00	0.00000E+00
38	8.85513E-01	1.60300E+00	8.79391E-01	3.27654E-03	0.00000E+00	0.00000E+00
39	8.59417E-01	1.64233E+00	8.78852E-01	3.23216E-03	0.00000E+00	0.00000E+00
40	8.59963E-01	1.67983E+00	8.78354E-01	3.18498E-03	0.00000E+00	0.00000E+00
41	8.41635E-01	1.71917E+00	8.77413E-01	3.24197E-03	0.00000E+00	0.00000E+00
42	8.28632E-01	1.75767E+00	8.76193E-01	3.38704E-03	0.00000E+00	0.00000E+00
43	8.76950E-01	1.79617E+00	8.76212E-01	3.30345E-03	0.00000E+00	0.00000E+00
44	8.54718E-01	1.83550E+00	8.75700E-01	3.26420E-03	0.00000E+00	0.00000E+00
45	8.75969E-01	1.87383E+00	8.75706E-01	3.18739E-03	0.00000E+00	0.00000E+00
46	8.51691E-01	1.91417E+00	8.75161E-01	3.16158E-03	0.00000E+00	0.00000E+00
47	8.88452E-01	1.95350E+00	8.75456E-01	3.10461E-03	0.00000E+00	0.00000E+00
48	8.66703E-01	1.99467E+00	8.75266E-01	3.04232E-03	0.00000E+00	0.00000E+00
49	9.09273E-01	2.03417E+00	8.75989E-01	3.06356E-03	0.00000E+00	0.00000E+00
50	9.25346E-01	2.07433E+00	8.77017E-01	3.17043E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	9.12580E-01	3.79325E+01	8.74693E-01	7.88441E-04	0.00000E+00	0.00000E+00
951	8.77250E-01	3.79728E+01	8.74696E-01	7.87614E-04	0.00000E+00	0.00000E+00
952	8.25017E-01	3.80130E+01	8.74643E-01	7.88521E-04	0.00000E+00	0.00000E+00
953	8.91366E-01	3.80523E+01	8.74661E-01	7.87888E-04	0.00000E+00	0.00000E+00
954	8.87194E-01	3.80927E+01	8.74674E-01	7.87170E-04	0.00000E+00	0.00000E+00
955	8.86207E-01	3.81338E+01	8.74686E-01	7.86436E-04	0.00000E+00	0.00000E+00
956	8.45087E-01	3.81750E+01	8.74655E-01	7.86224E-04	0.00000E+00	0.00000E+00
957	8.91207E-01	3.82145E+01	8.74673E-01	7.85591E-04	0.00000E+00	0.00000E+00
958	8.60877E-01	3.82547E+01	8.74658E-01	7.84902E-04	0.00000E+00	0.00000E+00
959	8.46833E-01	3.82958E+01	8.74629E-01	7.84620E-04	0.00000E+00	0.00000E+00
960	8.96081E-01	3.83380E+01	8.74652E-01	7.84121E-04	0.00000E+00	0.00000E+00
961	8.93618E-01	3.83792E+01	8.74671E-01	7.83552E-04	0.00000E+00	0.00000E+00
962	8.75231E-01	3.84195E+01	8.74672E-01	7.82736E-04	0.00000E+00	0.00000E+00
963	8.82148E-01	3.84588E+01	8.74680E-01	7.81960E-04	0.00000E+00	0.00000E+00
964	8.83276E-01	3.84992E+01	8.74689E-01	7.81197E-04	0.00000E+00	0.00000E+00
965	9.39025E-01	3.85403E+01	8.74755E-01	7.83240E-04	0.00000E+00	0.00000E+00
966	8.54465E-01	3.85807E+01	8.74734E-01	7.82710E-04	0.00000E+00	0.00000E+00
967	8.62119E-01	3.86208E+01	8.74721E-01	7.82008E-04	0.00000E+00	0.00000E+00
968	9.00442E-01	3.86620E+01	8.74748E-01	7.81652E-04	0.00000E+00	0.00000E+00
969	9.06123E-01	3.87023E+01	8.74780E-01	7.81517E-04	0.00000E+00	0.00000E+00
970	8.80081E-01	3.87427E+01	8.74786E-01	7.80728E-04	0.00000E+00	0.00000E+00
971	8.84026E-01	3.87828E+01	8.74795E-01	7.79980E-04	0.00000E+00	0.00000E+00
972	8.94924E-01	3.88232E+01	8.74816E-01	7.79452E-04	0.00000E+00	0.00000E+00
973	8.85826E-01	3.88625E+01	8.74827E-01	7.78732E-04	0.00000E+00	0.00000E+00
974	8.68249E-01	3.89020E+01	8.74821E-01	7.77959E-04	0.00000E+00	0.00000E+00
975	8.54260E-01	3.89432E+01	8.74800E-01	7.77447E-04	0.00000E+00	0.00000E+00
976	8.57751E-01	3.89843E+01	8.74782E-01	7.76845E-04	0.00000E+00	0.00000E+00
977	8.82894E-01	3.90237E+01	8.74790E-01	7.76093E-04	0.00000E+00	0.00000E+00
978	8.72030E-01	3.90630E+01	8.74788E-01	7.75302E-04	0.00000E+00	0.00000E+00
979	8.78149E-01	3.91033E+01	8.74791E-01	7.74516E-04	0.00000E+00	0.00000E+00
980	8.44656E-01	3.91427E+01	8.74760E-01	7.74337E-04	0.00000E+00	0.00000E+00
981	8.61601E-01	3.91820E+01	8.74747E-01	7.73662E-04	0.00000E+00	0.00000E+00
982	8.43346E-01	3.92213E+01	8.74715E-01	7.73536E-04	0.00000E+00	0.00000E+00
983	8.84908E-01	3.92617E+01	8.74725E-01	7.72817E-04	0.00000E+00	0.00000E+00
984	9.07479E-01	3.93010E+01	8.74758E-01	7.72750E-04	0.00000E+00	0.00000E+00
985	8.60259E-01	3.93385E+01	8.74744E-01	7.72105E-04	0.00000E+00	0.00000E+00

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

986	8.88639E-01	3.93788E+01	8.74758E-01	7.71449E-04	0.00000E+00	0.00000E+00
987	8.55669E-01	3.94182E+01	8.74738E-01	7.70909E-04	0.00000E+00	0.00000E+00
988	8.79341E-01	3.94575E+01	8.74743E-01	7.70141E-04	0.00000E+00	0.00000E+00
989	8.67160E-01	3.94970E+01	8.74735E-01	7.69398E-04	0.00000E+00	0.00000E+00
990	9.00607E-01	3.95353E+01	8.74762E-01	7.69065E-04	0.00000E+00	0.00000E+00
991	9.00635E-01	3.95757E+01	8.74788E-01	7.68732E-04	0.00000E+00	0.00000E+00
992	8.65557E-01	3.96160E+01	8.74778E-01	7.68012E-04	0.00000E+00	0.00000E+00
993	8.94843E-01	3.96553E+01	8.74799E-01	7.67504E-04	0.00000E+00	0.00000E+00
994	8.91900E-01	3.96947E+01	8.74816E-01	7.66924E-04	0.00000E+00	0.00000E+00
995	8.95329E-01	3.97340E+01	8.74837E-01	7.66429E-04	0.00000E+00	0.00000E+00
996	8.69236E-01	3.97725E+01	8.74831E-01	7.65679E-04	0.00000E+00	0.00000E+00
997	8.88701E-01	3.98128E+01	8.74845E-01	7.65036E-04	0.00000E+00	0.00000E+00
998	8.67711E-01	3.98522E+01	8.74838E-01	7.64301E-04	0.00000E+00	0.00000E+00
999	8.86853E-01	3.98905E+01	8.74850E-01	7.63629E-04	0.00000E+00	0.00000E+00
1000	9.24879E-01	3.99300E+01	8.74900E-01	7.64509E-04	0.00000E+00	0.00000E+00
1001	9.02462E-01	3.99683E+01	8.74928E-01	7.64241E-04	0.00000E+00	0.00000E+00
1002	8.44655E-01	4.00068E+01	8.74897E-01	7.64076E-04	0.00000E+00	0.00000E+00
1003	8.62537E-01	4.00462E+01	8.74885E-01	7.63413E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

LIFETIME = 3.47632E-05 + OR - 7.31644E-08 GENERATION TIME = 2.46340E-05 + OR - 3.61676E-08
NU BAR = 2.44326E+00 + OR - 6.80982E-05 AVERAGE FISSION GROUP = 2.15520E+01 + OR - 3.93530E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 3.17412E-01 + OR - 9.89744E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.87488	+ OR - 0.00076	0.87412 TO 0.87565	0.87336 TO 0.87641	0.87259 TO 0.87718	1000000
4	0.87491	+ OR - 0.00076	0.87415 TO 0.87567	0.87338 TO 0.87644	0.87262 TO 0.87720	999000
5	0.87491	+ OR - 0.00077	0.87414 TO 0.87567	0.87338 TO 0.87644	0.87261 TO 0.87720	998000
6	0.87491	+ OR - 0.00077	0.87415 TO 0.87568	0.87338 TO 0.87644	0.87261 TO 0.87721	997000
7	0.87494	+ OR - 0.00077	0.87418 TO 0.87571	0.87341 TO 0.87647	0.87264 TO 0.87724	996000
8	0.87495	+ OR - 0.00077	0.87419 TO 0.87572	0.87342 TO 0.87649	0.87265 TO 0.87725	995000
9	0.87494	+ OR - 0.00077	0.87418 TO 0.87571	0.87341 TO 0.87648	0.87264 TO 0.87725	994000
10	0.87492	+ OR - 0.00077	0.87416 TO 0.87569	0.87339 TO 0.87646	0.87262 TO 0.87723	993000
11	0.87492	+ OR - 0.00077	0.87415 TO 0.87569	0.87338 TO 0.87646	0.87261 TO 0.87723	992000
12	0.87492	+ OR - 0.00077	0.87415 TO 0.87569	0.87338 TO 0.87646	0.87261 TO 0.87723	991000
17	0.87489	+ OR - 0.00077	0.87412 TO 0.87566	0.87334 TO 0.87643	0.87257 TO 0.87721	986000
22	0.87485	+ OR - 0.00077	0.87408 TO 0.87562	0.87330 TO 0.87640	0.87253 TO 0.87717	981000
27	0.87480	+ OR - 0.00078	0.87403 TO 0.87558	0.87325 TO 0.87636	0.87248 TO 0.87713	976000
32	0.87471	+ OR - 0.00078	0.87393 TO 0.87548	0.87315 TO 0.87626	0.87237 TO 0.87704	971000
37	0.87473	+ OR - 0.00078	0.87395 TO 0.87551	0.87317 TO 0.87629	0.87238 TO 0.87707	966000
42	0.87483	+ OR - 0.00078	0.87405 TO 0.87561	0.87326 TO 0.87640	0.87248 TO 0.87718	961000
47	0.87486	+ OR - 0.00079	0.87407 TO 0.87564	0.87329 TO 0.87643	0.87250 TO 0.87722	956000
52	0.87474	+ OR - 0.00079	0.87396 TO 0.87553	0.87317 TO 0.87632	0.87238 TO 0.87710	951000
57	0.87470	+ OR - 0.00079	0.87391 TO 0.87549	0.87312 TO 0.87628	0.87233 TO 0.87707	946000
62	0.87473	+ OR - 0.00079	0.87393 TO 0.87552	0.87314 TO 0.87631	0.87235 TO 0.87710	941000
67	0.87464	+ OR - 0.00079	0.87384 TO 0.87543	0.87305 TO 0.87623	0.87226 TO 0.87702	936000
72	0.87462	+ OR - 0.00080	0.87383 TO 0.87542	0.87303 TO 0.87622	0.87223 TO 0.87701	931000
77	0.87463	+ OR - 0.00080	0.87383 TO 0.87543	0.87303 TO 0.87623	0.87223 TO 0.87703	926000
82	0.87460	+ OR - 0.00080	0.87380 TO 0.87541	0.87300 TO 0.87621	0.87220 TO 0.87701	921000
87	0.87460	+ OR - 0.00081	0.87379 TO 0.87540	0.87299 TO 0.87621	0.87218 TO 0.87701	916000
92	0.87462	+ OR - 0.00081	0.87381 TO 0.87542	0.87300 TO 0.87623	0.87220 TO 0.87704	911000

Figure 6.7.1-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

                                   FREQUENCY FOR GENERATIONS     4 TO 1003
0.7909 TO 0.7949      *
0.7949 TO 0.7990      *
0.7990 TO 0.8030
0.8030 TO 0.8070      *
0.8070 TO 0.8111
0.8111 TO 0.8151      *
0.8151 TO 0.8192      **
0.8192 TO 0.8232      *****
0.8232 TO 0.8273      ***********
0.8273 TO 0.8313      ***************
0.8313 TO 0.8354      **********
0.8354 TO 0.8394      *********************
0.8394 TO 0.8435      ***********************************
0.8435 TO 0.8475      ****************************************
0.8475 TO 0.8516      ***************************************
0.8516 TO 0.8556      *******************************************
0.8556 TO 0.8597      ****************************************
0.8597 TO 0.8637      ****************************************************************
0.8637 TO 0.8678      *******************************************************************
0.8678 TO 0.8718      ***********************************************************************************
0.8718 TO 0.8759      *********************************************************************
0.8759 TO 0.8799      *******************************************************************
0.8799 TO 0.8840      ****************************************************************
0.8840 TO 0.8880      *******************************************************************
0.8880 TO 0.8921      ********************************************************
0.8921 TO 0.8961      ***********************************************
0.8961 TO 0.9001      ****************************************
0.9001 TO 0.9042      *********************************************
0.9042 TO 0.9082      ******************************
0.9082 TO 0.9123      ************************
0.9123 TO 0.9163      *****************
0.9163 TO 0.9204      **********
0.9204 TO 0.9244      ********
0.9244 TO 0.9285      ********
0.9285 TO 0.9325      ***
0.9325 TO 0.9366      ***
0.9366 TO 0.9406      **
0.9406 TO 0.9447      ***
0.9447 TO 0.9487
0.9487 TO 0.9528
0.9528 TO 0.9568      **
0.9568 TO 0.9609
0.9609 TO 0.9649
0.9649 TO 0.9690      *
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - water in fuel clad gap
  '
  '       File tf-mr-wg.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE TRANSFER CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '                       WITH WATER IN THE FUEL CLAD GAP
  '
  '             PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '       INTERIOR MODERATOR (MATERIAL  3) VOLUME FRACTION = 1.0
  '       EXTERIOR MODERATOR (MATERIAL 10) VOLUME FRACTION = 1.0
  '      WATER GAP MODERATOR (MATERIAL 11) VOLUME FRACTION = 1.0
  '
  27GROUPNDF4 LATTICECELL
  UO2         1              0.95     293.0 92235 4.0 92238 96.0 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
  B-10        6  DEN=2.6226 0.0450  293.0                      END
  B-11        6  DEN=2.6226 0.2736  293.0                      END
  C           6  DEN=2.6226 0.0927  293.0                      END
  AL          6  DEN=2.6226 0.5737  293.0                      END
  PB          7              1.0      293.0                      END
  H           8  DEN=1.6291 0.060   293.0                      END
  O           8  DEN=1.6291 0.425   293.0                      END
  C           8  DEN=1.6291 0.277   293.0                      END
  N           8  DEN=1.6291 0.020   293.0                      END
  AL          8  DEN=1.6291 0.214   293.0                      END
  B-10        8  DEN=1.6291 0.001   293.0                      END
  B-11        8  DEN=1.6291 0.004   293.0                      END
  CARBONSTEEL 9              1.0      293.0                      END
  H2O        10              1.0      293.0                      END
  H2O        11              1.0      293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 11 END
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - water in fuel clad gap
  READ PARAM RUN=yes PLT=NO  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER 11 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER 11 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0      10.1615  0.0
HOLE  14   0.0      -10.1615 0.0
HOLE  15   10.1615  0.0      0.0
HOLE  15   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                         2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      -0.1584      0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      0.1584       0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.0          0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.0          0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.1584       0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.1584       0.0
UNIT 57
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  50   0.1584   -0.1584       0.0
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  50   -0.1584   -0.1584       0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                           2P0.6604
CUBOID 5 1 4P10.0661                          2P0.6604
CUBOID 3 1 4P10.25681                         2P0.6604
HOLE  16   0.0      10.1615  0.0
HOLE  16   0.0      -10.1615 0.0
HOLE  17   10.1615  0.0      0.0
HOLE  17   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                          2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.0      -0.1584      0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.0      0.1584       0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   0.0          0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   0.0          0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   0.1584       0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   0.1584       0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   -0.1584       0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   -0.1584       0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                           2P0.6604
CUBOID 5 1 4P10.0661                          2P0.6604
CUBOID 3 1 4P10.25681                         2P0.6604
HOLE  16   0.0      10.1615  0.0
HOLE  16   0.0      -10.1615 0.0
HOLE  17   10.1615  0.0      0.0
HOLE  17   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                          2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.0      -0.1584      0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.0      0.1584       0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   0.0          0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   0.0          0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   0.1584       0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
HOLE  70   -0.1584   0.1584       0.0
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   -0.1584       0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN TRANSFER CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253     2P2.1400
HOLE 80     -69.0614 0.0 0.0
HOLE 82     -46.1912 0.0 0.0
HOLE 81      69.0614 0.0 0.0
HOLE 83      46.1912 0.0 0.0
CYLINDER  5 1  89.7128    2P2.1400
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
CYLINDER  0 1  90.805      2P2.1400
CYLINDER  9 1  92.71       2P2.1400
CYLINDER  7 1 101.6        2P2.1400
CYLINDER  8 1 106.68       2P2.1400
CYLINDER  9 1 109.855      2P2.1400
CUBOID   10 1 4P159.855    2P2.1400
UNIT 111
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
HOLE 93       46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
UNIT 112
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249       2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -159.855 -159.855 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 4 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
53
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
FILL
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
74
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

END DATA
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (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

    11             11                  //      11        7777777777777              //   99999999999     666666666666
   111            111                 //      111        777777777777              //   9999999999999  6666666666666
  1111           1111                //      1111        77        77             //   99         99  66
    11             11               //        11                77             //   99         99  66
    11             11              //         11               77            //   99         99  66
    11             11             //          11             77           //   9999999999999  666666666666
    11             11            //           11             77          //    999999999999  6666666666666
    11             11           //            11            77         //                99  66         66
    11             11          //             11            77        //                 99  66         66
    11             11         //              11            77       //                  99  66         66
 11111111       11111111     //             11111111        77      //   9999999999999  6666666666666
 11111111       11111111    //              11111111        77     //    999999999999    66666666666

    11        5555555555555                 5555555555555   22222222222                    11        33333333333
   111        5555555555555                 5555555555555  2222222222222                  111       3333333333333
  1111        55                   :::      55             22         22       :::       1111       33         33
    11        55                   :::      55                        22       :::         11                   33
    11        55                   :::      55                        22       :::         11                   33
    11        555555555555                  555555555555            22                    11                 333
    11        5555555555555                 5555555555555         22                      11                 333
    11                  55         :::                  55       22              :::       11                  33
    11                  55         :::                  55     22                :::       11                  33
    11        55        55         :::      55        55   22                    :::       11        33        33
 11111111     5555555555555                 5555555555555  2222222222222                11111111   3333333333333
 11111111      55555555555                   55555555555   2222222222222                11111111    33333333333
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
 SSSSSSSSSS    CCCCCCCCCC     AAAAAAAAA    LL          EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC   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
SSSSSSSSSSSS  CCCCCCCCCCCC   AA       AA   LLLLLLLLLLLL EEEEEEEEEEEEE                PP             CCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC    AA       AA   LLLLLLLLLLLL EEEEEEEEEEEEE                PP              CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                PROGRAM VERIFICATION INFORMATION                   *****
*****                                                                   *****
*****              CODE SYSTEM:  SCALE-PC VERSION:  4.3                 *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                                                                   *****
*****            PROGRAM:  CSAS                                         *****
*****                                                                   *****
*****      CREATION DATE:  03-08-96                                     *****
*****                                                                   *****
*****            VOLUME:   ENG                                          *****
*****                                                                   *****
*****            LIBRARY:  G:\scale43\exe                               *****
*****                                                                   *****
*****                                                                   *****
*****    PRODUCTION DOCE:  CSAS                                         *****
*****                                                                   *****
*****            VERSION:  3.1                                          *****
*****                                                                   *****
*****            JOBNAME:  SCALE-PC                                     *****
*****                                                                   *****
*****  DATE OF EXECUTION:  11/17/96                                     *****
*****                                                                   *****
*****  TIME OF EXECUTION:  15:52:13                                     *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

    **** 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  B-10         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.0450 VOLUME FRACTION
    ROTH      2.6226 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        0.2736 VOLUME FRACTION
    ROTH      2.6226 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        0.0927 VOLUME FRACTION
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012      1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.5737 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027      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  H             STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0600 VOLUME FRACTION
ROTH      1.6291 SPECIFIED 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.
VF        0.4250 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            8016      1.00 ATOM/MOLECULE
END

SC  C             STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2770 VOLUME FRACTION
ROTH      1.6291 SPECIFIED 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.
VF        0.0200 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            7014      1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2140 VOLUME FRACTION
ROTH      1.6291 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             8 MIXTURE NO.
VF        0.0010 VOLUME FRACTION
ROTH      1.6291 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             8 MIXTURE NO.
VF        0.0040 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            5011      1.00 ATOM/MOLECULE
END
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
SC  CARBONSTEEL  STANDARD COMPOSITION
MX             9 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  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

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     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 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 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                         ********** 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:\svv\yankee\wrr5402\tf-mr-wg\FT11F001                  SHORT CROSS SECTION LIBRARY ***
***                                                                                               ***
***         90     C:\svv\yankee\wrr5402\tf-mr-wg\FT90F001                  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                                    ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

CONTROL MODULE CSAS25   IS COMPLETE.
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (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

SSSSSSSSSS    CCCCCCCCCC     AAAAAAAAA    LL            EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC   AAAAAAAAAA   LL            EEEEEEEEEEEEE                PPPPPPPPPPPPP   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
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
SSSSSSSSSSSS  CCCCCCCCCCCC   AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                PP              CCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC    AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                PP               CCCCCCCCCC

  11          11                //     11        7777777777777          //   99999999999    666666666666
 111         111               //     111        777777777777          //   9999999999999  6666666666666
1111        1111              //     1111       77        77         //   99         99  66
  11         11              //       11                77        //   99         99  66
  11         11             //        11               77        //   99         99  66
  11         11            //         11              77        //   9999999999999  666666666666
  11         11           //          11             77        //     999999999999  6666666666666
  11         11          //           11            77        //                99  66         66
  11         11         //            11           77        //                 99  66         66
  11         11        //             11          77        //                  99  66         66
11111111   11111111   //              11111111    77        //   9999999999999  6666666666666
11111111   11111111  //               11111111    77        //   999999999999   66666666666

  11       5555555555555                5555555555555   22222222222                22222222222    99999999999
 111       5555555555555                5555555555555  2222222222222              2222222222222  9999999999999
1111       55                   :::     55             22         22     :::     22         22  99         99
  11       55                   :::     55                        22     :::                22  99         99
  11       55                   :::     55                        22     :::                22  99         99
  11       555555555555                 555555555555          22                     22     9999999999999
  11       5555555555555                5555555555555       22                   22         999999999999
  11                 55         :::                 55     22             :::         22                99
  11                 55         :::                 55   22               :::       22                  99
  11       55        55         :::     55        55  22                 :::     22                    99
11111111   5555555555555                5555555555555  2222222222222              2222222222222  9999999999999
11111111    55555555555                  55555555555   2222222222222              2222222222222  999999999999
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP     CCCCCCCCCCC
SSSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCCC    AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP             CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCCC     AA         AA  LLLLLLLLLLLL    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:  11/17/96                                    *****
*****                                                                   *****
*****   TIME OF EXECUTION:  15:52:29                                    *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                               ***
*****************************************************************************************************
***                          ******      NUMERIC PARAMETERS      ******                           ***
***                                                                                               ***
***                                                                                               ***
***          TME     MAXIMUM PROBLEM TIME (MIN)                          500.00                   ***
***                                                                                               ***
***          TBA     TIME PER GENERATION (MIN)                             0.50                   ***
***                                                                                               ***
***          GEN     NUMBER OF GENERATIONS                                 1003                   ***
***                                                                                               ***
***          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 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
*****************************************************************************************************
***                                                                                                 ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                                 ***
*****************************************************************************************************
***                          ******      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 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***        UNIT                                          VOLUME                                   ***
***       NUMBER              DATA SET NAME              NAME        UNIT FUNCTION               ***
***       ------              -------------              ----        -------------               ***
***                                                                                               ***
***    XSC  14     C:\svv\yankee\wrr5402\tf-mr-wg\FT14F001                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:\svv\yankee\wrr5402\tf-mr-wg\FT95F001                BINARY INPUT DATA           ***
***                                                                                               ***
***    RST  95     C:\svv\yankee\wrr5402\tf-mr-wg\FT95F001                READ RESTART DATA           ***
***                                                                                               ***
***    LIB   4     C:\svv\yankee\wrr5402\tf-mr-wg\FT04F001                INPUT AMPX WORKING LIBRARY  ***
***                                                                                               ***
***           8     C:\svv\yankee\wrr5402\tf-mr-wg\FT08F001                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 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP
                                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) =  2.5833
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA      AWT              NUCLIDE TITLE
   6005010  7.09799E-03  4.56855E-02    5010    10.0130     B-10 1273 218NGP 042375 P-3 293K                       UPDATED
08/12/94
   6005011  3.92499E-02  2.77771E-01    5011    11.0096      BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   6006012  1.22006E-02  9.41116E-02    6000    12.0001      CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   6013027  3.35812E-02  5.82432E-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) =  1.6307
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA      AWT              NUCLIDE TITLE
   8001001  5.84084E-02  5.99323E-02    1001     1.0077      HYDROGEN        ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   8005010  9.79802E-05  9.99025E-04    5010    10.0130     B-10 1273 218NGP 042375 P-3 293K                       UPDATED
08/12/94
   8005011  3.56450E-04  3.99615E-03    5011    11.0096      BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   8006012  2.26463E-02  2.76729E-01    6000    12.0001      CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   8007014  1.40121E-03  1.99805E-02    7014    14.0033      NITROGEN-14    ENDF/B-IV MAT 1275                    UPDATED
08/12/94
   8008016  2.60749E-02  4.24574E-01    8016    15.9904      OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
   8013027  7.78110E-03  2.13789E-01   13027    26.9818     AL-27 1193 218 GP 040375(5)                            UPDATED
08/12/94

MIXTURE =     9          DENSITY(G/CC) =  7.8212
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA      AWT              NUCLIDE TITLE
   9006012  3.92503E-03  1.00001E-02    6000    12.0001      CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   9026000  8.34982E-02  9.90000E-01   26000    55.8447      IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =    10          DENSITY(G/CC) = 0.99817
   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

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

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*****************************************************************************************
***                                                                                   ***
***          TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP   ***
***                                                                                   ***
*****************************************************************************************
*****************************************************************************************
***                                                                                   ***
***                              ****** ADDITIONAL INFORMATION ******                 ***
***                                                                                   ***
***  NUMBER OF ENERGY GROUPS                27       USE LATTICE GEOMETRY                YES  ***
***                                                                                   ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP   1        GLOBAL ARRAY NUMBER                 60  ***
***                                                                                   ***
***  NO. OF SCATTERING ANGLES IN XSECS      2        NUMBER OF UNITS IN THE GLOBAL X DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK   33        NUMBER OF UNITS IN THE GLOBAL Y DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE FISSION BANK   26        NUMBER OF UNITS IN THE GLOBAL Z DIR.  4  ***
***                                                                                   ***
***  NUMBER OF MIXTURES USED               11        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                      48  ***
***                                                                                   ***
***  TOTAL INPUT GEOMETRY REGIONS         133        MAXIMUM HOLE NESTING LEVEL            3  ***
***                                                                                   ***
***  NUMBER OF GEOMETRY REGIONS USED      133        USE NESTED ARRAYS                   YES  ***
***                                                                                   ***
***  LARGEST GEOMETRY UNIT NUMBER         120        NUMBER OF ARRAYS USED                27  ***
***                                                                                   ***
***  LARGEST ARRAY NUMBER                  60        MAXIMUM ARRAY NESTING LEVEL           4  ***
***                                                                                   ***
***                                                                                   ***
***  +X BOUNDARY CONDITION            REFLECT        -X BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Y BOUNDARY CONDITION            REFLECT        -Y BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Z BOUNDARY CONDITION                PER        -Z BOUNDARY CONDITION                PER  ***
***                                                                                   ***
*****************************************************************************************
```

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY 960 INDEPENDENT FISSION POINTS WERE GENERATED				
1	8.38679E-01	1.08833E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	9.42980E-01	1.48167E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY 932 INDEPENDENT FISSION POINTS WERE GENERATED				
3	8.79994E-01	1.86667E-01	8.79994E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.82794E-01	2.27000E-01	8.81394E-01	1.40035E-03	0.00000E+00	0.00000E+00
5	8.34080E-01	2.66333E-01	8.65623E-01	1.57920E-02	0.00000E+00	0.00000E+00
6	8.72462E-01	3.07500E-01	8.67333E-01	1.12968E-02	0.00000E+00	0.00000E+00
7	8.52487E-01	3.56000E-01	8.64363E-01	9.24043E-03	0.00000E+00	0.00000E+00
8	8.86952E-01	4.00000E-01	8.68128E-01	8.43192E-03	0.00000E+00	0.00000E+00
9	9.00160E-01	4.40333E-01	8.72704E-01	8.46893E-03	0.00000E+00	0.00000E+00
10	9.27940E-01	4.77833E-01	8.79609E-01	1.00729E-02	0.00000E+00	0.00000E+00
11	8.82204E-01	5.19000E-01	8.79897E-01	8.88814E-03	0.00000E+00	0.00000E+00
12	9.06370E-01	5.60167E-01	8.82544E-01	8.37898E-03	0.00000E+00	0.00000E+00
13	9.02590E-01	5.99500E-01	8.84367E-01	7.79507E-03	0.00000E+00	0.00000E+00
14	8.60403E-01	6.38833E-01	8.82370E-01	7.39080E-03	0.00000E+00	0.00000E+00
15	8.63454E-01	6.82833E-01	8.80914E-01	6.95252E-03	0.00000E+00	0.00000E+00
16	8.77766E-01	7.22167E-01	8.80690E-01	6.44070E-03	0.00000E+00	0.00000E+00
17	8.84876E-01	7.62500E-01	8.80969E-01	6.00246E-03	0.00000E+00	0.00000E+00
18	8.73653E-01	8.01833E-01	8.80511E-01	5.63338E-03	0.00000E+00	0.00000E+00
19	8.76214E-01	8.40333E-01	8.80259E-01	5.29767E-03	0.00000E+00	0.00000E+00
20	8.83080E-01	8.78667E-01	8.80415E-01	4.99715E-03	0.00000E+00	0.00000E+00
21	8.86274E-01	9.18167E-01	8.80724E-01	4.73688E-03	0.00000E+00	0.00000E+00
22	8.81537E-01	9.56500E-01	8.80764E-01	4.49398E-03	0.00000E+00	0.00000E+00
23	8.49911E-01	9.97667E-01	8.79295E-01	4.52007E-03	0.00000E+00	0.00000E+00
24	8.97669E-01	1.03617E+00	8.80130E-01	4.38990E-03	0.00000E+00	0.00000E+00
25	8.52765E-01	1.07550E+00	8.78941E-01	4.36017E-03	0.00000E+00	0.00000E+00
26	9.06153E-01	1.11500E+00	8.80074E-01	4.32579E-03	0.00000E+00	0.00000E+00
27	8.73814E-01	1.15433E+00	8.79824E-01	4.15670E-03	0.00000E+00	0.00000E+00
28	8.85887E-01	1.19367E+00	8.80057E-01	4.00044E-03	0.00000E+00	0.00000E+00
29	8.88861E-01	1.23300E+00	8.80383E-01	3.86321E-03	0.00000E+00	0.00000E+00
30	9.03642E-01	1.27233E+00	8.81214E-01	3.81423E-03	0.00000E+00	0.00000E+00
31	9.16851E-01	1.31267E+00	8.82443E-01	3.88009E-03	0.00000E+00	0.00000E+00
32	8.58351E-01	1.35300E+00	8.81640E-01	3.83358E-03	0.00000E+00	0.00000E+00
33	8.87792E-01	1.39133E+00	8.81838E-01	3.71316E-03	0.00000E+00	0.00000E+00
34	8.76488E-01	1.43067E+00	8.81671E-01	3.59914E-03	0.00000E+00	0.00000E+00
35	8.81292E-01	1.46917E+00	8.81660E-01	3.48839E-03	0.00000E+00	0.00000E+00
36	8.48341E-01	1.50850E+00	8.80680E-01	3.52326E-03	0.00000E+00	0.00000E+00
37	8.68676E-01	1.54783E+00	8.80337E-01	3.43826E-03	0.00000E+00	0.00000E+00
38	8.83753E-01	1.58733E+00	8.80431E-01	3.34274E-03	0.00000E+00	0.00000E+00
39	8.71009E-01	1.62667E+00	8.80177E-01	3.26110E-03	0.00000E+00	0.00000E+00
40	8.74951E-01	1.66600E+00	8.80039E-01	3.17710E-03	0.00000E+00	0.00000E+00
41	8.93585E-01	1.70450E+00	8.80387E-01	3.11399E-03	0.00000E+00	0.00000E+00
42	8.90604E-01	1.74383E+00	8.80642E-01	3.04587E-03	0.00000E+00	0.00000E+00
43	8.84406E-01	1.78967E+00	8.80734E-01	2.97207E-03	0.00000E+00	0.00000E+00
44	9.19408E-01	1.82900E+00	8.81655E-01	3.04310E-03	0.00000E+00	0.00000E+00
45	8.67636E-01	1.87200E+00	8.81329E-01	2.98932E-03	0.00000E+00	0.00000E+00
46	8.64888E-01	1.91583E+00	8.80955E-01	2.94440E-03	0.00000E+00	0.00000E+00
47	8.74001E-01	1.95533E+00	8.80800E-01	2.88237E-03	0.00000E+00	0.00000E+00
48	8.70232E-01	1.99467E+00	8.80571E-01	2.82836E-03	0.00000E+00	0.00000E+00
49	9.08330E-01	2.03500E+00	8.81161E-01	2.82985E-03	0.00000E+00	0.00000E+00
50	8.93306E-01	2.07433E+00	8.81414E-01	2.78180E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	8.61184E-01	3.76597E+01	8.83707E-01	7.49771E-04	0.00000E+00	0.00000E+00
951	9.38198E-01	3.76998E+01	8.83765E-01	7.51178E-04	0.00000E+00	0.00000E+00
952	8.70550E-01	3.77402E+01	8.83751E-01	7.50516E-04	0.00000E+00	0.00000E+00
953	8.62074E-01	3.77805E+01	8.83728E-01	7.50073E-04	0.00000E+00	0.00000E+00
954	8.87262E-01	3.78198E+01	8.83732E-01	7.49294E-04	0.00000E+00	0.00000E+00
955	8.75056E-01	3.78592E+01	8.83723E-01	7.48562E-04	0.00000E+00	0.00000E+00
956	8.85677E-01	3.79003E+01	8.83725E-01	7.47780E-04	0.00000E+00	0.00000E+00
957	8.60378E-01	3.79397E+01	8.83700E-01	7.47396E-04	0.00000E+00	0.00000E+00
958	9.04548E-01	3.79790E+01	8.83722E-01	7.46933E-04	0.00000E+00	0.00000E+00
959	9.11408E-01	3.80193E+01	8.83751E-01	7.46712E-04	0.00000E+00	0.00000E+00
960	8.77433E-01	3.80597E+01	8.83745E-01	7.45962E-04	0.00000E+00	0.00000E+00
961	9.30274E-01	3.80982E+01	8.83793E-01	7.46761E-04	0.00000E+00	0.00000E+00
962	8.70589E-01	3.81383E+01	8.83779E-01	7.46110E-04	0.00000E+00	0.00000E+00
963	8.76762E-01	3.81787E+01	8.83772E-01	7.45369E-04	0.00000E+00	0.00000E+00
964	9.30255E-01	3.82190E+01	8.83820E-01	7.46160E-04	0.00000E+00	0.00000E+00
965	8.86082E-01	3.82602E+01	8.83823E-01	7.45388E-04	0.00000E+00	0.00000E+00
966	8.37636E-01	3.83003E+01	8.83775E-01	7.46154E-04	0.00000E+00	0.00000E+00
967	9.13884E-01	3.83398E+01	8.83806E-01	7.46033E-04	0.00000E+00	0.00000E+00
968	9.01212E-01	3.83782E+01	8.83824E-01	7.45479E-04	0.00000E+00	0.00000E+00
969	8.98383E-01	3.84185E+01	8.83839E-01	7.44859E-04	0.00000E+00	0.00000E+00
970	9.02978E-01	3.84578E+01	8.83859E-01	7.44352E-04	0.00000E+00	0.00000E+00
971	9.18267E-01	3.84982E+01	8.83894E-01	7.44431E-04	0.00000E+00	0.00000E+00
972	8.78049E-01	3.85375E+01	8.83888E-01	7.43688E-04	0.00000E+00	0.00000E+00
973	8.52884E-01	3.85797E+01	8.83856E-01	7.43607E-04	0.00000E+00	0.00000E+00
974	8.45918E-01	3.86190E+01	8.83817E-01	7.43866E-04	0.00000E+00	0.00000E+00
975	8.58468E-01	3.86583E+01	8.83791E-01	7.43558E-04	0.00000E+00	0.00000E+00
976	9.44680E-01	3.86968E+01	8.83854E-01	7.45420E-04	0.00000E+00	0.00000E+00
977	9.16211E-01	3.87362E+01	8.83887E-01	7.45394E-04	0.00000E+00	0.00000E+00
978	8.71239E-01	3.87755E+01	8.83874E-01	7.44743E-04	0.00000E+00	0.00000E+00
979	8.98959E-01	3.88167E+01	8.83889E-01	7.44141E-04	0.00000E+00	0.00000E+00
980	9.29580E-01	3.88578E+01	8.83936E-01	7.44846E-04	0.00000E+00	0.00000E+00
981	8.87870E-01	3.88973E+01	8.83940E-01	7.44096E-04	0.00000E+00	0.00000E+00
982	9.04001E-01	3.89367E+01	8.83961E-01	7.43618E-04	0.00000E+00	0.00000E+00
983	8.56109E-01	3.89768E+01	8.83932E-01	7.43402E-04	0.00000E+00	0.00000E+00
984	8.79591E-01	3.90163E+01	8.83928E-01	7.42657E-04	0.00000E+00	0.00000E+00
985	9.29226E-01	3.90557E+01	8.83974E-01	7.43331E-04	0.00000E+00	0.00000E+00
986	8.77684E-01	3.90950E+01	8.83968E-01	7.42603E-04	0.00000E+00	0.00000E+00

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

987	8.91019E-01	3.91353E+01	8.83975E-01	7.41883E-04	0.00000E+00	0.00000E+00
988	8.83327E-01	3.91747E+01	8.83974E-01	7.41131E-04	0.00000E+00	0.00000E+00
989	8.90881E-01	3.92130E+01	8.83981E-01	7.40412E-04	0.00000E+00	0.00000E+00
990	8.95827E-01	3.92533E+01	8.83993E-01	7.39760E-04	0.00000E+00	0.00000E+00
991	8.83975E-01	3.92937E+01	8.83993E-01	7.39012E-04	0.00000E+00	0.00000E+00
992	8.88243E-01	3.93338E+01	8.83997E-01	7.38277E-04	0.00000E+00	0.00000E+00
993	8.61167E-01	3.93742E+01	8.83974E-01	7.37891E-04	0.00000E+00	0.00000E+00
994	8.94656E-01	3.94145E+01	8.83985E-01	7.37226E-04	0.00000E+00	0.00000E+00
995	8.47387E-01	3.94547E+01	8.83948E-01	7.37405E-04	0.00000E+00	0.00000E+00
996	9.31154E-01	3.94950E+01	8.83996E-01	7.38192E-04	0.00000E+00	0.00000E+00
997	8.82171E-01	3.95343E+01	8.83994E-01	7.37452E-04	0.00000E+00	0.00000E+00
998	8.57257E-01	3.95755E+01	8.83967E-01	7.37200E-04	0.00000E+00	0.00000E+00
999	8.41131E-01	3.96150E+01	8.83924E-01	7.37712E-04	0.00000E+00	0.00000E+00
1000	9.17187E-01	3.96552E+01	8.83957E-01	7.37726E-04	0.00000E+00	0.00000E+00
1001	9.33352E-01	3.96937E+01	8.84007E-01	7.38644E-04	0.00000E+00	0.00000E+00
1002	8.90597E-01	3.97358E+01	8.84013E-01	7.37934E-04	0.00000E+00	0.00000E+00
1003	8.92086E-01	3.97742E+01	8.84021E-01	7.37241E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

LIFETIME = 3.45256E-05 + OR - 6.86456E-08 GENERATION TIME = 2.47901E-05 + OR - 3.68122E-08
NU BAR = 2.44276E+00 + OR - 6.93264E-05 AVERAGE FISSION GROUP = 2.16172E+01 + OR - 3.98797E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 3.02159E-01 + OR - 9.59208E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.88403	+ OR - 0.00074	0.88329 TO 0.88476	0.88255 TO 0.88550	0.88181 TO 0.88624	1000000
4	0.88403	+ OR - 0.00074	0.88329 TO 0.88477	0.88255 TO 0.88550	0.88181 TO 0.88624	999000
5	0.88408	+ OR - 0.00074	0.88334 TO 0.88481	0.88260 TO 0.88555	0.88186 TO 0.88629	998000
6	0.88409	+ OR - 0.00074	0.88335 TO 0.88483	0.88261 TO 0.88557	0.88187 TO 0.88630	997000
7	0.88412	+ OR - 0.00074	0.88338 TO 0.88486	0.88264 TO 0.88560	0.88190 TO 0.88634	996000
8	0.88412	+ OR - 0.00074	0.88338 TO 0.88486	0.88264 TO 0.88560	0.88190 TO 0.88633	995000
9	0.88410	+ OR - 0.00074	0.88336 TO 0.88484	0.88262 TO 0.88558	0.88188 TO 0.88632	994000
10	0.88406	+ OR - 0.00074	0.88332 TO 0.88480	0.88258 TO 0.88554	0.88184 TO 0.88627	993000
11	0.88406	+ OR - 0.00074	0.88332 TO 0.88480	0.88258 TO 0.88554	0.88184 TO 0.88628	992000
12	0.88404	+ OR - 0.00074	0.88330 TO 0.88478	0.88256 TO 0.88552	0.88182 TO 0.88626	991000
17	0.88407	+ OR - 0.00074	0.88332 TO 0.88481	0.88258 TO 0.88555	0.88184 TO 0.88630	986000
22	0.88409	+ OR - 0.00075	0.88334 TO 0.88483	0.88259 TO 0.88558	0.88185 TO 0.88633	981000
27	0.88413	+ OR - 0.00075	0.88338 TO 0.88488	0.88263 TO 0.88563	0.88188 TO 0.88637	976000
32	0.88410	+ OR - 0.00075	0.88334 TO 0.88485	0.88259 TO 0.88560	0.88184 TO 0.88635	971000
37	0.88415	+ OR - 0.00075	0.88340 TO 0.88491	0.88265 TO 0.88566	0.88189 TO 0.88642	966000
42	0.88416	+ OR - 0.00076	0.88340 TO 0.88492	0.88265 TO 0.88568	0.88189 TO 0.88643	961000
47	0.88417	+ OR - 0.00076	0.88341 TO 0.88493	0.88265 TO 0.88569	0.88189 TO 0.88645	956000
52	0.88411	+ OR - 0.00076	0.88334 TO 0.88487	0.88258 TO 0.88563	0.88182 TO 0.88639	951000
57	0.88413	+ OR - 0.00076	0.88336 TO 0.88489	0.88260 TO 0.88565	0.88183 TO 0.88642	946000
62	0.88417	+ OR - 0.00077	0.88341 TO 0.88494	0.88264 TO 0.88571	0.88187 TO 0.88647	941000
67	0.88417	+ OR - 0.00077	0.88341 TO 0.88494	0.88264 TO 0.88571	0.88187 TO 0.88647	936000
72	0.88421	+ OR - 0.00077	0.88344 TO 0.88498	0.88267 TO 0.88575	0.88190 TO 0.88652	931000
77	0.88422	+ OR - 0.00077	0.88345 TO 0.88499	0.88267 TO 0.88577	0.88190 TO 0.88654	926000
82	0.88424	+ OR - 0.00077	0.88346 TO 0.88501	0.88269 TO 0.88578	0.88191 TO 0.88656	921000
87	0.88421	+ OR - 0.00078	0.88343 TO 0.88499	0.88265 TO 0.88576	0.88188 TO 0.88654	916000
92	0.88414	+ OR - 0.00078	0.88336 TO 0.88492	0.88258 TO 0.88570	0.88179 TO 0.88648	911000

Figure 6.7.1-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

                                FREQUENCY FOR GENERATIONS    4 TO 1003
0.8068 TO 0.8099     *
0.8099 TO 0.8130
0.8130 TO 0.8160
0.8160 TO 0.8191     **
0.8191 TO 0.8222     *
0.8222 TO 0.8253     *
0.8253 TO 0.8283     ***
0.8283 TO 0.8314     ***
0.8314 TO 0.8345     *******
0.8345 TO 0.8376     ***
0.8376 TO 0.8406     ************
0.8406 TO 0.8437     *********
0.8437 TO 0.8468     *************
0.8468 TO 0.8499     ******************
0.8499 TO 0.8529     **********************
0.8529 TO 0.8560     *************************
0.8560 TO 0.8591     ****************************
0.8591 TO 0.8621     **********************************
0.8621 TO 0.8652     ****************************************
0.8652 TO 0.8683     ****************************************
0.8683 TO 0.8714     ******************************************************
0.8714 TO 0.8744     ********************************************
0.8744 TO 0.8775     *******************************************************
0.8775 TO 0.8806     ************************************************
0.8806 TO 0.8837     ******************************************************
0.8837 TO 0.8867     ********************************************************************
0.8867 TO 0.8898     ********************************************
0.8898 TO 0.8929     ************************************************************
0.8929 TO 0.8960     ************************************************
0.8960 TO 0.8990     ************************************************
0.8990 TO 0.9021     ****************************************
0.9021 TO 0.9052     *********************************
0.9052 TO 0.9082     ************************************
0.9082 TO 0.9113     ******************************
0.9113 TO 0.9144     ******************************
0.9144 TO 0.9175     ******************************
0.9175 TO 0.9205     ********************
0.9205 TO 0.9236     **********
0.9236 TO 0.9267     ******
0.9267 TO 0.9298     *******
0.9298 TO 0.9328     ******
0.9328 TO 0.9359     *******
0.9359 TO 0.9390     *****
0.9390 TO 0.9421     **
0.9421 TO 0.9451     ****
0.9451 TO 0.9482
0.9482 TO 0.9513
0.9513 TO 0.9543     ***
0.9543 TO 0.9574
0.9574 TO 0.9605     *
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  WRR EC455-5302 YANKEE Storage CASK KENO-Va MODEL Base Case
  '
  '   File: storage.in
  '
  '   THIS IS A BASE CASE MODEL OF THE NAC-MPC BASKET
  '   LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '           INSERTED INTO THE STORAGE CASK
  '
  '   The normal condition is dry (0.0001) everywhere
  '
  '
  '        material     volume
  '         number     fraction
  '        --------    --------
  '            3        0.0001     inside canister
  '            7        0.0001     canister/VCC gap
  '           10        0.0001     external to VCC
  '
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  27GROUPNDF4 LATTICECELL
  UO2          1              0.95     293.0 92235 4.0 92238 96.0 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
  B-10         6  DEN=2.6226 0.0450    293.0                      END
  B-11         6  DEN=2.6226 0.2736    293.0                      END
  C            6  DEN=2.6226 0.0927    293.0                      END
  AL           6  DEN=2.6226 0.5737    293.0                      END
  H2O          7              0.0001   293.0                      END
  CARBONSTEEL  8              1.0      293.0                      END
  REG-CONCRETE 9  DEN=2.243  1.0       293.0                      END
  H2O         10              0.0001   293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 0 END
  WRR EC455-5302 YANKEE Storage CASK KENO-Va MODEL Base Case
  READ PARAM RUN=yes PLT=YES GEN=1003 NPG=1000 tme=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1654
  CYLINDER  0 1  0.4026    2P2.1654
  CYLINDER  2 1  0.4635    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1654
  CYLINDER  5 1  0.5442    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.635
  CYLINDER  0 1  0.4026   2P0.635
  CYLINDER  2 1  0.4635   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.635
  CYLINDER  5 1  0.5442   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1654
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1654
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1654
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1654
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.635
CUBOID 4 1 2P9.144 2P0.0953 2P0.635
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.635
CUBOID 4 1 2P0.0953 2P9.144 2P0.635
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4826 2P0.9525 2P2.1654
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4826 2P1.0287 2P2.1654
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4826 2P1.1112 2P2.1654
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1112 2P79.5630 2P2.1654
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4826 2P0.9525 2P0.635
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4826 2P1.0287 2P0.635
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4826 2P1.1112 2P0.635
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1112 2P79.5630 2P0.635
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4445 2P0.9906 2P0.635
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4445 2P1.0668 2P0.635
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4445 2P1.1493 2P0.635
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1493 2P79.5249 2P0.635
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='WATER LEVEL ASSEMBLY CELL'
ARRAY  1  -9.5104 -9.5104 -2.1654
CUBOID 3 1 4P9.906                          2P2.1654
CUBOID 5 1 4P10.028                         2P2.1654
CUBOID 3 1 4P10.2187                        2P2.1654
HOLE  14   0.0       10.1234  0.0
HOLE  14   0.0       -10.1234 0.0
HOLE  15   10.1234  0.0       0.0
HOLE  15   -10.1234 0.0       0.0
CUBOID 5 1 4P10.267                         2P2.1654
CUBOID 3 1 4P10.4826                        2P2.1654
UNIT 51
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4826                        2P2.1654

'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='SUPPORT DISK ASSEMBLY CELL'
ARRAY  2  -9.5104 -9.5104 -0.635
CUBOID 3 1 4P9.906                          2P0.635
CUBOID 5 1 4P10.028                         2P0.635
CUBOID 3 1 4P10.2187                        2P0.635
HOLE  16   0.0       10.1234  0.0
HOLE  16   0.0       -10.1234 0.0
HOLE  17   10.1234  0.0       0.0
HOLE  17   -10.1234 0.0       0.0
CUBOID 5 1 4P10.267                         2P0.635
CUBOID 3 1 4P10.4826                        2P0.635
UNIT 61
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4826                        2P0.635

'
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='HEAT TRANSFER ASSEMBLY CELL'
ARRAY  2  -9.5104 -9.5104 -0.635
CUBOID 3 1 4P9.906                              2P0.635
CUBOID 5 1 4P10.028                             2P0.635
CUBOID 3 1 4P10.2187                            2P0.635
HOLE  16   0.0       10.1234  0.0
HOLE  16   0.0      -10.1234 0.0
HOLE  17   10.1234  0.0       0.0
HOLE  17   -10.1234 0.0       0.0
CUBOID 5 1 4P10.267                             2P0.635
CUBOID 3 1 4P10.4445                            2P0.635
UNIT 71
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4445                            2P0.635

'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY)'
ARRAY 20 -10.4826 -33.6702 -2.1654
UNIT 81
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 21 -10.4826 -56.6928 -2.1654
UNIT 82
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY)'
ARRAY 22 -10.4826 -79.5630 -2.1654
UNIT 83
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 23 -10.4826 -79.5630 -2.1654
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY)'
ARRAY 30 -10.4826 -33.6702 -0.635
UNIT 91
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 31 -10.4826 -56.6928 -0.635
UNIT 92
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY)'
ARRAY 32 -10.4826 -79.5630 -0.635
UNIT 93
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 33 -10.4826 -79.5630 -0.635
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY)'
ARRAY 40 -10.4445 -33.6321 -0.635
UNIT 101
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 41 -10.4445 -56.6547 -0.635
UNIT 102
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY)'
ARRAY 42 -10.4445 -79.5249 -0.635
UNIT 103
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 43 -10.4445 -79.5249 -0.635
'
'  BASKET ARRAY IN STORAGE CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6702 -79.5630 -2.1654
CYLINDER 3 1 88.1253      2P2.1654
HOLE 80      -69.0804 0.0 0.0
HOLE 81      -46.2102 0.0 0.0
HOLE 80       69.0804 0.0 0.0
HOLE 81       46.2102 0.0 0.0
CYLINDER  5 1  89.7128     2P2.1654
CYLINDER  7 1 100.33       2P2.1654
CYLINDER  8 1 109.22       2P2.1654
CYLINDER  9 1 162.56       2P2.1654
CUBOID   10 1 4P228.60     2P2.1654
UNIT 111
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6702 -79.5630 -0.635
CYLINDER 5 1 87.6046      2P0.635
HOLE 90      -69.0804 0.0 0.0
HOLE 91      -46.2102 0.0 0.0
HOLE 90       69.0804 0.0 0.0
HOLE 91       46.2102 0.0 0.0
CYLINDER  3 1  88.1253     2P0.635
CYLINDER  5 1  89.7128     2P0.635
CYLINDER  7 1 100.33       2P0.635
CYLINDER  8 1 109.22       2P0.635
CYLINDER  9 1 162.56       2P0.635
CUBOID   10 1 4P228.60     2P0.635
UNIT 112
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6321 -79.5249 -0.635
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
CYLINDER 4 1 87.249       2P0.635
HOLE 100     -69.0804 0.0 0.0
HOLE 101     -46.2102 0.0 0.0
HOLE 100      69.0804 0.0 0.0
HOLE 101      46.2102 0.0 0.0
CYLINDER  3 1  88.1253     2P0.635
CYLINDER  5 1  89.7128     2P0.635
CYLINDER  7 1 100.33       2P0.635
CYLINDER  8 1 109.22       2P0.635
CYLINDER  9 1 162.56       2P0.635
CUBOID   10 1 4P228.60     2P0.635
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -228.60  -228.60  0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
50
22
50
22
50
END FILL
ARA=21  NUX=1 NUY=9 NUZ=1
FILL
50
21
50
22
50
22
50
21
50
END FILL
ARA=22  NUX=1 NUY=13 NUZ=1
FILL
50
20
50
21
50
22
50
22
50
21
50
20
50
END FILL
ARA=23  NUX=1 NUY=13 NUZ=1
FILL
50
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
20
50
21
50
22
51
22
50
21
50
20
50
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
60
32
60
32
60
END FILL
ARA=31  NUX=1 NUY=9 NUZ=1
FILL
60
31
60
32
60
32
60
31
60
END FILL
ARA=32  NUX=1 NUY=13 NUZ=1
FILL
60
30
60
31
60
32
60
32
60
31
60
30
60
END FILL
ARA=33  NUX=1 NUY=13 NUZ=1
FILL
60
30
60
31
60
32
61
32
60
31
60
30
60
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
70
42
70
42
70
END FILL
ARA=41  NUX=1 NUY=9 NUZ=1
FILL
70
41
70
42
70
42
70
41
70
END FILL
ARA=42  NUX=1 NUY=13 NUZ=1
FILL
70
40
70
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
41
70
42
70
42
70
41
70
40
70
END FILL
ARA=43  NUX=1 NUY=13 NUZ=1
FILL
70
40
70
41
70
42
71
42
70
41
70
40
70
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
82 23 83 23 82
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
92 33 93 33 92
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
102 43 103 43 102
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

READ PLOT
SCR=YES PIC=MAT LPI=10
clr=0 255 255 255
    1   0   0   0
    2   0 238   0
    3 135 206 250
    4 205 205   0
    5 238   0   0
    6 160  32 240
    7 238 118  33
    8 255 165   0
    9 150 150 150
   10  60 179 113  end color
'
' WHOLE BASKET HORIZONTAL SLICES
'
TTL='BASKET X-Y CROSS SECTION AT Z= 0.635 HEAT TRANSFER DISK LEVEL'
XUL=  -175 YUL=  175  ZUL= 0.635
XLR=   175 YLR= -175  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 3.44 WATER LEVEL'
XUL=  -175 YUL=  175  ZUL= 3.44
XLR=   175 YLR= -175  ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 6.236 SS DISK LEVEL'
XUL=  -175 YUL=  175  ZUL= 6.236
XLR=   175 YLR= -175  ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' HEAT TRANSFER DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANTD I HEAT TRANSFER DISK'
XUL=   0.   YUL= 80     ZUL= 0.635
XLR=  80.0  YLR=  0.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II HEAT TRANSFER DISK'
XUL=   0.0 YUL= -0.0   ZUL= 0.635
XLR=  80   YLR= -80     ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III HEAT TRANSFER DISK'
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
XUL= -80.0  YUL=  -0.0  ZUL= 0.635
XLR=  -0.0  YLR= -80.0  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV HEAT TRANSFER DISK'
XUL= -80.0  YUL= 80.0   ZUL= 0.635
XLR=  -0.0  YLR=  0.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' WATER LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=   0.    YUL=  80     ZUL= 3.44
XLR=  80.0   YLR=   0.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=   0.0   YUL=  -0.0   ZUL= 3.44
XLR=  80     YLR= -80     ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0   YUL=  -0.0   ZUL= 3.44
XLR=  -0.0   YLR= -80.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0   YUL= 80.0    ZUL= 3.44
XLR=  -0.0   YLR=  0.0    ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' SUPPORT DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=   0.    YUL=  80     ZUL= 6.236
XLR=  80.0   YLR=   0.0   ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=   0.0   YUL=  -0.0   ZUL= 6.236
XLR=  80     YLR= -80     ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0   YUL=  -0.0   ZUL= 6.236
XLR=  -0.0   YLR= -80.0   ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0   YUL= 80.0    ZUL= 6.236
XLR=  -0.0   YLR=  0.0    ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
'  VERTICAL SLICES
'
TTL='BASKET X-Z CROSS SECTION ALUMINUM LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 1.27
XLR=  90  YLR=0.4   ZLR= -.1
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION WATER LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 4.318
XLR=  90  YLR=0.4   ZLR= 1.27
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION SS LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 6.858
XLR=  90  YLR=0.4   ZLR= 5.588
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION ENTIRE MODEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 12
XLR=  90  YLR=0.4   ZLR= 0
UAX=1.0 WDN=-1.0 NAX=1500 END
END PLOT
END DATA
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (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         22  55
CC             SS             AA         AA  SS             22         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

    11        22222222222              //    0000000     7777777777777              //   99999999999    666666666666
   111        2222222222222            //   000000000    777777777777               //  9999999999999  6666666666666
  1111        22         22           //   00       00  77         77              //  99         99  66
    11                   22          //   00         00          77              //  99         99  66
    11                   22         //    00         00         77               //  99         99  66
    11                22            //     00         00        77               //  9999999999999  666666666666
    11             22               //     00         00        77               //   999999999999  6666666666666
    11          22                  //     00         00       77                //             99  66         66
    11       22                     //     00         00       77                //             99  66         66
    11    22                        //      00       00       77                 //             99  66         66
  11111111  2222222222222           //       000000000       77                 //  9999999999999  6666666666666
  11111111  2222222222222          //         0000000        77                //   999999999999   66666666666

   0000000     666666666666                    11        88888888888                  5555555555555     0000000
  000000000   6666666666666                   111       8888888888888                 5555555555555    000000000
 00       00  66                  :::        1111       88         88        :::     55             00       00
00         00 66                  :::          11       88         88        :::     55            00         00
00         00 66                  :::          11       88         88        :::     55            00         00
00         00 666666666666                     11        88888888888                555555555555  00         00
00         00 6666666666666                    11        88888888888                5555555555555 00         00
00         00 66         66       :::          11       88         88        :::                55  00         00
00         00 66         66       :::          11       88         88        :::                55  00         00
 00       00  66         66       :::          11       88         88        :::     55         55   00       00
  000000000  6666666666666                  11111111   8888888888888                5555555555555    000000000
   0000000    66666666666                  11111111    88888888888                  55555555555      0000000
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
 SSSSSSSSSS    CCCCCCCCCC     AAAAAAAAA    LL            EEEEEEEEEEEEE                  PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC   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
SSSSSSSSSSSS  CCCCCCCCCCCC   AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP             CCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC    AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP              CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                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:  12/07/96                                     *****
*****                                                                   *****
*****  TIME OF EXECUTION:  06:18:50                                     *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

    **** PROBLEM PARAMETERS ****

    LIB 27GROUPNDF4  LIBRARY
    MXX           10 MIXTURES
    MSC           13 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  B-10         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.0450 VOLUME FRACTION
    ROTH      2.6226 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        0.2736 VOLUME FRACTION
    ROTH      2.6226 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
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
MX            6 MIXTURE NO.
VF       0.0927 VOLUME FRACTION
ROTH     2.6226 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
           6012      1.00 ATOM/MOLECULE
END

SC  AL          STANDARD COMPOSITION
MX            6 MIXTURE NO.
VF       0.5737 VOLUME FRACTION
ROTH     2.6226 SPECIFIED DENSITY
NEL           1 NO. ELEMENTS
ICP           1 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
          13027      1.00 ATOM/MOLECULE
END

SC  H2O         STANDARD COMPOSITION
MX            7 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  CARBONSTEEL  STANDARD COMPOSITION
MX            8 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  REG-CONCRETE STANDARD COMPOSITION
MX            9 MIXTURE NO.
VF       1.0000 VOLUME FRACTION
ROTH     2.2430 SPECIFIED DENSITY
NEL           7 NO. ELEMENTS
ICP           0 0/1 MIXTURE/COMPOUND
TEMP      293.0 DEG KELVIN
          26000     1.400 WT%
           1001     1.000 WT%
          13027     3.400 WT%
          20000     4.400 WT%
           8016    53.200 WT%
          14000    33.700 WT%
          11023     2.900 WT%
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    1.1887 CM CENTER TO CENTER SPACING
FUELOD   0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL         1 MIXTURE NO. OF FUEL
MMOD          3 MIXTURE NO. OF MODERATOR
CLADOD   0.9271 CM CLAD OUTER DIAMETER
MCLAD         2 MIXTURE NO. OF CLAD
GAPOD    0.8052 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 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                        WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE             ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                          ********** 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:\svv\wrr5302\storage\FT11F001                          SHORT CROSS SECTION LIBRARY   ***
***                                                                                               ***
***         90     C:\svv\wrr5302\storage\FT90F001                          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                                    ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

CONTROL MODULE CSAS25   IS COMPLETE.
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
KK          KK  EEEEEEEEEEEEE  NN          NN  OOOOOOOOOOOO                  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   OOOOOOOOOOOO                       V

SSSSSSSSSS    CCCCCCCCCC    AAAAAAAAA   LL          EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC  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            AAAAAAAAAAAA  LL          EEEEEEEEE    -------------   PPPPPPPPPPPPP   CC
 SSSSSSSSSSSS CC            AAAAAAAAAAAA  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
SSSSSSSSSSSS  CCCCCCCCCCCC  AA       AA  LLLLLLLLLLLL EEEEEEEEEEEEE               PP              CCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC   AA       AA  LLLLLLLLLLLL EEEEEEEEEEEEE               PP               CCCCCCCCCC

    11        22222222222          //    0000000     7777777777777          //   99999999999    666666666666
   111        2222222222222        //   000000000    777777777777           //  9999999999999  6666666666666
  1111        22        22        //   00      00   77        77           //  99        99   66
    11                  22       //    00        00        77            //   99        99   66
    11                  22      //     00        00       77             //   99        99   66
    11                22         //    00        00     77               //   9999999999999  666666666666
    11              22          //     00        00    77                //    999999999999  6666666666666
    11            22            //     00        00   77                 //              99   66        66
    11          22              //     00        00  77                  //              99   66        66
    11        22                //      00      00  77                   //              99   66        66
  11111111    2222222222222    //        000000000  77                   //   9999999999999  6666666666666
  11111111    2222222222222   //          0000000  77                   //   999999999999   66666666666

   0000000      666666666666                  11       99999999999                 0000000     7777777777777
  000000000     6666666666666               111       9999999999999              000000000    777777777777
 00       00    66                  :::    1111       99        99       :::    00       00   77         77
00         00   66                  :::      11       99        99       :::   00         00        77
00         00   66                  :::      11       99        99       :::   00         00       77
00         00   666666666666                 11       9999999999999            00         00      77
00         00   6666666666666                11        999999999999             00         00      77
00         00   66        66        :::      11                 99       :::   00         00     77
00         00   66        66        :::      11                 99       :::   00         00     77
 00       00    66        66        :::      11                 99       :::    00       00    77
  000000000     6666666666666           11111111   9999999999999                000000000     77
   0000000       66666666666            11111111   999999999999                  0000000       77
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   CCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                    PPPPPPPPPPPPP   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
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
SSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP              CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC     AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP               CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                 PROGRAM VERIFICATION INFORMATION                  *****
*****                                                                   *****
*****                 CODE SYSTEM:  SCALE-PC VERSION:  4.3              *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                                                                   *****
*****             PROGRAM:  000009                                      *****
*****                                                                   *****
*****        CREATION DATE:  03-08-96                                   *****
*****                                                                   *****
*****             VOLUME:   ENG                                         *****
*****                                                                   *****
*****             LIBRARY:  G:\scale43\exe                              *****
*****                                                                   *****
*****                                                                   *****
*****      PRODUCTION CODE:  KENOVA                                     *****
*****                                                                   *****
*****             VERSION:  3.1                                         *****
*****                                                                   *****
*****             JOBNAME:  SCALE-PC                                    *****
*****                                                                   *****
*****    DATE OF EXECUTION:  12/07/96                                   *****
*****                                                                   *****
*****    TIME OF EXECUTION:  06:19:07                                   *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************
***                                                                                   ***
***                    WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE     ***
***                                                                                   ***
*****************************************************************************************
***                        ******      NUMERIC PARAMETERS      ******                 ***
***                                                                                   ***
***                                                                                   ***
***          TME     MAXIMUM PROBLEM TIME (MIN)                      500.00           ***
***                                                                                   ***
***          TBA     TIME PER GENERATION (MIN)                         0.50           ***
***                                                                                   ***
***          GEN     NUMBER OF GENERATIONS                             1003           ***
***                                                                                   ***
***          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 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                    WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE                 ***
***                                                                                               ***
*****************************************************************************************************
***                          ******      LOGICAL PARAMETERS        ******                         ***
***                                                                                               ***
***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA    YES          PLT  PLOT PICTURE MAP(S)            YES ***
***                                                                                               ***
***  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 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                        WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE             ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***        UNIT                                                VOLUME                             ***
***       NUMBER              DATA SET NAME                     NAME        UNIT FUNCTION         ***
***       ------              -------------                     ----        -------------         ***
***                                                                                               ***
***    XSC  14     C:\svv\wrr5302\storage\FT14F001                         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:\svv\wrr5302\storage\FT95F001                         BINARY INPUT DATA      ***
***                                                                                               ***
***    RST  95     C:\svv\wrr5302\storage\FT95F001                         READ RESTART DATA      ***
***                                                                                               ***
***    LIB   4     C:\svv\wrr5302\storage\FT04F001                         INPUT AMPX WORKING LIBRARY ***
***                                                                                               ***
***           8    C:\svv\wrr5302\storage\FT08F001                         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 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
                    WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

                                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) =  2.5833
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   6005010  7.09799E-03  4.56855E-02   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                       UPDATED
08/12/94
   6005011  3.92499E-02  2.77771E-01   5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   6006012  1.22006E-02  9.41116E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   6013027  3.35812E-02  5.82432E-01  13027    26.9818    AL-27 1193 218 GP 040375(5)                            UPDATED
08/12/94

MIXTURE =     7          DENSITY(G/CC) = 0.99817E-04
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   7001001  6.67692E-06  1.11927E-01   1001     1.0077     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   7008016  3.33846E-06  8.88074E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94

MIXTURE =     8          DENSITY(G/CC) =  7.8212
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   8006012  3.92503E-03  1.00001E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   8026000  8.34982E-02  9.90000E-01  26000    55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =     9          DENSITY(G/CC) =  2.2430
   NUCLIDE   ATOM-DENS.  WGT. FRAC.     ZA      AWT            NUCLIDE TITLE
   9001001  1.34031E-02  9.99867E-03   1001     1.0077     HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   9008016  4.49394E-02  5.31997E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
   9011023  1.70392E-03  2.90003E-02  11023    22.9895     SODIUM-23      ENDF/B-IV MAT 1156                    UPDATED
08/12/94
   9013027  1.70211E-03  3.40003E-02  13027    26.9818    AL-27 1193 218 GP 040375(5)                            UPDATED
08/12/94
   9014000  1.62080E-02  3.37003E-01  14000    28.0853     SILICON        ENDF/B-IV MAT 1194                    UPDATED
08/12/94
   9020000  1.48287E-03  4.40004E-02  20000    40.0803    CALCIUM ENDF/B-IV MAT 1195                             UPDATED
08/12/94
   9026000  3.38630E-04  1.40001E-02  26000    55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =    10          DENSITY(G/CC) = 0.99817E-04
   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
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Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

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*****************************************************************************************
***                                                                                   ***
***          WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE               ***
***                                                                                   ***
*****************************************************************************************
*****************************************************************************************
***                                                                                   ***
***                              ****** ADDITIONAL INFORMATION ******                 ***
***                                                                                   ***
***  NUMBER OF ENERGY GROUPS                27      USE LATTICE GEOMETRY          YES  ***
***                                                                                   ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP    1      GLOBAL ARRAY NUMBER            60  ***
***                                                                                   ***
***  NO. OF SCATTERING ANGLES IN XSECS       2      NUMBER OF UNITS IN THE GLOBAL X DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK    32      NUMBER OF UNITS IN THE GLOBAL Y DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE FISSION BANK    25      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                24  ***
***                                                                                   ***
***  TOTAL INPUT GEOMETRY REGIONS           97      MAXIMUM HOLE NESTING LEVEL      2  ***
***                                                                                   ***
***  NUMBER OF GEOMETRY REGIONS USED         97      USE NESTED ARRAYS             YES  ***
***                                                                                   ***
***  LARGEST GEOMETRY UNIT NUMBER           120      NUMBER OF ARRAYS USED          18  ***
***                                                                                   ***
***  LARGEST ARRAY NUMBER                    60      MAXIMUM ARRAY NESTING LEVEL     4  ***
***                                                                                   ***
***                                                                                   ***
***  +X BOUNDARY CONDITION             REFLECT      -X BOUNDARY CONDITION       REFLECT  ***
***                                                                                   ***
***  +Y BOUNDARY CONDITION             REFLECT      -Y BOUNDARY CONDITION       REFLECT  ***
***                                                                                   ***
***  +Z BOUNDARY CONDITION                 PER      -Z BOUNDARY CONDITION           PER  ***
***                                                                                   ***
*****************************************************************************************
```

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	475 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	4.11868E-01	6.25517E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	477 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	4.19477E-01	6.55817E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	511 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	4.40874E-01	6.86483E+00	4.40874E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	4.31155E-01	7.17333E+00	4.36014E-01	4.85970E-03	0.00000E+00	0.00000E+00
5	4.38865E-01	7.49550E+00	4.36965E-01	2.96232E-03	0.00000E+00	0.00000E+00
6	4.17054E-01	7.80133E+00	4.31987E-01	5.40036E-03	0.00000E+00	0.00000E+00
7	4.24368E-01	8.11900E+00	4.30463E-01	4.45201E-03	0.00000E+00	0.00000E+00
8	4.17726E-01	8.43017E+00	4.28340E-01	4.20951E-03	0.00000E+00	0.00000E+00
9	4.26347E-01	8.74600E+00	4.28056E-01	3.56907E-03	0.00000E+00	0.00000E+00
10	4.31943E-01	9.06183E+00	4.28542E-01	3.12887E-03	0.00000E+00	0.00000E+00
11	4.34519E-01	9.37583E+00	4.29206E-01	2.83822E-03	0.00000E+00	0.00000E+00
12	4.34790E-01	9.69900E+00	4.29764E-01	2.59928E-03	0.00000E+00	0.00000E+00
13	4.36472E-01	1.00185E+01	4.30374E-01	2.42892E-03	0.00000E+00	0.00000E+00
14	4.35529E-01	1.03362E+01	4.30804E-01	2.25852E-03	0.00000E+00	0.00000E+00
15	4.38165E-01	1.06510E+01	4.31370E-01	2.15332E-03	0.00000E+00	0.00000E+00
16	4.41168E-01	1.09660E+01	4.32070E-01	2.11286E-03	0.00000E+00	0.00000E+00
17	4.50614E-01	1.12882E+01	4.33306E-01	2.32321E-03	0.00000E+00	0.00000E+00
18	4.42851E-01	1.16077E+01	4.33903E-01	2.25356E-03	0.00000E+00	0.00000E+00
19	4.31047E-01	1.19188E+01	4.33735E-01	2.12351E-03	0.00000E+00	0.00000E+00
20	4.43283E-01	1.22375E+01	4.34265E-01	2.07115E-03	0.00000E+00	0.00000E+00
21	4.31275E-01	1.25487E+01	4.34108E-01	1.96543E-03	0.00000E+00	0.00000E+00
22	4.22313E-01	1.28553E+01	4.33518E-01	1.95561E-03	0.00000E+00	0.00000E+00
23	4.16142E-01	1.31638E+01	4.32690E-01	2.03588E-03	0.00000E+00	0.00000E+00
24	4.38541E-01	1.34760E+01	4.32956E-01	1.95927E-03	0.00000E+00	0.00000E+00
25	4.22596E-01	1.37863E+01	4.32506E-01	1.92557E-03	0.00000E+00	0.00000E+00
26	4.43309E-01	1.40985E+01	4.32956E-01	1.89775E-03	0.00000E+00	0.00000E+00
27	4.29567E-01	1.44117E+01	4.32821E-01	1.82530E-03	0.00000E+00	0.00000E+00
28	4.32907E-01	1.47247E+01	4.32824E-01	1.75369E-03	0.00000E+00	0.00000E+00
29	4.30161E-01	1.50332E+01	4.32725E-01	1.69037E-03	0.00000E+00	0.00000E+00
30	4.45822E-01	1.53545E+01	4.33193E-01	1.69471E-03	0.00000E+00	0.00000E+00
31	4.58676E-01	1.56703E+01	4.34072E-01	1.85638E-03	0.00000E+00	0.00000E+00
32	4.43808E-01	1.59733E+01	4.34396E-01	1.82256E-03	0.00000E+00	0.00000E+00
33	4.41420E-01	1.62827E+01	4.34623E-01	1.77729E-03	0.00000E+00	0.00000E+00
34	4.38101E-01	1.65940E+01	4.34732E-01	1.72428E-03	0.00000E+00	0.00000E+00
35	4.20226E-01	1.68997E+01	4.34292E-01	1.72806E-03	0.00000E+00	0.00000E+00
36	4.30418E-01	1.72110E+01	4.34178E-01	1.68033E-03	0.00000E+00	0.00000E+00
37	4.40334E-01	1.75222E+01	4.34354E-01	1.64107E-03	0.00000E+00	0.00000E+00
38	4.29066E-01	1.78343E+01	4.34207E-01	1.60158E-03	0.00000E+00	0.00000E+00
39	4.26009E-01	1.81373E+01	4.33985E-01	1.57337E-03	0.00000E+00	0.00000E+00
40	4.30454E-01	1.84458E+01	4.33893E-01	1.53423E-03	0.00000E+00	0.00000E+00
41	4.28514E-01	1.87580E+01	4.33755E-01	1.50072E-03	0.00000E+00	0.00000E+00
42	4.34513E-01	1.90683E+01	4.33774E-01	1.46284E-03	0.00000E+00	0.00000E+00
43	4.30687E-01	1.93823E+01	4.33698E-01	1.42870E-03	0.00000E+00	0.00000E+00
44	4.14305E-01	1.96882E+01	4.33237E-01	1.46874E-03	0.00000E+00	0.00000E+00
45	4.18237E-01	2.00003E+01	4.32888E-01	1.47599E-03	0.00000E+00	0.00000E+00
46	4.29721E-01	2.03215E+01	4.32816E-01	1.44385E-03	0.00000E+00	0.00000E+00
47	4.32701E-01	2.06292E+01	4.32813E-01	1.41140E-03	0.00000E+00	0.00000E+00
48	4.18180E-01	2.09312E+01	4.32495E-01	1.41656E-03	0.00000E+00	0.00000E+00
49	4.33377E-01	2.12488E+01	4.32514E-01	1.38622E-03	0.00000E+00	0.00000E+00
50	4.35003E-01	2.15565E+01	4.32566E-01	1.35802E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	4.23082E-01	3.02703E+02	4.30921E-01	3.02884E-04	0.00000E+00	0.00000E+00
951	4.23632E-01	3.03085E+02	4.30913E-01	3.02662E-04	0.00000E+00	0.00000E+00
952	4.39814E-01	3.03453E+02	4.30922E-01	3.02489E-04	0.00000E+00	0.00000E+00
953	4.33060E-01	3.03762E+02	4.30925E-01	3.02179E-04	0.00000E+00	0.00000E+00
954	4.38819E-01	3.04109E+02	4.30933E-01	3.01975E-04	0.00000E+00	0.00000E+00
955	4.25373E-01	3.04472E+02	4.30927E-01	3.01715E-04	0.00000E+00	0.00000E+00
956	4.39266E-01	3.04828E+02	4.30936E-01	3.01525E-04	0.00000E+00	0.00000E+00
957	4.32237E-01	3.05156E+02	4.30937E-01	3.01212E-04	0.00000E+00	0.00000E+00
958	4.11043E-01	3.05477E+02	4.30916E-01	3.01616E-04	0.00000E+00	0.00000E+00
959	4.11484E-01	3.05803E+02	4.30896E-01	3.01984E-04	0.00000E+00	0.00000E+00
960	4.43532E-01	3.06125E+02	4.30909E-01	3.01957E-04	0.00000E+00	0.00000E+00
961	4.28865E-01	3.06449E+02	4.30907E-01	3.01649E-04	0.00000E+00	0.00000E+00
962	4.37268E-01	3.06771E+02	4.30914E-01	3.01408E-04	0.00000E+00	0.00000E+00
963	4.30274E-01	3.07099E+02	4.30913E-01	3.01094E-04	0.00000E+00	0.00000E+00
964	4.24956E-01	3.07414E+02	4.30907E-01	3.00845E-04	0.00000E+00	0.00000E+00
965	4.26253E-01	3.07715E+02	4.30902E-01	3.00571E-04	0.00000E+00	0.00000E+00
966	4.48713E-01	3.08029E+02	4.30921E-01	3.00827E-04	0.00000E+00	0.00000E+00
967	4.26241E-01	3.08331E+02	4.30916E-01	3.00554E-04	0.00000E+00	0.00000E+00
968	4.21349E-01	3.08625E+02	4.30906E-01	3.00406E-04	0.00000E+00	0.00000E+00
969	4.23477E-01	3.08963E+02	4.30898E-01	3.00194E-04	0.00000E+00	0.00000E+00
970	4.22261E-01	3.09289E+02	4.30889E-01	3.00016E-04	0.00000E+00	0.00000E+00
971	4.21615E-01	3.09630E+02	4.30880E-01	2.99859E-04	0.00000E+00	0.00000E+00
972	4.34719E-01	3.10055E+02	4.30884E-01	2.99576E-04	0.00000E+00	0.00000E+00
973	4.34609E-01	3.10379E+02	4.30888E-01	2.99292E-04	0.00000E+00	0.00000E+00
974	4.15198E-01	3.10694E+02	4.30871E-01	2.99419E-04	0.00000E+00	0.00000E+00
975	4.30697E-01	3.11024E+02	4.30871E-01	2.99112E-04	0.00000E+00	0.00000E+00
976	4.40992E-01	3.11341E+02	4.30882E-01	2.98985E-04	0.00000E+00	0.00000E+00
977	4.26609E-01	3.11709E+02	4.30877E-01	2.98710E-04	0.00000E+00	0.00000E+00
978	4.40731E-01	3.12052E+02	4.30887E-01	2.98575E-04	0.00000E+00	0.00000E+00
979	4.29475E-01	3.12365E+02	4.30886E-01	2.98273E-04	0.00000E+00	0.00000E+00
980	4.21792E-01	3.12669E+02	4.30877E-01	2.98113E-04	0.00000E+00	0.00000E+00
981	4.38641E-01	3.13015E+02	4.30884E-01	2.97913E-04	0.00000E+00	0.00000E+00
982	4.24572E-01	3.13313E+02	4.30878E-01	2.97679E-04	0.00000E+00	0.00000E+00
983	4.47810E-01	3.13628E+02	4.30895E-01	2.97876E-04	0.00000E+00	0.00000E+00
984	4.39955E-01	3.13948E+02	4.30905E-01	2.97715E-04	0.00000E+00	0.00000E+00
985	4.32729E-01	3.14266E+02	4.30906E-01	2.97418E-04	0.00000E+00	0.00000E+00

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

986	4.12678E-01	3.14578E+02	4.30888E-01	2.97693E-04	0.00000E+00	0.00000E+00
987	4.42827E-01	3.14927E+02	4.30900E-01	2.97637E-04	0.00000E+00	0.00000E+00
988	4.33477E-01	3.15251E+02	4.30903E-01	2.97347E-04	0.00000E+00	0.00000E+00
989	4.31513E-01	3.15611E+02	4.30903E-01	2.97046E-04	0.00000E+00	0.00000E+00
990	4.18927E-01	3.15916E+02	4.30891E-01	2.96993E-04	0.00000E+00	0.00000E+00
991	4.26421E-01	3.16219E+02	4.30887E-01	2.96727E-04	0.00000E+00	0.00000E+00
992	4.31255E-01	3.16526E+02	4.30887E-01	2.96427E-04	0.00000E+00	0.00000E+00
993	4.50152E-01	3.16845E+02	4.30906E-01	2.96765E-04	0.00000E+00	0.00000E+00
994	4.31645E-01	3.17155E+02	4.30907E-01	2.96467E-04	0.00000E+00	0.00000E+00
995	4.26160E-01	3.17469E+02	4.30902E-01	2.96206E-04	0.00000E+00	0.00000E+00
996	4.22311E-01	3.17781E+02	4.30894E-01	2.96035E-04	0.00000E+00	0.00000E+00
997	4.19499E-01	3.18098E+02	4.30882E-01	2.95959E-04	0.00000E+00	0.00000E+00
998	4.37252E-01	3.18400E+02	4.30889E-01	2.95730E-04	0.00000E+00	0.00000E+00
999	4.24955E-01	3.18710E+02	4.30883E-01	2.95494E-04	0.00000E+00	0.00000E+00
1000	4.26402E-01	3.19030E+02	4.30878E-01	2.95231E-04	0.00000E+00	0.00000E+00
1001	4.37645E-01	3.19351E+02	4.30885E-01	2.95014E-04	0.00000E+00	0.00000E+00
1002	4.38846E-01	3.19670E+02	4.30893E-01	2.94826E-04	0.00000E+00	0.00000E+00
1003	4.31258E-01	3.19986E+02	4.30893E-01	2.94531E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

LIFETIME = 2.46949E-04 + OR - 1.25870E-06 GENERATION TIME = 1.80874E-06 + OR - 7.97475E-09
NU BAR = 2.55392E+00 + OR - 2.02013E-04 AVERAGE FISSION GROUP = 6.60224E+00 + OR - 2.87354E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 8.67901E+04 + OR - 2.67219E+02

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.43088	+ OR - 0.00029	0.43059 TO 0.43118	0.43029 TO 0.43147	0.43000 TO 0.43177	1000000
4	0.43088	+ OR - 0.00029	0.43059 TO 0.43118	0.43029 TO 0.43147	0.43000 TO 0.43177	999000
5	0.43088	+ OR - 0.00030	0.43058 TO 0.43117	0.43028 TO 0.43147	0.42999 TO 0.43176	998000
6	0.43089	+ OR - 0.00030	0.43059 TO 0.43118	0.43030 TO 0.43148	0.43000 TO 0.43177	997000
7	0.43090	+ OR - 0.00030	0.43060 TO 0.43119	0.43030 TO 0.43149	0.43001 TO 0.43178	996000
8	0.43091	+ OR - 0.00030	0.43061 TO 0.43120	0.43032 TO 0.43150	0.43002 TO 0.43179	995000
9	0.43091	+ OR - 0.00030	0.43062 TO 0.43121	0.43032 TO 0.43150	0.43003 TO 0.43180	994000
10	0.43091	+ OR - 0.00030	0.43062 TO 0.43121	0.43032 TO 0.43150	0.43002 TO 0.43180	993000
11	0.43091	+ OR - 0.00030	0.43061 TO 0.43120	0.43032 TO 0.43150	0.43002 TO 0.43180	992000
12	0.43090	+ OR - 0.00030	0.43061 TO 0.43120	0.43031 TO 0.43150	0.43002 TO 0.43179	991000
17	0.43086	+ OR - 0.00030	0.43056 TO 0.43115	0.43026 TO 0.43145	0.42997 TO 0.43175	986000
22	0.43084	+ OR - 0.00030	0.43054 TO 0.43114	0.43024 TO 0.43144	0.42995 TO 0.43173	981000
27	0.43084	+ OR - 0.00030	0.43055 TO 0.43114	0.43025 TO 0.43144	0.42995 TO 0.43174	976000
32	0.43079	+ OR - 0.00030	0.43049 TO 0.43108	0.43019 TO 0.43138	0.42989 TO 0.43168	971000
37	0.43077	+ OR - 0.00030	0.43047 TO 0.43107	0.43017 TO 0.43137	0.42987 TO 0.43166	966000
42	0.43077	+ OR - 0.00030	0.43047 TO 0.43107	0.43017 TO 0.43137	0.42987 TO 0.43167	961000
47	0.43080	+ OR - 0.00030	0.43050 TO 0.43110	0.43020 TO 0.43140	0.42990 TO 0.43171	956000
52	0.43081	+ OR - 0.00030	0.43051 TO 0.43111	0.43020 TO 0.43141	0.42990 TO 0.43171	951000
57	0.43083	+ OR - 0.00030	0.43053 TO 0.43114	0.43023 TO 0.43144	0.42993 TO 0.43174	946000
62	0.43084	+ OR - 0.00030	0.43053 TO 0.43114	0.43023 TO 0.43145	0.42992 TO 0.43175	941000
67	0.43085	+ OR - 0.00031	0.43055 TO 0.43116	0.43024 TO 0.43146	0.42994 TO 0.43177	936000
72	0.43088	+ OR - 0.00031	0.43058 TO 0.43119	0.43027 TO 0.43150	0.42996 TO 0.43180	931000
77	0.43087	+ OR - 0.00031	0.43056 TO 0.43118	0.43025 TO 0.43148	0.42994 TO 0.43179	926000
82	0.43088	+ OR - 0.00031	0.43057 TO 0.43119	0.43026 TO 0.43150	0.42995 TO 0.43181	921000
87	0.43090	+ OR - 0.00031	0.43059 TO 0.43122	0.43028 TO 0.43153	0.42997 TO 0.43184	916000
92	0.43096	+ OR - 0.00031	0.43065 TO 0.43127	0.43034 TO 0.43158	0.43003 TO 0.43189	911000

Figure 6.7.1-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

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WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

                                FREQUENCY FOR GENERATIONS    4 TO 1003
0.3976 TO 0.3985      *
0.3985 TO 0.3994
0.3994 TO 0.4003
0.4003 TO 0.4013
0.4013 TO 0.4022
0.4022 TO 0.4031
0.4031 TO 0.4040
0.4040 TO 0.4050
0.4050 TO 0.4059
0.4059 TO 0.4068      *
0.4068 TO 0.4077      ***
0.4077 TO 0.4087      *
0.4087 TO 0.4096      *
0.4096 TO 0.4105      *
0.4105 TO 0.4115      *****
0.4115 TO 0.4124      ******
0.4124 TO 0.4133      ******
0.4133 TO 0.4142      *****
0.4142 TO 0.4152      ***********
0.4152 TO 0.4161      ***********
0.4161 TO 0.4170      ************
0.4170 TO 0.4179      **********************
0.4179 TO 0.4189      ******************
0.4189 TO 0.4198      **************
0.4198 TO 0.4207      ************************
0.4207 TO 0.4216      ******************************
0.4216 TO 0.4226      *******************************
0.4226 TO 0.4235      ******************************************
0.4235 TO 0.4244      ***************************
0.4244 TO 0.4253      ******************
0.4253 TO 0.4263      ************************************
0.4263 TO 0.4272      ************************************
0.4272 TO 0.4281      ********************************************
0.4281 TO 0.4290      ******************************
0.4290 TO 0.4300      ****************************************
0.4300 TO 0.4309      ************************************************
0.4309 TO 0.4318      ************************************
0.4318 TO 0.4327      *******************************************
0.4327 TO 0.4337      ********************************************************
0.4337 TO 0.4346      ************************************
0.4346 TO 0.4355      ******************************
0.4355 TO 0.4364      ******************************
0.4364 TO 0.4374      ******************************
0.4374 TO 0.4383      ************************************
0.4383 TO 0.4392      **************************
0.4392 TO 0.4401      *********************************
0.4401 TO 0.4411      **************************
0.4411 TO 0.4420      **************************
0.4420 TO 0.4429      ******************
0.4429 TO 0.4438      *************
0.4438 TO 0.4448      *********
0.4448 TO 0.4457      ********************
0.4457 TO 0.4466      ****
0.4466 TO 0.4475      *****
0.4475 TO 0.4485      *********
0.4485 TO 0.4494      *********
0.4494 TO 0.4503      *******
0.4503 TO 0.4513      *****
0.4513 TO 0.4522      *
0.4522 TO 0.4531      *****
0.4531 TO 0.4540      ***
0.4540 TO 0.4550
0.4550 TO 0.4559      *
0.4559 TO 0.4568      *
0.4568 TO 0.4577      *
0.4577 TO 0.4587      *
0.4587 TO 0.4596      *
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
  '
  '       File st-mr-wg.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE STORAGE CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '        material     volume
  '         number     fraction
  '        --------    --------
  '            3        1.0000     inside canister
  '            7        1.0000     canister/VCC gap
  '           10        1.0000     external to VCC
  '           11        1.0000     fuel/clad gap
  '
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  27GROUPNDF4 LATTICECELL
  UO2          1              0.95     293.0 92235 4.0 92238 96.0 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
  B-10         6  DEN=2.6226 0.0450  293.0                      END
  B-11         6  DEN=2.6226 0.2736  293.0                      END
  C            6  DEN=2.6226 0.0927  293.0                      END
  AL           6  DEN=2.6226 0.5737  293.0                      END
  H2O          7              1.0      293.0                      END
  CARBONSTEEL  8              1.0      293.0                      END
  REG-CONCRETE 9  DEN=2.243  1.0      293.0                      END
  H2O         10              1.0      293.0                      END
  H2O         11              1.0      293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 11 END
  WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
  READ PARAM RUN=yes PLT=no  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER 11 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER 11 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0      10.1615  0.0
HOLE  14   0.0      -10.1615 0.0
HOLE  15   10.1615  0.0      0.0
HOLE  15   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                         2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      -0.1584      0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      0.1584       0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.0          0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.0          0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.1584       0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.1584       0.0
UNIT 57
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   -0.1584       0.0
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  50   -0.1584   -0.1584       0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                           2P0.6604
CUBOID 5 1 4P10.0661                          2P0.6604
CUBOID 3 1 4P10.25681                         2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                          2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.0       -0.1584       0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.0       0.1584        0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   0.0           0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   0.0           0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   0.1584        0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   0.1584        0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   0.1584   -0.1584        0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  60   -0.1584   -0.1584        0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                           2P0.6604
CUBOID 5 1 4P10.0661                          2P0.6604
CUBOID 3 1 4P10.25681                         2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                          2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.0       -0.1584       0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.0       0.1584        0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   0.0           0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   0.0           0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   0.1584        0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   0.1584        0.0
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   -0.1584        0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN STORAGE CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253      2P2.1400
HOLE 80      -69.0614 0.0 0.0
HOLE 82      -46.1912 0.0 0.0
HOLE 81       69.0614 0.0 0.0
HOLE 83       46.1912 0.0 0.0
CYLINDER  5 1  89.7128     2P2.1400
CYLINDER  7 1 100.33       2P2.1400
CYLINDER  8 1 109.22       2P2.1400
CYLINDER  9 1 162.56       2P2.1400
CUBOID   10 1 4P228.60     2P2.1400
UNIT 111
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
HOLE 93       46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  7 1 100.33       2P0.6604
CYLINDER  8 1 109.22       2P0.6604
CYLINDER  9 1 162.56       2P0.6604
CUBOID   10 1 4P228.60     2P0.6604
UNIT 112
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249       2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  7 1 100.33       2P0.6604
CYLINDER  8 1 109.22       2P0.6604
CYLINDER  9 1 162.56       2P0.6604
CUBOID   10 1 4P228.60     2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -228.60 -228.60 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
53
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
74
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS
END DATA
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (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         22  55
CC             SS             AA         AA  SS             22         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                 PPPPPPPPPPPPP    CCCCCCCCCCC
SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL             EEEEEEEEEEEEE                 PPPPPPPPPPPPPP  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     -------------   PPPPPPPPPPPPPP   CC
 SSSSSSSSSSSS  CC             AAAAAAAAAAAAA  LL             EEEEEEEEE     -------------   PPPPPPPPPPPPP    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  LLLLLLLLLLLLL  EEEEEEEEEEEEE                 PP                CCCCCCCCCCC

     11         22222222222                //    0000000      99999999999                //  99999999999    666666666666
    111        2222222222222               //   000000000    9999999999999               //  9999999999999  6666666666666
   1111        22         22              //   00       00  99         99              //  99         99  66
     11                   22             //   00         00 99         99             //  99         99  66
     11                   22            //    00         00 99         99            //   99         99  66
     11                 22             //     00         00 9999999999999            //    9999999999999  666666666666
     11               22              //      00         00  999999999999             //     999999999999  6666666666666
     11             22               //       00         00            99             //                99  66         66
     11           22                //        00         00            99            //                 99  66         66
     11         22                 //         00       00              99           //                  99  66         66
   11111111    2222222222222      //           000000000    9999999999999          //  9999999999999  6666666666666
   11111111    2222222222222     //             0000000     999999999999         //   999999999999    66666666666

   0000000     7777777777777                     11         33333333333                 22222222222      0000000
  000000000    777777777777                     111        3333333333333               2222222222222    000000000
 00       00   77         77          :::       1111       33         33       :::    22         22   00         00
00         00          77            :::        11                  33       :::                 22   00         00
00         00         77             :::        11                  33       :::                 22   00         00
00         00        77                         11                333                       22     00         00
00         00        77                         11                333                     22       00         00
00         00       77            :::          11                  33       :::          22        00         00
00         00       77            :::          11                  33       :::        22          00         00
 00       00       77             :::          11         33       33       :::      22            00         00
  000000000        77                         11111111   3333333333333               2222222222222    000000000
   0000000         77                         11111111    33333333333                2222222222222     0000000
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL            EEEEEEEEEEEEE                  PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   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
 SSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCCC    AA         AA  LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP              CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC      AA         AA  LLLLLLLLLLLL  EEEEEEEEEEEEE                  PP               CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                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:  12/09/96                                   *****
*****                                                                   *****
*****    TIME OF EXECUTION:  07:13:20                                   *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX            11 MIXTURES
MSC            14 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  B-10          STANDARD COMPOSITION
MX              6 MIXTURE NO.
VF         0.0450 VOLUME FRACTION
ROTH       2.6226 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         0.2736 VOLUME FRACTION
ROTH       2.6226 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         0.0927 VOLUME FRACTION
ROTH       2.6226 SPECIFIED DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
TEMP        293.0 DEG KELVIN
             6012      1.00 ATOM/MOLECULE
END
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
SC  AL            STANDARD COMPOSITION
MX              6 MIXTURE NO.
VF         0.5737 VOLUME FRACTION
ROTH       2.6226 SPECIFIED DENSITY
NEL             1 NO. ELEMENTS
ICP             1 0/1 MIXTURE/COMPOUND
TEMP        293.0 DEG KELVIN
            13027      1.00 ATOM/MOLECULE
END

SC  H2O           STANDARD COMPOSITION
MX              7 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  CARBONSTEEL   STANDARD COMPOSITION
MX              8 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  REG-CONCRETE STANDARD COMPOSITION
MX              9 MIXTURE NO.
VF         1.0000 VOLUME FRACTION
ROTH       2.2430 SPECIFIED DENSITY
NEL             7 NO. ELEMENTS
ICP             0 0/1 MIXTURE/COMPOUND
TEMP        293.0 DEG KELVIN
            26000      1.400 WT%
             1001      1.000 WT%
            13027      3.400 WT%
            20000      4.400 WT%
             8016     53.200 WT%
            14000     33.700 WT%
            11023      2.900 WT%
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

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      1.1887 CM CENTER TO CENTER SPACING
FUELOD     0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL           1 MIXTURE NO. OF FUEL
MMOD            3 MIXTURE NO. OF MODERATOR
CLADOD     0.9271 CM CLAD OUTER DIAMETER
MCLAD           2 MIXTURE NO. OF CLAD
GAPOD      0.8052 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 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP            ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                         ********** 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:\svv\st-mr-wg\FT11F001                                 SHORT CROSS SECTION LIBRARY   ***
***                                                                                               ***
***         90     C:\svv\st-mr-wg\FT90F001                                 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                                     ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

CONTROL MODULE CSAS25   IS COMPLETE.
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (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

 SSSSSSSSSS    CCCCCCCCCC     AAAAAAAAA    LL            EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  CCCCCCCCCCCC   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
SSSSSSSSSSSS  CCCCCCCCCCCC   AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                PP             CCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC    AA       AA   LLLLLLLLLLLL  EEEEEEEEEEEEE                PP              CCCCCCCCCC

    11        22222222222            //    0000000      99999999999            //   99999999999    666666666666
   111       2222222222222           //   000000000     9999999999999          //   9999999999999  6666666666666
  1111       22        22           //   00       00   99         99         //   99         99  66
    11                 22          //   00        00  99         99        //   99         99  66
    11                 22          //   00        00  99         99        //   99         99  66
    11               22            //   00        00  9999999999999       //   9999999999999  666666666666
    11             22              //   00        00   999999999999      //    999999999999  6666666666666
    11           22                //   00        00              99    //                99  66        66
    11         22                  //   00        00              99   //                 99  66        66
    11       22                    //    00      00               99  //                  99  66        66
 11111111    2222222222222         //     000000000     9999999999999 //   9999999999999  6666666666666
 11111111    2222222222222        //       0000000     999999999999 //    999999999999   66666666666

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

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   CCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                    PPPPPPPPPPPPP   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              AAAAAAAAAAAAA  LL              EEEEEEEEE       -------------    PPPPPPPPPPPPP   CC
 SSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCC    AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP              CCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC     AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP               CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                PROGRAM VERIFICATION INFORMATION                   *****
*****                                                                   *****
*****              CODE SYSTEM:  SCALE-PC VERSION:  4.3                 *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                                                                   *****
*****            PROGRAM:  000009                                       *****
*****                                                                   *****
*****      CREATION DATE:  03-08-96                                     *****
*****                                                                   *****
*****            VOLUME:   ENG                                          *****
*****                                                                   *****
*****            LIBRARY:  G:\scale43\exe                               *****
*****                                                                   *****
*****                                                                   *****
*****     PRODUCTION CODE:  KENOVA                                      *****
*****                                                                   *****
*****            VERSION:  3.1                                          *****
*****                                                                   *****
*****            JOBNAME:  SCALE-PC                                     *****
*****                                                                   *****
*****   DATE OF EXECUTION:  12/09/96                                    *****
*****                                                                   *****
*****   TIME OF EXECUTION:  07:13:37                                    *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP            ***
***                                                                                               ***
*****************************************************************************************************
***                        ******      NUMERIC PARAMETERS      ******                             ***
***                                                                                               ***
***                                                                                               ***
***            TME     MAXIMUM PROBLEM TIME (MIN)                          500.00                 ***
***                                                                                               ***
***            TBA     TIME PER GENERATION (MIN)                             0.50                 ***
***                                                                                               ***
***            GEN     NUMBER OF GENERATIONS                                 1003                 ***
***                                                                                               ***
***            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 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                          WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP                  ***
***                                                                                                           ***
*****************************************************************************************************************
***                                  ******      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 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                        WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP        ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***        UNIT                                                  VOLUME                           ***
***       NUMBER                DATA SET NAME                     NAME        UNIT FUNCTION         ***
***       ------                -------------                     ----        -------------         ***
***                                                                                               ***
***    XSC  14     C:\svv\st-mr-wg\FT14F001                                   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:\svv\st-mr-wg\FT95F001                                   BINARY INPUT DATA     ***
***                                                                                               ***
***    RST  95     C:\svv\st-mr-wg\FT95F001                                   READ RESTART DATA     ***
***                                                                                               ***
***    LIB   4     C:\svv\st-mr-wg\FT04F001                                   INPUT AMPX WORKING LIBRARY ***
***                                                                                               ***
***           8    C:\svv\st-mr-wg\FT08F001                                   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 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
                    WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP
                                   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) =  2.5833
   NUCLIDE   ATOM-DENS.  WGT. FRAC.    ZA      AWT            NUCLIDE TITLE
   6005010  7.09799E-03  4.56855E-02  5010    10.0130     B-10 1273 218NGP 042375 P-3 293K                      UPDATED
08/12/94
   6005011  3.92499E-02  2.77771E-01  5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   6006012  1.22006E-02  9.41116E-02  6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   6013027  3.35812E-02  5.82432E-01  13027   26.9818     AL-27 1193 218 GP 040375(5)                           UPDATED
08/12/94

MIXTURE =     7          DENSITY(G/CC) = 0.99817
   NUCLIDE   ATOM-DENS.  WGT. FRAC.    ZA      AWT            NUCLIDE TITLE
   7001001  6.67692E-02  1.11927E-01  1001    1.0077      HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   7008016  3.33846E-02  8.88074E-01  8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94

MIXTURE =     8          DENSITY(G/CC) =  7.8212
   NUCLIDE   ATOM-DENS.  WGT. FRAC.    ZA      AWT            NUCLIDE TITLE
   8006012  3.92503E-03  1.00001E-02  6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   8026000  8.34982E-02  9.90000E-01  26000   55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =     9          DENSITY(G/CC) =  2.2430
   NUCLIDE   ATOM-DENS.  WGT. FRAC.    ZA      AWT            NUCLIDE TITLE
   9001001  1.34031E-02  9.99867E-03  1001    1.0077      HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   9008016  4.49394E-02  5.31997E-01  8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
   9011023  1.70392E-03  2.90003E-02  11023   22.9895     SODIUM-23      ENDF/B-IV MAT 1156                    UPDATED
08/12/94
   9013027  1.70211E-03  3.40003E-02  13027   26.9818     AL-27 1193 218 GP 040375(5)                           UPDATED
08/12/94
   9014000  1.62080E-02  3.37003E-01  14000   28.0853     SILICON        ENDF/B-IV MAT 1194                    UPDATED
08/12/94
   9020000  1.48287E-03  4.40004E-02  20000   40.0803     CALCIUM ENDF/B-IV MAT 1195                           UPDATED
08/12/94
   9026000  3.38630E-04  1.40001E-02  26000   55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =    10          DENSITY(G/CC) = 0.99817
   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

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

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************
***                                                                                   ***
***          WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP          ***
***                                                                                   ***
*****************************************************************************************
*****************************************************************************************
***                                                                                   ***
***                              ****** ADDITIONAL INFORMATION ******                 ***
***                                                                                   ***
***  NUMBER OF ENERGY GROUPS                27       USE LATTICE GEOMETRY                YES  ***
***                                                                                   ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP    1       GLOBAL ARRAY NUMBER                  60  ***
***                                                                                   ***
***  NO. OF SCATTERING ANGLES IN XSECS       2       NUMBER OF UNITS IN THE GLOBAL X DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK    33       NUMBER OF UNITS IN THE GLOBAL Y DIR.  1  ***
***                                                                                   ***
***  ENTRIES/NEUTRON IN THE FISSION BANK    26       NUMBER OF UNITS IN THE GLOBAL Z DIR.  4  ***
***                                                                                   ***
***  NUMBER OF MIXTURES USED                11       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                      48  ***
***                                                                                   ***
***  TOTAL INPUT GEOMETRY REGIONS          127       MAXIMUM HOLE NESTING LEVEL            3  ***
***                                                                                   ***
***  NUMBER OF GEOMETRY REGIONS USED       127       USE NESTED ARRAYS                   YES  ***
***                                                                                   ***
***  LARGEST GEOMETRY UNIT NUMBER          120       NUMBER OF ARRAYS USED                27  ***
***                                                                                   ***
***  LARGEST ARRAY NUMBER                   60       MAXIMUM ARRAY NESTING LEVEL           4  ***
***                                                                                   ***
***                                                                                   ***
***  +X BOUNDARY CONDITION             REFLECT       -X BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Y BOUNDARY CONDITION             REFLECT       -Y BOUNDARY CONDITION            REFLECT  ***
***                                                                                   ***
***  +Z BOUNDARY CONDITION                 PER       -Z BOUNDARY CONDITION                PER  ***
***                                                                                   ***
*****************************************************************************************
```

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	945 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	8.75112E-01	1.52000E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	946 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	8.62201E-01	1.90333E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	940 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	8.50943E-01	2.29667E-01	8.50943E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.68023E-01	2.69167E-01	8.59483E-01	8.53997E-03	0.00000E+00	0.00000E+00
5	8.80813E-01	3.08500E-01	8.66593E-01	8.65244E-03	0.00000E+00	0.00000E+00
6	8.93980E-01	3.48667E-01	8.73440E-01	9.18214E-03	0.00000E+00	0.00000E+00
7	8.98812E-01	3.88167E-01	8.78514E-01	8.73714E-03	0.00000E+00	0.00000E+00
8	8.47197E-01	4.27500E-01	8.73295E-01	8.83944E-03	0.00000E+00	0.00000E+00
9	8.54501E-01	4.66833E-01	8.70610E-01	7.93847E-03	0.00000E+00	0.00000E+00
10	9.10492E-01	5.05333E-01	8.75595E-01	8.49217E-03	0.00000E+00	0.00000E+00
11	8.71962E-01	5.44667E-01	8.75191E-01	7.50026E-03	0.00000E+00	0.00000E+00
12	8.74146E-01	5.82167E-01	8.75087E-01	6.70925E-03	0.00000E+00	0.00000E+00
13	8.90500E-01	6.22500E-01	8.76488E-01	6.22840E-03	0.00000E+00	0.00000E+00
14	9.06346E-01	6.61833E-01	8.78976E-01	6.20632E-03	0.00000E+00	0.00000E+00
15	8.56646E-01	7.01167E-01	8.77258E-01	5.96178E-03	0.00000E+00	0.00000E+00
16	8.87238E-01	7.40500E-01	8.77971E-01	5.56538E-03	0.00000E+00	0.00000E+00
17	8.59775E-01	7.79000E-01	8.76758E-01	5.32121E-03	0.00000E+00	0.00000E+00
18	8.72739E-01	8.18333E-01	8.76507E-01	4.98387E-03	0.00000E+00	0.00000E+00
19	9.20344E-01	8.58667E-01	8.79086E-01	5.34473E-03	0.00000E+00	0.00000E+00
20	8.86820E-01	8.98000E-01	8.79515E-01	5.05735E-03	0.00000E+00	0.00000E+00
21	8.94988E-01	9.37333E-01	8.80330E-01	4.85259E-03	0.00000E+00	0.00000E+00
22	8.22904E-01	9.78500E-01	8.77458E-01	5.42559E-03	0.00000E+00	0.00000E+00
23	8.95033E-01	1.01783E+00	8.78295E-01	5.22818E-03	0.00000E+00	0.00000E+00
24	8.61764E-01	1.05733E+00	8.77544E-01	5.04120E-03	0.00000E+00	0.00000E+00
25	8.54758E-01	1.09667E+00	8.76553E-01	4.91785E-03	0.00000E+00	0.00000E+00
26	8.56199E-01	1.13600E+00	8.75705E-01	4.78425E-03	0.00000E+00	0.00000E+00
27	9.04067E-01	1.17533E+00	8.76840E-01	4.72705E-03	0.00000E+00	0.00000E+00
28	8.47527E-01	1.21283E+00	8.75712E-01	4.67944E-03	0.00000E+00	0.00000E+00
29	8.77057E-01	1.25133E+00	8.75762E-01	4.50307E-03	0.00000E+00	0.00000E+00
30	8.71278E-01	1.29067E+00	8.75602E-01	4.34222E-03	0.00000E+00	0.00000E+00
31	8.89074E-01	1.33000E+00	8.76066E-01	4.21549E-03	0.00000E+00	0.00000E+00
32	8.82954E-01	1.36850E+00	8.76296E-01	4.07902E-03	0.00000E+00	0.00000E+00
33	8.89828E-01	1.40783E+00	8.76733E-01	3.96932E-03	0.00000E+00	0.00000E+00
34	8.42340E-01	1.44717E+00	8.75658E-01	3.99072E-03	0.00000E+00	0.00000E+00
35	9.05755E-01	1.48667E+00	8.76570E-01	3.97397E-03	0.00000E+00	0.00000E+00
36	8.49054E-01	1.52600E+00	8.75760E-01	3.93935E-03	0.00000E+00	0.00000E+00
37	9.04573E-01	1.56533E+00	8.76584E-01	3.91272E-03	0.00000E+00	0.00000E+00
38	8.49513E-01	1.60467E+00	8.75832E-01	3.87612E-03	0.00000E+00	0.00000E+00
39	8.83531E-01	1.64317E+00	8.76040E-01	3.77564E-03	0.00000E+00	0.00000E+00
40	8.74548E-01	1.68067E+00	8.76001E-01	3.67515E-03	0.00000E+00	0.00000E+00
41	9.01435E-01	1.71917E+00	8.76653E-01	3.63860E-03	0.00000E+00	0.00000E+00
42	8.52901E-01	1.75750E+00	8.76059E-01	3.59583E-03	0.00000E+00	0.00000E+00
43	8.85406E-01	1.79700E+00	8.76287E-01	3.51443E-03	0.00000E+00	0.00000E+00
44	8.89607E-01	1.83450E+00	8.76604E-01	3.44437E-03	0.00000E+00	0.00000E+00
45	9.31113E-01	1.87383E+00	8.77872E-01	3.59427E-03	0.00000E+00	0.00000E+00
46	9.03644E-01	1.91133E+00	8.78457E-01	3.56015E-03	0.00000E+00	0.00000E+00
47	9.05612E-01	1.94883E+00	8.79061E-01	3.53207E-03	0.00000E+00	0.00000E+00
48	8.97927E-01	1.98733E+00	8.79471E-01	3.47869E-03	0.00000E+00	0.00000E+00
49	9.02912E-01	2.02583E+00	8.79970E-01	3.44022E-03	0.00000E+00	0.00000E+00
50	8.96326E-01	2.06417E+00	8.80311E-01	3.38498E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	8.70416E-01	3.74143E+01	8.83893E-01	7.43957E-04	0.00000E+00	0.00000E+00
951	9.05133E-01	3.74527E+01	8.83915E-01	7.43510E-04	0.00000E+00	0.00000E+00
952	8.63683E-01	3.74930E+01	8.83894E-01	7.43032E-04	0.00000E+00	0.00000E+00
953	8.91555E-01	3.75315E+01	8.83902E-01	7.42294E-04	0.00000E+00	0.00000E+00
954	8.66491E-01	3.75698E+01	8.83884E-01	7.41739E-04	0.00000E+00	0.00000E+00
955	8.72970E-01	3.76093E+01	8.83872E-01	7.41049E-04	0.00000E+00	0.00000E+00
956	8.81615E-01	3.76477E+01	8.83870E-01	7.40276E-04	0.00000E+00	0.00000E+00
957	8.99857E-01	3.76862E+01	8.83887E-01	7.39690E-04	0.00000E+00	0.00000E+00
958	8.25766E-01	3.77247E+01	8.83826E-01	7.41412E-04	0.00000E+00	0.00000E+00
959	9.07246E-01	3.77622E+01	8.83850E-01	7.41041E-04	0.00000E+00	0.00000E+00
960	9.17018E-01	3.78007E+01	8.83885E-01	7.41076E-04	0.00000E+00	0.00000E+00
961	8.82141E-01	3.78390E+01	8.83883E-01	7.40306E-04	0.00000E+00	0.00000E+00
962	8.64857E-01	3.78783E+01	8.83863E-01	7.39799E-04	0.00000E+00	0.00000E+00
963	9.01438E-01	3.79168E+01	8.83882E-01	7.39256E-04	0.00000E+00	0.00000E+00
964	8.81430E-01	3.79553E+01	8.83879E-01	7.38491E-04	0.00000E+00	0.00000E+00
965	8.49840E-01	3.79938E+01	8.83844E-01	7.38570E-04	0.00000E+00	0.00000E+00
966	8.75750E-01	3.80313E+01	8.83835E-01	7.37851E-04	0.00000E+00	0.00000E+00
967	8.99929E-01	3.80697E+01	8.83852E-01	7.37275E-04	0.00000E+00	0.00000E+00
968	9.04655E-01	3.81082E+01	8.83873E-01	7.36826E-04	0.00000E+00	0.00000E+00
969	8.62628E-01	3.81467E+01	8.83851E-01	7.36392E-04	0.00000E+00	0.00000E+00
970	8.59757E-01	3.81850E+01	8.83827E-01	7.36051E-04	0.00000E+00	0.00000E+00
971	8.49649E-01	3.82235E+01	8.83791E-01	7.36137E-04	0.00000E+00	0.00000E+00
972	8.52009E-01	3.82628E+01	8.83759E-01	7.36107E-04	0.00000E+00	0.00000E+00
973	8.89858E-01	3.83023E+01	8.83765E-01	7.35376E-04	0.00000E+00	0.00000E+00
974	8.73960E-01	3.83407E+01	8.83755E-01	7.34688E-04	0.00000E+00	0.00000E+00
975	8.82652E-01	3.83800E+01	8.83754E-01	7.33933E-04	0.00000E+00	0.00000E+00
976	8.85957E-01	3.84195E+01	8.83756E-01	7.33183E-04	0.00000E+00	0.00000E+00
977	8.95017E-01	3.84588E+01	8.83767E-01	7.32521E-04	0.00000E+00	0.00000E+00
978	8.90552E-01	3.84982E+01	8.83774E-01	7.31804E-04	0.00000E+00	0.00000E+00
979	8.91674E-01	3.85367E+01	8.83782E-01	7.31099E-04	0.00000E+00	0.00000E+00
980	8.89774E-01	3.85768E+01	8.83789E-01	7.30377E-04	0.00000E+00	0.00000E+00
981	9.12959E-01	3.86153E+01	8.83818E-01	7.30238E-04	0.00000E+00	0.00000E+00
982	8.94913E-01	3.86528E+01	8.83830E-01	7.29581E-04	0.00000E+00	0.00000E+00
983	8.86619E-01	3.86922E+01	8.83833E-01	7.28842E-04	0.00000E+00	0.00000E+00
984	8.51460E-01	3.87317E+01	8.83800E-01	7.28845E-04	0.00000E+00	0.00000E+00
985	8.76222E-01	3.87710E+01	8.83792E-01	7.28144E-04	0.00000E+00	0.00000E+00

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

986	9.00091E-01	3.88093E+01	8.83808E-01	7.27593E-04	0.00000E+00	0.00000E+00
987	9.10388E-01	3.88478E+01	8.83835E-01	7.27354E-04	0.00000E+00	0.00000E+00
988	8.52857E-01	3.88863E+01	8.83804E-01	7.27295E-04	0.00000E+00	0.00000E+00
989	9.04577E-01	3.89257E+01	8.83825E-01	7.26863E-04	0.00000E+00	0.00000E+00
990	8.96359E-01	3.89650E+01	8.83838E-01	7.26237E-04	0.00000E+00	0.00000E+00
991	8.80578E-01	3.90053E+01	8.83834E-01	7.25510E-04	0.00000E+00	0.00000E+00
992	8.72468E-01	3.90428E+01	8.83823E-01	7.24868E-04	0.00000E+00	0.00000E+00
993	8.68384E-01	3.90822E+01	8.83807E-01	7.24304E-04	0.00000E+00	0.00000E+00
994	8.74362E-01	3.91215E+01	8.83798E-01	7.23636E-04	0.00000E+00	0.00000E+00
995	8.95072E-01	3.91610E+01	8.83809E-01	7.22996E-04	0.00000E+00	0.00000E+00
996	8.46965E-01	3.92012E+01	8.83772E-01	7.23219E-04	0.00000E+00	0.00000E+00
997	8.40963E-01	3.92397E+01	8.83729E-01	7.23771E-04	0.00000E+00	0.00000E+00
998	8.79300E-01	3.92782E+01	8.83725E-01	7.23058E-04	0.00000E+00	0.00000E+00
999	8.98173E-01	3.93165E+01	8.83739E-01	7.22478E-04	0.00000E+00	0.00000E+00
1000	9.04993E-01	3.93550E+01	8.83760E-01	7.22068E-04	0.00000E+00	0.00000E+00
1001	8.72868E-01	3.93935E+01	8.83750E-01	7.21427E-04	0.00000E+00	0.00000E+00
1002	8.84715E-01	3.94318E+01	8.83751E-01	7.20706E-04	0.00000E+00	0.00000E+00
1003	8.57689E-01	3.94712E+01	8.83724E-01	7.20456E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

LIFETIME = 3.61325E-05 + OR - 7.57716E-08 GENERATION TIME = 2.47869E-05 + OR - 3.65111E-08
NU BAR = 2.44283E+00 + OR - 7.03085E-05 AVERAGE FISSION GROUP = 2.16146E+01 + OR - 3.98016E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 3.02918E-01 + OR - 9.69277E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.88376	+ OR - 0.00072	0.88304 TO 0.88448	0.88232 TO 0.88520	0.88160 TO 0.88592	1000000
4	0.88377	+ OR - 0.00072	0.88305 TO 0.88449	0.88233 TO 0.88521	0.88161 TO 0.88594	999000
5	0.88378	+ OR - 0.00072	0.88305 TO 0.88450	0.88233 TO 0.88522	0.88161 TO 0.88594	998000
6	0.88377	+ OR - 0.00072	0.88304 TO 0.88449	0.88232 TO 0.88521	0.88160 TO 0.88593	997000
7	0.88375	+ OR - 0.00072	0.88303 TO 0.88447	0.88230 TO 0.88520	0.88158 TO 0.88592	996000
8	0.88379	+ OR - 0.00072	0.88306 TO 0.88451	0.88234 TO 0.88523	0.88162 TO 0.88596	995000
9	0.88382	+ OR - 0.00072	0.88309 TO 0.88454	0.88237 TO 0.88526	0.88165 TO 0.88599	994000
10	0.88379	+ OR - 0.00072	0.88307 TO 0.88451	0.88234 TO 0.88524	0.88162 TO 0.88596	993000
11	0.88380	+ OR - 0.00072	0.88308 TO 0.88453	0.88235 TO 0.88525	0.88163 TO 0.88597	992000
12	0.88381	+ OR - 0.00072	0.88309 TO 0.88454	0.88236 TO 0.88526	0.88164 TO 0.88598	991000
17	0.88383	+ OR - 0.00073	0.88310 TO 0.88456	0.88238 TO 0.88528	0.88165 TO 0.88601	986000
22	0.88385	+ OR - 0.00073	0.88313 TO 0.88458	0.88240 TO 0.88531	0.88167 TO 0.88603	981000
27	0.88390	+ OR - 0.00073	0.88317 TO 0.88463	0.88244 TO 0.88536	0.88172 TO 0.88609	976000
32	0.88395	+ OR - 0.00073	0.88322 TO 0.88469	0.88249 TO 0.88542	0.88176 TO 0.88615	971000
37	0.88398	+ OR - 0.00073	0.88325 TO 0.88472	0.88252 TO 0.88545	0.88179 TO 0.88618	966000
42	0.88404	+ OR - 0.00073	0.88331 TO 0.88478	0.88258 TO 0.88551	0.88184 TO 0.88625	961000
47	0.88394	+ OR - 0.00074	0.88321 TO 0.88468	0.88247 TO 0.88541	0.88174 TO 0.88615	956000
52	0.88392	+ OR - 0.00074	0.88318 TO 0.88466	0.88244 TO 0.88540	0.88170 TO 0.88613	951000
57	0.88396	+ OR - 0.00074	0.88322 TO 0.88470	0.88248 TO 0.88544	0.88174 TO 0.88618	946000
62	0.88397	+ OR - 0.00074	0.88323 TO 0.88472	0.88249 TO 0.88546	0.88174 TO 0.88620	941000
67	0.88399	+ OR - 0.00075	0.88324 TO 0.88474	0.88250 TO 0.88548	0.88175 TO 0.88623	936000
72	0.88412	+ OR - 0.00075	0.88337 TO 0.88486	0.88262 TO 0.88561	0.88188 TO 0.88635	931000
77	0.88415	+ OR - 0.00075	0.88341 TO 0.88490	0.88266 TO 0.88565	0.88191 TO 0.88640	926000
82	0.88410	+ OR - 0.00075	0.88335 TO 0.88486	0.88260 TO 0.88561	0.88185 TO 0.88636	921000
87	0.88419	+ OR - 0.00075	0.88344 TO 0.88494	0.88269 TO 0.88570	0.88193 TO 0.88645	916000
92	0.88429	+ OR - 0.00076	0.88353 TO 0.88504	0.88278 TO 0.88580	0.88202 TO 0.88656	911000

Figure 6.7.1-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                                FREQUENCY FOR GENERATIONS     4 TO 1003
0.8075 TO 0.8107      *
0.8107 TO 0.8140
0.8140 TO 0.8173      *
0.8173 TO 0.8205
0.8205 TO 0.8238      **
0.8238 TO 0.8271      *
0.8271 TO 0.8303      ******
0.8303 TO 0.8336      *****
0.8336 TO 0.8369      *****
0.8369 TO 0.8401      ******
0.8401 TO 0.8434      ***********
0.8434 TO 0.8467      **********
0.8467 TO 0.8500      **********************
0.8500 TO 0.8532      *******************
0.8532 TO 0.8565      *************************
0.8565 TO 0.8598      ******************************
0.8598 TO 0.8630      ************************************************
0.8630 TO 0.8663      ****************************************
0.8663 TO 0.8696      ************************************************
0.8696 TO 0.8728      ********************************************
0.8728 TO 0.8761      ************************************************
0.8761 TO 0.8794      ****************************************************************
0.8794 TO 0.8826      ************************************************************************
0.8826 TO 0.8859      ****************************************************
0.8859 TO 0.8892      ************************************************
0.8892 TO 0.8925      ************************************************************
0.8925 TO 0.8957      ************************************************
0.8957 TO 0.8990      ************************************************
0.8990 TO 0.9023      ****************************************************************
0.9023 TO 0.9055      ****************************************
0.9055 TO 0.9088      ****************************************
0.9088 TO 0.9121      *************************
0.9121 TO 0.9153      ************************
0.9153 TO 0.9186      *********************
0.9186 TO 0.9219      ********************
0.9219 TO 0.9251      **************
0.9251 TO 0.9284      *********
0.9284 TO 0.9317      ******
0.9317 TO 0.9349      *****
0.9349 TO 0.9382      ****
0.9382 TO 0.9415      *
0.9415 TO 0.9448      **
0.9448 TO 0.9480      *
0.9480 TO 0.9513
0.9513 TO 0.9546
0.9546 TO 0.9578
0.9578 TO 0.9611      *
0.9611 TO 0.9644
0.9644 TO 0.9676
0.9676 TO 0.9709      *
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
   WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
   '
   '       File st-mr-wg_r1.in
   '
   '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE STORAGE CASK
   '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
   '                       WITH MODIFIED TUBE ASSEMBLY 98
   '
   '            PRODUCED FOR THE YANKEE ROWE
   '               STC LICENSE AMENDMENT
   '
   '        material     volume
   '         number     fraction
   '        --------    --------
   '            3        1.0000     inside canister
   '            7        1.0000     canister/VCC gap
   '           10        1.0000     external to VCC
   '           11        1.0000     fuel/clad gap
   '
   '
   '            PRODUCED FOR THE YANKEE ROWE
   '               STC LICENSE AMENDMENT
   '
   27GROUPNDF4 LATTICECELL
   UO2          1              0.95     293.0 92235 4.0 92238 96.0 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
   B-10         6  DEN=2.6226 0.0450  293.0                      END
   B-11         6  DEN=2.6226 0.2736  293.0                      END
   C            6  DEN=2.6226 0.0927  293.0                      END
   AL           6  DEN=2.6226 0.5737  293.0                      END
   H2O          7              1.0      293.0                      END
   CARBONSTEEL  8              1.0      293.0                      END
   REG-CONCRETE 9  DEN=2.243  1.0      293.0                      END
   H2O         10              1.0      293.0                      END
   H2O         11              1.0      293.0                      END
   END COMP
   SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 11 END
   WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
   READ PARAM RUN=yes PLT=no  GEN=1003 NPG=1000 TME=500 END PARAM
   READ GEOM
   '
   '  WATER LEVEL UNIT CELLS
   '
   UNIT  1
   COM='FUEL PIN CELL - BETWEEN DISKS'
   CYLINDER  1 1  0.3943    2P2.1400
   CYLINDER 11 1  0.4026    2P2.1400
   CYLINDER  2 1  0.4635    2P2.1400
   CUBOID    3 1  4P0.5944  2P2.1400
   UNIT  2
   COM='WATER CELL - BETWEEN DISKS'
   CUBOID    3 1  4P0.5944  2P2.1400
   UNIT  3
   COM='DISPLACEMENT CELL - BETWEEN DISKS'
   CYLINDER  2 1  0.4635    2P2.1400
   CUBOID    3 1  4P0.5944  2P2.1400
   UNIT  4
   COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
   CYLINDER  3 1  0.4998    2P2.1400
   CYLINDER  5 1  0.5442    2P2.1400
   CUBOID    3 1  4P0.5944  2P2.1400
   '
   '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
   '
   UNIT  5
   COM='FUEL PIN CELL - WITH SS DISK'
   CYLINDER  1 1  0.3943   2P0.6604
   CYLINDER 11 1  0.4026   2P0.6604
   CYLINDER  2 1  0.4635   2P0.6604
   CUBOID    3 1  4P0.5944 2P0.6604
   UNIT  6
   COM='WATER CELL - WITH SS DISK'
   CUBOID    3 1  4P0.5944 2P0.6604
   UNIT  7
   COM='DISPLACEMENT CELL - WITH SS DISK'
   CYLINDER  2 1  0.4635   2P0.6604
   CUBOID    3 1  4P0.5944 2P0.6604
   UNIT  8
   COM='INSTRUMENT TUBE CELL - WITH SS DISK'
   CYLINDER  3 1  0.4998   2P0.6604
   CYLINDER  5 1  0.5442   2P0.6604
   CUBOID    3 1  4P0.5944 2P0.6604
   '
   '  WATER LEVEL BORAL SHEETS
   '
   UNIT 14
   COM='X-X BORAL SHEET BETWEEN DISKS'
   CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
   CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
   UNIT 15
   COM='Y-Y BORAL SHEET BETWEEN DISKS'
   CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0      10.1615  0.0
HOLE  14   0.0      -10.1615 0.0
HOLE  15   10.1615  0.0      0.0
HOLE  15   -10.1615 0.0      0.0
CUBOID 5 1 4P10.3051                         2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      -0.1584      0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.0      0.1584       0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   -0.1584   0.0          0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.0          0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50   0.1584   0.1584       0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   -0.1584   0.1584       0.0
UNIT 57
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   0.1584   -0.1584       0.0
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   -0.1584   -0.1584       0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                                2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.0       -0.1584      0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.0       0.1584       0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   0.0           0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   0.0           0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   0.1584       0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   0.1584       0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   0.1584   -0.1584      0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  60   -0.1584   -0.1584       0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.0       -0.1584      0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.0       0.1584       0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   -0.1584   0.0           0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  70   0.1584   0.0           0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   0.1584       0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   0.1584       0.0
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   0.1584   -0.1584       0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  70   -0.1584   -0.1584       0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                          2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN STORAGE CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - WATER LEVEL'
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253     2P2.1400
HOLE 80     -69.0614 0.0 0.0
HOLE 82     -46.1912 0.0 0.0
HOLE 81      69.0614 0.0 0.0
HOLE 83      46.1912 0.0 0.0
CYLINDER  5 1  89.7128    2P2.1400
CYLINDER  7 1 100.33      2P2.1400
CYLINDER  8 1 109.22      2P2.1400
CYLINDER  9 1 162.56      2P2.1400
CUBOID   10 1 4P228.60    2P2.1400
UNIT 111
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046     2P0.6604
HOLE 90     -69.0614 0.0 0.0
HOLE 92     -46.1912 0.0 0.0
HOLE 91      69.0614 0.0 0.0
HOLE 93      46.1912 0.0 0.0
CYLINDER  3 1  88.1253    2P0.6604
CYLINDER  5 1  89.7128    2P0.6604
CYLINDER  7 1 100.33      2P0.6604
CYLINDER  8 1 109.22      2P0.6604
CYLINDER  9 1 162.56      2P0.6604
CUBOID   10 1 4P228.60    2P0.6604
UNIT 112
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249      2P0.6604
HOLE 100    -69.0614 0.0 0.0
HOLE 102    -46.1912 0.0 0.0
HOLE 101     69.0614 0.0 0.0
HOLE 103     46.1912 0.0 0.0
CYLINDER  3 1  88.1253    2P0.6604
CYLINDER  5 1  89.7128    2P0.6604
CYLINDER  7 1 100.33      2P0.6604
CYLINDER  8 1 109.22      2P0.6604
CYLINDER  9 1 162.56      2P0.6604
CUBOID   10 1 4P228.60    2P0.6604
'
UNIT 130
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P10.1473                          2P2.1400
CUBOID 5 1 4P10.26922                         2P2.1400
CUBOID 3 1 4P10.3051                          2P2.1400
UNIT 131
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  130   0.1584   0.1584       0.0
UNIT 132
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  130   -0.1584   0.1584       0.0
UNIT 133
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  130   0.1584   -0.1584       0.0
UNIT 134
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  130   -0.1584   -0.1584       0.0
'
UNIT 140
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604
UNIT 141
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  140   0.1584   0.1584       0.0
UNIT 142
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  140   -0.1584   0.1584       0.0
UNIT 143
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  140   0.1584   -0.1584       0.0
UNIT 144
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  140   -0.1584   -0.1584       0.0
'
UNIT 150
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604
UNIT 151
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  150   0.1584   0.1584       0.0
UNIT 152
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  150   -0.1584   0.1584       0.0
UNIT 153
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  150   0.1584   -0.1584       0.0
UNIT 154
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                2P0.6604
HOLE  150   -0.1584   -0.1584       0.0
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -228.60 -228.60 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
53
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
131
21
55
22
54
22
57
21
133
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
132
21
56
22
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
53
22
58
21
134
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
141
31
65
32
64
32
67
31
143
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
142
31
66
32
63
32
68
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
31
144
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
151
41
75
42
74
42
77
41
153
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
152
41
76
42
73
42
78
41
154
END FILL
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS
READ PLOT
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1500
'
' WHOLE BASKET HORIZONTAL SLICES
'
TTL='BASKET X-Y CROSS SECTION AT Z= 0.635 HEAT TRANSFER DISK LEVEL'
XUL=  -130 YUL=  130  ZUL= 0.635
XLR=   130 YLR= -130  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 3.44 WATER LEVEL'
XUL=  -130 YUL=  130  ZUL= 3.44
XLR=   130 YLR= -130  ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 6.236 SS DISK LEVEL'
XUL=  -130 YUL=  130  ZUL= 6.236
XLR=   130 YLR= -130  ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
' HEAT TRANSFER DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANTD I HEAT TRANSFER DISK'
XUL=  12.   YUL= 80      ZUL= 0.635
XLR=  80.0  YLR= 12.0    ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II HEAT TRANSFER DISK'
XUL=  12.0 YUL= -12.0    ZUL= 0.635
XLR=  80   YLR= -80      ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III HEAT TRANSFER DISK'
XUL= -80.0  YUL= -12.0   ZUL= 0.635
XLR= -12.0  YLR= -80.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV HEAT TRANSFER DISK'
XUL= -80.0  YUL= 80.0    ZUL= 0.635
XLR= -12.0  YLR= 12.0    ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' WATER LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=  12.    YUL=  80     ZUL= 3.44
XLR=  80.0   YLR=  12.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=  12.0   YUL= -12.0   ZUL= 3.44
XLR=  80     YLR= -80     ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0   YUL= -12.0   ZUL= 3.44
XLR= -12.0   YLR= -80.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0   YUL= 80.0    ZUL= 3.44
XLR= -12.0   YLR= 12.0    ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
'
'  VERTICAL SLICES
'
TTL='BASKET X-Z CROSS SECTION ALUMINUM LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 1.27
XLR=  90  YLR=0.4   ZLR= -.1
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION WATER LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 4.318
XLR=  90  YLR=0.4   ZLR= 1.27
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION SS LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 6.858
XLR=  90  YLR=0.4   ZLR= 5.588
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION ENTIRE MODEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 12
XLR=  90  YLR=0.4   ZLR= 0
UAX=1.0 WDN=-1.0 NAX=1500 END
END PLOT
END DATA

SECONDARY MODULE 000008   HAS BEEN CALLED.

MODULE 000008   IS FINISHED. COMPLETION CODE     0. CPU TIME USED     0.99 (SECONDS).

SECONDARY MODULE 000002   HAS BEEN CALLED.

MODULE 000002   IS FINISHED. COMPLETION CODE     0. CPU TIME USED     7.09 (SECONDS).

SECONDARY MODULE 000009   HAS BEEN CALLED.

MODULE 000009   IS FINISHED. COMPLETION CODE     0. CPU TIME USED  1185.78 (SECONDS).

MODULE CSAS25   IS FINISHED. COMPLETION CODE     0. CPU TIME USED  1197.92 (SECONDS).
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (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         22  55
CC             SS             AA         AA  SS             22         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                 PPPPPPPPPPPPP    CCCCCCCCCCC
SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL             EEEEEEEEEEEEE                 PPPPPPPPPPPPPP  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              //      11        5555555555555              //    0000000        0000000
  000000000    8888888888888            //      111        5555555555555            //    000000000      000000000
 00       00   88         88           //      1111        55                     //    00       00    00       00
00         00  88         88          //        11        55                    //    00         00  00         00
00         00  88         88         //         11        55                   //    00         00  00         00
00         00   88888888888         //          11        555555555555        //    00         00  00         00
00         00   88888888888        //           11        5555555555555      //    00         00  00         00
00         00  88         88      //            11                  55    //    00         00  00         00
00         00  88         88     //             11                  55   //    00         00  00         00
 00       00   88         88    //              11        55        55  //     00       00    00       00
  000000000    8888888888888   //              11111111   5555555555555 //      000000000      000000000
   0000000      88888888888   //               11111111    55555555555 //       0000000        0000000

   0000000      88888888888                     0000000   7777777777777                      0000000      99999999999
  000000000    8888888888888                   000000000   777777777777                     000000000    9999999999999
 00       00   88         88        :::       00       00  77         77        :::        00       00  99         99
00         00  88         88        :::      00         00         77        :::       00         00  99         99
00         00  88         88        :::      00         00        77         :::       00         00  99         99
00         00   88888888888                  00         00       77                    00         00  9999999999999
00         00   88888888888                  00         00       77                    00         00   999999999999
00         00  88         88        :::      00         00      77         :::        00         00              99
00         00  88         88        :::      00         00      77         :::        00         00              99
 00       00   88         88        :::       00       00      77         :::         00       00               99
  000000000    8888888888888                  000000000        77                     000000000    9999999999999
   0000000      88888888888                    0000000         77                      0000000     999999999999
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX           11 MIXTURES
MSC           14 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  B-10         STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.0450 VOLUME FRACTION
ROTH      2.6226 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        0.2736 VOLUME FRACTION
ROTH      2.6226 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.
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
VF        0.0927 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012      1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.5737 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027      1.00 ATOM/MOLECULE
END

SC  H2O           STANDARD COMPOSITION
MX             7 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  CARBONSTEEL  STANDARD COMPOSITION
MX             8 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  REG-CONCRETE STANDARD COMPOSITION
MX             9 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      2.2430 SPECIFIED DENSITY
NEL            7 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           26000     1.400 WT%
            1001     1.000 WT%
           13027     3.400 WT%
           20000     4.400 WT%
            8016    53.200 WT%
           14000    33.700 WT%
           11023     2.900 WT%
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

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     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 CM GAP OUTER DIAMETER
MGAP          11 MIXTURE NO. OF GAP


ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

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

*****************************************************************************************************
***                                                                                               ***
***                         WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP       ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                          ********** 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:\zjr\Yankee\st-mr-wg_r1\FT11F001                       SHORT CROSS SECTION LIBRARY   ***
***                                                                                               ***
***         90     D:\zjr\Yankee\st-mr-wg_r1\FT90F001                       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                                    ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

                 ........    0 IO'S WERE USED BEFORE READING KENO V DATA    ........

                 ........    0 IO'S WERE USED READING THE KENO V PARAMETER DATA    ........
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
KK          KK  EEEEEEEEEEEEE  NN          NN  00000000000                    VV          VV
KK         KK   EEEEEEEEEEEEE  NNN         NN  0000000000000                  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
KKKKKKKKK        EEEEEEEEE      NN    NN    NN  OO         OO  -------------   VV          VV
KKKKKKKKK        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                       VVV
KK         KK    EEEEEEEEEEEEE  NN         NNN  0000000000000                        V
KK          KK   EEEEEEEEEEEEE  NN          NN   00000000000

 SSSSSSSSSS    CCCCCCCCCCC     AAAAAAAAA    LL             EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCCC
SSSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCCC  AA       AA   LLLLLLLLLLLL   EEEEEEEEEEEEE                PP              CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCCC   AA       AA   LLLLLLLLLLLL   EEEEEEEEEEEEE                PP               CCCCCCCCCCC

  0000000      88888888888          //      11        5555555555555          //    0000000        0000000
 000000000    8888888888888         //     111        5555555555555          //   000000000      000000000
00       00   88         88        //    1111        55                     //  00       00    00       00
00        00  88         88       //      11        55                     //  00        00   00        00
00        00  88         88      //       11        55                     //  00        00   00        00
00        00   88888888888      //        11        555555555555           //  00        00   00        00
00        00   88888888888     //         11        5555555555555          //  00        00   00        00
00        00  88         88   //          11                  55          //  00        00   00        00
00        00  88         88  //           11                  55          //  00        00   00        00
00       00   88         88 //            11        55        55          //  00       00    00       00
 000000000    8888888888888//             11111111  5555555555555          //   000000000      000000000
  0000000      88888888888//              11111111   55555555555          //    0000000        0000000

  0000000      88888888888                 0000000   7777777777777              22222222222        11
 000000000    8888888888888               000000000   777777777777              2222222222222      111
00       00   88         88     :::      00       00  77        77     :::     22         22     1111
00        00  88         88     :::     00         00        77      :::                22       11
00        00  88         88     :::     00         00       77       :::                22       11
00        00   88888888888             00         00      77                       22          11
00        00   88888888888             00         00      77                     22            11
00        00  88         88     :::    00         00     77        :::       22              11
00        00  88         88     :::    00         00     77        :::     22                11
00       00   88         88     :::     00       00     77        :::    22                   11
 000000000    8888888888888               000000000      77                2222222222222     11111111
  0000000      88888888888                 0000000       77                2222222222222     11111111
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   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
SSSSSSSSSSSS   CCCCCCCCCCCCC   AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP              CCCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC     AA         AA   LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP               CCCCCCCCCC

*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                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:  08/15/00                                    *****
*****                                                                   *****
*****   TIME OF EXECUTION:  08:07:21                                    *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP            ***
***                                                                                               ***
*****************************************************************************************************
***                        ******      NUMERIC PARAMETERS      ******                             ***
***                                                                                               ***
***                                                                                               ***
***          TME     MAXIMUM PROBLEM TIME (MIN)                                500.00             ***
***                                                                                               ***
***          TBA     TIME PER GENERATION (MIN)                                   0.50             ***
***                                                                                               ***
***          GEN     NUMBER OF GENERATIONS                                      1003              ***
***                                                                                               ***
***          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 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
*****************************************************************************************************
*****************************************************************************************************
***                                                                                                 ***
***                         WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP         ***
***                                                                                                 ***
*****************************************************************************************************
***                              ******      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 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	987 INDEPENDENT FISSION POINTS WERE GENERATED			
1	8.75868E-01	4.83333E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	9.22861E-01	5.02667E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
3	8.88857E-01	5.22833E-01	8.88857E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	9.23395E-01	5.42000E-01	9.06126E-01	1.72693E-02	0.00000E+00	0.00000E+00
5	8.85830E-01	5.61167E-01	8.99361E-01	1.20490E-02	0.00000E+00	0.00000E+00
6	8.91758E-01	5.81333E-01	8.97460E-01	8.72936E-03	0.00000E+00	0.00000E+00
7	8.99659E-01	6.00667E-01	8.97900E-01	6.77603E-03	0.00000E+00	0.00000E+00
8	9.36794E-01	6.20667E-01	9.04382E-01	8.52234E-03	0.00000E+00	0.00000E+00
9	8.85372E-01	6.39000E-01	9.01666E-01	7.69767E-03	0.00000E+00	0.00000E+00
10	9.14031E-01	6.59167E-01	9.03212E-01	6.84320E-03	0.00000E+00	0.00000E+00
11	9.23556E-01	6.78333E-01	9.05472E-01	6.44456E-03	0.00000E+00	0.00000E+00
12	8.89991E-01	6.97667E-01	9.03924E-01	5.96846E-03	0.00000E+00	0.00000E+00
13	8.75175E-01	7.16833E-01	9.01311E-01	5.99803E-03	0.00000E+00	0.00000E+00
14	9.05971E-01	7.35167E-01	9.01699E-01	5.48918E-03	0.00000E+00	0.00000E+00
15	9.20962E-01	7.54333E-01	9.03181E-01	5.26225E-03	0.00000E+00	0.00000E+00
16	9.23156E-01	7.73667E-01	9.04608E-01	5.07653E-03	0.00000E+00	0.00000E+00
17	8.86681E-01	7.92833E-01	9.03413E-01	4.87475E-03	0.00000E+00	0.00000E+00
18	9.33465E-01	8.12000E-01	9.05291E-01	4.93160E-03	0.00000E+00	0.00000E+00
19	9.25579E-01	8.31333E-01	9.06484E-01	4.78368E-03	0.00000E+00	0.00000E+00
20	9.05866E-01	8.50500E-01	9.06450E-01	4.51023E-03	0.00000E+00	0.00000E+00
21	8.54464E-01	8.70667E-01	9.03714E-01	5.06825E-03	0.00000E+00	0.00000E+00
22	9.12559E-01	8.89000E-01	9.04156E-01	4.82846E-03	0.00000E+00	0.00000E+00
23	8.88758E-01	9.08167E-01	9.03423E-01	4.65095E-03	0.00000E+00	0.00000E+00
24	9.26259E-01	9.26500E-01	9.04461E-01	4.55437E-03	0.00000E+00	0.00000E+00
25	8.98415E-01	9.45667E-01	9.04198E-01	4.35978E-03	0.00000E+00	0.00000E+00
26	9.33678E-01	9.65000E-01	9.05426E-01	4.35116E-03	0.00000E+00	0.00000E+00
27	8.98446E-01	9.84167E-01	9.05147E-01	4.18282E-03	0.00000E+00	0.00000E+00
28	8.58693E-01	1.00433E+00	9.03360E-01	4.39799E-03	0.00000E+00	0.00000E+00
29	9.34384E-01	1.02267E+00	9.04509E-01	4.38519E-03	0.00000E+00	0.00000E+00
30	9.15111E-01	1.04183E+00	9.04888E-01	4.24260E-03	0.00000E+00	0.00000E+00
31	9.01583E-01	1.06200E+00	9.04774E-01	4.09528E-03	0.00000E+00	0.00000E+00
32	8.87784E-01	1.08033E+00	9.04208E-01	3.99674E-03	0.00000E+00	0.00000E+00
33	8.63775E-01	1.10033E+00	9.02903E-01	4.07977E-03	0.00000E+00	0.00000E+00
34	9.16330E-01	1.11967E+00	9.03323E-01	3.97244E-03	0.00000E+00	0.00000E+00
35	9.00021E-01	1.13883E+00	9.03223E-01	3.85148E-03	0.00000E+00	0.00000E+00
36	9.35889E-01	1.15900E+00	9.04184E-01	3.85803E-03	0.00000E+00	0.00000E+00
37	9.25096E-01	1.17733E+00	9.04781E-01	3.79353E-03	0.00000E+00	0.00000E+00
38	9.11777E-01	1.19750E+00	9.04976E-01	3.69177E-03	0.00000E+00	0.00000E+00
39	9.09725E-01	1.21667E+00	9.05104E-01	3.59290E-03	0.00000E+00	0.00000E+00
40	9.22737E-01	1.23583E+00	9.05568E-01	3.52772E-03	0.00000E+00	0.00000E+00
41	8.96417E-01	1.25517E+00	9.05333E-01	3.44408E-03	0.00000E+00	0.00000E+00
42	8.65232E-01	1.27433E+00	9.04331E-01	3.50338E-03	0.00000E+00	0.00000E+00
43	9.08818E-01	1.29267E+00	9.04440E-01	3.41861E-03	0.00000E+00	0.00000E+00
44	9.68511E-01	1.31183E+00	9.05966E-01	3.66845E-03	0.00000E+00	0.00000E+00
45	9.25887E-01	1.33200E+00	9.06429E-01	3.61195E-03	0.00000E+00	0.00000E+00
46	9.56570E-01	1.35033E+00	9.07569E-01	3.70835E-03	0.00000E+00	0.00000E+00
47	9.13857E-01	1.37050E+00	9.07708E-01	3.62770E-03	0.00000E+00	0.00000E+00
48	9.63483E-01	1.38967E+00	9.08921E-01	3.74942E-03	0.00000E+00	0.00000E+00
49	9.04368E-01	1.40883E+00	9.08824E-01	3.67006E-03	0.00000E+00	0.00000E+00
50	9.07780E-01	1.42717E+00	9.08802E-01	3.59285E-03	0.00000E+00	0.00000E+00
51	9.09784E-01	1.44733E+00	9.08822E-01	3.51882E-03	0.00000E+00	0.00000E+00
52	8.83362E-01	1.46650E+00	9.08313E-01	3.48512E-03	0.00000E+00	0.00000E+00
53	8.80060E-01	1.48583E+00	9.07759E-01	3.46073E-03	0.00000E+00	0.00000E+00
54	8.60773E-01	1.50500E+00	9.06855E-01	3.51176E-03	0.00000E+00	0.00000E+00
55	8.63661E-01	1.52433E+00	9.06040E-01	3.53995E-03	0.00000E+00	0.00000E+00
56	8.78347E-01	1.54433E+00	9.05528E-01	3.51143E-03	0.00000E+00	0.00000E+00
57	8.97689E-01	1.56267E+00	9.05385E-01	3.44994E-03	0.00000E+00	0.00000E+00
58	9.25195E-01	1.58200E+00	9.05739E-01	3.40620E-03	0.00000E+00	0.00000E+00
59	8.87534E-01	1.60017E+00	9.05419E-01	3.36111E-03	0.00000E+00	0.00000E+00
60	9.45276E-01	1.61950E+00	9.06107E-01	3.37339E-03	0.00000E+00	0.00000E+00
61	8.95178E-01	1.63867E+00	9.05921E-01	3.32089E-03	0.00000E+00	0.00000E+00
			.			
			.			
			.			
982	9.13165E-01	1.93393E+01	9.00210E-01	7.38297E-04	0.00000E+00	0.00000E+00
983	9.05154E-01	1.93595E+01	9.00215E-01	7.37562E-04	0.00000E+00	0.00000E+00
984	9.20277E-01	1.93787E+01	9.00235E-01	7.37093E-04	0.00000E+00	0.00000E+00
985	9.09457E-01	1.93980E+01	9.00245E-01	7.36403E-04	0.00000E+00	0.00000E+00
986	9.36009E-01	1.94172E+01	9.00281E-01	7.36551E-04	0.00000E+00	0.00000E+00
987	8.65285E-01	1.94373E+01	9.00246E-01	7.36661E-04	0.00000E+00	0.00000E+00
988	9.13454E-01	1.94565E+01	9.00259E-01	7.36035E-04	0.00000E+00	0.00000E+00
989	8.81034E-01	1.94767E+01	9.00240E-01	7.35547E-04	0.00000E+00	0.00000E+00
990	8.77721E-01	1.94958E+01	9.00217E-01	7.35155E-04	0.00000E+00	0.00000E+00
991	9.34091E-01	1.95160E+01	9.00251E-01	7.35210E-04	0.00000E+00	0.00000E+00
992	8.89492E-01	1.95352E+01	9.00240E-01	7.34547E-04	0.00000E+00	0.00000E+00
993	8.63431E-01	1.95545E+01	9.00203E-01	7.34745E-04	0.00000E+00	0.00000E+00
994	8.99801E-01	1.95737E+01	9.00203E-01	7.34004E-04	0.00000E+00	0.00000E+00
995	9.08361E-01	1.95920E+01	9.00211E-01	7.33311E-04	0.00000E+00	0.00000E+00
996	8.53183E-01	1.96112E+01	9.00163E-01	7.34099E-04	0.00000E+00	0.00000E+00
997	9.20125E-01	1.96295E+01	9.00184E-01	7.33635E-04	0.00000E+00	0.00000E+00
998	9.10900E-01	1.96487E+01	9.00194E-01	7.32977E-04	0.00000E+00	0.00000E+00
999	9.00123E-01	1.96680E+01	9.00194E-01	7.32241E-04	0.00000E+00	0.00000E+00
1000	9.08699E-01	1.96872E+01	9.00203E-01	7.31557E-04	0.00000E+00	0.00000E+00
1001	9.48439E-01	1.97065E+01	9.00251E-01	7.32418E-04	0.00000E+00	0.00000E+00
1002	8.96629E-01	1.97257E+01	9.00247E-01	7.31694E-04	0.00000E+00	0.00000E+00
1003	8.78059E-01	1.97448E+01	9.00225E-01	7.31299E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

LIFETIME = 4.26508E-05 + OR - 9.00307E-08 GENERATION TIME = 2.74062E-05 + OR - 4.36880E-08
NU BAR = 2.44196E+00 + OR - 6.56319E-05 AVERAGE FISSION GROUP = 2.17266E+01 + OR - 3.78541E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 2.79833E-01 + OR - 8.70609E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.90024	+ OR - 0.00073	0.89950 TO 0.90097	0.89877 TO 0.90170	0.89804 TO 0.90243	1000000
4	0.90021	+ OR - 0.00073	0.89948 TO 0.90095	0.89875 TO 0.90168	0.89802 TO 0.90241	999000
5	0.90023	+ OR - 0.00073	0.89949 TO 0.90096	0.89876 TO 0.90169	0.89803 TO 0.90243	998000
6	0.90024	+ OR - 0.00073	0.89950 TO 0.90097	0.89877 TO 0.90170	0.89804 TO 0.90244	997000
7	0.90024	+ OR - 0.00073	0.89950 TO 0.90097	0.89877 TO 0.90171	0.89803 TO 0.90244	996000
8	0.90020	+ OR - 0.00073	0.89947 TO 0.90093	0.89873 TO 0.90167	0.89800 TO 0.90240	995000
9	0.90022	+ OR - 0.00073	0.89948 TO 0.90095	0.89875 TO 0.90168	0.89801 TO 0.90242	994000
10	0.90020	+ OR - 0.00074	0.89947 TO 0.90094	0.89873 TO 0.90167	0.89800 TO 0.90241	993000
11	0.90018	+ OR - 0.00074	0.89944 TO 0.90091	0.89871 TO 0.90165	0.89797 TO 0.90238	992000
12	0.90019	+ OR - 0.00074	0.89945 TO 0.90092	0.89872 TO 0.90166	0.89798 TO 0.90240	991000
17	0.90018	+ OR - 0.00074	0.89944 TO 0.90092	0.89870 TO 0.90165	0.89796 TO 0.90239	986000
22	0.90015	+ OR - 0.00074	0.89941 TO 0.90088	0.89867 TO 0.90162	0.89793 TO 0.90236	981000
27	0.90010	+ OR - 0.00074	0.89936 TO 0.90084	0.89861 TO 0.90158	0.89787 TO 0.90233	976000
32	0.90010	+ OR - 0.00074	0.89936 TO 0.90085	0.89861 TO 0.90159	0.89787 TO 0.90233	971000
37	0.90006	+ OR - 0.00075	0.89932 TO 0.90081	0.89857 TO 0.90155	0.89783 TO 0.90230	966000
42	0.90005	+ OR - 0.00075	0.89931 TO 0.90080	0.89856 TO 0.90155	0.89781 TO 0.90230	961000
47	0.89987	+ OR - 0.00074	0.89913 TO 0.90062	0.89838 TO 0.90136	0.89764 TO 0.90211	956000
			. . .			
912	0.90027	+ OR - 0.00233	0.89795 TO 0.90260	0.89562 TO 0.90493	0.89329 TO 0.90726	91000
917	0.89976	+ OR - 0.00241	0.89735 TO 0.90217	0.89494 TO 0.90458	0.89253 TO 0.90699	86000
922	0.90015	+ OR - 0.00250	0.89765 TO 0.90264	0.89515 TO 0.90514	0.89266 TO 0.90764	81000
927	0.90026	+ OR - 0.00264	0.89762 TO 0.90290	0.89498 TO 0.90554	0.89234 TO 0.90818	76000
932	0.90160	+ OR - 0.00272	0.89888 TO 0.90432	0.89617 TO 0.90703	0.89345 TO 0.90975	71000
937	0.90149	+ OR - 0.00281	0.89868 TO 0.90430	0.89587 TO 0.90711	0.89305 TO 0.90992	66000
942	0.90143	+ OR - 0.00292	0.89851 TO 0.90434	0.89559 TO 0.90726	0.89268 TO 0.91018	61000
947	0.90105	+ OR - 0.00294	0.89811 TO 0.90399	0.89517 TO 0.90693	0.89223 TO 0.90987	56000
952	0.90114	+ OR - 0.00314	0.89800 TO 0.90428	0.89486 TO 0.90742	0.89173 TO 0.91056	51000
957	0.89959	+ OR - 0.00339	0.89621 TO 0.90298	0.89282 TO 0.90637	0.88944 TO 0.90975	46000
962	0.90114	+ OR - 0.00370	0.89745 TO 0.90484	0.89375 TO 0.90854	0.89006 TO 0.91223	41000
967	0.89911	+ OR - 0.00351	0.89559 TO 0.90262	0.89208 TO 0.90613	0.88857 TO 0.90964	36000
972	0.89894	+ OR - 0.00387	0.89506 TO 0.90281	0.89119 TO 0.90669	0.88732 TO 0.91056	31000
977	0.89964	+ OR - 0.00456	0.89508 TO 0.90420	0.89052 TO 0.90876	0.88596 TO 0.91331	26000
982	0.90094	+ OR - 0.00542	0.89551 TO 0.90636	0.89009 TO 0.91179	0.88467 TO 0.91721	21000
987	0.89897	+ OR - 0.00624	0.89274 TO 0.90521	0.88650 TO 0.91144	0.88027 TO 0.91768	16000
992	0.89889	+ OR - 0.00799	0.89090 TO 0.90688	0.88290 TO 0.91487	0.87491 TO 0.92286	11000
997	0.90714	+ OR - 0.00954	0.89761 TO 0.91668	0.88807 TO 0.92621	0.87854 TO 0.93575	6000

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

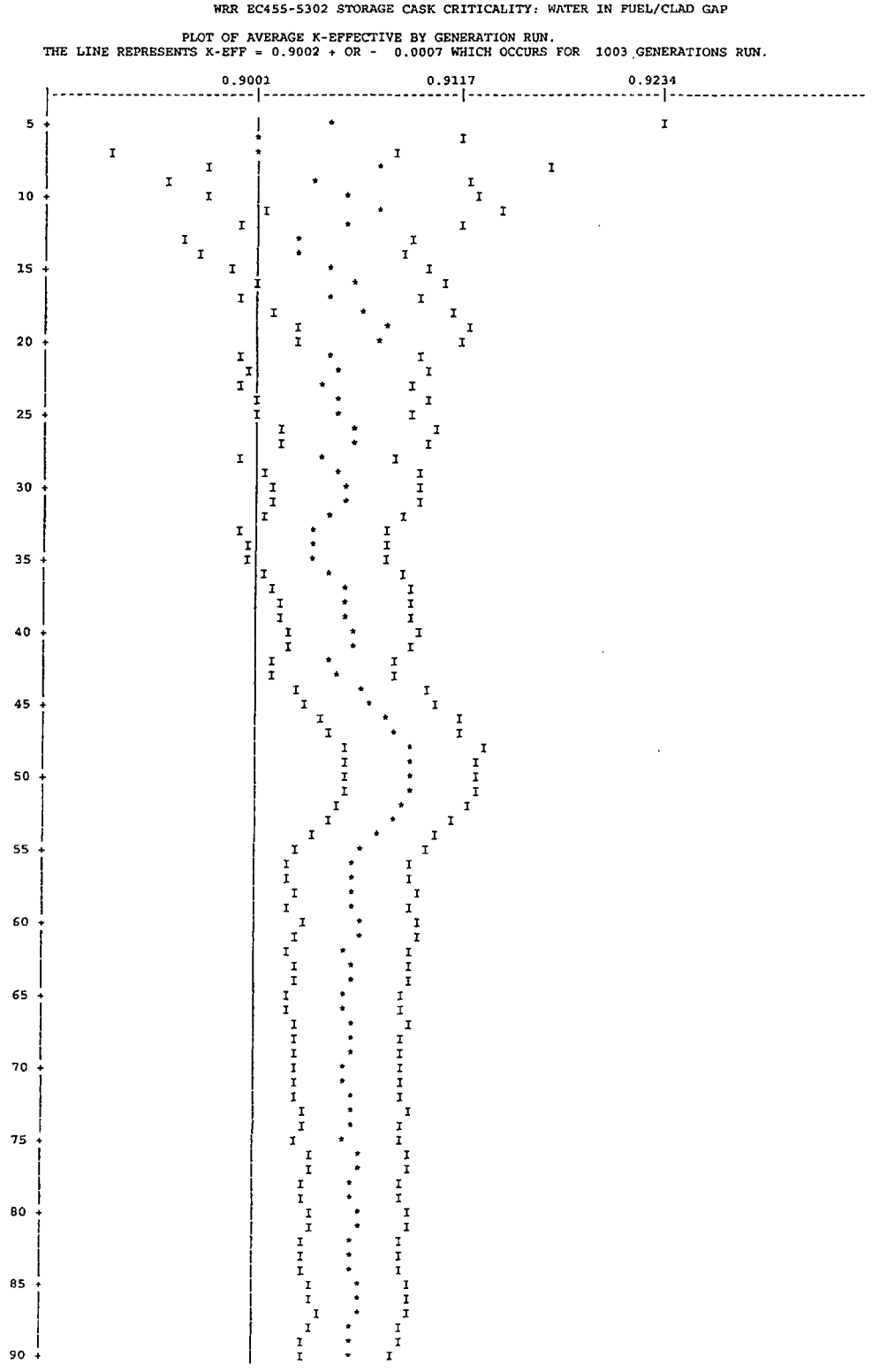

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

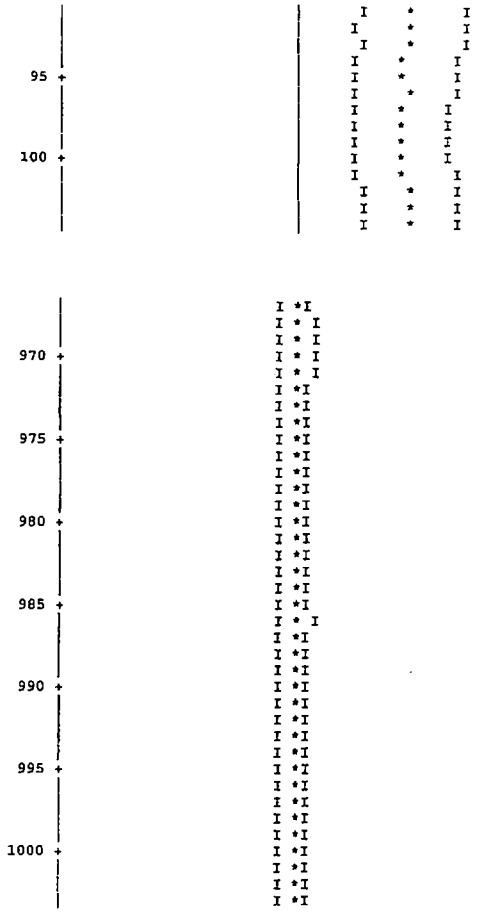

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
                    WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                 PLOT OF AVERAGE K-EFFECTIVE BY GENERATION SKIPPED.
   THE LINE REPRESENTS K-EFF = 0.9002 + OR -  0.0007 WHICH OCCURS FOR     3 GENERATIONS SKIPPED.

                     0.8873                 0.8982                 0.9090
     |----------------------|----------------------|----------------------|----------------------
     |
     |                                          I* I
   5 +                                          I* I
     |                                          I* I
     |                                          I* I
     |                                         I * I
     |                                          I* I
  10 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                          I* I
     |                                          I* I
  15 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
  20 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
  25 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
  30 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
  35 +                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
     |                                         I * I
  40 +                                         I *I
     |                                         I *I
     |                                         I * I
     |                                         I * I
     |                                         I *I
  45 +                                         I *I
     |                                         I*|I
     |                                         I*|I
     |                                         I*|I
     |                                         I*|I
  50 +                                         I*|I
     |                                         I*|I
     |                                         I*|I
                                                .
                                                .
                                                .
|                                       I    *   I
     |                                       I    *    I
 885 +                                       I    *   I
     |                                       I    *    I
     |                                        I   *    I
     |                                       I    *    I
     |                                       I    *    I
 890 +                                       I    *   I
     |                                        I   *    I
     |                                       I    *    I
     |                                       I    *   I
     |                                       I    *    I
 895 +                                       I    *    I
     |                                       I    *    I
     |                                      I    *|   I
     |                                        I   *    I
     |                                        I   |*    I
 900 +                                        I   *    I
     |                                        I   |*    I
     |                                       I    *    I
     |                                       I    *    I
     |                                       I    *     I
 905 +                                       I    *     I
     |                                        I   |*    I
     |                                        I   |*    I
     |                                       I    *    I
     |                                        I   |*    I
 910 +                                       I    *     I
     |                                        I   |*    I
     |                                       I    *    I
     |                                       I    *    I
     |                                       I    *    I
 915 +                                       I    *    I
     |                                       I    *    I
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

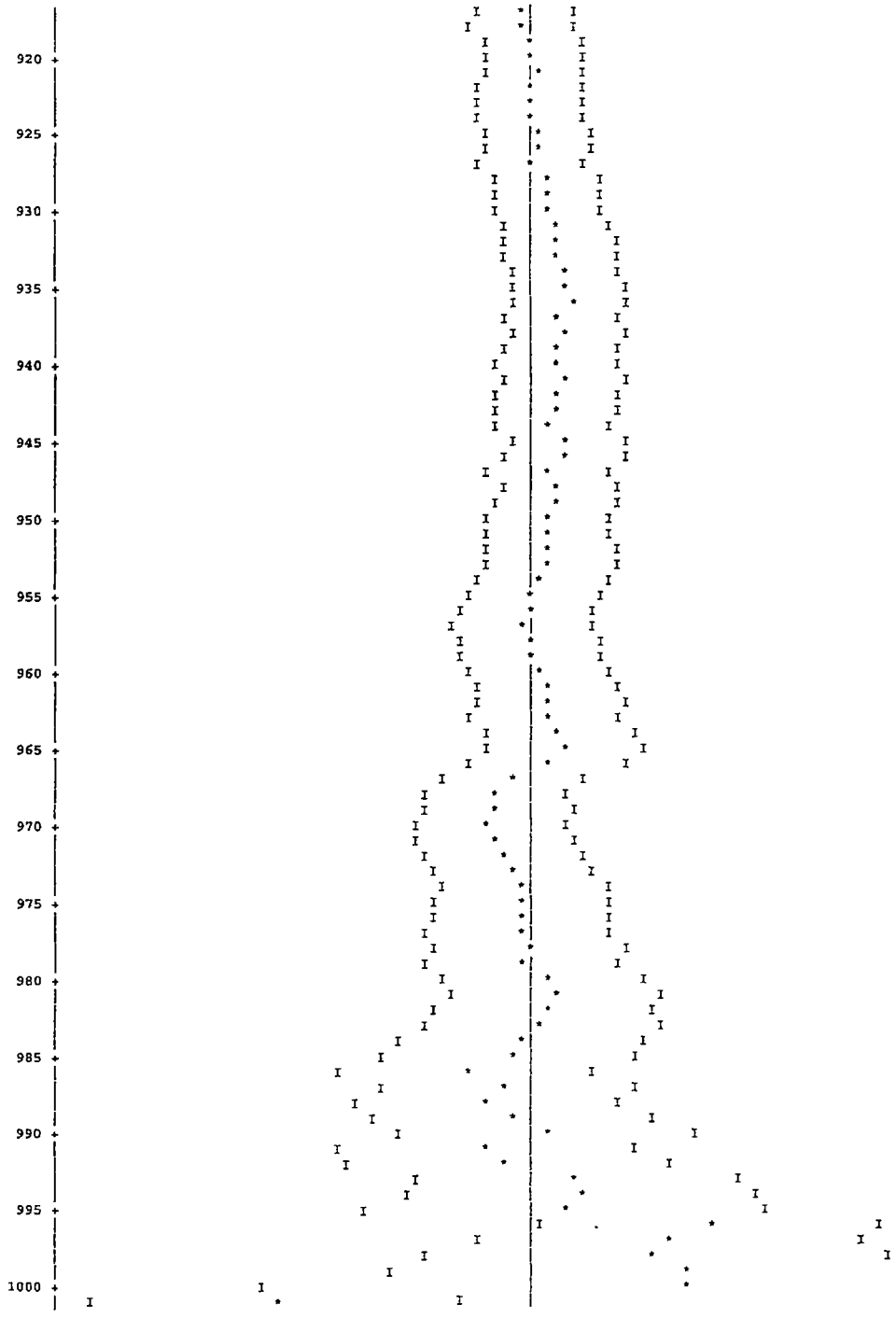

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                                FREQUENCY FOR GENERATIONS    4 TO 1003
0.8257 TO 0.8291     *
0.8291 TO 0.8324
0.8324 TO 0.8357     *
0.8357 TO 0.8391     ****
0.8391 TO 0.8424
0.8424 TO 0.8457     **
0.8457 TO 0.8491     **
0.8491 TO 0.8524     ****
0.8524 TO 0.8557     *************
0.8557 TO 0.8590     ************
0.8590 TO 0.8624     ***********
0.8624 TO 0.8657     ************************
0.8657 TO 0.8690     *****************
0.8690 TO 0.8724     ****************************
0.8724 TO 0.8757     ****************************************
0.8757 TO 0.8790     ************************************
0.8790 TO 0.8823     *******************************************
0.8823 TO 0.8857     ************************************************
0.8857 TO 0.8890     ********************************************************
0.8890 TO 0.8923     ************************************************************
0.8923 TO 0.8957     *******************************************
0.8957 TO 0.8990     ****************************************************************************
0.8990 TO 0.9023     ************************************************
0.9023 TO 0.9057     ***************************************************
0.9057 TO 0.9090     ************************************************************
0.9090 TO 0.9123     ****************************************************************
0.9123 TO 0.9156     ****************************************************
0.9156 TO 0.9190     ************************************
0.9190 TO 0.9223     *******************************************
0.9223 TO 0.9256     ************************************************
0.9256 TO 0.9290     ********************************
0.9290 TO 0.9323     ************************
0.9323 TO 0.9356     ******************
0.9356 TO 0.9390     ************
0.9390 TO 0.9423     *********
0.9423 TO 0.9456     *************
0.9456 TO 0.9489     ************
0.9489 TO 0.9523     *****
0.9523 TO 0.9556     ****
0.9556 TO 0.9589     ***
0.9589 TO 0.9623
0.9623 TO 0.9656     **
0.9656 TO 0.9689     **
0.9689 TO 0.9723     *
0.9723 TO 0.9756     *
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                                FREQUENCY FOR GENERATIONS  254 TO 1003
0.8257 TO 0.8291     *
0.8291 TO 0.8324
0.8324 TO 0.8357     *
0.8357 TO 0.8391     **
0.8391 TO 0.8424
0.8424 TO 0.8457     **
0.8457 TO 0.8491     *
0.8491 TO 0.8524     ****
0.8524 TO 0.8557     **********
0.8557 TO 0.8590     *********
0.8590 TO 0.8624     *********
0.8624 TO 0.8657     *****************
0.8657 TO 0.8690     *************
0.8690 TO 0.8724     *****************
0.8724 TO 0.8757     ******************************
0.8757 TO 0.8790     ******************************
0.8790 TO 0.8823     ******************************
0.8823 TO 0.8857     *********************************
0.8857 TO 0.8890     ************************************************
0.8890 TO 0.8923     ****************************************************
0.8923 TO 0.8957     *********************************
0.8957 TO 0.8990     ************************************************************
0.8990 TO 0.9023     *********************************
0.9023 TO 0.9057     ************************************
0.9057 TO 0.9090     *******************************************
0.9090 TO 0.9123     *********************************************
0.9123 TO 0.9156     ****************************************
0.9156 TO 0.9190     ******************************
0.9190 TO 0.9223     ******************************
0.9223 TO 0.9256     *********************************
0.9256 TO 0.9290     ************************
0.9290 TO 0.9323     ******************
0.9323 TO 0.9356     *************
0.9356 TO 0.9390     *******
0.9390 TO 0.9423     ********
0.9423 TO 0.9456     *****
0.9456 TO 0.9489     *******
0.9489 TO 0.9523     ***
0.9523 TO 0.9556     ***
0.9556 TO 0.9589     *
0.9589 TO 0.9623
0.9623 TO 0.9656     *
0.9656 TO 0.9689     *
0.9689 TO 0.9723     *
0.9723 TO 0.9756     *
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                                FREQUENCY FOR GENERATIONS  504 TO 1003
0.8257 TO 0.8291      *
0.8291 TO 0.8324
0.8324 TO 0.8357
0.8357 TO 0.8391      *
0.8391 TO 0.8424
0.8424 TO 0.8457      *
0.8457 TO 0.8491      *
0.8491 TO 0.8524      **
0.8524 TO 0.8557      *******
0.8557 TO 0.8590      ***
0.8590 TO 0.8624      ******
0.8624 TO 0.8657      ************
0.8657 TO 0.8690      ******
0.8690 TO 0.8724      *************
0.8724 TO 0.8757      ************************
0.8757 TO 0.8790      *************************
0.8790 TO 0.8823      **********************
0.8823 TO 0.8857      *******************
0.8857 TO 0.8890      ***************************
0.8890 TO 0.8923      ****************************************
0.8923 TO 0.8957      **********************
0.8957 TO 0.8990      ************************************
0.8990 TO 0.9023      *******************
0.9023 TO 0.9057      *************************
0.9057 TO 0.9090      *********************************
0.9090 TO 0.9123      ***************************
0.9123 TO 0.9156      ******************************
0.9156 TO 0.9190      ***************
0.9190 TO 0.9223      *******************
0.9223 TO 0.9256      *******************
0.9256 TO 0.9290      *****************
0.9290 TO 0.9323      *********
0.9323 TO 0.9356      ********
0.9356 TO 0.9390      ****
0.9390 TO 0.9423      ******
0.9423 TO 0.9456      *****
0.9456 TO 0.9489      *******
0.9489 TO 0.9523      **
0.9523 TO 0.9556      ***
0.9556 TO 0.9589      *
0.9589 TO 0.9623
0.9623 TO 0.9656      *
0.9656 TO 0.9689
0.9689 TO 0.9723
0.9723 TO 0.9756      *
```

Figure 6.7.1-5 CSAS Input/Output Summary for Enlarged Fuel Tube Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                                FREQUENCY FOR GENERATIONS  754 TO 1003
0.8257 TO 0.8291
0.8291 TO 0.8324
0.8324 TO 0.8357
0.8357 TO 0.8391     *
0.8391 TO 0.8424
0.8424 TO 0.8457     *
0.8457 TO 0.8491
0.8491 TO 0.8524     **
0.8524 TO 0.8557     ****
0.8557 TO 0.8590
0.8590 TO 0.8624     *
0.8624 TO 0.8657     *****
0.8657 TO 0.8690     ***
0.8690 TO 0.8724     ****
0.8724 TO 0.8757     ************
0.8757 TO 0.8790     ****************
0.8790 TO 0.8823     ***************
0.8823 TO 0.8857     ********
0.8857 TO 0.8890     **********
0.8890 TO 0.8923     ************************
0.8923 TO 0.8957     *************
0.8957 TO 0.8990     ******************
0.8990 TO 0.9023     *******
0.9023 TO 0.9057     ***************
0.9057 TO 0.9090     ***************
0.9090 TO 0.9123     *************
0.9123 TO 0.9156     *******************
0.9156 TO 0.9190     **********
0.9190 TO 0.9223     *********
0.9223 TO 0.9256     ********
0.9256 TO 0.9290     ******
0.9290 TO 0.9323     **
0.9323 TO 0.9356     **
0.9356 TO 0.9390     ***
0.9390 TO 0.9423     **
0.9423 TO 0.9456     *
0.9456 TO 0.9489     *****
0.9489 TO 0.9523     *
0.9523 TO 0.9556     *
0.9556 TO 0.9589
0.9589 TO 0.9623
0.9623 TO 0.9656
0.9656 TO 0.9689
0.9689 TO 0.9723
0.9723 TO 0.9756     *
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions

```
        PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 cm) (IVF = 1.0) (EVF = 1.0
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET
  '   LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '                        WITH MODIFIED TUBE ASSEMBLY 98
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '       INTERIOR MODERATOR VOLUME FRACTION = 1.0
  '       EXTERIOR MODERATOR VOLUME FRACTION = 1.0
  '           CASK TO CASK PITCH = 300 cm
  '               FLOODED PELLET CLAD GAP
  '               NEUTRON SHIELD REMOVED
  '
  27GROUPNDF4 LATTICECELL
  UO2         1              0.95     293.0 92235 4.0 92238 96.0 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
  B-10        6  DEN=2.6226 0.0450  293.0                      END
  B-11        6  DEN=2.6226 0.2736  293.0                      END
  C           6  DEN=2.6226 0.0927  293.0                      END
  AL          6  DEN=2.6226 0.5737  293.0                      END
  PB          7              1.0      293.0                      END
  H           8  DEN=1.6291 0.060   293.0                      END
  O           8  DEN=1.6291 0.425   293.0                      END
  C           8  DEN=1.6291 0.277   293.0                      END
  N           8  DEN=1.6291 0.020   293.0                      END
  AL          8  DEN=1.6291 0.214   293.0                      END
  B-10        8  DEN=1.6291 0.001   293.0                      END
  B-11        8  DEN=1.6291 0.004   293.0                      END
  H2O         9              1.0      293.0                      END
  H2O         10             1.0      293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 10 END
  TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 cm) (IVF = 1.0) (EVF = 1.0
  READ PARAM RUN=YES PLT=YES GEN=1003 NPG=1000 TBA=15 RND=321 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER 10 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER 10 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.0768 -9.0768 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0       10.1615  0.0
HOLE  14   0.0       -10.1615 0.0
HOLE  15   10.1615  0.0       0.0
HOLE  15   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                         2P2.1400


UNIT 350
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL LR'
ARRAY  301  -9.9440 -9.0768 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0       10.1615  0.0
HOLE  14   0.0       -10.1615 0.0
HOLE  15   10.1615  0.0       0.0
HOLE  15   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                         2P2.1400

UNIT 550
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL UR'
ARRAY  501  -9.9440 -9.9440 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14   0.0       10.1615  0.0
HOLE  14   0.0       -10.1615 0.0
HOLE  15   10.1615  0.0       0.0
HOLE  15   -10.1615 0.0       0.0
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
CUBOID 5 1 4P10.3051                                2P2.1400

UNIT 750
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL UL'
ARRAY  701  -9.0768 -9.9440 -2.1400
CUBOID 3 1 4P9.9441                                 2P2.1400
CUBOID 5 1 4P10.0661                                2P2.1400
CUBOID 3 1 4P10.25681                               2P2.1400
HOLE  14   0.0       10.1615  0.0
HOLE  14   0.0       -10.1615 0.0
HOLE  15   10.1615  0.0       0.0
HOLE  15   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P2.1400


UNIT 51
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  750   0.0       -0.1584       0.0
UNIT 52
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   0.0       0.1584        0.0
UNIT 53
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  550   -0.1584   0.0           0.0
UNIT 54
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  750   0.1584   0.0           0.0
UNIT 55
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  50   0.1584   0.1584        0.0
UNIT 56
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  350   -0.1584   0.1584        0.0
UNIT 57
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  750   0.1584   -0.1584        0.0
UNIT 58
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X -Y'
CUBOID 3 1 4P10.4635                                2P2.1400
HOLE  550   -0.1584   -0.1584        0.0
UNIT 59
COM='CENTRAL HOLE'
CUBOID 3 1 4P10.4636                                2P2.1400
'
'   DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - DISK LEVEL'
ARRAY  2  -9.0768 -9.0768 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P0.6604


UNIT 360
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL LR'
ARRAY  302  -9.9440 -9.0768 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P0.6604

UNIT 560
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL UR'
ARRAY  502  -9.9440 -9.9440 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
CUBOID 3 1 4P10.25681                               2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                2P0.6604

UNIT 760
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL UL'
ARRAY  702  -9.0768 -9.9440 -0.6604
CUBOID 3 1 4P9.9441                                 2P0.6604
CUBOID 5 1 4P10.0661                                2P0.6604
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
CUBOID 3 1 4P10.25681                                  2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0      -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                   2P0.6604


UNIT 61
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  760   0.0       -0.1584       0.0
UNIT 62
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  60   0.0       0.1584        0.0
UNIT 63
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  560   -0.1584   0.0           0.0
UNIT 64
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  760   0.1584   0.0           0.0
UNIT 65
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  60   0.1584   0.1584        0.0
UNIT 66
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  360   -0.1584   0.1584        0.0
UNIT 67
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS X -Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  760   0.1584   -0.1584        0.0
UNIT 68
COM='ASSEMBLY CELL WITH 4 BORAL SHEETS -X -Y'
CUBOID 3 1 4P10.4635                                   2P0.6604
HOLE  560   -0.1584   -0.1584        0.0
UNIT 69
COM='CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY-X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY  X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY  X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN TRANSPORT CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN TRANSPORT CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253      2P2.1400
HOLE 80      -69.0614 0.0 0.0
HOLE 82      -46.1912 0.0 0.0
HOLE 81       69.0614 0.0 0.0
HOLE 83       46.1912 0.0 0.0
CYLINDER 5 1 89.7128      2P2.1400
CYLINDER 3 1 90.170       2P2.1400
CYLINDER 5 1 93.98        2P2.1400
CYLINDER 7 1 103.4288     2P2.1400
CYLINDER 5 1 110.109      2P2.1400
CYLINDER 9 1 124.714      2P2.1400
CYLINDER 9 1 125.349      2P2.1400
CUBOID   9 1 4P150        2P2.1400
UNIT 111
COM='BASKET ARRAY IN TRANSPORT CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
HOLE 93       46.1912 0.0 0.0
CYLINDER 3 1 88.1253      2P0.6604
CYLINDER 5 1 89.7128      2P0.6604
CYLINDER 3 1 90.170       2P0.6604
CYLINDER 5 1 93.98        2P0.6604
CYLINDER 7 1 103.4288     2P0.6604
CYLINDER 5 1 110.109      2P0.6604
CYLINDER 9 1 124.714      2P0.6604
CYLINDER 9 1 125.349      2P0.6604
CUBOID   9 1 4P150        2P0.6604
UNIT 112
COM='BASKET ARRAY IN TRANSPORT CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.2490      2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER 3 1 88.1253      2P0.6604
CYLINDER 5 1 89.7128      2P0.6604
CYLINDER 3 1 90.170       2P0.6604
CYLINDER 5 1 93.98        2P0.6604
CYLINDER 7 1 103.4288     2P0.6604
CYLINDER 5 1 110.109      2P0.6604
CYLINDER 9 1 124.714      2P0.6604
CYLINDER 9 1 125.349      2P0.6604
CUBOID   9 1 4P150        2P0.6604
'
UNIT 130
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- WATER LEVEL'
ARRAY  3  -8.8736 -8.8736 -2.1400
CUBOID 3 1 4P10.1473                          2P2.1400
CUBOID 5 1 4P10.26922                         2P2.1400
CUBOID 3 1 4P10.3051                          2P2.1400


UNIT 330
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- WATER LEVEL LR'
ARRAY  303  -10.1472 -8.8736 -2.1400
CUBOID 3 1 4P10.1473                          2P2.1400
CUBOID 5 1 4P10.26922                         2P2.1400
CUBOID 3 1 4P10.3051                          2P2.1400

UNIT 530
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- WATER LEVEL UR'
ARRAY  503  -10.1472 -10.1472 -2.1400
CUBOID 3 1 4P10.1473                          2P2.1400
CUBOID 5 1 4P10.26922                         2P2.1400
CUBOID 3 1 4P10.3051                          2P2.1400
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
UNIT 730
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- WATER LEVEL UL'
ARRAY  703  -8.8736 -10.1472 -2.1400
CUBOID 3 1 4P10.1473                          2P2.1400
CUBOID 5 1 4P10.26922                         2P2.1400
CUBOID 3 1 4P10.3051                          2P2.1400


UNIT 131
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  130   0.1584   0.1584       0.0
UNIT 132
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  330   -0.1584   0.1584       0.0
UNIT 133
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  730   0.1584   -0.1584       0.0
UNIT 134
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P2.1400
HOLE  530   -0.1584   -0.1584       0.0
'
UNIT 140
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- DISK LEVEL'
ARRAY  4  -8.8736 -8.8736 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604


UNIT 340
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- DISK LEVEL LR'
ARRAY  304  -10.1472 -8.8736 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604

UNIT 540
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- DISK LEVEL UR'
ARRAY  504  -10.1472 -10.1472 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604

UNIT 740
COM='OVERSIZED FUEL TUBE AND ASSEMBLY 98- DISK LEVEL UL'
ARRAY  704  -8.8736 -10.1472 -0.6604
CUBOID 3 1 4P10.1473                          2P0.6604
CUBOID 5 1 4P10.26922                         2P0.6604
CUBOID 3 1 4P10.3051                          2P0.6604


UNIT 141
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  140   0.1584   0.1584       0.0
UNIT 142
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  340   -0.1584   0.1584       0.0
UNIT 143
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  740   0.1584   -0.1584       0.0
UNIT 144
COM='OVERSIZED FUEL TUBE AND ASSEMBLY - DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                          2P0.6604
HOLE  540   -0.1584   -0.1584       0.0
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -175.349 -175.349 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
ARA=3 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1
1 1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
3 1 1 1 1 2 1 2 1 2 1 2 1 1 1 1
2 1 1 1 2 1 1 1 4 1 1 1 2 1 1 1
2 1 1 1 1 2 1 2 1 2 1 2 1 1 1 1
2 1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
2 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1
2 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=4 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 6 5 5 5 5 5 5 5
5 5 5 5 5 5 5 6 5 6 5 5 5 5 5 5
5 5 5 5 5 5 6 5 5 5 6 5 5 5 5 5
7 5 5 5 5 6 5 6 5 6 5 6 5 5 5 5
6 5 5 5 6 5 5 5 8 5 5 5 6 5 5 5
6 5 5 5 5 6 5 6 5 6 5 6 5 5 5 5
6 5 5 5 5 5 6 5 5 5 6 5 5 5 5 5
6 5 5 5 5 5 5 6 5 6 5 5 5 5 5 5
6 5 5 5 5 5 5 5 6 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
ARA=301 NUX=16 NUY=16 NUZ=1  FILL
2 2 2 2 2 2 2 2 3 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
1 1 1 1 1 1 1 4 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
END FILL
ARA=302 NUX=16 NUY=16 NUZ=1  FILL
6 6 6 6 6 6 6 7 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 7
5 5 5 5 5 5 5 8 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
END FILL
ARA=303 NUX=16 NUY=16 NUZ=1  FILL
2 2 2 2 2 2 2 2 3 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1 1
1 1 1 1 2 1 2 1 2 1 2 1 1 1 1 3
1 1 1 2 1 1 1 4 1 1 1 2 1 1 1 2
1 1 1 1 2 1 2 1 2 1 2 1 1 1 1 2
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1 2
1 1 1 1 1 1 2 1 2 1 1 1 1 1 1 2
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
END FILL
ARA=304 NUX=16 NUY=16 NUZ=1  FILL
6 6 6 6 6 6 6 6 7 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 6 5 5 5 5 5 5 5 5
5 5 5 5 5 5 6 5 6 5 5 5 5 5 5 5
5 5 5 5 5 6 5 5 5 6 5 5 5 5 5 5
5 5 5 5 6 5 6 5 6 5 6 5 5 5 5 7
5 5 5 6 5 5 5 8 5 5 5 6 5 5 5 6
5 5 5 5 6 5 6 5 6 5 6 5 5 5 5 6
5 5 5 5 5 6 5 5 5 6 5 5 5 5 5 6
5 5 5 5 5 5 6 5 6 5 5 5 5 5 5 6
5 5 5 5 5 5 5 6 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
END FILL
ARA=501 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 4 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 2 2 2 2 2 2 2 3 1 1 1 1 1 1 1
END FILL
ARA=502 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 8 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 7
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 6 6 6 6 6 6 6 7 5 5 5 5 5 5 5
END FILL
ARA=503 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 2
1 1 1 1 1 1 2 1 2 1 1 1 1 1 1 2
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1 2
1 1 1 1 2 1 2 1 2 1 2 1 1 1 1 2
1 1 1 2 1 1 1 4 1 1 1 2 1 1 1 2
1 1 1 1 2 1 2 1 2 1 2 1 1 1 1 3
1 1 1 1 1 2 1 1 1 2 1 1 1 1 1 1
1 1 1 1 1 1 2 1 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 2 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 2 2 2 2 2 2 2 3 1 1 1 1 1 1 1
END FILL
ARA=504 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 6
5 5 5 5 5 5 5 6 5 5 5 5 5 5 5 6
5 5 5 5 5 5 6 5 6 5 5 5 5 5 5 6
5 5 5 5 5 6 5 5 5 6 5 5 5 5 5 6
5 5 5 5 6 5 6 5 6 5 6 5 5 5 5 6
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
5 5 5 6 5 5 5 8 5 5 5 6 5 5 5 6
5 5 5 5 6 5 6 5 6 5 6 5 5 5 5 7
5 5 5 5 5 6 5 5 5 6 5 5 5 5 5 5
5 5 5 5 5 5 6 5 6 5 5 5 5 5 5 5
5 5 5 5 5 5 5 6 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 6 6 6 6 6 6 6 7 5 5 5 5 5 5 5
END FILL
ARA=701 NUX=16 NUY=16 NUZ=1  FILL
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
END FILL
ARA=702 NUX=16 NUY=16 NUZ=1  FILL
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
END FILL
ARA=703 NUX=16 NUY=16 NUZ=1  FILL
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
2 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1
2 1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
2 1 1 1 1 2 1 2 1 2 1 2 1 1 1 1
2 1 1 1 2 1 1 1 4 1 1 1 2 1 1 1
3 1 1 1 1 2 1 2 1 2 1 2 1 1 1 1
1 1 1 1 1 1 2 1 1 1 2 1 1 1 1 1
1 1 1 1 1 1 1 2 1 2 1 1 1 1 1 1
1 1 1 1 1 1 1 1 2 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
END FILL
ARA=704 NUX=16 NUY=16 NUZ=1  FILL
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 6 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 6 5 6 5 5 5 5 5
6 5 5 5 5 5 6 5 5 5 6 5 5 5 5 5
6 5 5 5 5 6 5 6 5 6 5 6 5 5 5 5
6 5 5 5 6 5 5 5 8 5 5 5 6 5 5 5
7 5 5 5 5 6 5 6 5 6 5 6 5 5 5 5
5 5 5 5 5 5 6 5 5 5 6 5 5 5 5 5
5 5 5 5 5 5 5 6 5 6 5 5 5 5 5 5
5 5 5 5 5 5 5 5 6 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
57
22
57
22
55
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
58
22
56
22
56
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
131
21
57
22
57
22
55
21
133
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
132
21
58
22
56
22
56
21
134
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
57
22
55
22
55
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
58
22
59
22
55
21
57
20
57
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
58
22
58
22
56
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
67
32
67
32
65
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
68
32
66
32
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
66
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
141
31
67
32
67
32
65
31
143
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
142
31
68
32
66
32
66
31
144
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
67
32
65
32
65
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
68
32
69
32
65
31
67
30
67
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
68
32
68
32
66
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
67
42
67
42
65
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
68
42
66
42
66
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
141
41
67
42
67
42
65
41
143
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
142
41
68
42
66
42
66
41
144
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
65
40
65
41
67
42
65
42
65
41
67
40
67
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
66
40
66
41
68
42
69
42
65
41
67
40
67
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
66
40
66
41
68
42
68
42
66
41
68
40
68
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
86 23 85 23 84
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
96 33 95 33 94
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
106 43 105 43 104
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
END ARRAY
READ BOUNDS ZFC=PER YXF=MIR END BOUNDS
READ PLOT
SCR=YES PIC=MAT LPI=10
UAX=1.0 VDN=-1.0 NAX=1500
'
' WHOLE BASKET HORIZONTAL SLICES
'
TTL='BASKET X-Y CROSS SECTION AT Z= 0.635 HEAT TRANSFER DISK LEVEL'
XUL=  -130 YUL=  130  ZUL= 0.635
XLR=   130 YLR= -130  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 3.44 WATER LEVEL'
XUL=  -130 YUL=  130  ZUL= 3.44
XLR=   130 YLR= -130  ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 6.236 SS DISK LEVEL'
XUL=  -130 YUL=  130  ZUL= 6.236
XLR=   130 YLR= -130  ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' HEAT TRANSFER DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANTD I HEAT TRANSFER DISK'
XUL=  12.   YUL= 80     ZUL= 0.635
XLR=  80.0  YLR= 12.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II HEAT TRANSFER DISK'
XUL=  12.0 YUL= -12.0   ZUL= 0.635
XLR=  80   YLR= -80     ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III HEAT TRANSFER DISK'
XUL= -80.0  YUL= -12.0  ZUL= 0.635
XLR= -12.0  YLR= -80.0  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV HEAT TRANSFER DISK'
XUL= -80.0  YUL= 80.0   ZUL= 0.635
XLR= -12.0  YLR= 12.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' WATER LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=  12.    YUL=  80     ZUL= 3.44
XLR=  80.0   YLR=  12.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=  12.0   YUL= -12.0   ZUL= 3.44
XLR=  80     YLR= -80     ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0   YUL= -12.0   ZUL= 3.44
XLR= -12.0   YLR= -80.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0   YUL= 80.0    ZUL= 3.44
XLR= -12.0   YLR= 12.0    ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
'
'  VERTICAL SLICES
'
TTL='BASKET X-Z CROSS SECTION ALUMINUM LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 1.27
XLR=  90  YLR=0.4   ZLR= -.1
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION WATER LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 4.318
XLR=  90  YLR=0.4   ZLR= 1.27
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION SS LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 6.858
XLR=  90  YLR=0.4   ZLR= 5.588
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION ENTIRE MODEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 12
XLR=  90  YLR=0.4   ZLR= 0
UAX=1.0 WDN=-1.0 NAX=1500 END
END PLOT
END DATA

SECONDARY MODULE 000008   HAS BEEN CALLED.

MODULE 000008   IS FINISHED. COMPLETION CODE     0. CPU TIME USED     0.44 (SECONDS).

SECONDARY MODULE 000002   HAS BEEN CALLED.

MODULE 000002   IS FINISHED. COMPLETION CODE     0. CPU TIME USED     3.07 (SECONDS).

SECONDARY MODULE 000009   HAS BEEN CALLED.

MODULE 000009   IS FINISHED. COMPLETION CODE     0. CPU TIME USED   697.72 (SECONDS).

MODULE CSAS25   IS FINISHED. COMPLETION CODE     0. CPU TIME USED   703.54 (SECONDS).
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (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         22  55
CC             SS             AA         AA  SS             22         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                 PPPPPPPPPPPPP    CCCCCCCCCCC
SSSSSSSSSSSSS  CCCCCCCCCCCCC   AAAAAAAAAAA   LL             EEEEEEEEEEEEE                 PPPPPPPPPPPPPP  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     -------------   PPPPPPPPPPPPPP  CC
 SSSSSSSSSSSS  CC             AAAAAAAAAAAAA  LL             EEEEEEEEE     -------------   PPPPPPPPPPPPP   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  EEEEEEEEEEEEEE                PP              CCCCCCCCCCCCC
 SSSSSSSSSSS    CCCCCCCCCCC    AA         AA  LLLLLLLLLLLLL  EEEEEEEEEEEEEE                PP               CCCCCCCCCCC


   0000000      33333333333              //  22222222222   5555555555555              //    0000000      22222222222
  000000000    3333333333333             //  2222222222222  5555555555555             //   000000000    2222222222222
 00       00   33         33            //  22         22  55                        //  00       00  22         22
00         00            33           //              22  55                       //  00         00            22
00         00            33          //               22  55                      //  00         00            22
00         00          333          //               22    555555555555            //  00         00          22
00         00          333         //               22      5555555555555         //  00         00        22
00         00            33       //              22                  55         //  00         00      22
00         00            33      //             22                    55        //  00         00    22
 00       00   33         33    //             22  55         55    //            00       00   22
  000000000   3333333333333   //             2222222222222  5555555555555  //       000000000   2222222222222
   0000000     33333333333   //             2222222222222   55555555555   //        0000000    2222222222222


     11        33333333333                     0000000          11                   22222222222   22222222222
    111       3333333333333                   000000000        111                  2222222222222 2222222222222
   1111       33         33        :::       00       00      1111          :::     22         22 22         22
     11                 33        :::      00         00       11          :::                 22            22
     11                 33        :::      00         00       11          :::                 22            22
     11               333                   00         00       11                           22          22
     11               333                   00         00       11                        22          22
     11                 33        :::      00         00       11          :::        22          22
     11                 33        :::      00         00       11          :::      22          22
     11         33      33        :::       00       00       11          :::    22          22
  11111111    3333333333333                 000000000      11111111                2222222222222 2222222222222
  11111111     33333333333                   0000000       11111111                2222222222222 2222222222222
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
**** 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     4.000 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  B-10         STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.0450 VOLUME FRACTION
ROTH      2.6226 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        0.2736 VOLUME FRACTION
ROTH      2.6226 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        0.0927 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012      1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.5737 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027      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  H             STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0600 VOLUME FRACTION
ROTH      1.6291 SPECIFIED 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.
VF        0.4250 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
             8016      1.00 ATOM/MOLECULE
END

SC  C             STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2770 VOLUME FRACTION
ROTH      1.6291 SPECIFIED 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.
VF        0.0200 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
             7014      1.00 ATOM/MOLECULE
END

SC  AL            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2140 VOLUME FRACTION
ROTH      1.6291 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             8 MIXTURE NO.
VF        0.0010 VOLUME FRACTION
ROTH      1.6291 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             8 MIXTURE NO.
VF        0.0040 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
             5011      1.00 ATOM/MOLECULE
END
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
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     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 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 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                    ********** DATA LIBRARY INFORMATION **********                              ***
***                                                                                               ***
***        UNIT                                          VOLUME                                   ***
***       NUMBER            DATA SET NAME                 NAME        UNIT FUNCTION               ***
***       ------            -------------                 ----        -------------               ***
***                                                                                               ***
***         89     M:\scale43\DATALIB\FT89F001                        STANDARD COMPOSITION LIBRARY ***
***                                                                                               ***
***         82     M:\scale43\DATALIB\FT82F001                        CROSS SECTION LIBRARY        ***
***                                                                                               ***
***         11     D:\Projects\YAEC\5501\Runs\reflected_disk_st       SHORT CROSS SECTION LIBRARY  ***
***                                                                                               ***
***         90     D:\Projects\YAEC\5501\Runs\reflected_disk_st       INPUT DATA DIRECT ACCESS     ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                                                                                               ***
***                          STANDARD COMPOSITION LIBRARY DATA                                    ***
***                          ---------------------------------                                    ***
***                                                                                               ***
***        UNIT NUMBER  :  89                                                                     ***
***                                                                                               ***
***        DATASET NAME :  M:\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 :  M:\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                                      ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************

                .......    0 IO'S WERE USED BEFORE READING KENO V DATA    .......

                .......    0 IO'S WERE USED READING THE KENO V PARAMETER DATA    .......
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
KK          KK  EEEEEEEEEEEEE  NN          NN   OOOOOOOOOOOO                  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    OOOOOOOOOOOO                       V

SSSSSSSSSS    CCCCCCCCCC     AAAAAAAAA    LL            EEEEEEEEEEEEE                PPPPPPPPPPPP    CCCCCCCCCC
SSSSSSSSSSSS  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
SSSSSSSSSSSS  CCCCCCCCCCCCC  AA       AA   LLLLLLLLLLLLL EEEEEEEEEEEEE                PP              CCCCCCCCCCCCC
 SSSSSSSSSS    CCCCCCCCCC    AA       AA   LLLLLLLLLLLLL EEEEEEEEEEEEE                PP               CCCCCCCCCC

  0000000      33333333333          //  22222222222  5555555555555          //   0000000      22222222222
 000000000    3333333333333         //  2222222222222 5555555555555         //  000000000    2222222222222
00       00  33          33         //  22        22  55                    //  00       00  22          22
00        00            33         //            22  55                    //  00        00            22
00        00            33         //            22  55                    //  00        00            22
00        00          333          //          22    555555555555          //  00        00          22
00        00          333          //        22      5555555555555         //  00        00        22
00        00            33         //      22                  55          //  00        00      22
00        00            33         //    22                    55          //  00        00    22
00       00  33         33         //  22                  55  55          //  00       00  22
 000000000  3333333333333          //  2222222222222 5555555555555         //   000000000    2222222222222
  0000000     33333333333          //  2222222222222  55555555555          //    0000000     2222222222222

   11         33333333333                 0000000          11                  22222222222   7777777777777
  111        3333333333333                000000000        111                 2222222222222  777777777777
 1111        33          33     :::     00        00     1111        :::     22          22  77          77
   11                    33     :::    00          00     11         :::                 22            77
   11                    33     :::    00          00     11         :::                 22           77
   11                  333            00          00     11                           22           77
   11                  333            00          00     11                         22             77
   11                    33     :::    00          00     11         :::           22               77
   11                    33     :::    00          00     11         :::         22                 77
   11          33        33     :::     00        00     11         :::       22                   77
 11111111     3333333333333              000000000      11111111                2222222222222        77
 11111111      33333333333                0000000       11111111                2222222222222        77
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
 SSSSSSSSSS     CCCCCCCCCC      AAAAAAAAA     LL              EEEEEEEEEEEEE                    PPPPPPPPPPPP     CCCCCCCCCC
SSSSSSSSSSSS   CCCCCCCCCCCC    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                    PPPPPPPPPPPPP   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
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
SSSSSSSSSSSS   CCCCCCCCCCCC    AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP              CCCCCCCCCCCC
 SSSSSSSSSS     CCCCCCCCCC     AA         AA  LLLLLLLLLLLL    EEEEEEEEEEEEE                    PP               CCCCCCCCCC
```

```
*****************************************************************************
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                PROGRAM VERIFICATION INFORMATION                   *****
*****                                                                   *****
*****               CODE SYSTEM:  SCALE-PC VERSION:  4.3                *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****                                                                   *****
*****                                                                   *****
*****            PROGRAM:  000009                                       *****
*****                                                                   *****
*****      CREATION DATE:  03/08/96                                     *****
*****                                                                   *****
*****            VOLUME:   Eng                                          *****
*****                                                                   *****
*****            LIBRARY:  M:\SCALE43\WIN_NT\EXE                        *****
*****                                                                   *****
*****                                                                   *****
*****     PRODUCTION CODE:  KENOVA                                      *****
*****                                                                   *****
*****            VERSION:  3.1                                          *****
*****                                                                   *****
*****            JOBNAME:  SCALE-PC                                     *****
*****                                                                   *****
*****   DATE OF EXECUTION:  03/25/02                                    *****
*****                                                                   *****
*****   TIME OF EXECUTION:  13:01:27                                    *****
*****                                                                   *****
*****                                                                   *****
*****************************************************************************
*****************************************************************************
*****************************************************************************
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                    TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0***
***                                                                                               ***
*****************************************************************************************************
***                        ******      NUMERIC PARAMETERS      ******                             ***
***                                                                                               ***
***                                                                                               ***
***          TME     MAXIMUM PROBLEM TIME (MIN)                          30.00                    ***
***                                                                                               ***
***          TBA     TIME PER GENERATION (MIN)                           15.00                    ***
***                                                                                               ***
***          GEN     NUMBER OF GENERATIONS                                1003                    ***
***                                                                                               ***
***          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                                321                    ***
***                                                                                               ***
***          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 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
*****************************************************************************************************************
*****************************************************************************************************************
***                                                                                                           ***
***                          TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0***
***                                                                                                           ***
*****************************************************************************************************************
***                                  ******      LOGICAL PARAMETERS        ******                             ***
***                                                                                                           ***
***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA     YES          PLT  PLOT PICTURE MAP(S)                   YES ***
***                                                                                                           ***
***  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 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY 966 INDEPENDENT FISSION POINTS WERE GENERATED				
1	8.86430E-01	1.63583E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	9.30216E-01	1.64600E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY 968 INDEPENDENT FISSION POINTS WERE GENERATED				
3	8.62103E-01	1.65600E+00	8.62103E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	9.59846E-01	1.66517E+00	9.10975E-01	4.88714E-02	0.00000E+00	0.00000E+00
5	9.26128E-01	1.67533E+00	9.16026E-01	2.86645E-02	0.00000E+00	0.00000E+00
6	9.06831E-01	1.68533E+00	9.13727E-01	2.03988E-02	0.00000E+00	0.00000E+00
7	9.34797E-01	1.69450E+00	9.17941E-01	1.63531E-02	0.00000E+00	0.00000E+00
8	8.84345E-01	1.70450E+00	9.12342E-01	1.44788E-02	0.00000E+00	0.00000E+00
9	8.84580E-01	1.71467E+00	9.08376E-01	1.28635E-02	0.00000E+00	0.00000E+00
10	8.83476E-01	1.72383E+00	9.05263E-01	1.15667E-02	0.00000E+00	0.00000E+00
11	9.15707E-01	1.73383E+00	9.06424E-01	1.02667E-02	0.00000E+00	0.00000E+00
12	9.44775E-01	1.74383E+00	9.10259E-01	9.95150E-03	0.00000E+00	0.00000E+00
13	9.44424E-01	1.75300E+00	9.13365E-01	9.52225E-03	0.00000E+00	0.00000E+00
14	9.38542E-01	1.76400E+00	9.15463E-01	8.94221E-03	0.00000E+00	0.00000E+00
15	9.05427E-01	1.77317E+00	9.14691E-01	8.26178E-03	0.00000E+00	0.00000E+00
16	9.05457E-01	1.78333E+00	9.14031E-01	7.67731E-03	0.00000E+00	0.00000E+00
17	9.07366E-01	1.79250E+00	9.13587E-01	7.16098E-03	0.00000E+00	0.00000E+00
18	9.47593E-01	1.80150E+00	9.15712E-01	7.02758E-03	0.00000E+00	0.00000E+00
19	8.96175E-01	1.81167E+00	9.14563E-01	6.70055E-03	0.00000E+00	0.00000E+00
20	8.92676E-01	1.82167E+00	9.13347E-01	6.43330E-03	0.00000E+00	0.00000E+00
21	8.97286E-01	1.83083E+00	9.12502E-01	6.14372E-03	0.00000E+00	0.00000E+00
22	9.18874E-01	1.84100E+00	9.12820E-01	5.83715E-03	0.00000E+00	0.00000E+00
23	9.16554E-01	1.85100E+00	9.12998E-01	5.55508E-03	0.00000E+00	0.00000E+00
24	9.24305E-01	1.86117E+00	9.13512E-01	5.32144E-03	0.00000E+00	0.00000E+00
25	9.50884E-01	1.87117E+00	9.15137E-01	5.33812E-03	0.00000E+00	0.00000E+00
26	9.03892E-01	1.88033E+00	9.14668E-01	5.13230E-03	0.00000E+00	0.00000E+00
27	8.67111E-01	1.89033E+00	9.12766E-01	5.27749E-03	0.00000E+00	0.00000E+00
28	9.20762E-01	1.90050E+00	9.13074E-01	5.07977E-03	0.00000E+00	0.00000E+00
29	9.28867E-01	1.91050E+00	9.13659E-01	4.92288E-03	0.00000E+00	0.00000E+00
30	8.98241E-01	1.92067E+00	9.13108E-01	4.77566E-03	0.00000E+00	0.00000E+00
31	9.41922E-01	1.92967E+00	9.14102E-01	4.71394E-03	0.00000E+00	0.00000E+00
32	9.25394E-01	1.93983E+00	9.14478E-01	4.56963E-03	0.00000E+00	0.00000E+00
33	8.83837E-01	1.94983E+00	9.13490E-01	4.52894E-03	0.00000E+00	0.00000E+00
34	8.99376E-01	1.96000E+00	9.13049E-01	4.40725E-03	0.00000E+00	0.00000E+00
35	9.19662E-01	1.97000E+00	9.13249E-01	4.27631E-03	0.00000E+00	0.00000E+00
36	9.35925E-01	1.98017E+00	9.13916E-01	4.20189E-03	0.00000E+00	0.00000E+00
37	9.17451E-01	1.99017E+00	9.14017E-01	4.08132E-03	0.00000E+00	0.00000E+00
38	9.42446E-01	2.00017E+00	9.14807E-01	4.04418E-03	0.00000E+00	0.00000E+00
39	9.39725E-01	2.01033E+00	9.15480E-01	3.99060E-03	0.00000E+00	0.00000E+00
40	9.07176E-01	2.01950E+00	9.15262E-01	3.89031E-03	0.00000E+00	0.00000E+00
41	9.36038E-01	2.02950E+00	9.15794E-01	3.82651E-03	0.00000E+00	0.00000E+00
42	9.08300E-01	2.03967E+00	9.15607E-01	3.73432E-03	0.00000E+00	0.00000E+00
43	9.23285E-01	2.04967E+00	9.15794E-01	3.64691E-03	0.00000E+00	0.00000E+00
44	9.10821E-01	2.05967E+00	9.15676E-01	3.56099E-03	0.00000E+00	0.00000E+00
45	8.87317E-01	2.06983E+00	9.15016E-01	3.53918E-03	0.00000E+00	0.00000E+00
46	9.11245E-01	2.07983E+00	9.14931E-01	3.45887E-03	0.00000E+00	0.00000E+00
47	9.33556E-01	2.08900E+00	9.15344E-01	3.40637E-03	0.00000E+00	0.00000E+00
48	9.12917E-01	2.09917E+00	9.15292E-01	3.33192E-03	0.00000E+00	0.00000E+00
49	9.29311E-01	2.10817E+00	9.15590E-01	3.27387E-03	0.00000E+00	0.00000E+00
50	9.32855E-01	2.11833E+00	9.15950E-01	3.22506E-03	0.00000E+00	0.00000E+00
51	9.01676E-01	2.12833E+00	9.15658E-01	3.17196E-03	0.00000E+00	0.00000E+00
52	9.51940E-01	2.13850E+00	9.16384E-01	3.19147E-03	0.00000E+00	0.00000E+00
53	8.92347E-01	2.14850E+00	9.15913E-01	3.16357E-03	0.00000E+00	0.00000E+00
54	9.59600E-01	2.15867E+00	9.16753E-01	3.21389E-03	0.00000E+00	0.00000E+00
55	8.95899E-01	2.16867E+00	9.16359E-01	3.17712E-03	0.00000E+00	0.00000E+00
56	9.18557E-01	2.17783E+00	9.16400E-01	3.11800E-03	0.00000E+00	0.00000E+00
57	9.43905E-01	2.18783E+00	9.16900E-01	3.10137E-03	0.00000E+00	0.00000E+00
58	9.20120E-01	2.19800E+00	9.16958E-01	3.04603E-03	0.00000E+00	0.00000E+00
59	9.37297E-01	2.20800E+00	9.17314E-01	3.01331E-03	0.00000E+00	0.00000E+00
60	9.87268E-01	2.21817E+00	9.18521E-01	3.19713E-03	0.00000E+00	0.00000E+00
61	9.23956E-01	2.22817E+00	9.18613E-01	3.14382E-03	0.00000E+00	0.00000E+00
			. . .			
982	9.04672E-01	1.14153E+01	9.24700E-01	7.36990E-04	0.00000E+00	0.00000E+00
983	9.36419E-01	1.14255E+01	9.24712E-01	7.36335E-04	0.00000E+00	0.00000E+00
984	9.14772E-01	1.14355E+01	9.24702E-01	7.35654E-04	0.00000E+00	0.00000E+00
985	9.17418E-01	1.14447E+01	9.24694E-01	7.34943E-04	0.00000E+00	0.00000E+00
986	8.89156E-01	1.14547E+01	9.24658E-01	7.35083E-04	0.00000E+00	0.00000E+00
987	9.54606E-01	1.14648E+01	9.24689E-01	7.34966E-04	0.00000E+00	0.00000E+00
988	9.07762E-01	1.14740E+01	9.24671E-01	7.34421E-04	0.00000E+00	0.00000E+00
989	9.32998E-01	1.14840E+01	9.24680E-01	7.33725E-04	0.00000E+00	0.00000E+00
990	9.24344E-01	1.14942E+01	9.24680E-01	7.32982E-04	0.00000E+00	0.00000E+00
991	9.27070E-01	1.15042E+01	9.24682E-01	7.32244E-04	0.00000E+00	0.00000E+00
992	9.49672E-01	1.15133E+01	9.24707E-01	7.31940E-04	0.00000E+00	0.00000E+00
993	9.60024E-01	1.15233E+01	9.24743E-01	7.32069E-04	0.00000E+00	0.00000E+00
994	9.75624E-01	1.15335E+01	9.24794E-01	7.33127E-04	0.00000E+00	0.00000E+00
995	9.04812E-01	1.15435E+01	9.24774E-01	7.32664E-04	0.00000E+00	0.00000E+00
996	9.18264E-01	1.15537E+01	9.24767E-01	7.31956E-04	0.00000E+00	0.00000E+00
997	9.32982E-01	1.15628E+01	9.24776E-01	7.31267E-04	0.00000E+00	0.00000E+00
998	9.05779E-01	1.15728E+01	9.24757E-01	7.30781E-04	0.00000E+00	0.00000E+00
999	9.34645E-01	1.15828E+01	9.24767E-01	7.30115E-04	0.00000E+00	0.00000E+00
1000	9.34634E-01	1.15930E+01	9.24776E-01	7.29450E-04	0.00000E+00	0.00000E+00
1001	8.95950E-01	1.16022E+01	9.24748E-01	7.29291E-04	0.00000E+00	0.00000E+00
1002	9.32221E-01	1.16122E+01	9.24755E-01	7.28600E-04	0.00000E+00	0.00000E+00
1003	9.03383E-01	1.16223E+01	9.24734E-01	7.28184E-04	0.00000E+00	0.00000E+00

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

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

LIFETIME = 4.29740E-05 + OR - 8.70199E-08 GENERATION TIME = 2.88492E-05 + OR - 4.67432E-08
NU BAR = 2.44142E+00 + OR - 6.38806E-05 AVERAGE FISSION GROUP = 2.17829E+01 + OR - 3.80771E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 2.67732E-01 + OR - 8.25407E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.92480	+ OR - 0.00073	0.92407 TO 0.92552	0.92334 TO 0.92625	0.92262 TO 0.92698	1000000
4	0.92476	+ OR - 0.00073	0.92404 TO 0.92549	0.92331 TO 0.92621	0.92258 TO 0.92694	999000
5	0.92476	+ OR - 0.00073	0.92403 TO 0.92549	0.92331 TO 0.92621	0.92258 TO 0.92694	998000
6	0.92478	+ OR - 0.00073	0.92405 TO 0.92551	0.92332 TO 0.92623	0.92260 TO 0.92696	997000
7	0.92477	+ OR - 0.00073	0.92404 TO 0.92550	0.92331 TO 0.92622	0.92258 TO 0.92695	996000
8	0.92481	+ OR - 0.00073	0.92408 TO 0.92554	0.92335 TO 0.92626	0.92263 TO 0.92699	995000
9	0.92485	+ OR - 0.00073	0.92412 TO 0.92558	0.92339 TO 0.92630	0.92267 TO 0.92703	994000
10	0.92489	+ OR - 0.00073	0.92416 TO 0.92562	0.92344 TO 0.92634	0.92271 TO 0.92707	993000
11	0.92490	+ OR - 0.00073	0.92417 TO 0.92563	0.92345 TO 0.92635	0.92272 TO 0.92708	992000
12	0.92488	+ OR - 0.00073	0.92415 TO 0.92561	0.92342 TO 0.92634	0.92270 TO 0.92706	991000
17	0.92490	+ OR - 0.00073	0.92417 TO 0.92563	0.92344 TO 0.92636	0.92271 TO 0.92709	986000
22	0.92498	+ OR - 0.00073	0.92424 TO 0.92571	0.92351 TO 0.92644	0.92278 TO 0.92717	981000
27	0.92504	+ OR - 0.00073	0.92431 TO 0.92577	0.92358 TO 0.92650	0.92284 TO 0.92724	976000
32	0.92505	+ OR - 0.00074	0.92432 TO 0.92579	0.92358 TO 0.92652	0.92284 TO 0.92726	971000
37	0.92512	+ OR - 0.00074	0.92438 TO 0.92586	0.92365 TO 0.92660	0.92291 TO 0.92733	966000
42	0.92511	+ OR - 0.00074	0.92437 TO 0.92585	0.92363 TO 0.92659	0.92289 TO 0.92733	961000
47	0.92518	+ OR - 0.00074	0.92443 TO 0.92592	0.92369 TO 0.92666	0.92295 TO 0.92740	956000
			. . .			
912	0.92641	+ OR - 0.00227	0.92414 TO 0.92868	0.92186 TO 0.93096	0.91959 TO 0.93323	91000
917	0.92684	+ OR - 0.00235	0.92449 TO 0.92919	0.92214 TO 0.93154	0.91979 TO 0.93388	86000
922	0.92810	+ OR - 0.00235	0.92574 TO 0.93045	0.92339 TO 0.93281	0.92104 TO 0.93516	81000
927	0.92697	+ OR - 0.00239	0.92458 TO 0.92937	0.92218 TO 0.93176	0.91979 TO 0.93416	76000
932	0.92664	+ OR - 0.00250	0.92414 TO 0.92915	0.92163 TO 0.93165	0.91913 TO 0.93416	71000
937	0.92719	+ OR - 0.00264	0.92455 TO 0.92983	0.92190 TO 0.93248	0.91926 TO 0.93512	66000
942	0.92638	+ OR - 0.00282	0.92356 TO 0.92920	0.92074 TO 0.93202	0.91792 TO 0.93484	61000
947	0.92701	+ OR - 0.00302	0.92399 TO 0.93003	0.92098 TO 0.93305	0.91796 TO 0.93607	56000
952	0.92705	+ OR - 0.00320	0.92385 TO 0.93025	0.92065 TO 0.93345	0.91745 TO 0.93665	51000
957	0.92734	+ OR - 0.00349	0.92386 TO 0.93083	0.92037 TO 0.93432	0.91688 TO 0.93781	46000
962	0.92770	+ OR - 0.00357	0.92413 TO 0.93127	0.92055 TO 0.93485	0.91698 TO 0.93842	41000
967	0.92517	+ OR - 0.00374	0.92143 TO 0.92891	0.91770 TO 0.93264	0.91396 TO 0.93638	36000
972	0.92346	+ OR - 0.00404	0.91942 TO 0.92749	0.91538 TO 0.93153	0.91135 TO 0.93557	31000
977	0.92528	+ OR - 0.00416	0.92112 TO 0.92945	0.91696 TO 0.93361	0.91279 TO 0.93778	26000
982	0.92631	+ OR - 0.00479	0.92153 TO 0.93110	0.91674 TO 0.93588	0.91196 TO 0.94067	21000
987	0.92751	+ OR - 0.00544	0.92207 TO 0.93295	0.91663 TO 0.93839	0.91120 TO 0.94383	16000
992	0.92712	+ OR - 0.00749	0.91963 TO 0.93461	0.91213 TO 0.94210	0.90464 TO 0.94960	11000
997	0.91777	+ OR - 0.00731	0.91045 TO 0.92508	0.90314 TO 0.93240	0.89583 TO 0.93971	6000

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

PLOT OF AVERAGE K-EFFECTIVE BY GENERATION RUN.
THE LINE REPRESENTS K-EFF = 0.9248 + OR - 0.0007 WHICH OCCURS FOR 1003 GENERATIONS RUN.

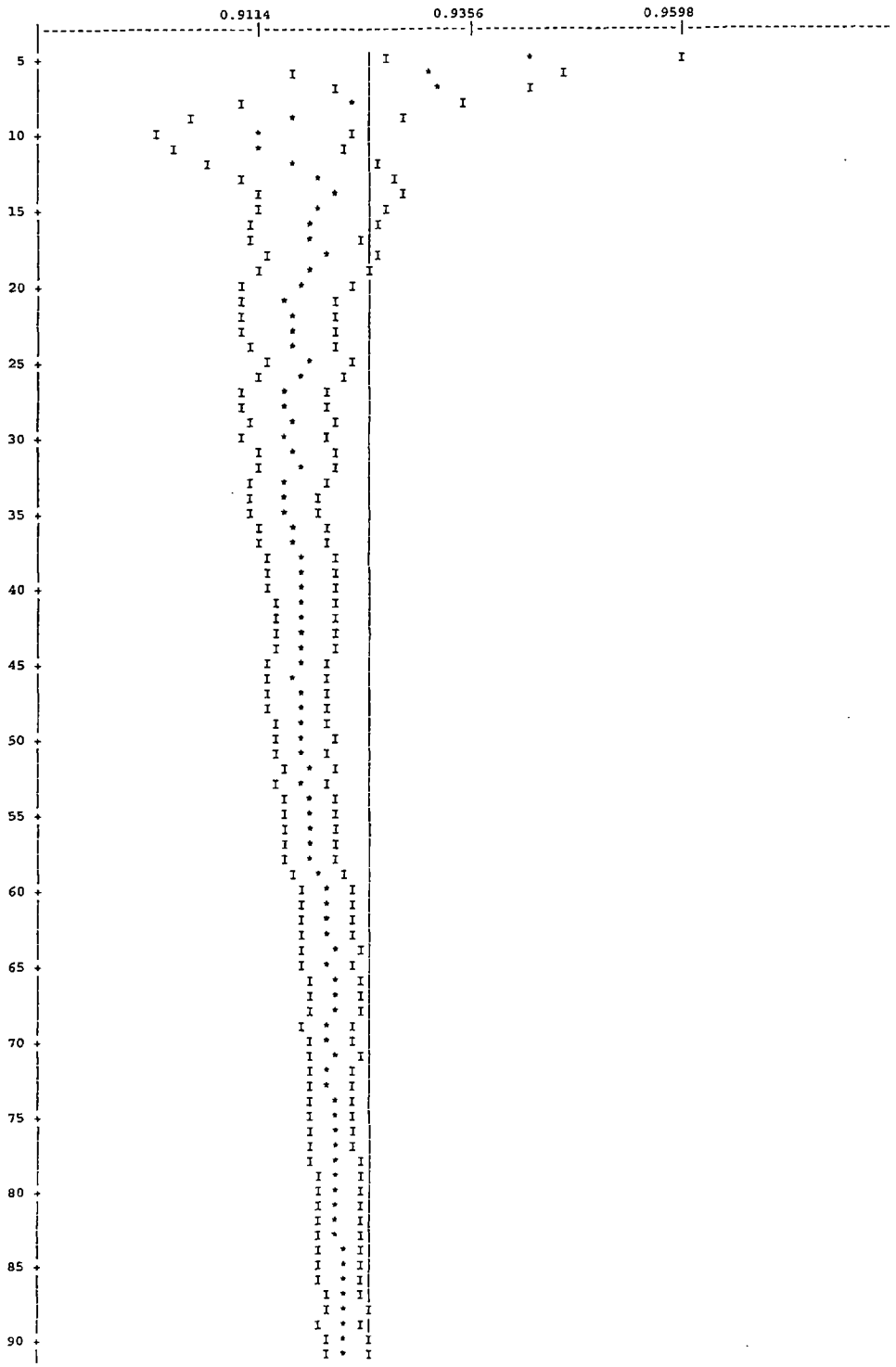

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

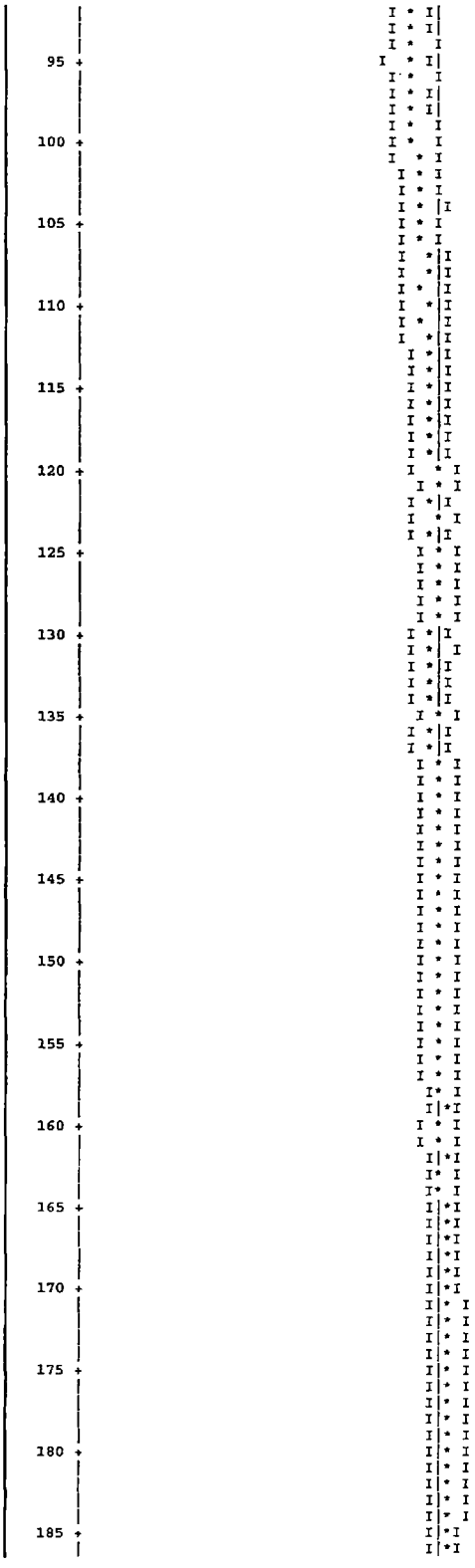

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
                                I|* I
                                I|*I
                                I|*I
190 +                           I|* I
                                I|*I
                                I|* I
                                I|*I
                                I|* I
195 +                           I|*I
                                I|*I
                                I|*I
                                I|*I
                                I|*I
200 +                           I|*I
                                I|*I
                                I|*I
                                I|*I
                                I|* I
205 +                           I|* I
                                I|*I
                                I|* I
                                I|* I
                                I|*I
210 +                           I|*I
                                I|*I
                                I|*I
                                I|*I
                                I|*I
215 +                           I* I
                                I|*I
                                I* I
                                I|*I
                                I|*I
220 +                           I|*I
                                I|*I
                                I* I
                                I|*I
                                I|*I
225 +                           I|*I
                                I|*I
                                I* I
                                I* I
                                I* I
230 +                           I* I
                                I* I
                                I* I
                                I* I
                                I* I
235 +                           I* I
                                I* I
                                I|*I
                                I|*I
                                I|*I
240 +                           I|*I
                                I|*I
                                I|*I
                                I|*I
                                I|*I
245 +                           I|*I
                                I|*I
                                I|*I
                                I|*I
                                 I* I
250 +                           I|*I
                                I|*I
                                I|*I
                                 I* I
                                 I* I
255 +                            I *I
                                 I *I
                                 I *I
                                 I *I
                                 I *I
260 +                            I *I
                                 I *I
                                 I *I
                                 I *I
                                 I *I
265 +                            I *I
                                 I *I
                                 I *I
                                 I *I
                                 |I* I
270 +                            |I* I
                                 |I*I
                                 |I*I
                                 |I*I
                                 |I* I
275 +                            |I*I
                                 I *I
905 +                           I*I
                                I*I
                                I*I
                                I*I
                                I*I
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
910 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
915 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
920 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
925 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
930 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
935 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
940 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
945 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
950 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
955 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
960 +                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
    |                                   I*I
965 +                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
970 +                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
975 +                                   I*I
    |                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
980 +                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
985 +                                    *I
    |                                   I*I
    |                                    *I
    |                                   I*I
    |                                   I*I
990 +                                   I*I
    |                                   I*I
    |                                    *I
    |                                    *I
    |                                    *I
995 +                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
    |                                    *I
1000 +                                   *I
    |                                    *I
    |                                    *I
    |                                    *I
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

PLOT OF AVERAGE K-EFFECTIVE BY GENERATION SKIPPED.
THE LINE REPRESENTS K-EFF = 0.9248 + OR - 0.0007 WHICH OCCURS FOR     4 GENERATIONS SKIPPED.

                0.9105                0.9198                0.9291
     |----------------------|----------------------|----------------------|----------------------
     |
     |                                                I * I
   5 +                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
  10 +                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
  15 +                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
  20 +                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
  25 +                                                I * I
     |                                                I * I
     |                                                I * I
     |                                                I * I
  30 +                                                I * I
     |                                                I * I
     |
     |                                                  I * I
     |                                                  I * I
     |                                                  I * I
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

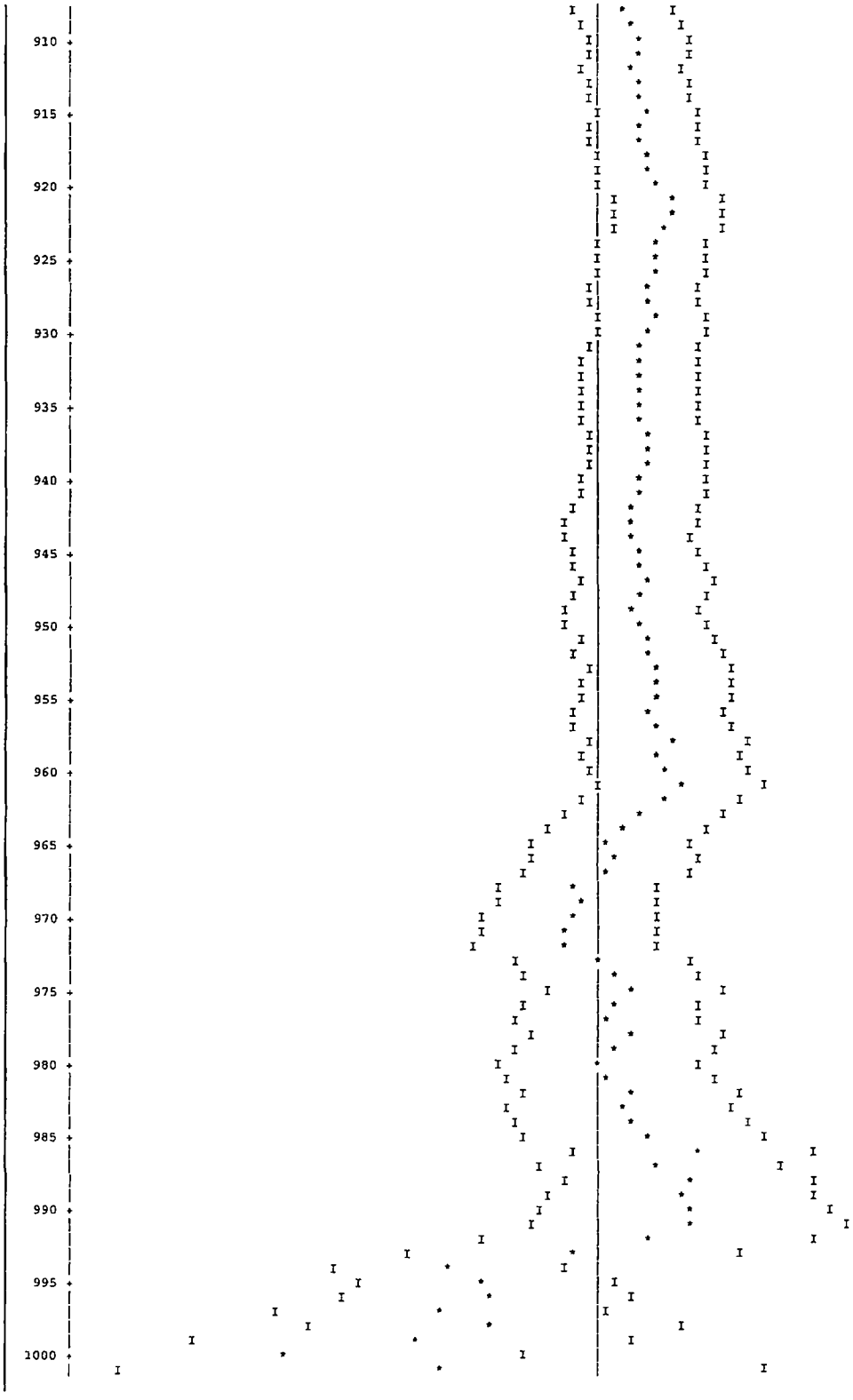

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

                                FREQUENCY FOR GENERATIONS    4 TO 1003
0.8469 TO 0.8499     *
0.8499 TO 0.8529
0.8529 TO 0.8560     *
0.8560 TO 0.8590
0.8590 TO 0.8620     *
0.8620 TO 0.8650
0.8650 TO 0.8680     **
0.8680 TO 0.8710     ****
0.8710 TO 0.8741     ****
0.8741 TO 0.8771     *
0.8771 TO 0.8801     ********
0.8801 TO 0.8831     *******
0.8831 TO 0.8861     *************
0.8861 TO 0.8891     *******************
0.8891 TO 0.8922     **********************
0.8922 TO 0.8952     ****************
0.8952 TO 0.8982     ************************************
0.8982 TO 0.9012     ******************************
0.9012 TO 0.9042     ************************************
0.9042 TO 0.9072     ***************************************************
0.9072 TO 0.9103     **********************************************
0.9103 TO 0.9133     *********************************************
0.9133 TO 0.9163     ****************************************
0.9163 TO 0.9193     *********************************************
0.9193 TO 0.9223     ****************************************************
0.9223 TO 0.9253     *********************************************
0.9253 TO 0.9284     ****************************************************************
0.9284 TO 0.9314     ******************************************************
0.9314 TO 0.9344     ********************************************************************
0.9344 TO 0.9374     ***************************************************
0.9374 TO 0.9404     ****************************************
0.9404 TO 0.9434     ****************************************
0.9434 TO 0.9465     *********************************
0.9465 TO 0.9495     ****************************************
0.9495 TO 0.9525     ***********************************
0.9525 TO 0.9555     ************************
0.9555 TO 0.9585     ************************
0.9585 TO 0.9615     *******************
0.9615 TO 0.9646     **********
0.9646 TO 0.9676     *************
0.9676 TO 0.9706     ****
0.9706 TO 0.9736     ******
0.9736 TO 0.9766     ********
0.9766 TO 0.9796
0.9796 TO 0.9827     ****
0.9827 TO 0.9857     **
0.9857 TO 0.9887     *
0.9887 TO 0.9917     **
0.9917 TO 0.9947
0.9947 TO 0.9977
0.9977 TO 1.0008     *
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

                                FREQUENCY FOR GENERATIONS  254 TO 1003
0.8469 TO 0.8499     *
0.8499 TO 0.8529
0.8529 TO 0.8560     *
0.8560 TO 0.8590
0.8590 TO 0.8620     *
0.8620 TO 0.8650
0.8650 TO 0.8680     *
0.8680 TO 0.8710     ****
0.8710 TO 0.8741     ****
0.8741 TO 0.8771     *
0.8771 TO 0.8801     *******
0.8801 TO 0.8831     *****
0.8831 TO 0.8861     ********
0.8861 TO 0.8891     ************
0.8891 TO 0.8922     **************
0.8922 TO 0.8952     **************
0.8952 TO 0.8982     ********************************
0.8982 TO 0.9012     **********************
0.9012 TO 0.9042     ************************
0.9042 TO 0.9072     ************************************
0.9072 TO 0.9103     ****************************************
0.9103 TO 0.9133     ************************************
0.9133 TO 0.9163     ******************************
0.9163 TO 0.9193     ******************************
0.9193 TO 0.9223     ****************************************
0.9223 TO 0.9253     **********************************
0.9253 TO 0.9284     ************************************************
0.9284 TO 0.9314     ****************************************************
0.9314 TO 0.9344     ************************************************
0.9344 TO 0.9374     ********************************
0.9374 TO 0.9404     **************************
0.9404 TO 0.9434     ******************************
0.9434 TO 0.9465     **********************
0.9465 TO 0.9495     ********************************
0.9495 TO 0.9525     **************************
0.9525 TO 0.9555     ****************
0.9555 TO 0.9585     ******************
0.9585 TO 0.9615     **************
0.9615 TO 0.9646     ********
0.9646 TO 0.9676     ********
0.9676 TO 0.9706     ****
0.9706 TO 0.9736     *****
0.9736 TO 0.9766     ******
0.9766 TO 0.9796
0.9796 TO 0.9827     ***
0.9827 TO 0.9857     **
0.9857 TO 0.9887
0.9887 TO 0.9917
0.9917 TO 0.9947
0.9947 TO 0.9977
0.9977 TO 1.0008     *
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

                                FREQUENCY FOR GENERATIONS  504 TO 1003
0.8469 TO 0.8499      *
0.8499 TO 0.8529
0.8529 TO 0.8560      *
0.8560 TO 0.8590
0.8590 TO 0.8620
0.8620 TO 0.8650
0.8650 TO 0.8680      *
0.8680 TO 0.8710      ****
0.8710 TO 0.8741      ***
0.8741 TO 0.8771      *
0.8771 TO 0.8801      ****
0.8801 TO 0.8831      **
0.8831 TO 0.8861      *******
0.8861 TO 0.8891      *****
0.8891 TO 0.8922      *********
0.8922 TO 0.8952      *********
0.8952 TO 0.8982      *******************
0.8982 TO 0.9012      *****************
0.9012 TO 0.9042      ****************
0.9042 TO 0.9072      ***************************
0.9072 TO 0.9103      **********************
0.9103 TO 0.9133      ************************
0.9133 TO 0.9163      *****************
0.9163 TO 0.9193      ******************
0.9193 TO 0.9223      *******************
0.9223 TO 0.9253      **********************
0.9253 TO 0.9284      ******************************
0.9284 TO 0.9314      *******************************
0.9314 TO 0.9344      ******************************
0.9344 TO 0.9374      ******************
0.9374 TO 0.9404      ****************
0.9404 TO 0.9434      ******************
0.9434 TO 0.9465      *****************
0.9465 TO 0.9495      **********************
0.9495 TO 0.9525      *************
0.9525 TO 0.9555      ************
0.9555 TO 0.9585      **************
0.9585 TO 0.9615      **********
0.9615 TO 0.9646      ******
0.9646 TO 0.9676      *******
0.9676 TO 0.9706      ****
0.9706 TO 0.9736      ***
0.9736 TO 0.9766      ****
0.9766 TO 0.9796
0.9796 TO 0.9827      *
0.9827 TO 0.9857      *
0.9857 TO 0.9887
0.9887 TO 0.9917
0.9917 TO 0.9947
0.9947 TO 0.9977
0.9977 TO 1.0008      *
```

Figure 6.7.1-6 CSAS Input/Output Summary for Damaged Fuel Can Configuration – Normal Conditions (Continued)

```
TRANSPORT CRITICALITY: NORMAL CONDITIONS (PITCH = 300 CM) (IVF = 1.0) (EVF = 1.0

                                FREQUENCY FOR GENERATIONS  754 TO 1003
0.8469 TO 0.8499     *
0.8499 TO 0.8529
0.8529 TO 0.8560
0.8560 TO 0.8590
0.8590 TO 0.8620
0.8620 TO 0.8650
0.8650 TO 0.8680
0.8680 TO 0.8710     ***
0.8710 TO 0.8741     *
0.8741 TO 0.8771
0.8771 TO 0.8801     ****
0.8801 TO 0.8831     **
0.8831 TO 0.8861     ****
0.8861 TO 0.8891     **
0.8891 TO 0.8922     *****
0.8922 TO 0.8952     *****
0.8952 TO 0.8982     *********
0.8982 TO 0.9012     **************
0.9012 TO 0.9042     *******
0.9042 TO 0.9072     ***************
0.9072 TO 0.9103     ********
0.9103 TO 0.9133     ************
0.9133 TO 0.9163     ******
0.9163 TO 0.9193     *********
0.9193 TO 0.9223     ********
0.9223 TO 0.9253     ******
0.9253 TO 0.9284     ******************
0.9284 TO 0.9314     *************
0.9314 TO 0.9344     ****************
0.9344 TO 0.9374     ************
0.9374 TO 0.9404     **************
0.9404 TO 0.9434     *********
0.9434 TO 0.9465     **********
0.9465 TO 0.9495     ********
0.9495 TO 0.9525     ******
0.9525 TO 0.9555     ******
0.9555 TO 0.9585     *********
0.9585 TO 0.9615     ***
0.9615 TO 0.9646     **
0.9646 TO 0.9676     ***
0.9676 TO 0.9706     *
0.9706 TO 0.9736     **
0.9736 TO 0.9766     ****
0.9766 TO 0.9796
0.9796 TO 0.9827     *
0.9827 TO 0.9857
0.9857 TO 0.9887
0.9887 TO 0.9917
0.9917 TO 0.9947
0.9947 TO 0.9977
0.9977 TO 1.0008
```

6.7.2 Supplemental Data for Connecticut Yankee Fuel

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition

```
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: 15/ 9/2000 -  17.34.12

            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.            *
 *********************************************************

 ****************************************************************
 ***            ANSWERS Software Licensing Procedure          ***
 ****************************************************************

 *** The timelock password has been successfully verified.
 *** This password expires at midnight on 30/ 6/2001

 *** Successful authorisation achieved on system 57NST
 *** This system has the identification number  131008778

 ****************************************************************
  This is a licensed ANSWERS software product made available to
   NAC International.
  The use of this program is restricted within the terms of your
  licence agreement with AEA Technology.
  This copy is registered with version identifier - PCNT9
 ****************************************************************
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
*****************************************************************
          ***          End of ANSWERS Software Licensing Checks          ***
          *****************************************************************

1PRINT OF INPUT DATA SET
 ========================
 *                                        *
 * Connecticut Yankee STC Transfer Cask Model *
 *                                        *

 always convert
! Always converts intergers to real numbers

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

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

 ********************************
 < FPF LABEL FUELPARAM
 < CPF LABEL TUBEPARAM
 < CPF LABEL BASKPARAM
 < CPF LABEL CANPARAM
 ********************************

 * The following parameters need to be updated

 ********************************************
 @tscMAT   = 15                                    ! Last material number of TSC going into cask
 @tscNUM   = 20                                    ! Last part number of TSC going into cask
 @fuelMAT  = 1                                     ! Material number of fuel from TSC model
 ********************************************

 * The remaining parameters should stay the same unless the drawings change.

 @cpi      = 2.54                                  ! Centimeters per inch
 @tscHT    = 151.75                                ! Height of TSC going into cask = 151.75*2.54
 @tscOD    = 70.64                                 ! Outer diameter of TSC going into cask = 70.64*2.54

 @tfrOD    = 89.0                                  ! Transfer cask OD = 89.0*2.54

 @cavMAT   = 4                                     ! Cavity Material additive

 @btmplHT  = 1                                     ! Bottom plate height = 1.0*2.54
 @btmplMAT = 1                                     ! Bottom plate material additive

 @inshlHT  = 150.0                                 ! Inner shell height  = 149.8*2.54
 @inshlID  = 71.5                                  ! Inner shell inner Diameter = 71.5*2.54
 @inshlTH  = 0.75                                  ! Inner shell thickness = 0.75*2.54
 @inshlMAT = 1                                     ! Inner shell material additive

 @pbshlTH  = 4.0                                   ! Lead shell thickness = 4.0*2.54
 @pbshlMAT = 2                                     ! Lead shell material additive

 @ns4frGAP = 4                                     ! Gap above Lead filled w/ NS-4-FR = 3*2.54
 @n4shlMAT = 3                                     ! NS-4-FR shell material additive

 @otshlTH  = 1.25                                  ! Outer shell thickness = 1.25*2.54
 @otshlMAT = 1                                     ! Outer shell material additive

 @topplHT  = 2.0                                   ! Top plate height = 2.0*2.54
 @topplMAT = 1                                     ! Top plate material additive

 @rtnrnHT  = 0.75                                  ! Retaining ring height = 0.75*2.54
 @rtnrnID  = 68.5                                  ! Retaining ring inner diameter = 68.5*2.54
 @rtnrnOD  = 80.8                                  ! Retaining ring outer diameter = 80.8*2.54
 @rtnrnMAT = 1                                     ! Retaining ring material additive

 @shldrHT  = 9.50                                  ! Shield door height = 9.50*2.54
 @shldrMAT = 1                                     ! Shield door material additive
 @drrailID = 75.5                                  ! Shield door rail inner dimension  = 75.5*2.54
 @drrailWD = 4.5                                   ! Shield door rail width = 4.5

 @trunzcor = 15.00                                 ! Distance b/w origen of trunion cylinder and retaining ri
 @trunOD   = 10.00                                 ! Diameter of trunions = 10*2.54
 @trunMAT  = 1                                     ! Trunion material additive

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

 NORMALISE

 ********************************
 < FMF LABEL FUELMIX
 ********************************

 NMATERIALS [@tscMAT + 5]

 ********************************
 * Inserting TSC Materials Here  *
 *                               *
 < FMF LABEL FUELMAT
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
< CMF LABEL TUBEMAT
< CMF LABEL BASKETMAT
< CMF LABEL CANMAT
********************************

WEIGHT
MATERIAL [@tscMAT + 1]  STAINLESS 304L STEEL              !Steel components of Transfer Cask

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

ATOMS
MATERIAL [@tscMAT + 3]  DENSITY 0.0                       !NS-4-FR
B10   PROP 8.553E-5
B11   PROP 3.422E-4
AL27  PROP 7.796E-3
H1    PROP 5.854E-2
O16   PROP 2.609E-2
C     PROP 2.264E-2
N     PROP 1.394E-3

ATOMS
MATERIAL [@tscMAT + 4]  DENSITY 0.9982                    ! Material (water) outside of Basket
H1    PROP 2
O16   PROP 1

ATOMS
MATERIAL [@tscMAT + 5]  DENSITY 0.9982                    ! Additional water for future use
H1    PROP 2
O16   PROP 1
END

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

*********************************
*  Inserting TSC Geometry Here  *
*                               *
< cgf Label BASKGEOM            *
*********************************
!234567890123456789012345678901234567890123456789012345678901234567890123456789012
PART [@tscNUM + 1]
ZROD 1 3*0  [@cpi*@tscOD/2] [@cpi*@tscHT]                                  ! TSC
ZROD 2 3*0  [@cpi*@inshlID/2] [@cpi*(@btmplHT+@inshlHT+@topplHT)]          ! Cask cavity
ZROD 3 3*0  [@cpi*@tfrOD/2] [@cpi*@btmplHT]                                ! Bottom plate
ZROD 4 2*0  [@cpi*@btmplHT] [@cpi*(((@inshlID/2)+@inshlTH)]
                  [@cpi*@inshlHT]                                          ! Inner shell
ZROD 5 2*0  [@cpi*@btmplHT] [@cpi*(((@inshlID/2)+@inshlTH+@pbshlTH)]
                  [@cpi*(@inshlHT-@ns4frGAP)]                              ! Lead shell
ZROD 6 2*0  [@cpi*@btmplHT] [@cpi*(((@tfrOD/2)-@otshlTH)]
                  [@cpi*@inshlHT]                                          ! NS-4-FR shell
ZROD 7 2*0  [@cpi*@btmplHT] [@cpi*(@tfrOD/2)] [@cpi*@inshlHT]              ! Outer shell
ZROD 8 2*0  [@cpi*(@btmplHT+@inshlHT)]  [@cpi*(@tfrOD/2)]
                  [@cpi*@topplHT]                                          ! Top plate
ZROD 9 2*0  [@cpi*(@btmplHT+@inshlHT+@topplHT)] [@cpi*@rtnrnID/2]
                  [@cpi*@rtnrnHT]                                          ! Area inside retaining ring
ZROD 10 2*0 [@cpi*(@btmplHT+@inshlHT+@topplHT)] [@cpi*@rtnrnOD/2]
                  [@cpi*@rtnrnHT]                                          ! Retaining ring
ZROD 11 2*0 [-@shldrHT*@cpi] [@cpi*@tfrOD/2] [@cpi*@shldrHT]               ! Shield doors and
YP   12  [@cpi*(((@drrailID/2)+@drrailWD)]                                 ! Y plane for shield door rail cu
YP   13  [-@cpi*(((@drrailID/2)+@drrailWD)]                                ! Y plane for shield door rail c
XROD 14  [-@cpi*@tfrOD/2] 0
                  [@cpi*(@btmplHT+@inshlHT+@topplHT - @trunzcor)]
                  [@cpi*@trunOD/2]    [@cpi*@tfrOD]                        ! Trunions
ZROD 15 2*0 [-1 * @cpi*@shldrHT] [@cpi*@tfrOD/2]
                  [@cpi*(@shldrHT+@btmplHT+@inshlHT+@topplHT+@rtnrnHT)]    ! Container

ZONES
P@tscNUM                  +1                                   ! TSC
M[@tscMAT + @cavMAT]      +2 -1                                ! Cask cavity
M[@tscMAT + @btmplMAT]    +3 -2                                ! Bottom plate
M[@tscMAT + @inshlMAT]    +4 -2 -14                            ! Inner shell
M[@tscMAT + @pbshlMAT]    +5 -4 -14                            ! Lead shell
M[@tscMAT + @n4shlMAT]    +6 -5 -4 -14                         ! NS-4-FR shell
M[@tscMAT + @otshlMAT]    +7 -6 -14                            ! Outer shell
M[@tscMAT + @topplMAT]    +8 -2                                ! Top plate
M[@tscMAT + @cavMAT]      +9                                   ! Area inside retaining ring
M[@tscMAT + @rtnrnMAT]    +10 -9                               ! Retaining ring
M[@tscMAT + @shldrMAT]    +11 -12 +13                          ! Shield doors and rails
M[@tscMAT + @cavMAT]      +11 +12                              ! Space outside of shield door
M[@tscMAT + @cavMAT]      +11 -13                              ! Space outside of shield door
M[@tscMAT + @trunMAT]     +14 +15 -2                           ! Trunions
M[@tscMAT + @cavMAT]      +15 -14 -11 -10 -8 -7 -3             ! Container of same material f

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

ALBEDO 1 1 1
PERIODIC

END

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

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

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

*********************************
* Inserting TSC Hole Data Here  *
*                               *
< FHF LABEL FUELHOLE
< CHF LABEL TUBEHOLE
< CHF LABEL BASKHOLE
*********************************

END

*************************************************
BEGIN CONTROL DATA
*************************************************

*READ   ! read and check each independently
*SEEK MULTIPLE DEFINITIONS

SEEDS 54321 54321
STAGES -3 810 1000 STDV 0.0008

END

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

ZONEMAT
ALL / MATERIAL @fuelMAT

END

    Changing  input to named channel:       FPF after reading
      15  lines from   named channel:     INPUT Total line count=   15
    Real     parameter number   1:rpitch              =  1.442700E+00
    Real     parameter number   2:lactfu              =  3.061970E+02
    Real     parameter number   3:odpellet            =  9.307000E-01
    Real     parameter number   4:odclad              =  1.066800E+00
    Real     parameter number   5:cladth              =  5.660000E-02
    Real     parameter number   6:odgt                =  1.346200E+00
    Real     parameter number   7:gtth                =  3.300000E-02
    Real     parameter number   8:odit                =  1.346200E+00
    Real     parameter number   9:itth                =  3.300000E-02
    Real     parameter number  10:lfu                 =  3.218688E+02
    Real     parameter number  11:ltcap               =  1.739900E+00
    Real     parameter number  12:lbcap               =  1.739900E+00
    Real     parameter number  13:lfexpb              =  0.000000E+00
    Real     parameter number  14:lattice             =  1.500000E+01
    Real     parameter number  15:lassem              =  3.481324E+02
    Real     parameter number  16:wfuel               =  2.164080E+01
    Real     parameter number  17:lbnozz              =  8.097500E+00
    Real     parameter number  18:ltnozz              =  1.724660E+01
    Real     parameter number  19:fgapb               =  0.000000E+00
    Real     parameter number  20:fuoffz              =  0.000000E+00
    Returning input to named channel:     INPUT after reading
      33  lines from   named channel:       FPF Total line count=   45

    Changing  input to named channel:       CPF after reading
      16  lines from   named channel:     INPUT Total line count=   46
    Real     parameter number  21:wft                 =  2.222500E+01
    Real     parameter number  22:ftth                =  1.219000E-01
    Real     parameter number  23:lfutube             =  3.357880E+02
    Real     parameter number  24:wfto                =  2.294130E+01
    Integer  parameter number  25:ftoffz              =          0
    Real     parameter number  26:asoffx              =  5.842000E-01
    Real     parameter number  27:asoffy              =  5.842000E-01
    Real     parameter number  28:asoffyp             =  2.921000E-01
    Real     parameter number  29:asoffxo             =  1.600200E+00
    Real     parameter number  30:asoffyo             =  1.600200E+00
    Real     parameter number  31:wbrl                =  2.025400E+01
    Real     parameter number  32:blt                 =  1.905000E-01
    Real     parameter number  33:blct                =  1.270000E-01
    Real     parameter number  34:lboral              =  3.261360E+02
    Real     parameter number  35:boffz               =  3.556000E-01
    Integer  parameter number  36:bshiftx             =          0
    Integer  parameter number  37:bshifty             =          0
    Integer  parameter number  38:bshiftyp            =          0
    Real     parameter number  39:cvst                =  4.570000E-02
    Real     parameter number  40:lcvs                =  3.284220E+02
    Real     parameter number  41:cvoffz              =  2.032000E+00
    Real     parameter number  42:tboffx              =  3.886000E-01
    Real     parameter number  43:tboffy              =  3.886000E-01
    Real     parameter number  44:tboffyp             =  1.943000E-01
    Real     parameter number  45:overs               =  1.016000E+00
    Returning input to named channel:     INPUT after reading
      47  lines from   named channel:       CPF Total line count=   87

    Changing  input to named channel:       CPF after reading
      17  lines from   named channel:     INPUT Total line count=   88
    Real     parameter number  46:diabw               =  1.752092E+02
    Real     parameter number  47:lbw                 =  5.080000E+00
    Real     parameter number  48:lbwd                =  1.270000E+00
    Real     parameter number  49:lbws                =  1.038860E+01
    Real     parameter number  50:diatpw              =  1.752092E+02
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
     Real    parameter number  51:ltpw              =  1.727200E+01
     Real    parameter number  52:ltpwd             =  1.270000E+00
     Real    parameter number  53:lspring           =  1.473200E+01
     Real    parameter number  54:thspring          =  1.270000E+00
     Real    parameter number  55:opspd             =  2.332990E+01
     Real    parameter number  56:diassp            =  1.756410E+02
     Real    parameter number  57:tspd              =  1.270000E+00
     Real    parameter number  58:wsspx1            =  1.353330E+01
     Real    parameter number  59:wsspx2            =  3.961910E+01
     Real    parameter number  60:wsspx3            =  6.545090E+01
     Real    parameter number  61:tsspy1            =  2.708420E+01
     Real    parameter number  62:tsspy2            =  5.926600E+01
     Real    parameter number  63:wsspxo            =  4.012710E+01
     Real    parameter number  64:tsspyo            =  5.405900E+01
     Real    parameter number  65:diaht             =  1.749298E+02
     Real    parameter number  66:thtd              =  1.270000E+00
     Integer parameter number  67:nhtd              =        27
     Real    parameter number  68:dsspht            =  4.559300E+00
     Real    parameter number  69:lbasket           =  3.594100E+02
     Real    parameter number  70:diskstack         =  3.160522E+02
     Integer parameter number  71:baskoff           =         0
     Returning input to named channel:     INPUT after reading
       96  lines from   named channel:       CPF Total line count=  133

     Changing  input to named channel:       CPF after reading
       18  lines from   named channel:     INPUT Total line count=  134
     Real    parameter number  72:canod             =  1.794256E+02
     Real    parameter number  73:canth             =  1.587500E+00
     Real    parameter number  74:canl              =  3.854450E+02
     Real    parameter number  75:canbot            =  4.445000E+00
     Real    parameter number  76:shield1           =  1.270000E+01
     Real    parameter number  77:structl           =  7.620000E+00
     Real    parameter number  78:cavheight         =  3.606800E+02
     Returning input to named channel:     INPUT after reading
      113  lines from   named channel:       CPF Total line count=  147
     Integer parameter number  79:tscMAT            =        15
     Integer parameter number  80:tscNUM            =        20
     Integer parameter number  81:fuelMAT           =         1
     Real    parameter number  82:cpi               =  2.540000E+00
     Real    parameter number  83:tscHT             =  1.517500E+02
     Real    parameter number  84:tscOD             =  7.064000E+01
     Real    parameter number  85:tfrOD             =  8.900000E+01
     Integer parameter number  86:cavMAT            =         4
     Integer parameter number  87:btmplHT           =         1
     Integer parameter number  88:btmplMAT          =         1
     Real    parameter number  89:inshlHT           =  1.500000E+02
     Real    parameter number  90:inshlID           =  7.150000E+01
     Real    parameter number  91:inshlTH           =  7.500000E-01
     Integer parameter number  92:inshlMAT          =         1
     Real    parameter number  93:pbshlTH           =  4.000000E+00
     Integer parameter number  94:pbshlMAT          =         2
     Integer parameter number  95:ns4frGAP          =         4
     Integer parameter number  96:n4shlMAT          =         3
     Real    parameter number  97:otshlTH           =  1.250000E+00
     Integer parameter number  98:otshlMAT          =         1
     Real    parameter number  99:topplHT           =  2.000000E+00
     Integer parameter number 100:topplMAT          =         1
     Real    parameter number 101:rtnrnHT           =  7.500000E-01
     Real    parameter number 102:rtnrnID           =  6.850000E+01
     Real    parameter number 103:rtnrnOD           =  8.080000E+01
     Integer parameter number 104:rtnrnMAT          =         1
     Real    parameter number 105:shldrHT           =  9.500000E+00
     Integer parameter number 106:shldrMAT          =         1
     Real    parameter number 107:drrailID          =  7.550000E+01
     Real    parameter number 108:drrailWD          =  4.500000E+00
     Real    parameter number 109:trunzcor          =  1.500000E+01
     Real    parameter number 110:trunOD            =  1.000000E+01
     Integer parameter number 111:trunMAT           =         1
1

 ***********************************************************
 *    ENTERING UNIT  9 TO READ MATERIAL SPECIFICATION     *
 ***********************************************************


     Free format reading told to echo all input lines      to channel  6

 NORMALISE
++++++FILE NAME KEY IS DICE96J2V5.DAT
DATABASE NAME IS  d:\answers\data_libraries\monk_matdbv2d.dat
 DATABASE HISTORY IS
          MONK MATERIAL SPECIFICATION MODULE DATABASE VERSION 2C, STRUCTURING :
          . DICEDAT1C.DAT
          . DICE96J2V4.DAT
          . OILDICE96V2.DAT
          . DICE97E6V1.DAT
          . DICEDAT1D.DAT
          . DICE97E6V2.DAT
          . DICE96J2V5.DAT
          . DICE97E6V3.DAT
          ***************************************************
          * FOR USE WITH MONK, NOT FOR MCBEND AND RANKERN    *
          *                                                  *
          * If a requested nuclide is not present in the     *
          * nuclear data library, a warning message will be  *
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
         * printed below and the nuclide will be omitted    *
         * from the material.                                *
         * CHECK CAREFULLY that this automatic correction    *
         * to the material composition is appropriate.       *
         ****************************************************

< FMF LABEL FUELMIX

    Changing  input to named channel:       FMF after reading
      80  lines from   named channel:     INPUT Total line count=  209

NMIXTURES 1
*************************************************
**********************************

ATOMS
MIXTURE 1
H1 2
O16 1

< UP
    Returning input to named channel:     INPUT after reading
      10  lines from   named channel:       FMF Total line count=  218

NMATERIALS [@tscMAT + 5]
**********************************
    The input characters        : [@tscMAT + 5]
    have been replaced by       : +20.00000

< FMF LABEL FUELMAT

    Changing  input to named channel:       FMF after reading
      88  lines from   named channel:     INPUT Total line count=  226

WEIGHT
MATERIAL 1 DENSITY 10.412          ! 95% UO2 theoretical density 4.2 wt% 235U
**********************************
* Inserting TSC Materials Here  *
*                               *
U235  PROP 0.04063
U238  PROP 0.84080
O16   PROP 0.11856

WEIGHT
MATERIAL 2 ZIRCONIUM               ! Fuel pin cladding / End Caps
                    ++++MATERIAL <   2>: USES MIXTURE <ZIRCONIUM>

ATOMS
                    ++++MATERIAL <   2>: DEFAULT PROPORTION=1.0
MATERIAL 3 DENSITY 0.9982          ! Water In Lattice and Tube
H1    PROP 2
O16   PROP 1

ATOMS
MATERIAL 4 DENSITY 0.9982          ! Water In Fuel Rod Clad Gap
H1    PROP 2
O16   PROP 1

WEIGHT
MATERIAL 5 ZIRCONIUM               ! Guide tube material
                    ++++MATERIAL <   5>: USES MIXTURE <ZIRCONIUM>

WEIGHT
                    ++++MATERIAL <   5>: DEFAULT PROPORTION=1.0
MATERIAL 6 ZIRCONIUM               ! Instrument Tube Material
                    ++++MATERIAL <   6>: USES MIXTURE <ZIRCONIUM>

VOLUME
                    ++++MATERIAL <   6>: DEFAULT PROPORTION=1.0
MATERIAL 7
STAINLESS 304L STEEL PROP 0.3031
                    ++++MATERIAL <   7>: USES MIXTURE <STAINLESS 304L STEEL>
MIXTURE 1 DENSITY 0.9982 PROP 0.6969     ! Lower Nozzle Material

MATERIAL 8
STAINLESS 304L STEEL PROP 0.1720
                    ++++MATERIAL <   8>: USES MIXTURE <STAINLESS 304L STEEL>
MIXTURE 1 DENSITY 0.9982 PROP 0.8280     ! Upper Nozzle Material

< UP
    Returning input to named channel:     INPUT after reading
      48  lines from   named channel:       FMF Total line count=  262
< CMF LABEL TUBEMAT

    Changing  input to named channel:       CMF after reading
      89  lines from   named channel:     INPUT Total line count=  263

WEIGHT
MATERIAL  9  STAINLESS 304L STEEL    ! Tube wall and cover sheet
                    ++++MATERIAL <   9>: USES MIXTURE <STAINLESS 304L STEEL>

VOLUME
                    ++++MATERIAL <   9>: DEFAULT PROPORTION=1.0
MATERIAL 10                          ! BORAL core
AL27  DENSITY 2.6226 PROP 0.5738
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
B10   DENSITY 2.6226 PROP 0.0450
B11   DENSITY 2.6226 PROP 0.2735
C     DENSITY 2.6226 PROP 0.0926
VOID PROP 0.0150

WEIGHT
MATERIAL 11 ALUMINIUM                  ! BORAL alumnimum clad

< UP
    Returning input to named channel:     INPUT after reading
      24  lines from   named channel:       CMF Total line count=  279
< CMF LABEL BASKETMAT

    Changing  input to named channel:       CMF after reading
      90  lines from   named channel:     INPUT Total line count=  280

WEIGHT
                    ++++MATERIAL <  11>: USES MIXTURE <ALUMINIUM>
                    ++++MATERIAL <  11>: DEFAULT PROPORTION=1.0
MATERIAL 12 STAINLESS 304L STEEL    ! Structural Disk Material
                    ++++MATERIAL <  12>: USES MIXTURE <STAINLESS 304L STEEL>

WEIGHT
                    ++++MATERIAL <  12>: DEFAULT PROPORTION=1.0
MATERIAL 13 STAINLESS 304L STEEL    ! Weldment Material
                    ++++MATERIAL <  13>: USES MIXTURE <STAINLESS 304L STEEL>

WEIGHT
                    ++++MATERIAL <  13>: DEFAULT PROPORTION=1.0
MATERIAL 14 ALUMINIUM                ! Heat Transfer Disk Material

< UP
    Returning input to named channel:     INPUT after reading
      41  lines from   named channel:       CMF Total line count=  291
< CMF LABEL CANMAT

    Changing  input to named channel:       CMF after reading
      91  lines from   named channel:     INPUT Total line count=  292

WEIGHT
                    ++++MATERIAL <  14>: USES MIXTURE <ALUMINIUM>
                    ++++MATERIAL <  14>: DEFAULT PROPORTION=1.0
MATERIAL 15 STAINLESS 304L STEEL    ! Canister Material
                    ++++MATERIAL <  15>: USES MIXTURE <STAINLESS 304L STEEL>

< UP
    Returning input to named channel:     INPUT after reading
      52  lines from   named channel:       CMF Total line count=  297

WEIGHT
                    ++++MATERIAL <  15>: DEFAULT PROPORTION=1.0
MATERIAL [@tscMAT + 1]  STAINLESS 304L STEEL                !Steel components of Transfer Cask
*********************************
    The input characters        : [@tscMAT + 1]
    have been replaced by       : +16.00000
                    ++++MATERIAL <  16>: USES MIXTURE <STAINLESS 304L STEEL>

WEIGHT
                    ++++MATERIAL <  16>: DEFAULT PROPORTION=1.0
MATERIAL [@tscMAT + 2]  DENSITY 11.04                       !LEAD
    The input characters        : [@tscMAT + 2]
    have been replaced by       : +17.00000
PB    PROP 1.0000

ATOMS
MATERIAL [@tscMAT + 3]  DENSITY 0.0                                  !NS-4-FR
    The input characters        : [@tscMAT + 3]
    have been replaced by       : +18.00000
B10   PROP 8.553E-5
B11   PROP 3.422E-4
AL27  PROP 7.796E-3
H1    PROP 5.854E-2
O16   PROP 2.609E-2
C     PROP 2.264E-2
N     PROP 1.394E-3

ATOMS
MATERIAL [@tscMAT + 4]  DENSITY 0.9982                      ! Material (water) outside of Basket
    The input characters        : [@tscMAT + 4]
    have been replaced by       : +19.00000
H1    PROP 2
O16   PROP 1

ATOMS
MATERIAL [@tscMAT + 5]  DENSITY 0.9982                      ! Additional water for future use
    The input characters        : [@tscMAT + 5]
    have been replaced by       : +20.00000
H1    PROP 2
O16   PROP 1
END
==========================================================================================
MATERIAL #    LIBRARY    DFN  MOULD  ALIAS      ATOM/B-CM      NADLIB  DENSITY  MASS        Z.A
              SUBSTANCE                                        /MEDLIB          FRACTION
MATERIAL   1  U235       9228   62   J2U235     1.08389E-03    U235 1.04120E+01 4.06304E-02 92.235
           1  U238       9237   63   J2U238     2.21469E-02    U238 1.04120E+01 8.40808E-01 92.238
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

	1	O16	825	33	J2O16	4.64778E-02	O	1.04120E+01	1.18561E-01	8.016
MATERIAL	2	ZR	4000	47	J2ZR	4.29096E-02	ZR	6.50000E+00	1.00000E+00	40.000
MATERIAL	3	H1	10293	64	J2HINH2O	6.67530E-02	H	9.98200E-01	1.11915E-01	1.001
	3	O16	825	33	J2O16	3.33765E-02	O	9.98200E-01	8.88085E-01	8.016
MATERIAL	4	H1	10293	64	J2HINH2O	6.67530E-02	H	9.98200E-01	1.11915E-01	1.001
	4	O16	825	33	J2O16	3.33765E-02	O	9.98200E-01	8.88085E-01	8.016
MATERIAL	5	ZR	4000	47	J2ZR	4.29096E-02	ZR	6.50000E+00	1.00000E+00	40.000
MATERIAL	6	ZR	4000	47	J2ZR	4.29096E-02	ZR	6.50000E+00	1.00000E+00	40.000
MATERIAL	7	FE54	2625	15	J2FE54	1.13160E-03	FE	3.09913E+00	3.27048E-02	26.054
	7	FE56	2631	66	J2FE56	1.75916E-02	FE	3.09913E+00	5.27228E-01	26.056
	7	FE57	2634	16	J2FE57	4.02773E-04	FE	3.09913E+00	1.22872E-02	26.057
	7	FE58	2637	17	J2FE58	5.37031E-05	FE	3.09913E+00	1.66701E-03	26.058
	7	CR50	2425	11	J2CR50	2.17721E-04	CR	3.09913E+00	5.82656E-03	24.050
	7	CR52	2431	53	J2CR52	4.19859E-03	CR	3.09913E+00	1.16848E-01	24.052
	7	CR53	2434	12	J2CR53	4.76031E-04	CR	3.09913E+00	1.35031E-02	24.053
	7	CR54	2437	13	J2CR54	1.18507E-04	CR	3.09913E+00	3.42495E-03	24.054
	7	NI58	2825	56	J2NI58	1.34311E-03	NI	3.09913E+00	4.16931E-02	28.058
	7	NI60	2831	57	J2NI60	5.17360E-04	NI	3.09913E+00	1.66132E-02	28.060
	7	NI61	2834	58	J2NI61	2.24913E-05	NI	3.09913E+00	7.34284E-04	28.061
	7	NI62	2837	59	J2NI62	7.16961E-05	NI	3.09913E+00	2.37900E-03	28.062
	7	NI64	2843	60	J2NI64	1.82693E-05	NI	3.09913E+00	6.25781E-04	28.064
	7	H1	10293	64	J2HINH2O	4.65202E-02	H	3.09913E+00	2.51210E-02	1.001
	7	O16	825	33	J2O16	2.32601E-02	O	3.09913E+00	1.99344E-01	8.016
MATERIAL	8	FE54	2625	15	J2FE54	6.42149E-04	FE	2.19041E+00	2.62583E-02	26.054
	8	FE56	2631	66	J2FE56	9.98270E-03	FE	2.19041E+00	4.23306E-01	26.056
	8	FE57	2634	16	J2FE57	2.28562E-04	FE	2.19041E+00	9.86528E-03	26.057
	8	FE58	2637	17	J2FE58	3.04749E-05	FE	2.19041E+00	1.33842E-03	26.058
	8	CR50	2425	11	J2CR50	1.23550E-04	CR	2.19041E+00	4.67809E-03	24.050
	8	CR52	2431	53	J2CR52	2.38257E-03	CR	2.19041E+00	9.38158E-02	24.052
	8	CR53	2434	12	J2CR53	2.70133E-04	CR	2.19041E+00	1.08415E-02	24.053
	8	CR54	2437	13	J2CR54	6.72489E-05	CR	2.19041E+00	2.74986E-03	24.054
	8	NI58	2825	56	J2NI58	7.62173E-04	NI	2.19041E+00	3.34750E-02	28.058
	8	NI60	2831	57	J2NI60	2.93586E-04	NI	2.19041E+00	1.33386E-02	28.060
	8	NI61	2834	58	J2NI61	1.27631E-05	NI	2.19041E+00	5.89549E-04	28.061
	8	NI62	2837	59	J2NI62	4.06853E-05	NI	2.19041E+00	1.91008E-03	28.062
	8	NI64	2843	60	J2NI64	1.03673E-05	NI	2.19041E+00	5.02433E-04	28.064
	8	H1	10293	64	J2HINH2O	5.52715E-02	H	2.19041E+00	4.22289E-02	1.001
	8	O16	825	33	J2O16	2.76358E-02	O	2.19041E+00	3.35102E-01	8.016
MATERIAL	9	FE54	2625	15	J2FE54	3.73343E-03	FE	7.92967E+00	4.21706E-02	26.054
	9	FE56	2631	66	J2FE56	5.80390E-02	FE	7.92967E+00	6.79825E-01	26.056
	9	FE57	2634	16	J2FE57	1.32885E-03	FE	7.92967E+00	1.58435E-02	26.057
	9	FE58	2637	17	J2FE58	1.77180E-04	FE	7.92967E+00	2.14949E-03	26.058
	9	CR50	2425	11	J2CR50	7.18316E-04	CR	7.92967E+00	7.51296E-03	24.050
	9	CR52	2431	53	J2CR52	1.38522E-02	CR	7.92967E+00	1.50667E-01	24.052
	9	CR53	2434	12	J2CR53	1.57054E-03	CR	7.92967E+00	1.74114E-02	24.053
	9	CR54	2437	13	J2CR54	3.90982E-04	CR	7.92967E+00	4.41624E-03	24.054
	9	NI58	2825	56	J2NI58	4.43124E-03	NI	7.92967E+00	5.37605E-02	28.058
	9	NI60	2831	57	J2NI60	1.70690E-03	NI	7.92967E+00	2.14216E-02	28.060
	9	NI61	2834	58	J2NI61	7.42043E-05	NI	7.92967E+00	9.46809E-04	28.061
	9	NI62	2837	59	J2NI62	2.36543E-04	NI	7.92967E+00	3.06756E-03	28.062
	9	NI64	2843	60	J2NI64	6.02748E-05	NI	7.92967E+00	8.06902E-04	28.064
MATERIAL	10	AL27	1325	1	J2AL27	3.35908E-02	AL	2.58326E+00	5.82597E-01	13.027
	10	B10	525	5	J2B10	7.09867E-03	B10	2.58326E+00	4.56899E-02	5.010
	10	B11	528	48	J2B11	3.92395E-02	B11	2.58326E+00	2.77693E-01	5.011
	10	C	600	6	J2C	1.21775E-02	C	2.58326E+00	9.40197E-02	6.000
MATERIAL	11	AL27	1325	1	J2AL27	6.02626E-02	AL	2.70000E+00	1.00000E+00	13.027
MATERIAL	12	FE54	2625	15	J2FE54	3.73343E-03	FE	7.92967E+00	4.21706E-02	26.054
	12	FE56	2631	66	J2FE56	5.80390E-02	FE	7.92967E+00	6.79825E-01	26.056
	12	FE57	2634	16	J2FE57	1.32885E-03	FE	7.92967E+00	1.58435E-02	26.057
	12	FE58	2637	17	J2FE58	1.77180E-04	FE	7.92967E+00	2.14949E-03	26.058
	12	CR50	2425	11	J2CR50	7.18316E-04	CR	7.92967E+00	7.51296E-03	24.050
	12	CR52	2431	53	J2CR52	1.38522E-02	CR	7.92967E+00	1.50667E-01	24.052
	12	CR53	2434	12	J2CR53	1.57054E-03	CR	7.92967E+00	1.74114E-02	24.053
	12	CR54	2437	13	J2CR54	3.90982E-04	CR	7.92967E+00	4.41624E-03	24.054
	12	NI58	2825	56	J2NI58	4.43124E-03	NI	7.92967E+00	5.37605E-02	28.058
	12	NI60	2831	57	J2NI60	1.70690E-03	NI	7.92967E+00	2.14216E-02	28.060
	12	NI61	2834	58	J2NI61	7.42043E-05	NI	7.92967E+00	9.46809E-04	28.061
	12	NI62	2837	59	J2NI62	2.36543E-04	NI	7.92967E+00	3.06756E-03	28.062
	12	NI64	2843	60	J2NI64	6.02748E-05	NI	7.92967E+00	8.06902E-04	28.064
MATERIAL	13	FE54	2625	15	J2FE54	3.73343E-03	FE	7.92967E+00	4.21706E-02	26.054
	13	FE56	2631	66	J2FE56	5.80390E-02	FE	7.92967E+00	6.79825E-01	26.056
	13	FE57	2634	16	J2FE57	1.32885E-03	FE	7.92967E+00	1.58435E-02	26.057
	13	FE58	2637	17	J2FE58	1.77180E-04	FE	7.92967E+00	2.14949E-03	26.058
	13	CR50	2425	11	J2CR50	7.18316E-04	CR	7.92967E+00	7.51296E-03	24.050
	13	CR52	2431	53	J2CR52	1.38522E-02	CR	7.92967E+00	1.50667E-01	24.052
	13	CR53	2434	12	J2CR53	1.57054E-03	CR	7.92967E+00	1.74114E-02	24.053
	13	CR54	2437	13	J2CR54	3.90982E-04	CR	7.92967E+00	4.41624E-03	24.054
	13	NI58	2825	56	J2NI58	4.43124E-03	NI	7.92967E+00	5.37605E-02	28.058
	13	NI60	2831	57	J2NI60	1.70690E-03	NI	7.92967E+00	2.14216E-02	28.060
	13	NI61	2834	58	J2NI61	7.42043E-05	NI	7.92967E+00	9.46809E-04	28.061
	13	NI62	2837	59	J2NI62	2.36543E-04	NI	7.92967E+00	3.06756E-03	28.062
	13	NI64	2843	60	J2NI64	6.02748E-05	NI	7.92967E+00	8.06902E-04	28.064
MATERIAL	14	AL27	1325	1	J2AL27	6.02626E-02	AL	2.70000E+00	1.00000E+00	13.027
MATERIAL	15	FE54	2625	15	J2FE54	3.73343E-03	FE	7.92967E+00	4.21706E-02	26.054
	15	FE56	2631	66	J2FE56	5.80390E-02	FE	7.92967E+00	6.79825E-01	26.056
	15	FE57	2634	16	J2FE57	1.32885E-03	FE	7.92967E+00	1.58435E-02	26.057
	15	FE58	2637	17	J2FE58	1.77180E-04	FE	7.92967E+00	2.14949E-03	26.058
	15	CR50	2425	11	J2CR50	7.18316E-04	CR	7.92967E+00	7.51296E-03	24.050
	15	CR52	2431	53	J2CR52	1.38522E-02	CR	7.92967E+00	1.50667E-01	24.052
	15	CR53	2434	12	J2CR53	1.57054E-03	CR	7.92967E+00	1.74114E-02	24.053
	15	CR54	2437	13	J2CR54	3.90982E-04	CR	7.92967E+00	4.41624E-03	24.054
	15	NI58	2825	56	J2NI58	4.43124E-03	NI	7.92967E+00	5.37605E-02	28.058
	15	NI60	2831	57	J2NI60	1.70690E-03	NI	7.92967E+00	2.14216E-02	28.060
	15	NI61	2834	58	J2NI61	7.42043E-05	NI	7.92967E+00	9.46809E-04	28.061
	15	NI62	2837	59	J2NI62	2.36543E-04	NI	7.92967E+00	3.06756E-03	28.062

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
          15  NI64      2843   60  J2NI64      6.02748E-05      NI 7.92967E+00 8.06902E-04 28.064
MATERIAL  16  FE54      2625   15  J2FE54      3.73343E-03      FE 7.92967E+00 4.21706E-02 26.054
          16  FE56      2631   66  J2FE56      5.80390E-02      FE 7.92967E+00 6.79825E-01 26.056
          16  FE57      2634   16  J2FE57      1.32885E-03      FE 7.92967E+00 1.58435E-02 26.057
          16  FE58      2637   17  J2FE58      1.77180E-04      FE 7.92967E+00 2.14949E-03 26.058
          16  CR50      2425   11  J2CR50      7.18316E-04      CR 7.92967E+00 7.51296E-03 24.050
          16  CR52      2431   53  J2CR52      1.38522E-02      CR 7.92967E+00 1.50667E-01 24.052
          16  CR53      2434   12  J2CR53      1.57054E-03      CR 7.92967E+00 1.74114E-02 24.053
          16  CR54      2437   13  J2CR54      3.90982E-04      CR 7.92967E+00 4.41624E-03 24.054
          16  NI58      2825   56  J2NI58      4.43124E-03      NI 7.92967E+00 5.37605E-02 28.058
          16  NI60      2831   57  J2NI60      1.70690E-03      NI 7.92967E+00 2.14216E-02 28.060
          16  NI61      2834   58  J2NI61      7.42043E-05      NI 7.92967E+00 9.46809E-04 28.061
          16  NI62      2837   59  J2NI62      2.36543E-04      NI 7.92967E+00 3.06756E-03 28.062
          16  NI64      2843   60  J2NI64      6.02748E-05      NI 7.92967E+00 8.06902E-04 28.064
MATERIAL  17  PB        8200   34  J2PB        3.20871E-02      PB 1.10400E+01 1.00000E+00 82.000
MATERIAL  18  B10        525    5  J2B10       8.55300E-05     B10 1.63187E+00 8.71455E-04  5.010
          18  B11        528   48  J2B11       3.42200E-04     B11 1.63187E+00 3.83359E-03  5.011
          18  AL27      1325    1  J2AL27      7.79600E-03      AL 1.63187E+00 2.14044E-01 13.027
          18  H1       10293   64  J2HINH2O    5.85400E-02       H 1.63187E+00 6.00348E-02  1.001
          18  O16        825   33  J2O16       2.60900E-02       O 1.63187E+00 4.24640E-01  8.016
          18  C          600    6  J2C         2.26400E-02       C 1.63187E+00 2.76707E-01  6.000
          18  N14        725   31  J2N14       1.38884E-03       N 1.63187E+00 1.97898E-02  7.014
          18  N15        728   32  J2N15       5.15780E-06       N 1.63187E+00 7.87271E-05  7.015
MATERIAL  19  H1       10293   64  J2HINH2O    6.67530E-02       H 9.98200E-01 1.11915E-01  1.001
          19  O16        825   33  J2O16       3.33765E-02       O 9.98200E-01 8.88085E-01  8.016
MATERIAL  20  H1       10293   64  J2HINH2O    6.67530E-02       H 9.98200E-01 1.11915E-01  1.001
          20  O16        825   33  J2O16       3.33765E-02       O 9.98200E-01 8.88085E-01  8.016
=================================================================================================

 BEGIN MATERIAL GEOMETRY
 ***********************************************
1

 ************************************************************
 *    ENTERING UNIT  2 TO READ MATERIAL GEOMETRY DATA.    *
 ************************************************************


     Changing  input to named channel:       CGF after reading
      129  lines from   named channel:     INPUT Total line count=  335

qs   NOTES ON PRINTING OF INPUT GEOMETRY DATA
     ==========================================
     Body and zone numbers in each part are local to that part.
     Abbreviations for body parameters:
     SPHERE      R = Radius
     BOX        XL = Length on X axis; YL = Length on Y axis ;  ZL = Length on Z axis
     (X)ROD      R = Radius          ;  H = Height of(X)axis.
     (X)CONE    RB = Radius of base  ; RT = Radius of top    ;   H = Height of(X)axis.
     TORUS      RB = Bigger radius   ; RS = Smaller radius.
     (X)REL      R = Radius          ; HH = Half hgt.(X)axis.
     (XY)PRISM   B = Length of(X)base;  H = Height of(Y)axis ;  L = Prism length (Z);
                 Base angles         :  P = Origin end       ;  Q = Other end of base.
     (X)SEC     R1 = Inner radius    ; R2 = Outer radius     ;  H = Height of(X)axis;
                 Angles from (Y) axis: T1 = lower theta      ; T2 = Upper theta.
     (X)HEMI     R = Radius
     (X)HEX      D = Half-width across the hexagonal X-section; Height of (X) axis
     RPP        XU = Upper X limit   ; YU = Upper Y limit    ; ZU = Upper Z limit
     All       [R] = Matrix of direction cosines for rotated bodies:
                Vx = new X axis      ; Vy = New Y axis       ; Vz = New Z axis
     ==========================================================================


     PART   1 (NEST   ) Bodies in earlier parts=   0
     ----------------------------------------------
     Body definitions. Numbers are local to this part.

     shape  number    X0         Y0         Z0    Shape dependent parameters (see notes)
     BOX       1     0.0000     0.0000     0.0000 XL    21.6408 YL    21.6408 ZL   348.1324

     Zone  Name       Contents          Region     Volume   Description (local bodies)
       1              Body Hole     1     1     1.630E+05   +1
       2   Exterior  (Extra zone created by code)            -1


     PART   2 Was created by copying PART    1
     ----------------------------------------
     Bodies     2 to   2 copied from bodies   1 to   1
     Zones      3 to   4 copied from zones    1 to   2
     Regions    2 to   2 replace regions      1 to   1


     PART   3 (NEST   ) Bodies in earlier parts=   2
     ----------------------------------------------
     Body definitions. Numbers are local to this part.

     shape  number    X0         Y0         Z0    Shape dependent parameters (see notes)
     BOX       1     0.0457     0.0000     0.3556 XL     0.1905 YL    20.2540 ZL   326.1360
     The input characters        : [@blt+@cvst]
     have been replaced by       : +.2362000
     BOX       2     0.0457     0.0000     0.0000 XL     0.1905 YL    20.2540 ZL   328.4220
     BOX       3     0.0000     0.0000     0.0000 XL     0.2362 YL    20.2540 ZL   328.4220

     Zone  Name       Contents          Region     Volume   Description (local bodies)
       5              Body Hole     6     3     1.258E+03   +1
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
  6              Material      3     4     8.820E+00   +2   -1
  7              Material      9     5     3.040E+02   +3   -2
  8   Exterior  (Extra zone created by code)           -3

PART   4 (NEST   ) Bodies in earlier parts=   5
---------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
BOX       1     0.0457     0.0000     0.3556 XL     0.1905 YL    21.2700 ZL   326.1360
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
BOX       2     0.0457     0.0000     0.0000 XL     0.1905 YL    21.2700 ZL   328.4220
BOX       3     0.0000     0.0000     0.0000 XL     0.2362 YL    21.2700 ZL   328.4220

Zone  Name       Contents          Region     Volume   Description (local bodies)
  9              Body Hole     6     6     1.321E+03   +1
 10              Material      3     7     9.263E+00   +2   -1
 11              Material      9     8     3.192E+02   +3   -2
 12   Exterior  (Extra zone created by code)           -3
The input characters        : [@ftth+@asoffx]
have been replaced by       : +.7061000
The input characters        : [@ftth+@asoffy]
have been replaced by       : +.7061000

PART   5 (FG PART) Bodies in earlier parts=   8
---------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1     0.7061     0.7061     0.0000 XL    21.6408 YL    21.6408 ZL   348.1324
The input characters        : [@baskoff+@lbw+@ftoffz]
have been replaced by       : +5.080000
BOX       2     0.1219     0.1219     0.0000 XL    22.2250 YL    22.2250 ZL   360.6800
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       3     0.0000     0.0000     5.0800 XL    22.4688 YL    22.4688 ZL   335.7880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       4     0.0000     0.0000     0.0000 XL    22.4688 YL    22.4688 ZL   360.6800

Zone  Name       Contents          Region  Code Vol.   Description (local bodies)
 13  FUEL ASSEM  Part No.      1     -     1.630E+05   +1
 14  SPACE IN T  Material      3     -     1.512E+04   +2   -1
 15  FUEL TUBE   Material      9     -    -8.637E+03   +3   -2
 16  CONTAINER   Material      3     -    -1.656E+05   +4   -3   -2
 17  Exterior   (Extra zone created by code)           -4

There is a one-to-one correspondence between regions and zones.
The code volumes (calculated from zone descriptions and body volumes) will be used.
Zones  13 to  16 map to regions   9 to   12
The input characters        : [@ftth+@asoffx]
have been replaced by       : +.7061000
The input characters        : [@ftth+@asoffyp]
have been replaced by       : +.4140000

PART   6 (FG PART) Bodies in earlier parts=  12
---------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1     0.7061     0.4140     0.0000 XL    21.6408 YL    21.6408 ZL   348.1324
The input characters        : [@baskoff+@lbw+@ftoffz]
have been replaced by       : +5.080000
BOX       2     0.1219     0.1219     0.0000 XL    22.2250 YL    22.2250 ZL   360.6800
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       3     0.0000     0.0000     5.0800 XL    22.4688 YL    22.4688 ZL   335.7880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       4     0.0000     0.0000     0.0000 XL    22.4688 YL    22.4688 ZL   360.6800

Zone  Name       Contents          Region  Code Vol.   Description (local bodies)
 18  FUEL ASSEM  Part No.      1     -     1.630E+05   +1
 19  SPACE IN T  Material      3     -     1.512E+04   +2   -1
 20  FUEL TUBE   Material      9     -    -8.637E+03   +3   -2
 21  CONTAINER   Material      3     -    -1.656E+05   +4   -3   -2
 22  Exterior   (Extra zone created by code)           -4
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
There is a one-to-one correspondence between regions and zones.
The code volumes (calculated from zone descriptions and body volumes) will be used.
Zones  18 to  21 map to regions  13 to   16
The input characters        : [@ftth+@asoffxo]
have been replaced by       : +1.722100
The input characters        : [@ftth+@asoffyo]
have been replaced by       : +1.722100


PART   7 (FG PART) Bodies in earlier parts=  16
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1     1.7221      1.7221     0.0000 XL    21.6408 YL    21.6408 ZL   348.1324
The input characters        : [@wft+@overs]
have been replaced by       : +23.24100
The input characters        : [@wft+@overs]
have been replaced by       : +23.24100
The input characters        : [@baskoff+@lbw+@ftoffz]
have been replaced by       : +5.080000
BOX       2     0.1219      0.1219     0.0000 XL    23.2410 YL    23.2410 ZL   360.6800
The input characters        : [@wft+2*@ftth+@overs]
have been replaced by       : +23.48480
The input characters        : [@wft+2*@ftth+@overs]
have been replaced by       : +23.48480
BOX       3     0.0000      0.0000     5.0800 XL    23.4848 YL    23.4848 ZL   335.7880
The input characters        : [@wft+2*@ftth+@overs]
have been replaced by       : +23.48480
The input characters        : [@wft+2*@ftth+@overs]
have been replaced by       : +23.48480
BOX       4     0.0000      0.0000     0.0000 XL    23.4848 YL    23.4848 ZL   360.6800

Zone  Name        Contents          Region  Code Vol.   Description (local bodies)
 23  FUEL ASSEM  Part No.      2     -     1.630E+05   +1
 24  SPACE IN T  Material      3     -     3.178E+04   +2   -1
 25  FUEL TUBE   Material      9     -    -9.620E+03   +3   -2
 26  CONTAINER   Material      3     -    -1.811E+05   +4   -3   -2
 27  Exterior    (Extra zone created by code)          -4

There is a one-to-one correspondence between regions and zones.
The code volumes (calculated from zone descriptions and body volumes) will be used.
Zones  23 to  26 map to regions  17 to   20


PART   8 (CLUSTER) Bodies in earlier parts=  20
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [@tboffx+@cvst+@blt]
have been replaced by       : +.6248000
The input characters        : [@tboffy+@cvst+@blt]
have been replaced by       : +.6248000
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       1     0.6248      0.6248     0.0000 XL    22.4688 YL    22.4688 ZL   360.6800
The input characters        : [@tboffy+(@wfto-@wbrl)/2.0+@bshifty]
have been replaced by       : +1.732250
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@tboffx+@wfto]
have been replaced by       : +23.32990
BOX       2     0.3886      1.7323     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
The input characters        : [@tboffy+(@wfto+@wbrl)/2.0+@bshifty]
have been replaced by       : +21.98625
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       3    23.3299     21.9862     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
         Vx   -1.00000     0.00000    0.00000
  [R]=   Vy    0.00000    -1.00000    0.00000
         Vz    0.00000     0.00000    1.00000
The input characters        : [@tboffx+(@wfto-@wbrl)/2.0+@bshiftx]
have been replaced by       : +1.732250
The input characters        : [@tboffy+@wfto]
have been replaced by       : +23.32990
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       4     1.7323     23.3299     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
         Vx    0.00000    -1.00000    0.00000
  [R]=   Vy    1.00000     0.00000    0.00000
         Vz    0.00000     0.00000    1.00000
The input characters        : [@tboffx+(@wfto+@wbrl)/2.0+@bshiftx]
have been replaced by       : +21.98625
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       5    21.9862     0.3886     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
        Vx     0.00000    1.00000    0.00000
  [R]=  Vy    -1.00000    0.00000    0.00000
        Vz     0.00000    0.00000    1.00000
BOX       6     0.0000     0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name        Contents          Region     Volume   Description (local bodies)
 28               Part No.      5    21     1.821E+05   +1
 29               Part No.      3    22     1.571E+03   +2
 30               Part No.      3    23     1.571E+03   +3
 31               Part No.      3    24     1.571E+03   +4
 32               Part No.      3    25     1.571E+03   +5
 33               Material      3    26     7.940E+03   +6   -1   -2   -3   -4   -5
 34   Exterior  (Extra zone created by code)            -6


PART   9 (CLUSTER) Bodies in earlier parts=  26
---------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [@tboffx+@cvst+@blt]
have been replaced by       : +.6248000
The input characters        : [@tboffyp+@cvst+@blt]
have been replaced by       : +.4305000
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
The input characters        : [@wft+2*@ftth]
have been replaced by       : +22.46880
BOX       1     0.6248     0.4305     0.0000 XL    22.4688 YL    22.4688 ZL   360.6800
The input characters        : [@tboffyp+(@wfto-@wbrl)/2.0+@bshiftyp]
have been replaced by       : +1.537950
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@tboffx+@wfto]
have been replaced by       : +23.32990
BOX       2     0.3886     1.5379     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
The input characters        : [@tboffyp+(@wfto+@wbrl)/2.0+@bshiftyp]
have been replaced by       : +21.79195
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       3    23.3299    21.7919     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
        Vx    -1.00000     0.00000    0.00000
  [R]=  Vy     0.00000    -1.00000    0.00000
        Vz     0.00000     0.00000    1.00000
The input characters        : [@tboffx+(@wfto-@wbrl)/2.0+@bshiftx]
have been replaced by       : +1.732250
The input characters        : [@tboffyp+@wfto]
have been replaced by       : +23.13560
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       4     1.7323    23.1356     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
        Vx     0.00000    -1.00000    0.00000
  [R]=  Vy     1.00000     0.00000    0.00000
        Vz     0.00000     0.00000    1.00000
The input characters        : [@tboffx+(@wfto+@wbrl)/2.0+@bshiftx]
have been replaced by       : +21.98625
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
BOX       5    21.9862     0.1943     7.1120 XL     0.2362 YL    20.2540 ZL   328.4220
        Vx     0.00000     1.00000    0.00000
  [R]=  Vy    -1.00000     0.00000    0.00000
        Vz     0.00000     0.00000    1.00000
BOX       6     0.0000     0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name        Contents          Region     Volume   Description (local bodies)
 35               Part No.      6    27     1.821E+05   +1
 36               Part No.      3    28     1.571E+03   +2
 37               Part No.      3    29     1.571E+03   +3
 38               Part No.      3    30     1.571E+03   +4
 39               Part No.      3    31     1.571E+03   +5
 40               Material      3    32     7.940E+03   +6   -1   -2   -3   -4   -5
 41   Exterior  (Extra zone created by code)            -6


PART  10 (CLUSTER) Bodies in earlier parts=  32
---------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [@tboffx+@cvst+@blt]
have been replaced by       : +.6248000
The input characters        : [@tboffy+@cvst+@blt]
have been replaced by       : +.6248000
The input characters        : [@wft+2*@ftth+@overs]
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
have been replaced by       : +23.48480
The input characters        : [@wft+2*@ftth+@overs]
have been replaced by       : +23.48480
BOX       1     0.6248     0.6248     0.0000 XL    23.4848 YL    23.4848 ZL   360.6800
The input characters        : [@tboffy+(@wfto-@wbrl)/2.0+@bshifty]
have been replaced by       : +1.732250
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
The input characters        : [@tboffx+@wfto+@overs]
have been replaced by       : +24.34590
BOX       2     0.3886     1.7323     7.1120 XL     0.2362 YL    21.2700 ZL   328.4220
The input characters        : [@tboffy+(@wfto+@wbrl)/2.0+@overs+@bshifty]
have been replaced by       : +23.00225
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
BOX       3    24.3459    23.0023     7.1120 XL     0.2362 YL    21.2700 ZL   328.4220
          Vx   -1.00000    0.00000    0.00000
  [R]=    Vy    0.00000   -1.00000    0.00000
          Vz    0.00000    0.00000    1.00000
The input characters        : [@tboffx+(@wfto-@wbrl)/2.0+@bshiftx]
have been replaced by       : +1.732250
The input characters        : [@tboffy+@wfto+@overs]
have been replaced by       : +24.34590
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
BOX       4     1.7323    24.3459     7.1120 XL     0.2362 YL    21.2700 ZL   328.4220
          Vx    0.00000   -1.00000    0.00000
  [R]=    Vy    1.00000    0.00000    0.00000
          Vz    0.00000    0.00000    1.00000
The input characters        : [@tboffx+(@wfto+@wbrl)/2.0+@overs+@bshiftx]
have been replaced by       : +23.00225
The input characters        : [@baskoff+@lbw+@ftoffz+@cvoffz]
have been replaced by       : +7.112000
The input characters        : [@blt+@cvst]
have been replaced by       : +.2362000
The input characters        : [@wbrl+@overs]
have been replaced by       : +21.27000
BOX       5    23.0023     0.3886     7.1120 XL     0.2362 YL    21.2700 ZL   328.4220
          Vx    0.00000    1.00000    0.00000
  [R]=    Vy   -1.00000    0.00000    0.00000
          Vz    0.00000    0.00000    1.00000
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
BOX       6     0.0000     0.0000     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 42              Part No.      7    33      1.989E+05   +1
 43              Part No.      4    34      1.650E+03   +2
 44              Part No.      4    35      1.650E+03   +3
 45              Part No.      4    36      1.650E+03   +4
 46              Part No.      4    37      1.650E+03   +5
 47              Material      3    38      8.255E+03   +6   -1   -2   -3   -4   -5
 48   Exterior  (Extra zone created by code)            -6


PART  11 (CLUSTER) Bodies in earlier parts=  38
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [-1.0*(@wsspxo+(@opspd+@overs)/2.0)]
have been replaced by       : -52.30005
The input characters        : [@tsspyo-(@opspd+@overs)/2.0]
have been replaced by       : +41.88605
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [-1.0*(@wsspx1+@opspd/2.0)]
have been replaced by       : -25.19825
The input characters        : [@tsspy2-@opspd/2.0]
have been replaced by       : +47.60105
BOX       1   -52.3000    41.8860   -15.4686 XL    24.3459 YL    24.3459 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx1-@opspd/2.0]
have been replaced by       : +1.868350
The input characters        : [@tsspy2-@opspd/2.0]
have been replaced by       : +47.60105
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
BOX       2   -25.1983    47.6011   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspxo-(@opspd+@overs)/2.0]
have been replaced by       : +27.95415
BOX       3    1.8683    47.6011   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [@tsspyo-(@opspd+@overs)/2.0]
have been replaced by       : +41.88605
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [-1.0*(@wsspx3+@opspd/2.0)]
have been replaced by       : -77.11584
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       4   27.9541    41.8860   -15.4686 XL    24.3459 YL    24.3459 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx2+@opspd/2.0)]
have been replaced by       : -51.28405
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       5  -77.1158    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx1+@opspd/2.0)]
have been replaced by       : -25.19825
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       6  -51.2841    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx1-@opspd/2.0]
have been replaced by       : +1.868350
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       7  -25.1983    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx2-@opspd/2.0]
have been replaced by       : +27.95415
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       8    1.8683    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx3-@opspd/2.0]
have been replaced by       : +53.78595
The input characters        : [@tsspy1-@opspd/2.0]
have been replaced by       : +15.41925
BOX       9   27.9541    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx3+@opspd/2.0)]
have been replaced by       : -77.11584
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
BOX      10   53.7859    15.4192   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx2+@opspd/2.0)]
have been replaced by       : -51.28405
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
BOX      11  -77.1158   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx1+@opspd/2.0)]
have been replaced by       : -25.19825
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
BOX      12  -51.2841   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx1-@opspd/2.0]
have been replaced by       : +1.868350
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
BOX      13  -25.1983   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx2-@opspd/2.0]
have been replaced by       : +27.95415
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
BOX      14    1.8683   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx3-@opspd/2.0]
have been replaced by       : +53.78595
The input characters        : [-1.0*@opspd/2.0]
have been replaced by       : -11.66495
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
BOX      15    27.9541   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx3+@opspd/2.0)]
have been replaced by       : -77.11584
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      16    53.7859   -11.6649   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx2+@opspd/2.0)]
have been replaced by       : -51.28405
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      17   -77.1158   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspx1+@opspd/2.0)]
have been replaced by       : -25.19825
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      18   -51.2841   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx1-@opspd/2.0]
have been replaced by       : +1.868350
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      19   -25.1983   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx2-@opspd/2.0]
have been replaced by       : +27.95415
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      20     1.8683   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx3-@opspd/2.0]
have been replaced by       : +53.78595
The input characters        : [-1.0*(@tsspy1+@opspd/2.0)]
have been replaced by       : -38.74915
BOX      21    27.9541   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@wsspxo+(@opspd+@overs)/2.0)]
have been replaced by       : -52.30005
BOX      22    53.7859   -38.7492   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@tsspyo+(@opspd+@overs)/2.0)]
have been replaced by       : -66.23195
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [-1.0*(@wsspx1+@opspd/2.0)]
have been replaced by       : -25.19825
The input characters        : [-1.0*(@tsspy2+@opspd/2.0)]
have been replaced by       : -70.93095
BOX      23   -52.3000   -66.2319   -15.4686 XL    24.3459 YL    24.3459 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspx1-@opspd/2.0]
have been replaced by       : +1.868350
The input characters        : [-1.0*(@tsspy2+@opspd/2.0)]
have been replaced by       : -70.93095
BOX      24   -25.1983   -70.9309   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@wsspxo-(@opspd+@overs)/2.0]
have been replaced by       : +27.95415
BOX      25     1.8683   -70.9309   -15.4686 XL    23.3299 YL    23.3299 ZL   360.6800
The input characters        : [-1.0*(@tsspyo+(@opspd+@overs)/2.0)]
have been replaced by       : -66.23195
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [@opspd+@overs]
have been replaced by       : +24.34590
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860
BOX      26    27.9541   -66.2319   -15.4686 XL    24.3459 YL    24.3459 ZL   360.6800
The input characters        : [@diaht/2.0]
have been replaced by       : +87.46490
ZROD     27     0.0000     0.0000   -15.4686  R    87.4649  H   360.6800

Zone  Name        Contents          Region     Volume   Description (local bodies)
 49               Part No.     16    39      2.138E+05   +1
 50               Part No.     12    40      1.963E+05   +2
 51               Part No.     13    41      1.963E+05   +3
 52               Part No.     17    42      2.138E+05   +4
 53               Part No.     12    43      1.963E+05   +5
 54               Part No.     12    44      1.963E+05   +6
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
 55              Part No.     12    45     1.963E+05   +7
 56              Part No.     13    46     1.963E+05   +8
 57              Part No.     13    47     1.963E+05   +9
 58              Part No.     13    48     1.963E+05  +10
 59              Part No.      9    49     1.963E+05  +11
 60              Material      3    50     1.963E+05  +12
 61              Part No.      9    51     1.963E+05  +13
 62              Part No.     15    52     1.963E+05  +14
 63              Material      3    53     1.963E+05  +15
 64              Part No.     15    54     1.963E+05  +16
 65              Part No.      8    55     1.963E+05  +17
 66              Part No.      8    56     1.963E+05  +18
 67              Part No.      8    57     1.963E+05  +19
 68              Part No.     14    58     1.963E+05  +20
 69              Part No.     14    59     1.963E+05  +21
 70              Part No.     14    60     1.963E+05  +22
 71              Part No.     10    61     2.138E+05  +23
 72              Part No.      8    62     1.963E+05  +24
 73              Part No.     14    63     1.963E+05  +25
 74              Part No.     18    64     2.138E+05  +26
 75              Hole Mat.     7    65     3.494E+06  +27   -1   -2   -3   -4   -5   -6
                                                       -7   -8   -9  -10  -11  -12  -13
                                                      -14  -15  -16  -17  -18  -19  -20
                                                      -21  -22  -23  -24  -25  -26
 76   Exterior  (Extra zone created by code)          -27

PART  12 (NEST   ) Bodies in earlier parts=  65
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1     0.0000     23.3299     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800
         Vx    0.00000    -1.00000    0.00000
  [R]=   Vy    1.00000     0.00000    0.00000
         Vz    0.00000     0.00000    1.00000
BOX       2     0.0000      0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 77              Part No.      8    66     1.963E+05   +1
 78              Material      3    67     0.000E+00   +2   -1
 79   Exterior  (Extra zone created by code)            -2

PART  13 (NEST   ) Bodies in earlier parts=  67
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1    23.3299     23.3299     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800
         Vx   -1.00000     0.00000    0.00000
  [R]=   Vy    0.00000    -1.00000    0.00000
         Vz    0.00000     0.00000    1.00000
BOX       2     0.0000      0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 80              Part No.      8    68     1.963E+05   +1
 81              Material      3    69     0.000E+00   +2   -1
 82   Exterior  (Extra zone created by code)            -2

PART  14 (NEST   ) Bodies in earlier parts=  69
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1    23.3299      0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800
         Vx    0.00000     1.00000    0.00000
  [R]=   Vy   -1.00000     0.00000    0.00000
         Vz    0.00000     0.00000    1.00000
BOX       2     0.0000      0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 83              Part No.      8    70     1.963E+05   +1
 84              Material      3    71     0.000E+00   +2   -1
 85   Exterior  (Extra zone created by code)            -2

PART  15 (NEST   ) Bodies in earlier parts=  71
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
BOX       1    23.3299     23.3299     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800
         Vx   -1.00000     0.00000    0.00000
  [R]=   Vy    0.00000    -1.00000    0.00000
         Vz    0.00000     0.00000    1.00000
BOX       2     0.0000      0.0000     0.0000 XL    23.3299 YL    23.3299 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 86              Part No.      9    72     1.963E+05   +1
 87              Material      3    73     0.000E+00   +2   -1
 88   Exterior  (Extra zone created by code)            -2
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
PART  16 (NEST   ) Bodies in earlier parts=  73
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       1     0.0000    24.3459     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800
        Vx    0.00000   -1.00000    0.00000
  [R]=  Vy    1.00000    0.00000    0.00000
        Vz    0.00000    0.00000    1.00000
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       2     0.0000     0.0000     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 89              Part No.     10    74     2.138E+05   +1
 90              Material      3    75     0.000E+00   +2   -1
 91   Exterior  (Extra zone created by code)           -2


PART  17 (NEST   ) Bodies in earlier parts=  75
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       1    24.3459    24.3459     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800
        Vx   -1.00000    0.00000    0.00000
  [R]=  Vy    0.00000   -1.00000    0.00000
        Vz    0.00000    0.00000    1.00000
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       2     0.0000     0.0000     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 92              Part No.     10    76     2.138E+05   +1
 93              Material      3    77     0.000E+00   +2   -1
 94   Exterior  (Extra zone created by code)           -2


PART  18 (NEST   ) Bodies in earlier parts=  77
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       1    24.3459     0.0000     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800
        Vx    0.00000    1.00000    0.00000
  [R]=  Vy   -1.00000    0.00000    0.00000
        Vz    0.00000    0.00000    1.00000
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
The input characters         : [@opspd+@overs]
have been replaced by        : +24.34590
BOX       2     0.0000     0.0000     0.0000 XL    24.3459 YL    24.3459 ZL   360.6800

Zone  Name       Contents          Region     Volume   Description (local bodies)
 95              Part No.     10    78     2.138E+05   +1
 96              Material      3    79     0.000E+00   +2   -1
 97   Exterior  (Extra zone created by code)           -2


PART  19 (NEST   ) Bodies in earlier parts=  79
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters         : [@diaht/2.0]
have been replaced by        : +87.46490
The input characters         : [@canod/2.0-@canth]
have been replaced by        : +88.12530
ZROD      1     0.0000     0.0000     0.0000  R    87.4649  H   360.6800
ZROD      2     0.0000     0.0000     0.0000  R    88.1253  H   360.6800
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
Zone  Name       Contents          Region     Volume   Description (local bodies)
 98              Part No.     11    80     8.668E+06   +1
 99              Material      3    81     1.314E+05   +2   -1
100   Exterior  (Extra zone created by code)            -2
The input characters        : [@canod/2.0-@canth]
have been replaced by       : +88.12530


PART  20 (FG PART) Bodies in earlier parts=  81
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [-1*@canbot]
have been replaced by       : -4.445000
The input characters        : [@canod/2.0]
have been replaced by       : +89.71280
ZROD      1      0.0000     0.0000      0.0000  R    88.1253  H   360.6800
The input characters        : [@canod/2.0-@canth]
have been replaced by       : +88.12530
ZROD      2      0.0000     0.0000     -4.4450  R    89.7128  H     4.4450
The input characters        : [@cavheight+@shield1]
have been replaced by       : +3.7338000E+02
The input characters        : [@canod/2.0-@canth]
have been replaced by       : +88.12530
ZROD      3      0.0000     0.0000    360.6800  R    88.1253  H    12.7000
The input characters        : [@canod/2.0-@canth]
have been replaced by       : +88.12530
The input characters        : [@can1-@canbot]
have been replaced by       : +3.8100000E+02
ZROD      4      0.0000     0.0000    373.3800  R    88.1253  H     7.6200
The input characters        : [@canod/2.0]
have been replaced by       : +89.71280
The input characters        : [@can1-@canbot]
have been replaced by       : +3.8100000E+02
ZROD      5      0.0000     0.0000      0.0000  R    88.1253  H   381.0000
The input characters        : [-1.*@canbot]
have been replaced by       : -4.445000
The input characters        : [@canod/2.0]
have been replaced by       : +89.71280
ZROD      6      0.0000     0.0000      0.0000  R    89.7128  H   381.0000
ZROD      7      0.0000     0.0000     -4.4450  R    89.7128  H   385.4450

Zone  Name       Contents          Region  Code Vol.   Description (local bodies)
101   CAVITY     Part No.     19     -     8.800E+06   +1
102   BOTTOMPLAT Material     15     -     1.124E+05   +2
103   SHIELDLID  Material     15     -     3.099E+05   +3
104   STRUCTLID  Material     15     -     1.859E+05   +4
105   SHELL      Material     15     -     3.379E+05   +6   -5
Returning input to named channel:     INPUT after reading
 422  lines from   named channel:      CGF Total line count=  756
The input characters        : [@tscNUM + 1]
have been replaced by       : +21.00000
106   CANISTER   Material      0     -    -1.859E+05   +7   -6   -4   -2
107   Exterior   (Extra zone created by code)           -7

There is a one-to-one correspondence between regions and zones.
The code volumes (calculated from zone descriptions and body volumes) will be used.
Zones 101 to 106 map to regions  82 to   87
The input characters        : [@cpi*@tscOD/2]
have been replaced by       : +89.71280
The input characters        : [@cpi*@tscHT]
have been replaced by       : +3.854450E+02


PART  21 (FG PART) Bodies in earlier parts=  88
-----------------------------------------------
Body definitions. Numbers are local to this part.

shape  number    X0          Y0          Z0    Shape dependent parameters (see notes)
The input characters        : [@cpi*@inshlID/2]
have been replaced by       : +90.80500
The input characters        : [@cpi*(@btmplHT+@inshlHT+@topplHT)]
have been replaced by       : +3.8862000E+02
ZROD      1      0.0000     0.0000      0.0000  R    89.7128  H   385.4450
The input characters        : [@cpi*@tfrOD/2]
have been replaced by       : +1.1303000E+02
The input characters        : [@cpi*@btmplHT]
have been replaced by       : +2.540000
ZROD      2      0.0000     0.0000      0.0000  R    90.8050  H   388.6200
The input characters        : [@cpi*@btmplHT]
have been replaced by       : +2.540000
The input characters        : [@cpi*((@inshlID/2)+@inshlTH)]
have been replaced by       : +92.71000
ZROD      3      0.0000     0.0000      0.0000  R   113.0300  H     2.5400
The input characters        : [@cpi*@inshlHT]
have been replaced by       : +3.8100000E+02
The input characters        : [@cpi*@btmplHT]
have been replaced by       : +2.540000
The input characters        : [@cpi*((@inshlID/2)+@inshlTH+@pbshlTH)]
have been replaced by       : +1.0287000E+02
ZROD      4      0.0000     0.0000      2.5400  R    92.7100  H   381.0000
The input characters        : [@cpi*(@inshlHT-@ns4frGAP)]
have been replaced by       : +3.7084000E+02
The input characters        : [@cpi*@btmplHT]
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
have been replaced by       : +2.540000
The input characters        : [@cpi*((@tfrOD/2)-@otshlTH)]
have been replaced by       : +1.0985500E+02
ZROD      5     0.0000     0.0000     2.5400  R   102.8700  H   370.8400
The input characters        : [@cpi*@inshlHT]
have been replaced by       : +3.8100000E+02
The input characters        : [@cpi*@btmplHT]
have been replaced by       : +2.540000
The input characters        : [@cpi*(@tfrOD/2)]
have been replaced by       : +1.1303000E+02
The input characters        : [@cpi*@inshlHT]
have been replaced by       : +3.8100000E+02
ZROD      6     0.0000     0.0000     2.5400  R   109.8550  H   381.0000
The input characters        : [@cpi*(@btmplHT+@inshlHT)]
have been replaced by       : +3.8354001E+02
The input characters        : [@cpi*(@tfrOD/2)]
have been replaced by       : +1.1303000E+02
ZROD      7     0.0000     0.0000     2.5400  R   113.0300  H   381.0000
The input characters        : [@cpi*@topplHT]
have been replaced by       : +5.080000
The input characters        : [@cpi*(@btmplHT+@inshlHT+@topplHT)]
have been replaced by       : +3.8862000E+02
The input characters        : [@cpi*@rtnrnID/2]
have been replaced by       : +86.99500
ZROD      8     0.0000     0.0000   383.5400  R   113.0300  H     5.0800
The input characters        : [@cpi*@rtnrnHT]
have been replaced by       : +1.905000
The input characters        : [@cpi*(@btmplHT+@inshlHT+@topplHT)]
have been replaced by       : +3.8862000E+02
The input characters        : [@cpi*@rtnrnOD/2]
have been replaced by       : +1.0261600E+02
ZROD      9     0.0000     0.0000   388.6200  R    86.9950  H     1.9050
The input characters        : [@cpi*@rtnrnHT]
have been replaced by       : +1.905000
The input characters        : [-@shldrHT*@cpi]
have been replaced by       : -24.13000
The input characters        : [@cpi*@tfrOD/2]
have been replaced by       : +1.1303000E+02
The input characters        : [@cpi*@shldrHT]
have been replaced by       : +24.13000
ZROD     10     0.0000     0.0000   388.6200  R   102.6160  H     1.9050
The input characters        : [@cpi*((@drrailID/2)+@drrailWD)]
have been replaced by       : +1.0731499E+02
ZROD     11     0.0000     0.0000   -24.1300  R   113.0300  H    24.1300
The input characters        : [-@cpi*((@drrailID/2)+@drrailWD)]
have been replaced by       : -1.0731499E+02
YP       12                                  At   107.3150
The input characters        : [-@cpi*@tfrOD/2]
have been replaced by       : -1.1303000E+02
YP       13                                  At  -107.3150
The input characters        : [@cpi*(@btmplHT+@inshlHT+@topplHT - @trunzcor)]
have been replaced by       : +3.5051999E+02
The input characters        : [@cpi*@trunOD/2]
have been replaced by       : +12.70000
The input characters        : [@cpi*@tfrOD]
have been replaced by       : +2.260600E+02
The input characters        : [-1 * @cpi*@shldrHT]
have been replaced by       : -24.13000
The input characters        : [@cpi*@tfrOD/2]
have been replaced by       : +1.1303000E+02
XROD     14  -113.0300     0.0000   350.5200  R    12.7000  H   226.0600
The input characters        : [@cpi*(@shldrHT+@btmplHT+@inshlHT+@topplHT+@rtnrnHT)]
have been replaced by       : +4.1465500E+02
ZROD     15     0.0000     0.0000   -24.1300  R   113.0300  H   414.6550

Zone  Name        Contents          Region  Code Vol.   Description (local bodies)
The input characters        : [@tscMAT + @cavMAT]
have been replaced by       : +19.00000
108               Part No.    20      -      9.746E+06   +1
The input characters        : [@tscMAT + @btmplMAT]
have been replaced by       : +16.00000
109               Material    19      -      3.210E+05   +2   -1
The input characters        : [@tscMAT + @inshlMAT]
have been replaced by       : +16.00000
110               Material    16      -     -9.965E+06   +3   -2
The input characters        : [@tscMAT + @pbshlMAT]
have been replaced by       : +17.00000
111               Material    16      -      1.065E+05   +4   -2  -14
The input characters        : [@tscMAT + @n4shlMAT]
have been replaced by       : +18.00000
112               Material    17      -      1.926E+06   +5   -4  -14
The input characters        : [@tscMAT + @otshlMAT]
have been replaced by       : +16.00000
113               Material    18      -     -8.286E+06   +6   -5   -4  -14
The input characters        : [@tscMAT + @topplMAT]
have been replaced by       : +16.00000
114               Material    16      -      7.325E+05   +7   -6  -14
The input characters        : [@tscMAT + @cavMAT]
have been replaced by       : +19.00000
115               Material    16      -     -9.863E+06   +8   -2
The input characters        : [@tscMAT + @rtnrnMAT]
have been replaced by       : +16.00000
116               Material    19      -      4.529E+04   +9
The input characters        : [@tscMAT + @shldrMAT]
have been replaced by       : +16.00000
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
117              Material     16     -     1.773E+04  +10   -9
The input characters        : [@tscMAT + @cavMAT]
have been replaced by       : +19.00000
118              Material     16     -     9.685E+05  +11  -12  +13
The input characters        : [@tscMAT + @cavMAT]
have been replaced by       : +19.00000
119              Material     19     -     9.685E+05  +11  +12
The input characters        : [@tscMAT + @trunMAT]
have been replaced by       : +16.00000
120              Material     19     -     9.685E+05  +11  -13
The input characters        : [@tscMAT + @cavMAT]
have been replaced by       : +19.00000
121              Material     16     -     6.690E+06  +14  +15   -2
122              Material     19     -    -1.011E+05  +15  -14  -11  -10   -8   -7   -3
123  Exterior   (Extra zone created by code)          -15

There is a one-to-one correspondence between regions and zones.
The code volumes (calculated from zone descriptions and body volumes) will be used.
Zones 108 to 122 map to regions  88 to  102


The input data has been expanded into a global model in which each occurrence
of a part becomes unique. The parts and bodies in this expanded scheme are
renumbered and referred to as 'Assembled' parts and bodies

Summary of part structure
-------------------------
The global part is input part number          21
Map of part structure. Numbers are input parts.

   21 Contains:
        20 Contains:
             19 Contains:
                  11 Contains:
                       16 Contains:
                            10 Contains:
                                 7 Contains:
                                      2 s.p.
                                 4 s.p.
                                 4 s.p.
                                 4 s.p.
                                 4 s.p.
                       12 Contains:
                            8 Contains:
                                 5 Contains:
                                      1 s.p.
                                 3 s.p.
                                 3 s.p.
                                 3 s.p.
                                 3 s.p.
                       13 Contains:
                            8 etc.
                                 5 etc.
                       17 Contains:
                            10 etc.
                                 7 etc.
                       12 etc.
                            8 etc.
                                 5 etc.
                       12 etc.
                            8 etc.
                                 5 etc.
                       12 etc.
                            8 etc.
                                 5 etc.
                       13 etc.
                            8 etc.
                                 5 etc.
                       13 etc.
                            8 etc.
                                 5 etc.
                       13 etc.
                            8 etc.
                                 5 etc.
                        9 Contains:
                            6 Contains:
                                 1 s.p.
                            3 s.p.
                            3 s.p.
                            3 s.p.
                            3 s.p.
                        9 etc.
                            6 etc.
                       15 Contains:
                            9 etc.
                                 6 etc.
                       15 etc.
                            9 etc.
                                 6 etc.
                        8 etc.
                            5 etc.
                        8 etc.
                            5 etc.
                        8 etc.
                            5 etc.
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
                    14 Contains:
                         8 etc.
                              5 etc.
                    14 etc.
                         8 etc.
                              5 etc.
                    14 etc.
                         8 etc.
                              5 etc.
                    10 etc.
                          7 etc.
                     8 etc.
                          5 etc.
                    14 etc.
                         8 etc.
                              5 etc.
                    18 Contains:
                        10 etc.
                              7 etc.

    Maximum level of nesting                    =    8
    Number of assembled parts                   =  189
    Number of assembled bodies                  =  637
    Number of uses of BODY HOLES                =    4
    Maximum HOLE material used                  =    7
    Number of uses of each input part:
       20    4   80   16   16    4    4   16    4    4
        1    4    4    4    2    1    1    1    1    1
        1

    Scoring region volumes have been multiplied by the number of uses of each part.

    External zone of global part is number  123 with definition:  -15

    The coordinate limits of the geometry are estimated to be:
    XMIN=  -113.030 XMAX=   113.030
    YMIN=  -113.030 YMAX=   113.030
    ZMIN=   -24.130 ZMAX=   390.525


    Albedo data for outer surface of global part   21
    Body number= 103 Shape number=  5
    The material number in the outside zone ( 123 ) has been reset to -4000

    Reflection coefficients for  3 surfaces are:
        1.0000    1.0000    1.0000
    A periodic boundary condition has been requested.

TIME TAKEN TO READ AND PROCESS GEOMETRY DATA=     1.563 SECS
STORAGE USED FOR GEOMETRY DATA (4BYTE WORDS)=     16814
MAXIMUM REAL MATERIAL NUMBER USED            =       19
MAXIMUM HOLE MATERIAL REFERENCED IN GEOMETRY=         7


*******************************************************
* SUCCESSFUL CONCLUSION TO UNIT  2 TO READ THE        *
* MATERIAL GEOMETRY DATA. NO ERRORS.                  *
*******************************************************

1

*******************************************************
*    ENTERING UNIT  3 TO READ HOLE DATA               *
*******************************************************


    Changing  input to named channel:       FHF after reading
     189  lines from   named channel:     INPUT Total line count=  816


HOLE  1      PLATE
-------

            DIRECTION COSINES OF PLATE NORMAL = 0.0000 0.0000 1.0000
            NO. OF EXPLICIT PLATE BOUNDARIES =  2
    The input characters        : [@lassem-@ltnozz]
    have been replaced by       : +3.3088577E+02
    The input characters        : [@lbnozz]
    have been replaced by       : +8.097500

            PLATE BOUNDARY          MATERIAL NO.

                                          8
                330.8858
                                         -2
                  8.0975
                                          7



HOLE  2      LATTICE
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
-------
    The input characters        : [-(@rpitch/2.0)-(@wfuel-@lattice*@rpitch)/2.0]
    have been replaced by       : -.7214997
    The input characters        : [-(@rpitch/2.0)-(@wfuel-@lattice*@rpitch)/2.0]
    have been replaced by       : -.7214997
    The input characters        : [@odgt/2.0]
    have been replaced by       : +.6731000
    The input characters        : [@odgt/2.]
    have been replaced by       : +.6731000

            NO. OF PINS IN THE X-DIRECTION =  15     NO. OF PINS IN THE Y-DIRECTION =  15
            LATTICE PITCH IN THE X-DIRECTION =   1.4427     LATTICE PITCH IN THE Y-DIRECTION =   1.4427
            ORIGIN SHIFT (X0,Y0) =  -0.7215  -0.7215

            ALL PINS HAVE INNER RADIUS   0.6731 AND OUTER RADIUS   0.6731

            PINS   1 TO  32 CONTAIN ROD MATERIAL NO. =  -3
            PINS  33 TO  33 CONTAIN ROD MATERIAL NO. =  -4
            PINS  34 TO  35 CONTAIN ROD MATERIAL NO. =  -3
            PINS  36 TO  36 CONTAIN ROD MATERIAL NO. =  -4
            PINS  37 TO  39 CONTAIN ROD MATERIAL NO. =  -3
            PINS  40 TO  40 CONTAIN ROD MATERIAL NO. =  -4
            PINS  41 TO  42 CONTAIN ROD MATERIAL NO. =  -3
            PINS  43 TO  43 CONTAIN ROD MATERIAL NO. =  -4
            PINS  44 TO  52 CONTAIN ROD MATERIAL NO. =  -3
            PINS  53 TO  53 CONTAIN ROD MATERIAL NO. =  -4
            PINS  54 TO  64 CONTAIN ROD MATERIAL NO. =  -3
            PINS  65 TO  65 CONTAIN ROD MATERIAL NO. =  -4
            PINS  66 TO  70 CONTAIN ROD MATERIAL NO. =  -3
            PINS  71 TO  71 CONTAIN ROD MATERIAL NO. =  -4
            PINS  72 TO  77 CONTAIN ROD MATERIAL NO. =  -3
            PINS  78 TO  78 CONTAIN ROD MATERIAL NO. =  -4
            PINS  79 TO  87 CONTAIN ROD MATERIAL NO. =  -3
            PINS  88 TO  88 CONTAIN ROD MATERIAL NO. =  -4
            PINS  89 TO 108 CONTAIN ROD MATERIAL NO. =  -3
            PINS 109 TO 109 CONTAIN ROD MATERIAL NO. =  -4
            PINS 110 TO 112 CONTAIN ROD MATERIAL NO. =  -3
            PINS 113 TO 113 CONTAIN ROD MATERIAL NO. =  -5
            PINS 114 TO 116 CONTAIN ROD MATERIAL NO. =  -3
            PINS 117 TO 117 CONTAIN ROD MATERIAL NO. =  -4
            PINS 118 TO 137 CONTAIN ROD MATERIAL NO. =  -3
            PINS 138 TO 138 CONTAIN ROD MATERIAL NO. =  -4
            PINS 139 TO 147 CONTAIN ROD MATERIAL NO. =  -3
            PINS 148 TO 148 CONTAIN ROD MATERIAL NO. =  -4
            PINS 149 TO 154 CONTAIN ROD MATERIAL NO. =  -3
            PINS 155 TO 155 CONTAIN ROD MATERIAL NO. =  -4
            PINS 156 TO 160 CONTAIN ROD MATERIAL NO. =  -3
            PINS 161 TO 161 CONTAIN ROD MATERIAL NO. =  -4
            PINS 162 TO 172 CONTAIN ROD MATERIAL NO. =  -3
            PINS 173 TO 173 CONTAIN ROD MATERIAL NO. =  -4
            PINS 174 TO 182 CONTAIN ROD MATERIAL NO. =  -3
            PINS 183 TO 183 CONTAIN ROD MATERIAL NO. =  -4
            PINS 184 TO 185 CONTAIN ROD MATERIAL NO. =  -3
            PINS 186 TO 186 CONTAIN ROD MATERIAL NO. =  -4
            PINS 187 TO 189 CONTAIN ROD MATERIAL NO. =  -3
            PINS 190 TO 190 CONTAIN ROD MATERIAL NO. =  -4
            PINS 191 TO 192 CONTAIN ROD MATERIAL NO. =  -3
            PINS 193 TO 193 CONTAIN ROD MATERIAL NO. =  -4
            PINS 194 TO 225 CONTAIN ROD MATERIAL NO. =  -3

            ALL PINS HAVE CAN MATERIAL NO. =   3

            OTHERWISE MATERIAL NO. =   3


HOLE  3     RZMESH
-------
    The input characters        : [@odpellet/2.0]
    have been replaced by       : +.4653500
    The input characters        : [(@odclad/2.0)-@cladth]
    have been replaced by       : +.4768000
    The input characters        : [@odclad/2.0]
    have been replaced by       : +.5334000

              3 R-MESHES WITH BOUNDARIES LOCATED AT :
     4.65350E-01 4.76800E-01 5.33400E-01
    The input characters        : [@lbnozz+@fgapb]
    have been replaced by       : +8.097500
    The input characters        : [@lbnozz+@fgapb+@lbcap]
    have been replaced by       : +9.837399
    The input characters        : [@lbnozz+@fgapb+@lbcap+@lfexpb]
    have been replaced by       : +9.837399
    The input characters        : [@lbnozz+@fgapb+@lbcap+@lfexpb+@lactfu]
    have been replaced by       : +3.1603439E+02
    The input characters        : [@lbnozz+@fgapb+@lfu-@ltcap]
    have been replaced by       : +3.2822641E+02
    The input characters        : [@lbnozz+@fgapb+@lfu]
    have been replaced by       : +3.2996631E+02
    The input characters        : [@lassem-@ltnozz]
    have been replaced by       : +3.3088577E+02

              7 Z-MESHES WITH BOUNDARIES LOCATED AT :
     8.09750E+00 8.09750E+00 9.83740E+00 9.83740E+00 3.16034E+02 3.28226E+02 3.29966E+02 3.30886E+02
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
            MATERIAL MAP
            ------------

            Z-MESH   1 :
               3   3   3

            Z-MESH   2 :
               2   2   2

            Z-MESH   3 :
               4   4   2

            Z-MESH   4 :
               1   4   2

            Z-MESH   5 :
               4   4   2

            Z-MESH   6 :
               2   2   2

            Z-MESH   7 :
               3   3   3

            MATERIAL OUTSIDE DEFINED MESHES :   3


HOLE  4     RZMESH
-------
    The input characters        : [(@odgt/2.0) - @gtth]
    have been replaced by       : +.6401000
    The input characters        : [@odgt/2.0]
    have been replaced by       : +.6731000

              2 R-MESHES WITH BOUNDARIES LOCATED AT :
     6.40100E-01 6.73100E-01
    The input characters        : [@lassem - @ltnozz]
    have been replaced by       : +3.3088577E+02

              1 Z-MESHES WITH BOUNDARIES LOCATED AT :
     8.09750E+00 3.30886E+02

            MATERIAL MAP
            ------------

            Z-MESH   1 :
               3   5

            MATERIAL OUTSIDE DEFINED MESHES :   3


HOLE  5     RZMESH
-------
    The input characters        : [(@odit/2.0) - @itth]
    have been replaced by       : +.6401000
    The input characters        : [@odit/2.0]
    have been replaced by       : +.6731000

              2 R-MESHES WITH BOUNDARIES LOCATED AT :
     6.40100E-01 6.73100E-01
    The input characters        : [@lassem - @ltnozz]
    have been replaced by       : +3.3088577E+02

              1 Z-MESHES WITH BOUNDARIES LOCATED AT :
     8.09750E+00 3.30886E+02

            MATERIAL MAP
            ------------

            Z-MESH   1 :
               3   6

            MATERIAL OUTSIDE DEFINED MESHES :   3
    Returning input to named channel:     INPUT after reading
      93  lines from   named channel:       FHF Total line count=  905

    Changing  input to named channel:       CHF after reading
     190  lines from   named channel:     INPUT Total line count=  906


HOLE  6     PLATE
-------

            DIRECTION COSINES OF PLATE NORMAL = 1.0000 0.0000 0.0000
            NO. OF EXPLICIT PLATE BOUNDARIES =  2
    The input characters        : [(@blt+@blct)/2.0]
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
have been replaced by       : +.1587500
The input characters        : [(@blt-@blct)/2.0]
have been replaced by       : +.0317500

        PLATE BOUNDARY          MATERIAL NO.

                                     11
              0.1587
                                     10
              0.0318
                                     11

Returning input to named channel:     INPUT after reading
  17  lines from   named channel:       CHF Total line count=  917

Changing  input to named channel:       CHF after reading
 191  lines from   named channel:     INPUT Total line count=  918


HOLE  7     PLATE
-------

        DIRECTION COSINES OF PLATE NORMAL = 0.0000 0.0000 1.0000
        NO. OF EXPLICIT PLATE BOUNDARIES =  5
The input characters        : [@lbasket-@lbws-@lbw]
have been replaced by       : +3.4394141E+02
The input characters        : [-1.0*(@lbw+@lbws)]
have been replaced by       : -15.46860
The input characters        : [-1.0*(@baskoff+@lbw+@lbws)]
have been replaced by       : -15.46860

        PLATE BOUNDARY          MATERIAL NO.

                                      3
            343.9414
                                     -8
            316.0522
                                    -10
              0.0000
                                     -9
            -15.4686
                                      3
            -15.4686
                                      3


HOLE  8     RZMESH
-------
The input characters        : [@diatpw/2.0]
have been replaced by       : +87.60460

          1 R-MESHES WITH BOUNDARIES LOCATED AT :
 8.76046E+01
The input characters        : [@lbasket-@lbws-@lbw-@ltpw]
have been replaced by       : +3.2666940E+02
The input characters        : [@lbasket-@lbws-@lbw-@ltpw+@ltpwd]
have been replaced by       : +3.2793939E+02

          1 Z-MESHES WITH BOUNDARIES LOCATED AT :
 3.26669E+02 3.27939E+02


        MATERIAL MAP
        ------------

        Z-MESH   1 :
          13


        MATERIAL OUTSIDE DEFINED MESHES :   3


HOLE  9     RZMESH
-------
The input characters        : [@diabw/2.0]
have been replaced by       : +87.60460

          1 R-MESHES WITH BOUNDARIES LOCATED AT :
 8.76046E+01
The input characters        : [-1.0*(@lbws+@lbwd)]
have been replaced by       : -11.65860
The input characters        : [-1.0*@lbws]
have been replaced by       : -10.38860

          1 Z-MESHES WITH BOUNDARIES LOCATED AT :
-1.16586E+01-1.03886E+01


        MATERIAL MAP
        ------------
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
          Z-MESH   1 :
            13

          MATERIAL OUTSIDE DEFINED MESHES :   3


HOLE 10     PLATE
-------

          DIRECTION COSINES OF PLATE NORMAL = 0.0000 0.0000 1.0000
          NO. OF EXPLICIT PLATE BOUNDARIES =  4
    The input characters        : [@tspd+@dsspht+@thtd+@dsspht]
    have been replaced by       : +11.65860

          REPEATED CELL OF WIDTH 1.16586E+01
    The input characters        : [@tspd+@dsspht+@thtd+@dsspht]
    have been replaced by       : +11.65860
    The input characters        : [@tspd+@dsspht+@thtd]
    have been replaced by       : +7.099300
    The input characters        : [@tspd+@dsspht]
    have been replaced by       : +5.829300

          PLATE BOUNDARY         MATERIAL NO.

                                       3
               11.6586
                                       3
                7.0993
                                      14
                5.8293
                                       3
                1.2700
                                      12



HOLE   1 : NO. OF MATERIALS =   8   MATERIAL LIST =   8   7   3   2   4   1   5   6
HOLE   2 : NO. OF MATERIALS =   6   MATERIAL LIST =   3   2   4   1   5   6
HOLE   3 : NO. OF MATERIALS =   4   MATERIAL LIST =   3   2   4   1
HOLE   4 : NO. OF MATERIALS =   2   MATERIAL LIST =   3   5
HOLE   5 : NO. OF MATERIALS =   2   MATERIAL LIST =   3   6
HOLE   6 : NO. OF MATERIALS =   2   MATERIAL LIST =  11  10
HOLE   7 : NO. OF MATERIALS =   4   MATERIAL LIST =   3  13  14  12
HOLE   8 : NO. OF MATERIALS =   2   MATERIAL LIST =  13   3
HOLE   9 : NO. OF MATERIALS =   2   MATERIAL LIST =  13   3
HOLE  10 : NO. OF MATERIALS =   3   MATERIAL LIST =   3  14  12
    Returning input to named channel:     INPUT after reading
      74  lines from   named channel:       CHF Total line count=  971


*********************************************************
* SUCCESSFUL CONCLUSION TO UNIT  3 TO READ THE          *
* HOLE DATA                NO ERRORS.                   *
*********************************************************

1

*********************************************************
*    ENTERING UNIT  4 TO READ PROBLEM CONTROL DATA.     *
*********************************************************

USER SUPPLIED RANDOM NUMBER SEEDS       =     54321
                                              54321
FOR A CRITICALITY CALCULATION :
NUMBER OF SUPER HISTORIES PER BATCH     =      1000
FIRST STAGE NUMBER                      =        -3
LAST  STAGE NUMBER                      =       810
MAXIMUM GENERATION NUMBER               =        10
ESTIMATE OF NUFACTOR                    =     1.000
FINAL STANDARD DEVIATION ON K(THREE)    =  0.000800

SAMPLING TIME ( SECONDS )               =  10000000
ERRORS PERMITTING,  AN  EXECUTION OF THE  SUPPLIED
DATA WILL BE ATTEMPTED


*********************************************************
* SUCCESSFUL CONCLUSION TO UNIT  4 TO READ THE          *
* PROBLEM CONTROL DATA.   NO ERRORS.                    *
*********************************************************

1

*********************************************************
*    ENTERING UNIT  5 TO READ SOURCE GEOMETRY DATA.     *
*********************************************************


SOURCE GEOMETRY SUCCESSFULLY INPUT
SOURCE WILL BE SAMPLED FROM    1 REGIONS
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
*********************************************************
* SUCCESSFUL CONCLUSION TO UNIT  5 TO READ THE          *
* SOURCE GEOMETRY DATA.   NO ERRORS.                    *
*********************************************************

1

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


*********************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO      *
* MODULE 25005 (FG TRACKING)                            *
*********************************************************



*********************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO      *
* MODULE 48321 (SCORING)                                *
*********************************************************

WARNING: Negative volumes have been found in the following regions:

    REGION          VOLUME
    ------          ------
       11          -1.382E+05
       12          -2.649E+06
       15          -3.455E+04
       16          -6.624E+05
       19          -3.848E+04
       20          -7.244E+05
       87          -1.859E+05
       90          -9.965E+06
       93          -8.286E+06
       95          -9.863E+06
      102          -1.011E+05

Inspect the FG printout to ensure that these do not correspond to scoring regions.

These negative volumes have been reset to 1.0


*********************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO      *
* MODULE 03435 (SIMPLE SOURCE)                          *
*********************************************************

SOURCE WILL BE SAMPLED FROM THE FOLLOWING ZONES:

-----------------------------------------------------------------------------------------------
                    ENVELOPE                                                RESTRICTION
  XHI          XLO          YHI          YLO          ZHI          ZLO        FGZONES     MATERIAL
-----------------------------------------------------------------------------------------------

 1.1303E+02 -1.1303E+02  1.1303E+02 -1.1303E+02  3.9052E+02 -2.4130E+01   108 122             1
-----------------------------------------------------------------------------------------------


          ****************************************************************
                   ANSWERS Software Licensing Procedure for Modules
                                Module name - MONK-CRIT
          ****************************************************************


          *** The timelock password has been successfully verified.
          *** This password expires at midnight on 30/ 6/2001


          *** Successful authorisation achieved on system 57NST
          *** This system has the identification number  131008778


          ****************************************************************
           This module is part of the ANSWERS program - MONK8A

           The use of this module is restricted within the terms of your
           licence agreement with AEA Technology.
          ****************************************************************
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
*************************************************************
***          End of ANSWERS Software Licensing Checks     ***
*************************************************************


*******************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO    *
* MODULE 36882 (POINT NEUTRON)                        *
*******************************************************

1

  DICE MK. VII Sept 92 (BOUND-ATOM THERMAL TREATMENT FOR CERTAIN NUCLIDES),  LIBRARY FORMAT VERSION  3
  ==========================================================================================================

                          NUCLEAR DATA READ FROM FILE: d:\answers\data_libraries\dice96j2v5.dat

THIS CASE IS BEING RUN FOR  20 MATERIAL(S) WITH 13193 CROSS-SECTION  ENERGY GROUPS FROM 1.50000E+01 MEV TO 1.00000E-11 MEV


                 THERMAL DATA READ FOR FOLLOWING NUCLIDES
                 ========================================
 NUCLIDE ID NO                    COMMENTS
 -------------                    --------
     10293          Data for hydrogen in H2O processed from JEF file JAN 92 by
                 D.E.Bendall using 3% fitting error and .1% integration error


                 ==============================================
                 THE THERMAL DATA OCCUPIES  14611 LOCATIONS;
                 THE TOTAL NUCLEAR DATA OCCUPIES 3618571 LOCATIONS;
                 THE DATA TOOK    4.1 SECS OF CPU TO PROCESS
                 ==============================================


 SUMMARY OF MATERIAL DATA
 ========================

 MATERIAL  1   DENSITY 1.04120E+01 GRMS/CC     NUMBER OF NUCLIDES  3     TEMPERATURE 293.0 DEGREES KELVIN
 -----------
               NUCLIDE NO.        NAME        ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE       DFN        LIBRARY NO.
               -----------        ----        ----------    ---------   ---------------       ---        -----------

                   1             J2U235          92           235.04      1.5546E-02        9228b          62
                   2             J2U238          92           238.05      3.1765E-01        9237b          63
                   3              J2O16           8            15.99      6.6681E-01         825b          33

 MATERIAL  2   DENSITY 6.50000E+00 GRMS/CC     NUMBER OF NUCLIDES  1     TEMPERATURE 293.0 DEGREES KELVIN
 -----------
               NUCLIDE NO.        NAME        ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE       DFN        LIBRARY NO.
               -----------        ----        ----------    ---------   ---------------       ---        -----------

                   1              J2ZR           40            91.22      1.0000E+00        4000b          47

 MATERIAL  3   DENSITY 9.98200E-01 GRMS/CC     NUMBER OF NUCLIDES  2     TEMPERATURE 293.0 DEGREES KELVIN
 -----------
               NUCLIDE NO.        NAME        ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE       DFN        LIBRARY NO.
               -----------        ----        ----------    ---------   ---------------       ---        -----------

                   1            J2HINH2O           1             1.01      6.6661E-01       10293           64
                   2              J2O16            8            15.99      3.3339E-01        825b           33

 MATERIAL  4   DENSITY 9.98200E-01 GRMS/CC     NUMBER OF NUCLIDES  2     TEMPERATURE 293.0 DEGREES KELVIN
 -----------
               NUCLIDE NO.        NAME        ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE       DFN        LIBRARY NO.
               -----------        ----        ----------    ---------   ---------------       ---        -----------

                   1            J2HINH2O           1             1.01      6.6661E-01       10293           64
                   2              J2O16            8            15.99      3.3339E-01        825b           33

 MATERIAL  5   DENSITY 6.50000E+00 GRMS/CC     NUMBER OF NUCLIDES  1     TEMPERATURE 293.0 DEGREES KELVIN
 -----------
               NUCLIDE NO.        NAME        ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE       DFN        LIBRARY NO.
               -----------        ----        ----------    ---------   ---------------       ---        -----------

                   1              J2ZR           40            91.22      1.0000E+00        4000b          47
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

MATERIAL 6 DENSITY 6.50000E+00 GRMS/CC NUMBER OF NUCLIDES 1 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2ZR	40	91.22	1.0000E+00	4000b	47

MATERIAL 7 DENSITY 3.09913E+00 GRMS/CC NUMBER OF NUCLIDES 15 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	1.1794E-02	2625b	15
2	J2FE56	26	55.94	1.8334E-01	2631b	66
3	J2FE57	26	56.94	4.1978E-03	2634b	16
4	J2FE58	26	57.93	5.5970E-04	2637b	17
5	J2CR50	24	49.95	2.2691E-03	2425b	11
6	J2CR52	24	51.94	4.3759E-02	2431b	53
7	J2CR53	24	52.94	4.9613E-03	2434b	12
8	J2CR54	24	53.94	1.2351E-03	2437b	13
9	J2NI58	28	57.94	1.3998E-02	2825b	56
10	J2NI60	28	59.93	5.3920E-03	2831b	57
11	J2NI61	28	60.93	2.3441E-04	2834b	58
12	J2NI62	28	61.93	7.4723E-04	2837b	59
13	J2NI64	28	63.93	1.9040E-04	2843b	60
14	J2HINH2O	1	1.01	4.8484E-01	10293	64
15	J2O16	8	15.99	2.4249E-01	825b	33

MATERIAL 8 DENSITY 2.19041E+00 GRMS/CC NUMBER OF NUCLIDES 15 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	6.5686E-03	2625b	15
2	J2FE56	26	55.94	1.0211E-01	2631b	66
3	J2FE57	26	56.94	2.3380E-03	2634b	16
4	J2FE58	26	57.93	3.1172E-04	2637b	17
5	J2CR50	24	49.95	1.2638E-03	2425b	11
6	J2CR52	24	51.94	2.4371E-02	2431b	53
7	J2CR53	24	52.94	2.7632E-03	2434b	12
8	J2CR54	24	53.94	6.8789E-04	2437b	13
9	J2NI58	28	57.94	7.7962E-03	2825b	56
10	J2NI60	28	59.93	3.0031E-03	2831b	57
11	J2NI61	28	60.93	1.3055E-04	2834b	58
12	J2NI62	28	61.93	4.1617E-04	2837b	59
13	J2NI64	28	63.93	1.0605E-04	2843b	60
14	J2HINH2O	1	1.01	5.6537E-01	10293	64
15	J2O16	8	15.99	2.8276E-01	825b	33

MATERIAL 9 DENSITY 7.92967E+00 GRMS/CC NUMBER OF NUCLIDES 13 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	4.3251E-02	2625b	15
2	J2FE56	26	55.94	6.7237E-01	2631b	66
3	J2FE57	26	56.94	1.5395E-02	2634b	16
4	J2FE58	26	57.93	2.0526E-03	2637b	17
5	J2CR50	24	49.95	8.3216E-03	2425b	11
6	J2CR52	24	51.94	1.6048E-01	2431b	53
7	J2CR53	24	52.94	1.8195E-02	2434b	12
8	J2CR54	24	53.94	4.5295E-03	2437b	13
9	J2NI58	28	57.94	5.1335E-02	2825b	56
10	J2NI60	28	59.93	1.9774E-02	2831b	57
11	J2NI61	28	60.93	8.5964E-04	2834b	58
12	J2NI62	28	61.93	2.7403E-03	2837b	59
13	J2NI64	28	63.93	6.9827E-04	2843b	60

MATERIAL 10 DENSITY 2.58326E+00 GRMS/CC NUMBER OF NUCLIDES 4 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2AL27	13	26.98	3.6469E-01	1325b	1
2	J2B10	5	10.01	7.7071E-02	525b	5
3	J2B11	5	11.01	4.2603E-01	528b	48
4	J2C	6	12.01	1.3221E-01	600b	6

MATERIAL 11 DENSITY 2.70000E+00 GRMS/CC NUMBER OF NUCLIDES 1 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2AL27	13	26.98	1.0000E+00	1325b	1

MATERIAL 12 DENSITY 7.92967E+00 GRMS/CC NUMBER OF NUCLIDES 13 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

1	J2FE54	26	53.94	4.3251E-02	2625b	15
2	J2FE56	26	55.94	6.7237E-01	2631b	66
3	J2FE57	26	56.94	1.5395E-02	2634b	16
4	J2FE58	26	57.93	2.0526E-03	2637b	17
5	J2CR50	24	49.95	8.3216E-03	2425b	11
6	J2CR52	24	51.94	1.6048E-01	2431b	53
7	J2CR53	24	52.94	1.8195E-02	2434b	12
8	J2CR54	24	53.94	4.5295E-03	2437b	13
9	J2NI58	28	57.94	5.1335E-02	2825b	56
10	J2NI60	28	59.93	1.9774E-02	2831b	57
11	J2NI61	28	60.93	8.5964E-04	2834b	58
12	J2NI62	28	61.93	2.7403E-03	2837b	59
13	J2NI64	28	63.93	6.9827E-04	2843b	60

MATERIAL 13 DENSITY 7.92967E+00 GRMS/CC NUMBER OF NUCLIDES 13 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	4.3251E-02	2625b	15
2	J2FE56	26	55.94	6.7237E-01	2631b	66
3	J2FE57	26	56.94	1.5395E-02	2634b	16
4	J2FE58	26	57.93	2.0526E-03	2637b	17
5	J2CR50	24	49.95	8.3216E-03	2425b	11
6	J2CR52	24	51.94	1.6048E-01	2431b	53
7	J2CR53	24	52.94	1.8195E-02	2434b	12
8	J2CR54	24	53.94	4.5295E-03	2437b	13
9	J2NI58	28	57.94	5.1335E-02	2825b	56
10	J2NI60	28	59.93	1.9774E-02	2831b	57
11	J2NI61	28	60.93	8.5964E-04	2834b	58
12	J2NI62	28	61.93	2.7403E-03	2837b	59
13	J2NI64	28	63.93	6.9827E-04	2843b	60

MATERIAL 14 DENSITY 2.70000E+00 GRMS/CC NUMBER OF NUCLIDES 1 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2AL27	13	26.98	1.0000E+00	1325b	1

MATERIAL 15 DENSITY 7.92967E+00 GRMS/CC NUMBER OF NUCLIDES 13 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	4.3251E-02	2625b	15
2	J2FE56	26	55.94	6.7237E-01	2631b	66
3	J2FE57	26	56.94	1.5395E-02	2634b	16
4	J2FE58	26	57.93	2.0526E-03	2637b	17
5	J2CR50	24	49.95	8.3216E-03	2425b	11
6	J2CR52	24	51.94	1.6048E-01	2431b	53
7	J2CR53	24	52.94	1.8195E-02	2434b	12
8	J2CR54	24	53.94	4.5295E-03	2437b	13
9	J2NI58	28	57.94	5.1335E-02	2825b	56
10	J2NI60	28	59.93	1.9774E-02	2831b	57
11	J2NI61	28	60.93	8.5964E-04	2834b	58
12	J2NI62	28	61.93	2.7403E-03	2837b	59
13	J2NI64	28	63.93	6.9827E-04	2843b	60

MATERIAL 16 DENSITY 7.92967E+00 GRMS/CC NUMBER OF NUCLIDES 13 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2FE54	26	53.94	4.3251E-02	2625b	15
2	J2FE56	26	55.94	6.7237E-01	2631b	66
3	J2FE57	26	56.94	1.5395E-02	2634b	16
4	J2FE58	26	57.93	2.0526E-03	2637b	17
5	J2CR50	24	49.95	8.3216E-03	2425b	11
6	J2CR52	24	51.94	1.6048E-01	2431b	53
7	J2CR53	24	52.94	1.8195E-02	2434b	12
8	J2CR54	24	53.94	4.5295E-03	2437b	13
9	J2NI58	28	57.94	5.1335E-02	2825b	56
10	J2NI60	28	59.93	1.9774E-02	2831b	57
11	J2NI61	28	60.93	8.5964E-04	2834b	58
12	J2NI62	28	61.93	2.7403E-03	2837b	59
13	J2NI64	28	63.93	6.9827E-04	2843b	60

MATERIAL 17 DENSITY 1.10400E+01 GRMS/CC NUMBER OF NUCLIDES 1 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.
1	J2PB	82	207.21	1.0000E+00	8200b	34

MATERIAL 18 DENSITY 1.63187E+00 GRMS/CC NUMBER OF NUCLIDES 8 TEMPERATURE 293.0 DEGREES KELVIN

NUCLIDE NO.	NAME	ATOMIC NO.	ATOMIC WT	PROP BY NUCLIDE	DFN	LIBRARY NO.

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
-----------        ----        ----------     ---------   ---------------     ---        -----------

     1             J2B10          5            10.01      7.3169E-04        525b            5
     2             J2B11          5            11.01      2.9274E-03        528b           48
     3            J2AL27         13            26.98      6.6692E-02       1325b            1
     4          J2HINH2O          1             1.01      5.0079E-01      10293            64
     5             J2O16          8            15.99      2.2325E-01        825b           33
     6               J2C          6            12.01      1.9368E-01        600b            6
     7             J2N14          7            14.00      1.1881E-02        725b           31
     8             J2N15          7            15.00      4.4123E-05        728b           32

MATERIAL 19   DENSITY 9.98200E-01 GRMS/CC    NUMBER OF NUCLIDES  2    TEMPERATURE 293.0 DEGREES KELVIN
-----------
              NUCLIDE NO.        NAME       ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE      DFN        LIBRARY NO.
              -----------        ----       ----------    ---------   ---------------      ---        -----------

     1          J2HINH2O          1             1.01      6.6661E-01      10293            64
     2             J2O16          8            15.99      3.3339E-01        825b           33

MATERIAL 20   DENSITY 9.98200E-01 GRMS/CC    NUMBER OF NUCLIDES  2    TEMPERATURE 293.0 DEGREES KELVIN
-----------
              NUCLIDE NO.        NAME       ATOMIC NO.    ATOMIC WT   PROP BY NUCLIDE      DFN        LIBRARY NO.
              -----------        ----       ----------    ---------   ---------------      ---        -----------

     1          J2HINH2O          1             1.01      6.6661E-01      10293            64
     2             J2O16          8            15.99      3.3339E-01        825b           33


*********************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO      *
* MODULE 37371 (HOLE MODULE)                            *
*********************************************************


NO. OF HOLES REFERENCED IN THE GEOMETRY DATA =          7
TOTAL NUMBER OF HOLES                        =         10
TOTAL NUMBER OF MATERIALS                    =         19


*********************************************************
* ENTERING ROUTINE TO DISTRIBUTE THE INPUT DATA TO      *
* MODULE 16724 (ACTION TALLIES)                         *
*********************************************************


THE FOLLOWING SCORES WILL BE TALLIED AND PRINTED:
    SOURCE DISTRIBUTION COUNTS
    BOUNDARY CROSSING COUNTS
    MATERIAL ACTION COUNTS
    REGION ACTION COUNTS
    NEUTRON PARAMETERS
    SYSTEM CATEGORISATION
    FLUXES
    SAMPLING GUIDANCE
    ACTION TALLIES WILL BE NORMALISED TO 10000 SAMPLES


********************Q2************************
*      END OF STAGE TWO PROCESSING            *
**********************************************


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  -3 COMPLETED AFTER      0.31 MIN - K(THREE)= 0.9072 ( 0.0106)
 STAGE  -2 COMPLETED AFTER      0.69 MIN - K(THREE)= 0.9167 ( 0.0068)
 STAGE  -1 COMPLETED AFTER      1.05 MIN - K(THREE)= 0.9240 ( 0.0054)
 STAGE   0 COMPLETED AFTER      1.42 MIN - K(THREE)= 0.9222 ( 0.0048)
 STAGE   1 COMPLETED AFTER      1.83 MIN - K(THREE)= 0.9087 ( 0.0096)
 STAGE   2 COMPLETED AFTER      2.28 MIN - K(THREE)= 0.9278 ( 0.0063)
 STAGE   3 COMPLETED AFTER      2.73 MIN - K(THREE)= 0.9303 ( 0.0052)
 STAGE   4 COMPLETED AFTER      3.15 MIN - K(THREE)= 0.9329 ( 0.0047)
 STAGE   5 COMPLETED AFTER      3.54 MIN - K(THREE)= 0.9295 ( 0.0042)
 STAGE   6 COMPLETED AFTER      3.98 MIN - K(THREE)= 0.9308 ( 0.0039)
 STAGE   7 COMPLETED AFTER      4.41 MIN - K(THREE)= 0.9309 ( 0.0036)
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
STAGE   8 COMPLETED AFTER      4.82 MIN - K(THREE)= 0.9316 ( 0.0034)
STAGE   9 COMPLETED AFTER      5.23 MIN - K(THREE)= 0.9308 ( 0.0032)
STAGE  10 COMPLETED AFTER      5.62 MIN - K(THREE)= 0.9291 ( 0.0030)
STAGE  11 COMPLETED AFTER      6.05 MIN - K(THREE)= 0.9295 ( 0.0029)
STAGE  12 COMPLETED AFTER      6.47 MIN - K(THREE)= 0.9289 ( 0.0028)
STAGE  13 COMPLETED AFTER      6.86 MIN - K(THREE)= 0.9279 ( 0.0027)
STAGE  14 COMPLETED AFTER      7.26 MIN - K(THREE)= 0.9279 ( 0.0025)
STAGE  15 COMPLETED AFTER      7.65 MIN - K(THREE)= 0.9271 ( 0.0025)
STAGE  16 COMPLETED AFTER      8.13 MIN - K(THREE)= 0.9280 ( 0.0024)
STAGE  17 COMPLETED AFTER      8.60 MIN - K(THREE)= 0.9286 ( 0.0023)
STAGE  18 COMPLETED AFTER      9.02 MIN - K(THREE)= 0.9284 ( 0.0022)
STAGE  19 COMPLETED AFTER      9.54 MIN - K(THREE)= 0.9298 ( 0.0022)
STAGE  20 COMPLETED AFTER      9.98 MIN - K(THREE)= 0.9300 ( 0.0021)
STAGE  21 COMPLETED AFTER     10.43 MIN - K(THREE)= 0.9302 ( 0.0020)
STAGE  22 COMPLETED AFTER     10.89 MIN - K(THREE)= 0.9305 ( 0.0020)
STAGE  23 COMPLETED AFTER     11.33 MIN - K(THREE)= 0.9309 ( 0.0020)
STAGE  24 COMPLETED AFTER     11.75 MIN - K(THREE)= 0.9314 ( 0.0019)
STAGE  25 COMPLETED AFTER     12.20 MIN - K(THREE)= 0.9315 ( 0.0019)
STAGE  26 COMPLETED AFTER     12.61 MIN - K(THREE)= 0.9313 ( 0.0019)
STAGE  27 COMPLETED AFTER     13.03 MIN - K(THREE)= 0.9310 ( 0.0018)
STAGE  28 COMPLETED AFTER     13.44 MIN - K(THREE)= 0.9311 ( 0.0018)
STAGE  29 COMPLETED AFTER     13.85 MIN - K(THREE)= 0.9311 ( 0.0018)
STAGE  30 COMPLETED AFTER     14.32 MIN - K(THREE)= 0.9311 ( 0.0017)
STAGE  31 COMPLETED AFTER     14.78 MIN - K(THREE)= 0.9315 ( 0.0017)
STAGE  32 COMPLETED AFTER     15.18 MIN - K(THREE)= 0.9317 ( 0.0017)
STAGE  33 COMPLETED AFTER     15.61 MIN - K(THREE)= 0.9319 ( 0.0017)
STAGE  34 COMPLETED AFTER     16.03 MIN - K(THREE)= 0.9319 ( 0.0016)
STAGE  35 COMPLETED AFTER     16.44 MIN - K(THREE)= 0.9316 ( 0.0016)
STAGE  36 COMPLETED AFTER     16.89 MIN - K(THREE)= 0.9318 ( 0.0016)
STAGE  37 COMPLETED AFTER     17.40 MIN - K(THREE)= 0.9320 ( 0.0016)
STAGE  38 COMPLETED AFTER     17.82 MIN - K(THREE)= 0.9316 ( 0.0015)
STAGE  39 COMPLETED AFTER     18.28 MIN - K(THREE)= 0.9318 ( 0.0015)
STAGE  40 COMPLETED AFTER     18.74 MIN - K(THREE)= 0.9315 ( 0.0015)
STAGE  41 COMPLETED AFTER     19.28 MIN - K(THREE)= 0.9319 ( 0.0015)
STAGE  42 COMPLETED AFTER     19.76 MIN - K(THREE)= 0.9321 ( 0.0015)
STAGE  43 COMPLETED AFTER     20.22 MIN - K(THREE)= 0.9318 ( 0.0014)
STAGE  44 COMPLETED AFTER     20.75 MIN - K(THREE)= 0.9320 ( 0.0014)
STAGE  45 COMPLETED AFTER     21.24 MIN - K(THREE)= 0.9322 ( 0.0014)
STAGE  46 COMPLETED AFTER     21.67 MIN - K(THREE)= 0.9321 ( 0.0014)
STAGE  47 COMPLETED AFTER     22.11 MIN - K(THREE)= 0.9319 ( 0.0014)
STAGE  48 COMPLETED AFTER     22.54 MIN - K(THREE)= 0.9317 ( 0.0014)
STAGE  49 COMPLETED AFTER     23.01 MIN - K(THREE)= 0.9316 ( 0.0013)
STAGE  50 COMPLETED AFTER     23.51 MIN - K(THREE)= 0.9320 ( 0.0013)
STAGE  51 COMPLETED AFTER     23.95 MIN - K(THREE)= 0.9320 ( 0.0013)
STAGE  52 COMPLETED AFTER     24.45 MIN - K(THREE)= 0.9322 ( 0.0013)
STAGE  53 COMPLETED AFTER     24.91 MIN - K(THREE)= 0.9322 ( 0.0013)
STAGE  54 COMPLETED AFTER     25.35 MIN - K(THREE)= 0.9320 ( 0.0013)
STAGE  55 COMPLETED AFTER     25.81 MIN - K(THREE)= 0.9320 ( 0.0013)
STAGE  56 COMPLETED AFTER     26.24 MIN - K(THREE)= 0.9318 ( 0.0013)
STAGE  57 COMPLETED AFTER     26.77 MIN - K(THREE)= 0.9321 ( 0.0012)
STAGE  58 COMPLETED AFTER     27.32 MIN - K(THREE)= 0.9324 ( 0.0012)
STAGE  59 COMPLETED AFTER     27.78 MIN - K(THREE)= 0.9324 ( 0.0012)
STAGE  60 COMPLETED AFTER     28.27 MIN - K(THREE)= 0.9326 ( 0.0012)
STAGE  61 COMPLETED AFTER     28.73 MIN - K(THREE)= 0.9326 ( 0.0012)
STAGE  62 COMPLETED AFTER     29.18 MIN - K(THREE)= 0.9325 ( 0.0012)
STAGE  63 COMPLETED AFTER     29.65 MIN - K(THREE)= 0.9324 ( 0.0012)
STAGE  64 COMPLETED AFTER     30.11 MIN - K(THREE)= 0.9323 ( 0.0012)
STAGE  65 COMPLETED AFTER     30.59 MIN - K(THREE)= 0.9323 ( 0.0012)
STAGE  66 COMPLETED AFTER     31.06 MIN - K(THREE)= 0.9323 ( 0.0012)
STAGE  67 COMPLETED AFTER     31.55 MIN - K(THREE)= 0.9324 ( 0.0011)
STAGE  68 COMPLETED AFTER     32.02 MIN - K(THREE)= 0.9326 ( 0.0011)
STAGE  69 COMPLETED AFTER     32.48 MIN - K(THREE)= 0.9326 ( 0.0011)
STAGE  70 COMPLETED AFTER     32.92 MIN - K(THREE)= 0.9328 ( 0.0011)
STAGE  71 COMPLETED AFTER     33.36 MIN - K(THREE)= 0.9328 ( 0.0011)
STAGE  72 COMPLETED AFTER     33.83 MIN - K(THREE)= 0.9330 ( 0.0011)
STAGE  73 COMPLETED AFTER     34.25 MIN - K(THREE)= 0.9327 ( 0.0011)
STAGE  74 COMPLETED AFTER     34.69 MIN - K(THREE)= 0.9326 ( 0.0011)
STAGE  75 COMPLETED AFTER     35.16 MIN - K(THREE)= 0.9327 ( 0.0011)
STAGE  76 COMPLETED AFTER     35.64 MIN - K(THREE)= 0.9327 ( 0.0011)
STAGE  77 COMPLETED AFTER     36.07 MIN - K(THREE)= 0.9325 ( 0.0011)
STAGE  78 COMPLETED AFTER     36.56 MIN - K(THREE)= 0.9325 ( 0.0011)
STAGE  79 COMPLETED AFTER     37.02 MIN - K(THREE)= 0.9324 ( 0.0011)
STAGE  80 COMPLETED AFTER     37.50 MIN - K(THREE)= 0.9326 ( 0.0011)
STAGE  81 COMPLETED AFTER     38.00 MIN - K(THREE)= 0.9326 ( 0.0010)
STAGE  82 COMPLETED AFTER     38.42 MIN - K(THREE)= 0.9327 ( 0.0010)
STAGE  83 COMPLETED AFTER     38.90 MIN - K(THREE)= 0.9327 ( 0.0010)
STAGE  84 COMPLETED AFTER     39.36 MIN - K(THREE)= 0.9326 ( 0.0010)
STAGE  85 COMPLETED AFTER     39.85 MIN - K(THREE)= 0.9326 ( 0.0010)
STAGE  86 COMPLETED AFTER     40.28 MIN - K(THREE)= 0.9324 ( 0.0010)
STAGE  87 COMPLETED AFTER     40.70 MIN - K(THREE)= 0.9323 ( 0.0010)
STAGE  88 COMPLETED AFTER     41.16 MIN - K(THREE)= 0.9322 ( 0.0010)
STAGE  89 COMPLETED AFTER     41.62 MIN - K(THREE)= 0.9321 ( 0.0010)
STAGE  90 COMPLETED AFTER     42.06 MIN - K(THREE)= 0.9320 ( 0.0010)
STAGE  91 COMPLETED AFTER     42.52 MIN - K(THREE)= 0.9321 ( 0.0010)
STAGE  92 COMPLETED AFTER     42.97 MIN - K(THREE)= 0.9320 ( 0.0010)
STAGE  93 COMPLETED AFTER     43.47 MIN - K(THREE)= 0.9321 ( 0.0010)
STAGE  94 COMPLETED AFTER     43.94 MIN - K(THREE)= 0.9322 ( 0.0010)
STAGE  95 COMPLETED AFTER     44.41 MIN - K(THREE)= 0.9322 ( 0.0010)
STAGE  96 COMPLETED AFTER     44.84 MIN - K(THREE)= 0.9322 ( 0.0010)
STAGE  97 COMPLETED AFTER     45.25 MIN - K(THREE)= 0.9321 ( 0.0010)
STAGE  98 COMPLETED AFTER     45.75 MIN - K(THREE)= 0.9322 ( 0.0010)
STAGE  99 COMPLETED AFTER     46.21 MIN - K(THREE)= 0.9320 ( 0.0010)
STAGE 100 COMPLETED AFTER     46.75 MIN - K(THREE)= 0.9322 ( 0.0009)
STAGE 101 COMPLETED AFTER     47.24 MIN - K(THREE)= 0.9321 ( 0.0009)
STAGE 102 COMPLETED AFTER     47.76 MIN - K(THREE)= 0.9319 ( 0.0009)
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
STAGE 103 COMPLETED AFTER     48.20 MIN - K(THREE)= 0.9319 ( 0.0009)
STAGE 104 COMPLETED AFTER     48.65 MIN - K(THREE)= 0.9319 ( 0.0009)
STAGE 105 COMPLETED AFTER     49.12 MIN - K(THREE)= 0.9319 ( 0.0009)
STAGE 106 COMPLETED AFTER     49.52 MIN - K(THREE)= 0.9316 ( 0.0009)
STAGE 107 COMPLETED AFTER     50.02 MIN - K(THREE)= 0.9317 ( 0.0009)
STAGE 108 COMPLETED AFTER     50.43 MIN - K(THREE)= 0.9316 ( 0.0009)
STAGE 109 COMPLETED AFTER     50.88 MIN - K(THREE)= 0.9315 ( 0.0009)
STAGE 110 COMPLETED AFTER     51.35 MIN - K(THREE)= 0.9315 ( 0.0009)
STAGE 111 COMPLETED AFTER     51.80 MIN - K(THREE)= 0.9314 ( 0.0009)
STAGE 112 COMPLETED AFTER     52.26 MIN - K(THREE)= 0.9313 ( 0.0009)
STAGE 113 COMPLETED AFTER     52.71 MIN - K(THREE)= 0.9311 ( 0.0009)
STAGE 114 COMPLETED AFTER     53.14 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 115 COMPLETED AFTER     53.63 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 116 COMPLETED AFTER     54.08 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 117 COMPLETED AFTER     54.52 MIN - K(THREE)= 0.9309 ( 0.0009)
STAGE 118 COMPLETED AFTER     54.99 MIN - K(THREE)= 0.9309 ( 0.0009)
STAGE 119 COMPLETED AFTER     55.47 MIN - K(THREE)= 0.9309 ( 0.0009)
STAGE 120 COMPLETED AFTER     55.92 MIN - K(THREE)= 0.9309 ( 0.0009)
STAGE 121 COMPLETED AFTER     56.42 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 122 COMPLETED AFTER     56.89 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 123 COMPLETED AFTER     57.32 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 124 COMPLETED AFTER     57.77 MIN - K(THREE)= 0.9310 ( 0.0009)
STAGE 125 COMPLETED AFTER     58.23 MIN - K(THREE)= 0.9311 ( 0.0009)
STAGE 126 COMPLETED AFTER     58.72 MIN - K(THREE)= 0.9311 ( 0.0008)
STAGE 127 COMPLETED AFTER     59.18 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 128 COMPLETED AFTER     59.61 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 129 COMPLETED AFTER     60.06 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 130 COMPLETED AFTER     60.56 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 131 COMPLETED AFTER     61.03 MIN - K(THREE)= 0.9311 ( 0.0008)
STAGE 132 COMPLETED AFTER     61.49 MIN - K(THREE)= 0.9311 ( 0.0008)
STAGE 133 COMPLETED AFTER     61.94 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 134 COMPLETED AFTER     62.40 MIN - K(THREE)= 0.9309 ( 0.0008)
STAGE 135 COMPLETED AFTER     62.90 MIN - K(THREE)= 0.9309 ( 0.0008)
STAGE 136 COMPLETED AFTER     63.43 MIN - K(THREE)= 0.9310 ( 0.0008)
STAGE 137 COMPLETED AFTER     63.94 MIN - K(THREE)= 0.9312 ( 0.0008)
STAGE 138 COMPLETED AFTER     64.47 MIN - K(THREE)= 0.9312 ( 0.0008)
STAGE 139 COMPLETED AFTER     64.97 MIN - K(THREE)= 0.9313 ( 0.0008)
STAGE 140 COMPLETED AFTER     65.39 MIN - K(THREE)= 0.9313 ( 0.0008)
STAGE 141 COMPLETED AFTER     65.84 MIN - K(THREE)= 0.9313 ( 0.0008)
STAGE 142 COMPLETED AFTER     66.30 MIN - K(THREE)= 0.9313 ( 0.0008)

*******************************************************
* REQUIRED ACCURACY (SD=  0.000800) REACHED BY K(THREE) *
* EXECUTION ENDS AFTER STAGE   142                      *
*******************************************************
1

OUTPUT FROM MONK8A (1/2/1998) AT 18.40.37 ON 15/ 9/2000
=====================QO=========================

NUMBER OF SUPERHISTORIES POST-SETTLING  =     142000
NUMBER OF SAMPLES POST-SETTLING         =    1426292
FIRST STAGE RUN                         =         -3
FINAL STAGE COMPLETED                   =        142
TOTAL C.P.U. TIME (SECONDS )            =   3977.996
AVERAGE TIME PER SAMPLE(SECONDS )       =      0.027
AVERAGE TIME PER STAGE(SECONDS )        =     27.247
AVERAGE SAMPLES PER SECONDS             =         36
NUMBER OF RANDOM NUMBERS USED           =  569634827
AFTER SEEDING WITH VALUES               =      54321       54321
TRAJECTORIES TRACKED THIS RUN           =   58521395
NUMBER OF COLLISIONS THIS RUN           =   75810555
ZONE SEARCH LOCATIONS USED(PAIRS)       =        350
1*****************************************************************************************************
*************************************  CUMULATIVE   K-EFFECTIVE   ESTIMATORS   ************************************
*****************************************************************************************************
*  STAGE    K(COLL)    STDV      K(SCORE)  STDV      A(SCORE)  STDV      ALPHA     BETA      K(THREE)  STDV     *
*****************************************************************************************************
*                                                                                                                *
*     1     0.9195    0.0129    0.9050    0.0124    0.9973    0.0077    0.0841    0.9162    0.9087    0.0096   *
*     2     0.9291    0.0086    0.9292    0.0088    1.0014    0.0052    0.1753    0.9592    0.9278    0.0063   *
*     3     0.9334    0.0068    0.9298    0.0074    1.0003    0.0044    0.2089    0.9211    0.9303    0.0052   *
*     4     0.9352    0.0060    0.9307    0.0065    0.9985    0.0038    0.2063    0.9112    0.9329    0.0047   *
*     5     0.9306    0.0054    0.9263    0.0060    0.9975    0.0034    0.2220    0.9323    0.9295    0.0042   *
*     6     0.9319    0.0049    0.9287    0.0056    0.9985    0.0032    0.2460    0.9143    0.9308    0.0039   *
*     7     0.9315    0.0045    0.9285    0.0052    0.9982    0.0030    0.2426    0.9183    0.9309    0.0036   *
*     8     0.9310    0.0043    0.9298    0.0049    0.9984    0.0028    0.2473    0.9013    0.9316    0.0034   *
*     9     0.9288    0.0040    0.9300    0.0045    0.9987    0.0027    0.2675    0.8580    0.9308    0.0032   *
*    10     0.9277    0.0039    0.9277    0.0043    0.9983    0.0026    0.2520    0.8649    0.9291    0.0030   *
*    11     0.9286    0.0037    0.9282    0.0041    0.9987    0.0025    0.2552    0.8648    0.9295    0.0029   *
*    12     0.9290    0.0035    0.9269    0.0040    0.9983    0.0024    0.2499    0.8760    0.9289    0.0028   *
*    13     0.9281    0.0034    0.9267    0.0038    0.9990    0.0023    0.2468    0.8830    0.9279    0.0027   *
*    14     0.9276    0.0033    0.9288    0.0037    1.0007    0.0022    0.2587    0.8642    0.9279    0.0025   *
*    15     0.9270    0.0032    0.9280    0.0036    1.0007    0.0021    0.2613    0.8652    0.9271    0.0025   *
*    16     0.9286    0.0030    0.9285    0.0034    1.0006    0.0020    0.2649    0.8676    0.9280    0.0024   *
*    17     0.9293    0.0029    0.9292    0.0033    1.0008    0.0020    0.2717    0.8546    0.9286    0.0023   *
*    18     0.9291    0.0029    0.9293    0.0032    1.0010    0.0019    0.2718    0.8564    0.9284    0.0022   *
*    19     0.9304    0.0028    0.9308    0.0031    1.0010    0.0018    0.2718    0.8519    0.9298    0.0022   *
*    20     0.9303    0.0027    0.9309    0.0030    1.0009    0.0018    0.2773    0.8525    0.9300    0.0021   *
*    21     0.9305    0.0026    0.9308    0.0030    1.0006    0.0017    0.2762    0.8594    0.9302    0.0020   *
*    22     0.9312    0.0026    0.9312    0.0029    1.0008    0.0017    0.2659    0.8723    0.9305    0.0020   *
*    23     0.9319    0.0025    0.9309    0.0028    1.0003    0.0017    0.2538    0.8826    0.9309    0.0020   *
*    24     0.9320    0.0025    0.9318    0.0028    1.0004    0.0016    0.2604    0.8793    0.9314    0.0019   *
*    25     0.9324    0.0024    0.9319    0.0027    1.0006    0.0016    0.2609    0.8816    0.9315    0.0019   *
*    26     0.9320    0.0024    0.9319    0.0027    1.0007    0.0016    0.2635    0.8757    0.9313    0.0019   *
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

*	27	0.9317	0.0023	0.9319	0.0026	1.0010	0.0015	0.2681	0.8707	0.9310	0.0018	*
*	28	0.9317	0.0023	0.9314	0.0026	1.0004	0.0015	0.2700	0.8676	0.9311	0.0018	*
*	29	0.9315	0.0022	0.9313	0.0025	1.0004	0.0015	0.2730	0.8701	0.9311	0.0018	*
*	30	0.9319	0.0022	0.9310	0.0025	1.0001	0.0014	0.2682	0.8695	0.9311	0.0017	*
*	31	0.9325	0.0022	0.9318	0.0024	1.0006	0.0014	0.2705	0.8697	0.9315	0.0017	*
*	32	0.9324	0.0021	0.9321	0.0024	1.0005	0.0014	0.2685	0.8785	0.9317	0.0017	*
*	33	0.9325	0.0021	0.9323	0.0024	1.0004	0.0014	0.2634	0.8817	0.9319	0.0017	*
*	34	0.9326	0.0021	0.9321	0.0023	1.0004	0.0014	0.2595	0.8862	0.9319	0.0016	*
*	35	0.9325	0.0020	0.9323	0.0023	1.0008	0.0013	0.2596	0.8896	0.9316	0.0016	*
*	36	0.9327	0.0020	0.9322	0.0023	1.0006	0.0013	0.2576	0.8974	0.9318	0.0016	*
*	37	0.9334	0.0020	0.9327	0.0022	1.0010	0.0013	0.2574	0.8996	0.9320	0.0016	*
*	38	0.9329	0.0020	0.9323	0.0022	1.0010	0.0013	0.2579	0.8990	0.9316	0.0015	*
*	39	0.9330	0.0019	0.9323	0.0022	1.0008	0.0013	0.2579	0.8980	0.9318	0.0015	*
*	40	0.9326	0.0019	0.9320	0.0022	1.0007	0.0013	0.2617	0.8943	0.9315	0.0015	*
*	41	0.9331	0.0019	0.9328	0.0021	1.0012	0.0012	0.2630	0.8960	0.9319	0.0015	*
*	42	0.9333	0.0019	0.9331	0.0021	1.0011	0.0012	0.2665	0.8916	0.9321	0.0015	*
*	43	0.9331	0.0018	0.9326	0.0021	1.0010	0.0012	0.2654	0.8908	0.9318	0.0014	*
*	44	0.9334	0.0018	0.9330	0.0021	1.0012	0.0012	0.2649	0.8900	0.9320	0.0014	*
*	45	0.9337	0.0018	0.9331	0.0020	1.0012	0.0012	0.2643	0.8919	0.9322	0.0014	*
*	46	0.9332	0.0018	0.9330	0.0020	1.0011	0.0012	0.2651	0.8927	0.9321	0.0014	*
*	47	0.9330	0.0018	0.9331	0.0020	1.0013	0.0012	0.2635	0.8964	0.9319	0.0014	*
*	48	0.9327	0.0017	0.9329	0.0020	1.0013	0.0011	0.2621	0.8966	0.9317	0.0014	*
*	49	0.9329	0.0017	0.9331	0.0020	1.0015	0.0011	0.2630	0.8949	0.9316	0.0013	*
*	50	0.9332	0.0017	0.9333	0.0019	1.0015	0.0011	0.2629	0.8946	0.9320	0.0013	*
*	51	0.9332	0.0017	0.9335	0.0019	1.0016	0.0011	0.2630	0.8947	0.9320	0.0013	*
*	52	0.9335	0.0017	0.9338	0.0019	1.0017	0.0011	0.2640	0.8956	0.9322	0.0013	*
*	53	0.9334	0.0017	0.9336	0.0019	1.0015	0.0011	0.2635	0.8952	0.9322	0.0013	*
*	54	0.9332	0.0016	0.9332	0.0019	1.0013	0.0011	0.2644	0.8939	0.9320	0.0013	*
*	55	0.9332	0.0016	0.9330	0.0019	1.0011	0.0011	0.2623	0.8962	0.9320	0.0013	*
*	56	0.9330	0.0016	0.9326	0.0018	1.0009	0.0011	0.2621	0.8976	0.9318	0.0013	*
*	57	0.9331	0.0016	0.9329	0.0018	1.0010	0.0011	0.2645	0.8948	0.9321	0.0012	*
*	58	0.9337	0.0016	0.9333	0.0018	1.0011	0.0011	0.2625	0.8972	0.9324	0.0012	*
*	59	0.9335	0.0016	0.9330	0.0018	1.0008	0.0010	0.2640	0.8949	0.9324	0.0012	*
*	60	0.9339	0.0016	0.9333	0.0018	1.0010	0.0010	0.2622	0.8942	0.9326	0.0012	*
*	61	0.9338	0.0015	0.9333	0.0018	1.0009	0.0010	0.2616	0.8951	0.9326	0.0012	*
*	62	0.9337	0.0015	0.9332	0.0017	1.0009	0.0010	0.2615	0.8935	0.9325	0.0012	*
*	63	0.9338	0.0015	0.9331	0.0017	1.0010	0.0010	0.2614	0.8938	0.9324	0.0012	*
*	64	0.9336	0.0015	0.9334	0.0017	1.0013	0.0010	0.2650	0.8914	0.9323	0.0012	*
*	65	0.9335	0.0015	0.9331	0.0017	1.0011	0.0010	0.2622	0.8940	0.9323	0.0012	*
*	66	0.9336	0.0015	0.9331	0.0017	1.0010	0.0010	0.2599	0.8965	0.9323	0.0012	*
*	67	0.9338	0.0015	0.9333	0.0017	1.0012	0.0010	0.2592	0.8984	0.9324	0.0011	*
*	68	0.9340	0.0015	0.9335	0.0017	1.0012	0.0010	0.2604	0.8981	0.9326	0.0011	*
*	69	0.9339	0.0015	0.9334	0.0017	1.0010	0.0010	0.2611	0.8974	0.9326	0.0011	*
*	70	0.9341	0.0014	0.9333	0.0016	1.0008	0.0010	0.2565	0.9018	0.9328	0.0011	*
*	71	0.9339	0.0014	0.9336	0.0016	1.0010	0.0010	0.2567	0.9052	0.9328	0.0011	*
*	72	0.9341	0.0014	0.9337	0.0016	1.0009	0.0010	0.2537	0.9092	0.9330	0.0011	*
*	73	0.9338	0.0014	0.9333	0.0016	1.0007	0.0009	0.2533	0.9070	0.9327	0.0011	*
*	74	0.9337	0.0014	0.9330	0.0016	1.0006	0.0009	0.2533	0.9056	0.9326	0.0011	*
*	75	0.9338	0.0014	0.9332	0.0016	1.0008	0.0009	0.2546	0.9057	0.9327	0.0011	*
*	76	0.9339	0.0014	0.9333	0.0016	1.0009	0.0009	0.2551	0.9055	0.9327	0.0011	*
*	77	0.9335	0.0014	0.9332	0.0016	1.0009	0.0009	0.2577	0.9037	0.9325	0.0011	*
*	78	0.9336	0.0014	0.9333	0.0016	1.0009	0.0009	0.2576	0.9038	0.9325	0.0011	*
*	79	0.9335	0.0014	0.9334	0.0016	1.0011	0.0009	0.2589	0.9023	0.9324	0.0011	*
*	80	0.9336	0.0014	0.9334	0.0015	1.0009	0.0009	0.2587	0.9021	0.9326	0.0011	*
*	81	0.9336	0.0013	0.9334	0.0015	1.0010	0.0009	0.2594	0.9025	0.9326	0.0010	*
*	82	0.9336	0.0013	0.9335	0.0015	1.0009	0.0009	0.2589	0.9052	0.9327	0.0010	*
*	83	0.9337	0.0013	0.9333	0.0015	1.0008	0.0009	0.2555	0.9085	0.9327	0.0010	*
*	84	0.9335	0.0013	0.9332	0.0015	1.0008	0.0009	0.2576	0.9064	0.9326	0.0010	*
*	85	0.9336	0.0013	0.9332	0.0015	1.0008	0.0009	0.2571	0.9071	0.9326	0.0010	*
*	86	0.9334	0.0013	0.9330	0.0015	1.0008	0.0009	0.2567	0.9072	0.9324	0.0010	*
*	87	0.9333	0.0013	0.9328	0.0015	1.0007	0.0009	0.2563	0.9070	0.9323	0.0010	*
*	88	0.9332	0.0013	0.9329	0.0015	1.0009	0.0009	0.2575	0.9058	0.9322	0.0010	*
*	89	0.9330	0.0013	0.9327	0.0015	1.0007	0.0009	0.2572	0.9039	0.9321	0.0010	*
*	90	0.9329	0.0013	0.9324	0.0015	1.0005	0.0008	0.2558	0.9041	0.9320	0.0010	*
*	91	0.9329	0.0013	0.9326	0.0014	1.0006	0.0008	0.2577	0.9042	0.9321	0.0010	*
*	92	0.9329	0.0013	0.9324	0.0014	1.0005	0.0008	0.2572	0.9042	0.9320	0.0010	*
*	93	0.9330	0.0013	0.9324	0.0014	1.0006	0.0008	0.2576	0.9038	0.9321	0.0010	*
*	94	0.9330	0.0013	0.9326	0.0014	1.0006	0.0008	0.2580	0.9040	0.9322	0.0010	*
*	95	0.9330	0.0012	0.9324	0.0014	1.0004	0.0008	0.2567	0.9043	0.9322	0.0010	*
*	96	0.9329	0.0012	0.9324	0.0014	1.0004	0.0008	0.2568	0.9041	0.9322	0.0010	*
*	97	0.9327	0.0012	0.9324	0.0014	1.0004	0.0008	0.2582	0.9024	0.9321	0.0010	*
*	98	0.9328	0.0012	0.9324	0.0014	1.0004	0.0008	0.2586	0.9018	0.9322	0.0010	*
*	99	0.9326	0.0012	0.9324	0.0014	1.0004	0.0008	0.2599	0.9000	0.9320	0.0010	*
*	100	0.9329	0.0012	0.9324	0.0014	1.0004	0.0008	0.2585	0.9017	0.9322	0.0009	*
*	101	0.9329	0.0012	0.9324	0.0014	1.0004	0.0008	0.2583	0.9031	0.9321	0.0009	*
*	102	0.9328	0.0012	0.9321	0.0014	1.0004	0.0008	0.2571	0.9031	0.9319	0.0009	*
*	103	0.9328	0.0012	0.9319	0.0014	1.0002	0.0008	0.2560	0.9032	0.9319	0.0009	*
*	104	0.9327	0.0012	0.9319	0.0014	1.0002	0.0008	0.2566	0.9045	0.9319	0.0009	*
*	105	0.9326	0.0012	0.9317	0.0013	1.0001	0.0008	0.2560	0.9041	0.9319	0.0009	*
*	106	0.9324	0.0012	0.9316	0.0013	1.0002	0.0008	0.2571	0.9028	0.9316	0.0009	*
*	107	0.9325	0.0012	0.9316	0.0013	1.0002	0.0008	0.2577	0.9028	0.9317	0.0009	*
*	108	0.9323	0.0012	0.9315	0.0013	1.0002	0.0008	0.2579	0.9011	0.9316	0.0009	*
*	109	0.9322	0.0012	0.9313	0.0013	1.0001	0.0008	0.2585	0.8998	0.9315	0.0009	*
*	110	0.9321	0.0012	0.9312	0.0013	1.0000	0.0008	0.2591	0.8989	0.9315	0.0009	*
*	111	0.9320	0.0012	0.9311	0.0013	1.0000	0.0008	0.2591	0.8987	0.9314	0.0009	*
*	112	0.9319	0.0012	0.9308	0.0013	0.9998	0.0008	0.2581	0.8979	0.9313	0.0009	*
*	113	0.9318	0.0011	0.9305	0.0013	0.9997	0.0008	0.2580	0.8973	0.9311	0.0009	*
*	114	0.9317	0.0011	0.9303	0.0013	0.9996	0.0008	0.2576	0.8956	0.9310	0.0009	*
*	115	0.9316	0.0011	0.9303	0.0013	0.9996	0.0008	0.2583	0.8943	0.9310	0.0009	*
*	116	0.9315	0.0011	0.9302	0.0013	0.9996	0.0007	0.2585	0.8944	0.9310	0.0009	*
*	117	0.9315	0.0011	0.9301	0.0013	0.9995	0.0007	0.2575	0.8960	0.9309	0.0009	*
*	118	0.9314	0.0011	0.9302	0.0013	0.9995	0.0007	0.2583	0.8941	0.9309	0.0009	*
*	119	0.9314	0.0011	0.9302	0.0013	0.9996	0.0007	0.2595	0.8925	0.9309	0.0009	*
*	120	0.9315	0.0011	0.9303	0.0013	0.9997	0.0007	0.2603	0.8925	0.9309	0.0009	*
*	121	0.9315	0.0011	0.9305	0.0013	0.9998	0.0007	0.2613	0.8919	0.9310	0.0009	*

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

122	0.9316	0.0011	0.9306	0.0013	0.9999	0.0007	0.2622	0.8911	0.9310	0.0009
123	0.9315	0.0011	0.9306	0.0012	0.9999	0.0007	0.2626	0.8916	0.9310	0.0009
124	0.9315	0.0011	0.9307	0.0012	0.9999	0.0007	0.2621	0.8914	0.9310	0.0009
125	0.9316	0.0011	0.9307	0.0012	0.9999	0.0007	0.2615	0.8913	0.9311	0.0009
126	0.9316	0.0011	0.9308	0.0012	0.9999	0.0007	0.2611	0.8921	0.9311	0.0008
127	0.9315	0.0011	0.9307	0.0012	0.9999	0.0007	0.2618	0.8908	0.9310	0.0008
128	0.9314	0.0011	0.9307	0.0012	0.9999	0.0007	0.2619	0.8903	0.9310	0.0008
129	0.9314	0.0011	0.9308	0.0012	1.0000	0.0007	0.2626	0.8898	0.9310	0.0008
130	0.9314	0.0011	0.9309	0.0012	1.0000	0.0007	0.2640	0.8893	0.9310	0.0008
131	0.9314	0.0011	0.9310	0.0012	1.0000	0.0007	0.2639	0.8902	0.9311	0.0008
132	0.9313	0.0011	0.9310	0.0012	1.0000	0.0007	0.2639	0.8897	0.9311	0.0008
133	0.9312	0.0011	0.9309	0.0012	1.0000	0.0007	0.2637	0.8900	0.9310	0.0008
134	0.9313	0.0011	0.9308	0.0012	1.0000	0.0007	0.2632	0.8913	0.9309	0.0008
135	0.9313	0.0010	0.9308	0.0012	1.0000	0.0007	0.2634	0.8914	0.9309	0.0008
136	0.9315	0.0010	0.9308	0.0012	1.0000	0.0007	0.2627	0.8926	0.9310	0.0008
137	0.9317	0.0010	0.9311	0.0012	1.0000	0.0007	0.2636	0.8924	0.9312	0.0008
138	0.9318	0.0010	0.9312	0.0012	1.0001	0.0007	0.2649	0.8915	0.9312	0.0008
139	0.9319	0.0010	0.9311	0.0012	1.0000	0.0007	0.2639	0.8922	0.9313	0.0008
140	0.9318	0.0010	0.9311	0.0012	1.0000	0.0007	0.2646	0.8914	0.9313	0.0008
141	0.9317	0.0010	0.9311	0.0012	1.0000	0.0007	0.2653	0.8897	0.9313	0.0008
142	0.9317	0.0010	0.9311	0.0012	1.0000	0.0007	0.2660	0.8886	0.9313	0.0008

1 INDIVIDUAL STAGE K-EFFECTIVE ESTIMATORS

STAGE	K(COLL)	STDV	K(SCORE)	STDV	A(SCORE)	STDV	ALPHA	BETA	K(THREE)	STDV
-3	0.8951	0.0140	0.9146	0.0159	1.0005	0.0087	0.3553	0.8636	0.9072	0.0106
-2	0.9166	0.0117	0.9278	0.0135	1.0003	0.0078	0.3260	0.8554	0.9239	0.0089
-1	0.9376	0.0131	0.9669	0.0144	1.0226	0.0086	0.2679	0.9749	0.9370	0.0089
0	0.9135	0.0130	0.9359	0.0169	1.0096	0.0095	0.4350	0.9297	0.9172	0.0096
1	0.9195	0.0129	0.9050	0.0124	0.9973	0.0077	0.0841	0.9162	0.9087	0.0096
2	0.9373	0.0114	0.9497	0.0121	1.0049	0.0071	0.2484	0.9644	0.9419	0.0081
3	0.9419	0.0113	0.9311	0.0137	0.9979	0.0081	0.2730	0.8389	0.9358	0.0093
4	0.9406	0.0125	0.9333	0.0131	0.9933	0.0072	0.2029	0.8754	0.9406	0.0099
5	0.9097	0.0120	0.9065	0.0157	0.9931	0.0084	0.3116	0.9744	0.9142	0.0100
6	0.9386	0.0119	0.9402	0.0148	1.0032	0.0086	0.3587	0.8313	0.9370	0.0099
7	0.9290	0.0121	0.9276	0.0139	0.9960	0.0083	0.2208	0.9440	0.9317	0.0095
8	0.9271	0.0123	0.9395	0.0135	0.9998	0.0086	0.2760	0.7975	0.9362	0.0091
9	0.9102	0.0120	0.9310	0.0125	1.0014	0.0077	0.4306	0.4924	0.9214	0.0092
10	0.9168	0.0133	0.9049	0.0150	0.9950	0.0105	0.0862	0.9637	0.9108	0.0101
11	0.9376	0.0113	0.9333	0.0129	1.0018	0.0077	0.2868	0.8682	0.9329	0.0086
12	0.9334	0.0119	0.9122	0.0150	0.9948	0.0093	0.1896	0.9959	0.9214	0.0098
13	0.9161	0.0139	0.9245	0.0140	1.0079	0.0075	0.2063	0.9937	0.9149	0.0102
14	0.9207	0.0124	0.9584	0.0127	1.0239	0.0081	0.4102	0.6152	0.9282	0.0088
15	0.9181	0.0135	0.9149	0.0154	1.0003	0.0078	0.2993	0.8925	0.9156	0.0115
16	0.9488	0.0105	0.9357	0.0130	0.9992	0.0074	0.3042	0.9064	0.9403	0.0084
17	0.9397	0.0108	0.9396	0.0126	1.0040	0.0079	0.3529	0.6970	0.9369	0.0085
18	0.9261	0.0129	0.9312	0.0146	1.0049	0.0085	0.2770	0.8820	0.9255	0.0103
19	0.9484	0.0099	0.9517	0.0108	1.0016	0.0068	0.2643	0.7812	0.9495	0.0074
20	0.9295	0.0123	0.9330	0.0146	0.9973	0.0073	0.3696	0.8931	0.9342	0.0101
21	0.9335	0.0107	0.9290	0.0134	0.9961	0.0080	0.2522	0.9922	0.9340	0.0081
22	0.9440	0.0135	0.9399	0.0141	1.0039	0.0078	0.0907	1.1192	0.9359	0.0102
23	0.9477	0.0134	0.9225	0.0133	0.9894	0.0073	0.0439	1.0775	0.9350	0.0104
24	0.9342	0.0112	0.9528	0.0135	1.0049	0.0076	0.4250	0.7931	0.9410	0.0087
25	0.9410	0.0114	0.9344	0.0134	1.0040	0.0073	0.2731	0.9427	0.9325	0.0093
26	0.9221	0.0129	0.9326	0.0139	1.0031	0.0082	0.3336	0.7299	0.9268	0.0104
27	0.9222	0.0110	0.9335	0.0133	1.0104	0.0078	0.3901	0.7173	0.9217	0.0082
28	0.9335	0.0124	0.9159	0.0150	0.9825	0.0075	0.3440	0.7236	0.9346	0.0116
29	0.9258	0.0118	0.9297	0.0152	1.0003	0.0082	0.3601	0.9382	0.9280	0.0095
30	0.9423	0.0120	0.9212	0.0125	0.9925	0.0073	0.1544	0.8211	0.9307	0.0099
31	0.9483	0.0104	0.9557	0.0124	1.0144	0.0078	0.3563	0.8204	0.9412	0.0078
32	0.9296	0.0142	0.9404	0.0157	0.9976	0.0080	0.1896	1.1882	0.9413	0.0109
33	0.9338	0.0133	0.9392	0.0130	0.9987	0.0081	0.1250	0.9802	0.9398	0.0091
34	0.9374	0.0123	0.9251	0.0138	0.9984	0.0086	0.1225	1.0395	0.9282	0.0094
35	0.9300	0.0122	0.9397	0.0144	1.0165	0.0085	0.2715	0.9898	0.9207	0.0089
36	0.9388	0.0115	0.9287	0.0139	0.9939	0.0076	0.1855	1.1751	0.9378	0.0089
37	0.9552	0.0112	0.9497	0.0127	1.0125	0.0073	0.2650	0.9421	0.9394	0.0085
38	0.9140	0.0136	0.9137	0.0159	1.0013	0.0090	0.2889	0.8661	0.9127	0.0114
39	0.9345	0.0125	0.9339	0.0140	0.9944	0.0080	0.2600	0.8631	0.9389	0.0100
40	0.9164	0.0104	0.9199	0.0142	0.9971	0.0086	0.4411	0.7032	0.9204	0.0085
41	0.9526	0.0103	0.9599	0.0119	1.0159	0.0075	0.3193	0.9036	0.9432	0.0072
42	0.9415	0.0111	0.9433	0.0139	1.0001	0.0082	0.4005	0.7294	0.9425	0.0093
43	0.9216	0.0113	0.9127	0.0131	0.9975	0.0088	0.2044	0.8667	0.9167	0.0086
44	0.9477	0.0117	0.9487	0.0124	1.0088	0.0072	0.2652	0.8369	0.9411	0.0089
45	0.9445	0.0116	0.9374	0.0136	1.0010	0.0077	0.2367	0.9730	0.9381	0.0089
46	0.9095	0.0124	0.9296	0.0143	0.9967	0.0079	0.3229	0.9268	0.9262	0.0093
47	0.9237	0.0144	0.9377	0.0146	1.0105	0.0081	0.1930	1.0598	0.9239	0.0102
48	0.9161	0.0141	0.9220	0.0142	1.0011	0.0084	0.1812	0.9084	0.9199	0.0105
49	0.9393	0.0116	0.9402	0.0142	1.0117	0.0089	0.3101	0.8215	0.9303	0.0092
50	0.9483	0.0113	0.9462	0.0137	1.0004	0.0083	0.2685	0.8802	0.9464	0.0084
51	0.9358	0.0129	0.9446	0.0143	1.0082	0.0087	0.2670	0.8964	0.9348	0.0094
52	0.9449	0.0114	0.9438	0.0143	1.0031	0.0081	0.3121	0.9253	0.9414	0.0090
53	0.9304	0.0117	0.9238	0.0135	0.9927	0.0082	0.2366	0.8668	0.9316	0.0096
54	0.9184	0.0114	0.9110	0.0144	0.9934	0.0087	0.3229	0.7995	0.9187	0.0094
55	0.9354	0.0116	0.9227	0.0134	0.9889	0.0081	0.1331	1.0369	0.9359	0.0090
56	0.9199	0.0124	0.9086	0.0150	0.9902	0.0081	0.2520	0.9731	0.9210	0.0106
57	0.9409	0.0110	0.9491	0.0136	1.0022	0.0081	0.3756	0.7595	0.9443	0.0084
58	0.9604	0.0110	0.9504	0.0125	1.0055	0.0077	0.2011	0.9601	0.9472	0.0081
59	0.9239	0.0110	0.9149	0.0151	0.9883	0.0090	0.4070	0.7126	0.9269	0.0102
60	0.9529	0.0132	0.9523	0.0129	1.0079	0.0076	0.1793	0.8312	0.9458	0.0100
61	0.9295	0.0124	0.9329	0.0145	0.9973	0.0089	0.2198	0.9589	0.9347	0.0093
62	0.9310	0.0122	0.9256	0.0133	1.0024	0.0081	0.2517	0.7817	0.9251	0.0096

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

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*   63    0.9349   0.0119   0.9291   0.0130   1.0030   0.0075   0.2553   0.9134        0.9278   0.0087   *
*   64    0.9205   0.0127   0.9553   0.0145   1.0231   0.0076   0.5181   0.7500        0.9199   0.0093   *
*   65    0.9313   0.0125   0.9155   0.0131   0.9893   0.0079   0.1116   1.0426        0.9284   0.0091   *
*   66    0.9395   0.0122   0.9276   0.0135   0.9968   0.0082   0.1073   1.0772        0.9324   0.0090   *
*   67    0.9483   0.0121   0.9458   0.0142   1.0087   0.0087   0.2338   0.9858        0.9378   0.0086   *
*   68    0.9431   0.0114   0.9478   0.0139   1.0027   0.0080   0.3315   0.8804        0.9439   0.0085   *
*   69    0.9268   0.0122   0.9272   0.0148   0.9916   0.0084   0.3204   0.8270        0.9340   0.0102   *
*   70    0.9480   0.0141   0.9246   0.0134   0.9835   0.0074  -0.0515   1.1876        0.9430   0.0105   *
*   71    0.9232   0.0151   0.9569   0.0167   1.0130   0.0094   0.2734   1.0548        0.9339   0.0103   *
*   72    0.9485   0.0138   0.9395   0.0138   0.9961   0.0082   0.1036   1.0984        0.9447   0.0095   *
*   73    0.9090   0.0134   0.9005   0.0145   0.9871   0.0088   0.2461   0.6694        0.9112   0.0115   *
*   74    0.9260   0.0118   0.9145   0.0135   0.9924   0.0082   0.2623   0.7693        0.9233   0.0096   *
*   75    0.9413   0.0122   0.9493   0.0137   1.0110   0.0080   0.3276   0.9196        0.9366   0.0079   *
*   76    0.9354   0.0115   0.9396   0.0139   1.0078   0.0084   0.2986   0.8857        0.9314   0.0088   *
*   77    0.9041   0.0117   0.9268   0.0151   1.0064   0.0086   0.4818   0.7575        0.9110   0.0085   *
*   78    0.9415   0.0115   0.9378   0.0135   1.0029   0.0083   0.2484   0.9104        0.9361   0.0090   *
*   79    0.9196   0.0118   0.9378   0.0136   1.0114   0.0083   0.3701   0.7806        0.9221   0.0088   *
*   80    0.9435   0.0113   0.9359   0.0125   0.9909   0.0073   0.2476   0.8885        0.9459   0.0087   *
*   81    0.9347   0.0107   0.9340   0.0139   1.0022   0.0081   0.3262   0.9097        0.9322   0.0087   *
*   82    0.9365   0.0144   0.9436   0.0154   0.9996   0.0076   0.2178   1.1815        0.9426   0.0105   *
*   83    0.9421   0.0129   0.9194   0.0126   0.9890   0.0076   0.0021   1.1353        0.9319   0.0092   *
*   84    0.9146   0.0115   0.9237   0.0149   1.0040   0.0082   0.4612   0.6578        0.9169   0.0094   *
*   85    0.9398   0.0112   0.9279   0.0127   0.9951   0.0071   0.2039   0.9628        0.9350   0.0094   *
*   86    0.9150   0.0128   0.9168   0.0140   1.0002   0.0081   0.2267   0.9265        0.9162   0.0098   *
*   87    0.9268   0.0150   0.9115   0.0148   0.9989   0.0075   0.1963   0.8652        0.9155   0.0122   *
*   88    0.9180   0.0120   0.9453   0.0132   1.0130   0.0078   0.3842   0.7888        0.9246   0.0086   *
*   89    0.9184   0.0124   0.9101   0.0125   0.9840   0.0071   0.2519   0.5945        0.9217   0.0104   *
*   90    0.9233   0.0127   0.9025   0.0134   0.9860   0.0075   0.1304   0.8784        0.9176   0.0108   *
*   91    0.9359   0.0119   0.9516   0.0148   1.0093   0.0080   0.4398   0.8921        0.9364   0.0090   *
*   92    0.9292   0.0121   0.9159   0.0132   0.9910   0.0077   0.2073   0.8861        0.9266   0.0096   *
*   93    0.9402   0.0115   0.9378   0.0128   1.0032   0.0073   0.2851   0.8707        0.9356   0.0090   *
*   94    0.9344   0.0115   0.9456   0.0140   1.0019   0.0084   0.2832   0.9231        0.9407   0.0087   *
*   95    0.9352   0.0127   0.9147   0.0138   0.9806   0.0079   0.1366   0.9134        0.9352   0.0107   *
*   96    0.9209   0.0134   0.9376   0.0141   1.0049   0.0084   0.2687   0.8925        0.9288   0.0092   *
*   97    0.9067   0.0135   0.9307   0.0160   1.0037   0.0092   0.4413   0.6620        0.9176   0.0106   *
*   98    0.9432   0.0123   0.9302   0.0145   0.9960   0.0079   0.2927   0.8608        0.9375   0.0105   *
*   99    0.9137   0.0107   0.9312   0.0138   1.0076   0.0088   0.4137   0.6576        0.9190   0.0077   *
*  100    0.9559   0.0113   0.9338   0.0126   0.9956   0.0069   0.1557   1.0458        0.9418   0.0091   *
*  101    0.9339   0.0118   0.9306   0.0134   1.0022   0.0074   0.2474   1.0442        0.9291   0.0089   *
*  102    0.9241   0.0118   0.9016   0.0130   0.9956   0.0086   0.1404   0.9052        0.9088   0.0090   *
*  103    0.9315   0.0134   0.9111   0.0136   0.9858   0.0079   0.1678   0.8515        0.9266   0.0102   *
*  104    0.9267   0.0123   0.9345   0.0154   0.9979   0.0086   0.3170   1.0249        0.9342   0.0092   *
*  105    0.9236   0.0126   0.9151   0.0138   0.9893   0.0083   0.1919   0.8749        0.9261   0.0102   *
*  106    0.8991   0.0132   0.9148   0.0149   1.0113   0.0084   0.4125   0.7450        0.8999   0.0102   *
*  107    0.9428   0.0120   0.9316   0.0147   0.9993   0.0083   0.3054   0.9145        0.9357   0.0097   *
*  108    0.9094   0.0144   0.9176   0.0151   0.9984   0.0093   0.2898   0.6919        0.9163   0.0114   *
*  109    0.9160   0.0120   0.9115   0.0142   0.9881   0.0080   0.3568   0.6876        0.9213   0.0105   *
*  110    0.9255   0.0120   0.9211   0.0146   0.9904   0.0080   0.3496   0.7460        0.9298   0.0107   *
*  111    0.9192   0.0119   0.9181   0.0138   0.9975   0.0079   0.2709   0.8695        0.9206   0.0095   *
*  112    0.9267   0.0119   0.8961   0.0119   0.9845   0.0073   0.1318   0.7111        0.9111   0.0099   *
*  113    0.9184   0.0119   0.8985   0.0133   0.9914   0.0080   0.2282   0.8004        0.9099   0.0100   *
*  114    0.9122   0.0130   0.9051   0.0130   0.9876   0.0083   0.2296   0.6337        0.9146   0.0101   *
*  115    0.9277   0.0115   0.9261   0.0134   0.9941   0.0075   0.3419   0.7219        0.9309   0.0096   *
*  116    0.9214   0.0118   0.9231   0.0137   0.9949   0.0075   0.2997   0.8945        0.9272   0.0095   *
*  117    0.9255   0.0133   0.9084   0.0145   0.9920   0.0083   0.1307   1.0806        0.9193   0.0104   *
*  118    0.9252   0.0117   0.9424   0.0122   1.0027   0.0071   0.3654   0.6279        0.9344   0.0087   *
*  119    0.9307   0.0110   0.9285   0.0137   1.0047   0.0081   0.3850   0.7430        0.9259   0.0089   *
*  120    0.9355   0.0132   0.9535   0.0150   1.0122   0.0085   0.3537   0.8683        0.9366   0.0098   *
*  121    0.9358   0.0112   0.9449   0.0136   1.0093   0.0075   0.3685   0.8108        0.9340   0.0087   *
*  122    0.9386   0.0116   0.9469   0.0136   1.0124   0.0081   0.3579   0.8001        0.9340   0.0087   *
*  123    0.9213   0.0129   0.9337   0.0153   1.0036   0.0087   0.3232   0.9504        0.9262   0.0097   *
*  124    0.9313   0.0132   0.9391   0.0138   1.0028   0.0085   0.2088   0.8743        0.9350   0.0098   *
*  125    0.9413   0.0131   0.9357   0.0137   0.9972   0.0081   0.1981   0.8731        0.9392   0.0099   *
*  126    0.9356   0.0113   0.9377   0.0124   0.9980   0.0074   0.2058   0.9977        0.9392   0.0081   *
*  127    0.9185   0.0112   0.9212   0.0135   1.0087   0.0084   0.3678   0.7453        0.9137   0.0090   *
*  128    0.9142   0.0131   0.9229   0.0139   0.9912   0.0079   0.2869   0.7784        0.9272   0.0100   *
*  129    0.9295   0.0118   0.9479   0.0141   1.0103   0.0086   0.3769   0.8090        0.9326   0.0089   *
*  130    0.9336   0.0104   0.9432   0.0139   1.0059   0.0080   0.4195   0.8109        0.9344   0.0079   *
*  131    0.9355   0.0123   0.9379   0.0137   1.0003   0.0072   0.2500   1.0264        0.9371   0.0095   *
*  132    0.9218   0.0126   0.9409   0.0123   1.0009   0.0076   0.2611   0.8039        0.9352   0.0084   *
*  133    0.9184   0.0125   0.9196   0.0147   1.0002   0.0091   0.2331   0.9375        0.9191   0.0093   *
*  134    0.9341   0.0120   0.9178   0.0140   0.9991   0.0074   0.1709   1.1236        0.9215   0.0097   *
*  135    0.9394   0.0105   0.9188   0.0138   0.9926   0.0080   0.2821   0.8896        0.9312   0.0092   *
*  136    0.9556   0.0107   0.9384   0.0133   1.0045   0.0081   0.1978   1.0134        0.9372   0.0085   *
*  137    0.9500   0.0113   0.9603   0.0133   1.0033   0.0074   0.3475   0.8754        0.9538   0.0087   *
*  138    0.9476   0.0107   0.9420   0.0138   1.0096   0.0077   0.4184   0.7942        0.9367   0.0092   *
*  139    0.9485   0.0120   0.9310   0.0130   0.9931   0.0074   0.1376   0.9936        0.9402   0.0097   *
*  140    0.9101   0.0132   0.9243   0.0150   0.9927   0.0085   0.3846   0.7448        0.9243   0.0106   *
*  141    0.9222   0.0119   0.9245   0.0134   0.9932   0.0076   0.3820   0.6121        0.9278   0.0099   *
*  142    0.9271   0.0111   0.9417   0.0134   1.0027   0.0084   0.3761   0.6994        0.9343   0.0084   *
*                                                                                                          *
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*                                                  NEUTRON    BALANCE    SUMMARY                              *
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*          ************ INDIVIDUAL STAGE COUNTS ************  *  ***************** CUMULATIVE COUNTS ***************  *
*  STAGE  SAMPLE SCATTER CAPTURE FISSION CHILDREN N,2N ESCAPE  *  SAMPLE  SCATTER  CAPTURE FISSION CHILDREN N,2N ESCAPE  *
*************************************************************************************************************
*                                                             *                                                           *
*   -3    7709  303968   4900   2812   6900    3     0       *                                                           *
*   -2    9933  388745   6234   3708   9105    8     0       *                                                           *
*   -1    9450  371158   5851   3609   8860   10     0       *                                                           *
*    0    9614  378133   6041   3580   8783    7     0       *                                                           *
*    1    9536  370098   5970   3574   8769    8     0       *   9536  370098   5970   3574   8769    8     0            *
*    2   11231  423892   6952   4288  10527    9     0       *  20767  793990  12922   7862  19295   17     0            *
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Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

*	3	10377	411650	6410	3978	9774	11	0	*	31144	1205640	19332	11840	29069	28	0	*
*	4	10321	396951	6381	3952	9708	12	0	*	41465	1602591	25713	15792	38777	40	0	*
*	5	9184	358888	5789	3402	8354	7	0	*	50649	1961479	31502	19194	47131	47	0	*
*	6	10490	404280	6490	4008	9846	8	0	*	61139	2365759	37992	23202	56977	55	0	*
*	7	10082	395128	6281	3811	9366	10	0	*	71221	2760887	44273	27013	66343	65	0	*
*	8	9689	377504	6046	3653	8982	10	0	*	80910	3138391	50319	30666	75326	75	0	*
*	9	9379	374832	5915	3475	8537	11	0	*	90289	3513223	56234	34141	83862	86	0	*
*	10	9104	356214	5713	3399	8347	8	0	*	99393	3869437	61947	37540	92209	94	0	*
*	11	10159	397342	6299	3874	9525	14	0	*	109552	4266779	68246	41414	101734	108	0	*
*	12	9897	382650	6143	3761	9238	7	0	*	119449	4649429	74389	45175	110972	115	0	*
*	13	9091	357957	5714	3389	8328	12	0	*	128540	5007386	80103	48564	119300	127	0	*
*	14	9295	369206	5816	3484	8558	5	0	*	137835	5376592	85919	52048	127857	132	0	*
*	15	9193	362142	5766	3435	8440	8	0	*	147028	5738734	91685	55483	136297	140	0	*
*	16	11400	442837	7008	4402	10816	10	0	*	158428	6181571	98693	59885	147113	150	0	*
*	17	11079	439274	6847	4238	10411	6	0	*	169507	6620845	105540	64123	157524	156	0	*
*	18	9655	387133	6016	3643	8942	4	0	*	179162	7007978	111556	67766	166466	160	0	*
*	19	12256	479280	7532	4732	11624	8	0	*	191418	7487258	119088	72498	178089	168	0	*
*	20	10435	413150	6501	3944	9699	10	0	*	201853	7900408	125589	76442	187789	178	0	*
*	21	10596	408462	6580	4028	9891	12	0	*	212449	8308870	132169	80470	197680	190	0	*
*	22	11059	429889	6817	4251	10440	9	0	*	223508	8738759	138986	84721	208120	199	0	*
*	23	10692	410293	6581	4125	10133	14	0	*	234200	9149052	145567	88846	218253	213	0	*
*	24	10046	387383	6230	3820	9384	4	0	*	244246	9536435	151797	92666	227637	217	0	*
*	25	10651	414808	6578	4081	10023	8	0	*	254897	9951243	158375	96747	237660	225	0	*
*	26	9471	375338	5926	3556	8733	11	0	*	264368	10326581	164301	100303	246394	236	0	*
*	27	9755	385220	6096	3665	8996	6	0	*	274123	10711801	170397	103968	255390	242	0	*
*	28	9954	381461	6187	3781	9292	14	0	*	284077	11093262	176584	107749	264682	256	0	*
*	29	9731	374928	6072	3670	9009	11	0	*	293808	11468190	182656	111419	273691	267	0	*
*	30	11135	441523	6874	4270	10493	9	0	*	304943	11909713	189530	115689	284184	276	0	*
*	31	10997	424271	6759	4248	10428	10	0	*	315940	12333984	196289	119937	294612	286	0	*
*	32	9548	366071	5941	3610	8876	3	0	*	325488	12700055	202230	123547	303487	289	0	*
*	33	10246	399032	6361	3893	9568	8	0	*	335734	13099087	208591	127440	313055	297	0	*
*	34	9957	385519	6159	3801	9334	3	0	*	345691	13484606	214750	131241	322389	300	0	*
*	35	9793	386211	6088	3711	9107	6	0	*	355484	13870817	220838	134952	331496	306	0	*
*	36	10613	409387	6560	4060	9964	7	0	*	366097	14280204	227398	139012	341460	313	0	*
*	37	10977	433629	6717	4269	10486	9	0	*	377074	14713833	234115	143281	351946	322	0	*
*	38	8678	342907	5462	3224	7932	8	0	*	385752	15056740	239577	146505	359878	330	0	*
*	39	10165	392203	6301	3866	9499	2	0	*	395917	15448943	245878	150371	369377	332	0	*
*	40	9784	379996	6146	3649	8966	11	0	*	405701	15828939	252024	154020	378343	343	0	*
*	41	11756	454332	7202	4564	11198	10	0	*	417457	16283271	259226	158584	389541	353	0	*
*	42	10567	411971	6523	4052	9949	8	0	*	428024	16695242	265749	162636	399490	361	0	*
*	43	9802	382644	6130	3679	9034	7	0	*	437826	17077886	271879	166315	408524	368	0	*
*	44	11285	447123	6933	4359	10695	7	0	*	449111	17525009	278812	170674	419218	375	0	*
*	45	10776	420644	6637	4147	10178	8	0	*	459887	17945653	285449	174821	429396	383	0	*
*	46	9187	355157	5795	3400	8355	8	0	*	469074	18300810	291244	178221	437752	391	0	*
*	47	9320	369224	5820	3507	8609	7	0	*	478394	18670034	297064	181728	446361	398	0	*
*	48	9125	358547	5732	3404	8360	11	0	*	487519	19028581	302796	185132	454720	409	0	*
*	49	9833	387945	6084	3757	9236	8	0	*	497352	19416526	308880	188889	463956	417	0	*
*	50	10863	424013	6680	4192	10302	9	0	*	508215	19840539	315560	193081	474258	426	0	*
*	51	9265	365015	5743	3528	8670	6	0	*	517480	20205554	321303	196609	482928	432	0	*
*	52	10751	422652	6629	4130	10159	8	0	*	528231	20628206	327932	200739	493087	440	0	*
*	53	10044	383143	6247	3803	9345	6	0	*	538275	21011349	334179	204542	502432	446	0	*
*	54	9340	364276	5853	3493	8578	6	0	*	547615	21375625	340032	208035	511010	452	0	*
*	55	10180	387203	6310	3878	9522	8	0	*	557795	21762828	346342	211913	520532	460	0	*
*	56	9401	360928	5889	3519	8648	7	0	*	567196	22123756	352231	215432	529180	467	0	*
*	57	11368	445909	7026	4350	10697	8	0	*	578564	22569665	359257	219782	539876	475	0	*
*	58	11943	467670	7282	4669	11469	8	0	*	590507	23037335	366539	224451	551346	483	0	*
*	59	10103	387518	6305	3802	9335	4	0	*	600610	23424853	372844	228253	560680	487	0	*
*	60	10551	413239	6465	4094	10054	8	0	*	611161	23838092	379309	232347	570735	495	0	*
*	61	9750	377179	6063	3691	9062	4	0	*	620911	24215271	385372	236038	579797	499	0	*
*	62	9538	373044	5928	3614	8880	4	0	*	630449	24588315	391300	239652	588677	503	0	*
*	63	10320	401207	6396	3930	9648	6	0	*	640769	24989522	397696	243582	598325	509	0	*
*	64	9653	381037	6045	3616	8886	8	0	*	650422	25370559	403741	247198	607210	517	0	*
*	65	10529	403921	6550	3992	9805	13	0	*	660951	25774480	410291	251190	617016	530	0	*
*	66	10152	389189	6284	3881	9538	12	0	*	671103	26163669	416575	255071	626554	542	0	*
*	67	10415	415196	6401	4017	9876	3	0	*	681518	26578865	422976	259088	636430	545	0	*
*	68	10299	395590	6355	3954	9713	10	0	*	691817	26974455	429331	263042	646144	555	0	*
*	69	9721	376525	6063	3668	9009	10	0	*	701538	27350980	435394	266710	655153	565	0	*
*	70	9747	373318	5996	3762	9240	11	0	*	711285	27724298	441390	270472	664393	576	0	*
*	71	9406	364063	5878	3534	8683	6	0	*	720691	28088361	447268	274006	673077	582	0	*
*	72	10157	390441	6241	3923	9634	7	0	*	730848	28478802	453509	277929	682710	589	0	*
*	73	8831	342957	5571	3271	8028	11	0	*	739679	28821759	459080	281200	690738	600	0	*
*	74	9587	365668	5976	3618	8878	7	0	*	749266	29187427	465056	284818	699616	607	0	*
*	75	10106	393760	6241	3874	9512	9	0	*	759372	29581187	471297	288692	709128	616	0	*
*	76	10476	407282	6505	3984	9799	13	0	*	769848	29988469	477802	292676	718927	629	0	*
*	77	8945	349689	5657	3292	8088	4	0	*	778793	30338158	483459	295968	727015	633	0	*
*	78	10529	409877	6503	4034	9913	8	0	*	789322	30748035	489962	300002	736928	641	0	*
*	79	9755	381335	6116	3651	8971	12	0	*	799077	31129370	496078	303653	745899	653	0	*
*	80	10691	402590	6590	4106	10087	5	0	*	809768	31531960	502668	307759	755986	658	0	*
*	81	10775	421272	6680	4097	10072	2	0	*	820543	31953232	509348	311856	766058	660	0	*
*	82	9152	353106	5666	3489	8570	3	0	*	829695	32306338	515014	315345	774628	663	0	*
*	83	10506	405308	6492	4028	9897	14	0	*	840201	32711646	521506	319373	784525	677	0	*
*	84	9627	376797	6047	3588	8804	8	0	*	849828	33088443	527553	322961	793330	685	0	*
*	85	10743	418817	6642	4110	10096	9	0	*	860571	33507260	534195	327071	803426	694	0	*
*	86	9061	353704	5692	3372	8291	3	0	*	869632	33860964	539887	330443	811717	697	0	*
*	87	8808	344454	5495	3325	8164	12	0	*	878440	34205418	545382	333768	819881	709	0	*
*	88	9702	386274	6084	3628	8906	10	0	*	888142	34591692	551466	337396	828787	719	0	*
*	89	9882	383794	6206	3691	9076	15	0	*	898024	34975486	557672	341087	837863	734	0	*
*	90	9375	368735	5859	3522	8656	6	0	*	907399	35344221	563531	344609	846519	740	0	*
*	91	9937	381849	6159	3789	9300	11	0	*	917336	35726070	569690	348398	855818	751	0	*
*	92	9655	375033	6013	3651	8972	9	0	*	926991	36101103	575703	352049	864790	760	0	*
*	93	10470	414806	6471	4010	9844	10	0	*	937461	36515909	582174	356059	874634	770	0	*
*	94	10145	395351	6292	3863	9479	10	0	*	947606	36911260	588466	359922	884113	780	0	*
*	95	10141	396303	6290	3858	9484	6	0	*	957747	37307563	594756	363780	893597	786	0	*
*	96	9144	354763	5726	3428	8420	10	0	*	966891	37662326	600482	367208	902017	796	0	*
*	97	8700	339068	5497	3213	7888	10	0	*	975591	38001394	605979	370421	909905	806	0	*

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
*    98    10503  419408   6479   4034   9907   10     0   *   986094 38420802  612458  374455  919812   816     0   *
*    99     9490  373098   5968   3532   8671   10     0   *   995584 38793900  618426  377987  928482   826     0   *
*   100    11597  457272   7099   4513  11085   15     0   *  1007181 39251172  625525  382500  939567   841     0   *
*   101    10223  401422   6348   3886   9548   11     0   *  1017404 39652594  631873  386386  949115   852     0   *
*   102    10794  428171   6739   4062   9974    7     0   *  1028198 40080765  638612  390448  959089   859     0   *
*   103     9424  366423   5856   3575   8778    7     0   *  1037622 40447188  644468  394023  967868   866     0   *
*   104     9613  379999   6000   3625   8909   12     0   *  1047235 40827187  650468  397648  976776   878     0   *
*   105    10085  394389   6299   3794   9314    8     0   *  1057320 41221576  656767  401442  986091   886     0   *
*   106     8326  331291   5288   3046   7486    8     0   *  1065646 41552867  662055  404488  993577   894     0   *
*   107    10726  420214   6620   4121  10112   14     0   *  1076372 41973081  668675  408609 1003689   908     0   *
*   108     8329  334121   5251   3083   7574    5     0   *  1084701 42307202  673926  411692 1011263   913     0   *
*   109     9668  376839   6074   3604   8855   10     0   *  1094369 42684041  680000  415296 1020119   923     0   *
*   110    10170  391351   6344   3832   9412    6     0   *  1104539 43075392  686344  419128 1029531   929     0   *
*   111     9621  377706   6028   3598   8844    5     0   *  1114160 43453098  692372  422726 1038375   934     0   *
*   112     9806  385311   6112   3700   9087    6     0   *  1123966 43838409  698484  426426 1047462   940     0   *
*   113     9480  377829   5944   3547   8706   11     0   *  1133446 44216238  704428  429973 1056168   951     0   *
*   114     9165  357364   5771   3400   8360    6     0   *  1142611 44573602  710199  433373 1064528   957     0   *
*   115    10419  413664   6491   3939   9666   11     0   *  1153030 44987266  716690  437312 1074193   968     0   *
*   116     9795  375112   6126   3676   9025    7     0   *  1162825 45362378  722816  440988 1083218   975     0   *
*   117     9341  360925   5831   3519   8645    9     0   *  1172166 45723303  728647  444507 1091864   984     0   *
*   118    10422  398939   6501   3929   9643    8     0   *  1182588 46122242  735148  448436 1101506   992     0   *
*   119    10291  405633   6398   3902   9578    9     0   *  1192879 46527875  741546  452338 1111084  1001     0   *
*   120     9525  371059   5900   3630   8911    5     0   *  1202404 46898934  747446  455968 1119995  1006     0   *
*   121    10765  415781   6673   4101  10074    9     0   *  1213169 47314715  754119  460069 1130068  1015     0   *
*   122    10070  393674   6224   3851   9452    5     0   *  1223239 47708389  760343  463920 1139520  1020     0   *
*   123     9285  357912   5816   3484   8555   14     0   *  1232524 48066301  766159  467404 1148075  1034     0   *
*   124     9810  378858   6099   3718   9136    7     0   *  1242334 48445159  772258  471122 1157211  1041     0   *
*   125     9798  382815   6052   3754   9222    7     0   *  1252132 48827974  778310  474876 1166433  1048     0   *
*   126    10566  402549   6547   4028   9886    9     0   *  1262698 49230523  784857  478904 1176319  1057     0   *
*   127     9934  388706   6228   3717   9125   11     0   *  1272632 49619229  791085  482621 1185444  1068     0   *
*   128     9068  354462   5701   3373   8290    6     0   *  1281700 49973691  796786  485994 1193733  1074     0   *
*   129     9682  381840   6028   3662   9000    8     0   *  1291382 50355531  802814  489656 1202733  1082     0   *
*   130    10651  414819   6614   4049   9944   12     0   *  1302033 50770350  809428  493705 1212677  1094     0   *
*   131    10541  405168   6531   4018   9861    8     0   *  1312574 51175518  815959  497723 1222538  1102     0   *
*   132     9645  380049   6028   3623   8891    5     0   *  1322219 51555567  821987  501346 1231429  1107     0   *
*   133     9425  370050   5905   3527   8656    7     0   *  1331644 51925617  827892  504873 1240084  1114     0   *
*   134    10136  388817   6293   3853   9468   10     0   *  1341780 52314434  834185  508726 1249553  1124     0   *
*   135    10866  422519   6718   4154  10208    6     0   *  1352646 52736953  840903  512880 1259760  1130     0   *
*   136    11492  450746   7026   4475  10982    9     0   *  1364138 53187699  847929  517355 1270742  1139     0   *
*   137    11319  433364   6960   4375  10753   16     0   *  1375457 53621063  854889  521730 1281495  1155     0   *
*   138    11593  443518   7123   4475  10985    5     0   *  1387050 54064581  862012  526205 1292481  1160     0   *
*   139    10690  422102   6568   4127  10139    5     0   *  1397740 54486683  868580  530332 1302620  1165     0   *
*   140     9075  349495   5723   3360   8259    8     0   *  1406815 54836178  874303  533692 1310879  1173     0   *
*   141     9566  368040   5986   3591   8822   11     0   *  1416381 55204218  880289  537283 1319701  1184     0   *
*   142     9911  386935   6173   3745   9188    7     0   *  1426292 55591153  886462  541028 1328889  1191     0   *
*                                                                                                                      *
*************************************************************************************************************************
1PLOT OF CUMULATIVE K(THREE) ESTIMATOR AGAINST STAGE NUMBER
-----------------------------------------------------------

 0.900     0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960
   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----I
  1 ----------------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                                                           I--X--I
 32                                                           I--X--I
 33                                                            I--X--I
 34                                                            I--X--I
 35                                                           I--X--I
 36                                                            I--X--I
 37                                                            I--X--I
 38                                                           I--X--I
 39                                                            I--X--I
 40                                                           I--X--I
 41                                                            I--X--I
 42                                                            I--X--I
 43                                                            I--X--I
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
 44                                                    I--X--I
 45                                                    I--X--I
 46                                                    I--X--I
 47                                                    I--X--I
 48                                                   I--X--I
 49                                                   I--X--I
 50                                                    I--X--I
 51                                                    I--X--I
 52                                                    I--X--I
 53                                                    I--X--I
 54                                                    I--X--I
 55                                                    I--X--I
 56                                                    I--X--I
 57                                                     I-X-I
 58                                                      I-X-I
 59                                                      I-X-I
 60                                                      I-X-I
 61                                                      I-X-I
 62                                                      I-X-I
 63                                                      I-X-I
 64                                                      I-X-I
 65                                                      I-X-I
 66                                                      I-X-I
 67                                                      I-X-I
 68                                                      I-X-I
 69                                                      I-X-I
 70                                                       I-X-I
 71                                                       I-X-I
 72                                                       I-X-I
 73                                                      I-X-I
 74                                                      I-X-I
 75                                                      I-X-I
 76                                                      I-X-I
 77                                                      I-X-I
 78                                                      I-X-I
 79                                                      I-X-I
 80                                                      I-X-I
 81                                                      I-X-I
 82                                                      I-X-I
 83                                                      I-X-I
 84                                                      I-X-I
 85                                                      I-X-I
 86                                                      I-X-I
 87                                                      I-X-I
 88                                                     I-X-I
 89                                                     I-X-I
 90                                                     I-X-I
 91                                                     I-X-I
 92                                                     I-X-I
 93                                                     I-X-I
 94                                                     I-X-I
 95                                                     I-X-I
 96                                                     I-X-I
 97                                                     I-X-I
 98                                                     I-X-I
 99                                                     I-X-I
100                                                     I-X-I
101                                                     I-X-I
102                                                     I-X-I
103                                                     I-X-I
104                                                     I-X-I
105                                                     I-X-I
106                                                    I-X-I
107                                                    I-X-I
108                                                    I-X-I
109                                                    I-X-I
110                                                    I-X-I
111                                                    I-X-I
112                                                    I-X-I
113                                                   I-X-I
114                                                   I-X-I
115                                                   I-X-I
116                                                   I-X-I
117                                                   I-X-I
118                                                   I-X-I
119                                                   I-X-I
120                                                   I-X-I
121                                                   I-X-I
122                                                   I-X-I
123                                                   I-X-I
124                                                   I-X-I
125                                                   I-X-I
126                                                   I-X-I
127                                                   I-X-I
128                                                   I-X-I
129                                                   I-X-I
130                                                   I-X-I
131                                                   I-X-I
132                                                   I-X-I
133                                                   I-X-I
134                                                   I-X-I
135                                                   I-X-I
136                                                   I-X-I
137                                                   I-X-I
138                                                   I-X-I
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
139                                                   I-X-I
140                                                   I-X-I
141                                                   I-X-I
142                                                   I-X-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----I----I----I
 0.900     0.905     0.910     0.915     0.920     0.925     0.930     0.935     0.940     0.945     0.950     0.955     0.960
```

```
*****************************************************************************
*****************************************************************************
**.........................................................................**
**.......                                                         .......**
**.......    FINAL VALUE OF K(THREE)  =  0.9313    ( STDV     = 0.0008 )   .......**
**.......                                                         .......**
**.........................................................................**
*****************************************************************************
*****************************************************************************
```

MATERIAL 1	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	24697	2031	3793	1934	8	0	32463
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	4.61608E-01	6.94569E-02	1.70799E-01	1.94914E+00	8.60120E+00	1.34114E+01	4.93664E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.80124E-03	4.55603E-06	2.96161E-07	1.40450E+00	8.48512E+00	1.33863E+01	9.33308E-04

MATERIAL 2	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	5351	33	0	165	1	0	5550
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	4.64942E-01	1.40058E-01	0.00000E+00	3.43412E+00	1.03403E+01	0.00000E+00	5.52029E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	4.80826E-03	2.44472E-05	0.00000E+00	3.09289E+00	1.02145E+01	0.00000E+00	5.65020E-03

MATERIAL 3	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	340381	1136	0	10	0	0	341527
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.13264E-01	1.32774E-01	0.00000E+00	8.38188E+00	0.00000E+00	0.00000E+00	1.13561E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	5.27875E-06	6.37601E-08	0.00000E+00	8.28618E+00	0.00000E+00	0.00000E+00	5.20383E-06

MATERIAL 4	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	4228	10	0	0	0	0	4238
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.77507E-01	2.89506E-01	0.00000E+00	8.40470E+00	0.00000E+00	0.00000E+00	1.78119E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	4.27597E-05	1.70817E-07	0.00000E+00	8.32974E+00	0.00000E+00	0.00000E+00	4.22101E-05

MATERIAL 5	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	445	4	0	12	0	0	461
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	4.07169E-01	9.98868E-02	0.00000E+00	3.41218E+00	1.11034E+01	0.00000E+00	4.84884E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	1.89588E-03	1.00722E-05	0.00000E+00	3.07082E+00	1.09153E+01	0.00000E+00	2.21200E-03

MATERIAL 6	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	28	0	0	1	0	0	29
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	4.22067E-01	2.36067E-03	0.00000E+00	3.25322E+00	0.00000E+00	0.00000E+00	4.92761E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.30975E-03	3.47591E-06	0.00000E+00	2.92416E+00	0.00000E+00	0.00000E+00	2.65788E-03

MATERIAL 7	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	371	7	0	1	0	0	379
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	7.18499E-02	5.57958E-03	0.00000E+00	3.09424E+00	0.00000E+00	0.00000E+00	7.65652E-02
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	1.55491E-06	4.41302E-08	0.00000E+00	2.61663E+00	0.00000E+00	0.00000E+00	1.50181E-06

MATERIAL 8	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	78	1	0	0	0	0	79
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	3.76073E-02	9.91264E-08	0.00000E+00	4.26081E+00	0.00000E+00	0.00000E+00	4.11879E-02
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.21942E-07	2.81823E-08	0.00000E+00	3.62755E+00	0.00000E+00	0.00000E+00	2.19275E-07

MATERIAL 9	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	2178	74	0	72	0	0	2324

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	2.99537E-01	1.04150E-01	0.00000E+00	2.99848E+00	9.20106E+00	0.00000E+00	3.76362E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	5.48850E-04	1.79516E-07	0.00000E+00	2.47153E+00	9.20106E+00	0.00000E+00	5.50012E-04
MATERIAL 10	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	804	2438	0	11	0	0	3253
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	5.28858E-01	3.13167E-03	0.00000E+00	3.61397E+00	0.00000E+00	0.00000E+00	1.44993E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	1.35957E-02	2.73188E-07	0.00000E+00	3.17318E+00	0.00000E+00	0.00000E+00	4.17480E-06
MATERIAL 11	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	236	2	0	9	0	0	247
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	6.70501E-01	5.22666E-01	0.00000E+00	3.37984E+00	0.00000E+00	0.00000E+00	7.64902E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	5.68548E-02	8.69063E-07	0.00000E+00	2.97044E+00	0.00000E+00	0.00000E+00	6.10537E-02
MATERIAL 12	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	4414	348	0	97	0	0	4859
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.99235E-01	2.66845E-02	0.00000E+00	2.96924E+00	1.28827E+01	0.00000E+00	2.42245E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	3.51658E-05	6.17651E-08	0.00000E+00	2.43490E+00	1.28708E+01	0.00000E+00	2.78969E-05
MATERIAL 13	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	10	1	0	0	0	0	11
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.48663E-01	2.90288E-07	0.00000E+00	2.78299E+00	0.00000E+00	0.00000E+00	1.72410E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	6.69739E-06	4.38876E-08	0.00000E+00	2.03083E+00	0.00000E+00	0.00000E+00	5.06549E-06
MATERIAL 14	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	1178	37	0	33	0	0	1248
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	5.24631E-01	8.37436E-02	0.00000E+00	3.42078E+00	0.00000E+00	0.00000E+00	5.88168E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.18188E-03	5.05591E-08	0.00000E+00	3.02060E+00	0.00000E+00	0.00000E+00	1.92676E-03
MATERIAL 15	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	535	46	0	9	0	0	590
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.60907E-01	1.80555E-02	0.00000E+00	2.96621E+00	0.00000E+00	0.00000E+00	1.91034E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	1.85183E-05	6.07273E-08	0.00000E+00	2.33399E+00	0.00000E+00	0.00000E+00	1.41039E-05
MATERIAL 16	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	489	19	0	10	0	0	518
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.99776E-01	5.03783E-02	0.00000E+00	2.57752E+00	8.44186E+00	0.00000E+00	2.39550E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.61709E-04	1.68898E-07	0.00000E+00	1.98260E+00	8.44186E+00	0.00000E+00	2.35646E-04
MATERIAL 17	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	605	1	0	9	0	0	615
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	3.19062E-01	3.37821E-02	0.00000E+00	3.16794E+00	9.51841E+00	0.00000E+00	3.61278E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	8.12752E-04	2.93113E-07	0.00000E+00	2.67219E+00	9.44834E+00	0.00000E+00	9.01029E-04
MATERIAL 18	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	627	24	0	0	0	0	651
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	1.03265E-01	1.20080E-02	0.00000E+00	3.68962E+00	0.00000E+00	0.00000E+00	1.01454E-01
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	2.68269E-05	7.99855E-08	0.00000E+00	2.95077E+00	0.00000E+00	0.00000E+00	2.18204E-05
MATERIAL 19	ELASTIC	CAPTURE	FISSION	(N,N*)	(N,2N)	(N,3N)	TOTAL
TOTAL NO. OF EVENTS	733	3	0	0	0	0	736
MEAN ENERGY OF NEUTRONS CAUSING EVENTS (MEV)	7.83762E-02	8.00542E-02	0.00000E+00	7.67502E+00	0.00000E+00	0.00000E+00	7.85274E-02
MEAN LOG(ENERGY) OF NEUTRONS CAUSING EVENTS (MEV)	3.08455E-06	5.90435E-08	0.00000E+00	7.67253E+00	0.00000E+00	0.00000E+00	3.03881E-06

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (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 = 0.5805

 LEAKAGE ......................... C = 1        FRACTION OF NEUTRONS LEAKING = 0.0000

 RESONANCE ABSORPTION ............ D = 3        FRACTION OF ABSORPTIONS IN RESONANCE PARTITION = 0.2563

 FAST FISSION .................... E = 1        MEASURE OF FAST FISSION = 0.0284

 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    6 FOR    46 STAGES

          The first  20 stages that this occurred are:

            -1    2    3    4    5    6   10   11   29   30   31   32   33   34   49   52   57   58   60

        NO PARTICLE TRACKS IN ZONE   10 FOR   115 STAGES

          The first  20 stages that this occurred are:

            -1    0    1    2    3    4    5    7    8   10   11   13   14   15   19   20   21   22   23

        NO PARTICLE TRACKS IN ZONE   16 FOR    26 STAGES

          The first  20 stages that this occurred are:

             7    8   15   27   30   32   52   59   60   77  112  114  115  116  117  118  124  128  130

        NO PARTICLE TRACKS IN ZONE   21 FOR    68 STAGES

          The first  20 stages that this occurred are:

            -1    0    2    3    4    5   11   13   15   24   25   26   27   28   29   30   31   32   33

        NO PARTICLE TRACKS IN ZONE   26 FOR    86 STAGES

          The first  20 stages that this occurred are:

            -2    0    1    2    5    7   13   15   16   21   22   24   25   27   28   30   31   33   34

        NO PARTICLE TRACKS IN ZONE   78 FOR   146 STAGES

          The first  20 stages that this occurred are:

            -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15

        NO PARTICLE TRACKS IN ZONE   81 FOR   146 STAGES

          The first  20 stages that this occurred are:
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE   84 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE   87 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE   90 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE   93 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE   96 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE  102 FOR STAGES:
      56   59   77  118  122  128  129  130  131  132  134  135  137  140
NO PARTICLE TRACKS IN ZONE  103 FOR   138 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   15   16
NO PARTICLE TRACKS IN ZONE  104 FOR   119 STAGES
     The first  20 stages that this occurred are:
      -3   -1    0    2    4    5    6    7    8    9   11   12   13   15   16   18   19   20   21
NO PARTICLE TRACKS IN ZONE  110 FOR   119 STAGES
     The first  20 stages that this occurred are:
      -3   -2    0    1    2    3    4    5    6    7    8   10   12   13   14   15   17   19   20
NO PARTICLE TRACKS IN ZONE  115 FOR   139 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE  116 FOR    95 STAGES
     The first  20 stages that this occurred are:
      -1    0    2    4    5    7    8    9   11   16   18   19   20   21   22   24   25   26   29
NO PARTICLE TRACKS IN ZONE  117 FOR   138 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE  118 FOR    28 STAGES
     The first  20 stages that this occurred are:
       2    4    5    7   32   52   55   56   58   61   74   76   77   81  117  118  120  122  128
NO PARTICLE TRACKS IN ZONE  119 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE  120 FOR   146 STAGES
     The first  20 stages that this occurred are:
      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15
NO PARTICLE TRACKS IN ZONE  121 FOR   145 STAGES
     The first  20 stages that this occurred are:
      -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16
```

Figure 6.7.2-1 MONK8a Output Summary for CY Transfer Cask – Maximum Reactivity Condition (Continued)

```
NO PARTICLE TRACKS IN ZONE  122 FOR   141 STAGES

    The first  20 stages that this occurred are:

      -3   -2   -1    0    1    2    3    4    5    6    7    8    9   10   11   12   13   14   15

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                 :    64
    A(SCORE)              :   1.02
    Difference in SD units:   3.05

4.  TEST FOR NORMALITY OF INDIVIDUAL STAGE ESTIMATORS
    (Level of significance > 1% for pass)

    K(COLL)        PASSED  Level of significance = 34.79%
    K(SCORE)       PASSED  Level of significance =  8.65%
    K(THREE)       PASSED  Level of significance =  5.57%

5.  CHI-SQUARED TEST FOR ADEQUATE SETTLING

              No. of            Chi squared per        Probability
              Settling stages   degree of freedom
    K(COLL)      4                   1.088                0.3551       PASSED
    K(SCORE)     4                   1.325                0.1546       PASSED
    K(THREE)     4                   1.653                0.0364       PASSED

    FINAL VALUE OF K(THREE)  =  0.9313    ( STDV     = 0.0008 )

    K(THREE) + (3 x STDV)    =  0.9337

    ********************************************************
    * MONK PROCESSING COMPLETED TO STAGE     3              *
    ********************************************************
```

Appendix 6.A CRITICALITY EVALUATION – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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6.A CRITICALITY EVALUATION OF THE MPC-LACBWR STORAGE SYSTEM

This appendix documents the method, input, and result of the criticality analysis of the LACBWR payload in the NAC-MPC system. The results demonstrate that the effective neutron multiplication factor, k_{eff}, of the system under normal conditions, or off-normal and accident events, is less than 0.95 including biases and uncertainties. The MPC-LACBWR system design meets the criticality requirements of 10 CFR 72 [A1] and Chapter 6 of NUREG-1536 [A2].

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6.A.1 Discussion and Results

The cask system consists of a TSC (Transportable Storage Canister), a transfer cask, and a concrete cask. The system is designed to safely store up to 68 LACBWR fuel assemblies of which up to 32 may be classified as damaged and be placed into damaged fuel cans (DFCs). The TSC is comprised of a stainless steel canister and a basket within which fuel is loaded. The DFC provides a screened container to prevent gross fissile material release into the TSC cavity from failed fuel rod clad. The TSC is loaded into the concrete cask for storage. A transfer cask is used for handling the TSC during loading of spent fuel. Fuel is loaded into the TSC contained within the transfer cask underwater in the spent fuel pool. Once loaded with fuel, the TSC closure lid is welded and the TSC is drained, dried and backfilled with helium. The transfer cask is then used to move the TSC into or out of the concrete cask. The transfer cask provides shielding during the TSC loading and transfer operations.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the TSC during the initial stages of fuel transfer. During draining and drying operations, moderator with varying density is present. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Normal, off-normal, and accident condition optimum moderator density studies cover pellet clad flooding, preferential flooding (i.e., independent variation in the DFC and TSC and outside the TSC) and partial flooding (i.e, variations in moderator elevations). Normal condition structural analysis in Section 3.A and off-normal and accident structural analysis of the fuel, basket, TSC and cask in Section 11.A demonstrate that no operating condition induces geometry variations in the system beyond those allowed by the manufacturing tolerances.

Structural analyses demonstrate that the TSC confinement boundary remains intact through all storage operating conditions. Therefore, moderator is not present in the TSC while it is in the concrete cask. However, access to the concrete cask interior environment is possible via the air inlets and outlets and the heat transfer annulus between the TSC and the cask steel liner. This access provides paths for moderator intrusion during a flood. Under off-normal and accident conditions, moderator intrusion into the convective heat transfer annulus is evaluated.

System criticality control is achieved through the use of neutron absorber sheets (BORAL®) attached to the exterior faces of the fuel tubes. Individual fuel assemblies are held in place by stainless steel structural disks. The basket design includes 68 fuel tubes, one tube per fuel assembly or DFC, with the DFC tubes having a slightly larger (oversized) opening.

Criticality evaluations rely on modeled neutron absorber ^{10}B loadings of 0.015 g/cm^2. The modeled areal density is arrived at by multiplying the minimum 0.02 g/cm^2 ^{10}B areal density specified for the absorber by a 75% efficiency factor.

MCNP [A3], a three-dimensional Monte Carlo code, is used in the system criticality analysis. Evaluations are primarily based on the ENDF/B-VI continuous energy neutron cross-section library [A4] available in the MCNP distribution. Nuclides for which no ENDF/B-VI data is available are set to the latest cross-section sets available in the code distribution. The code and cross-section libraries are benchmarked by comparison to a range of critical experiments relevant to light water reactor fuel in storage and transport casks. An upper subcritical limit (USL) for the system is determined based on guidance given in NUREG/CR-6361 [A9].

Key assembly physical characteristics and maximum initial enrichment for the loading of the two LACBWR fuel assembly types are shown in Table 6.A.1-1, with the allowed loading configuration shown in Figure 6.A.1-1. Maximum enrichment is defined as planar-average enrichment for the variably enriched Exxon (EX) assemblies.

Undamaged fuel assemblies are evaluated with a full, nominal set of fuel rods. Fuel rod (lattice) locations may contain filler rods. A filler rod must occupy, at a minimum, a volume equivalent to the fuel rod it displaces. Filler rods may be placed into the lattice after assembly in-core use or be designed to replace fuel rods prior to use. The undamaged Exxon assembly must contain its nominal set of inert rods.

The maximum multiplication factors (k_{eff} +2σ) are calculated, using conservative assumptions, for the transfer and concrete casks. The USL applied to the analysis results is 0.9372 per Section 6.A.5. Maximum reactivities are produced by the damaged fuel payloads. The results of the analyses are presented in detail in Section 6.A.3.4 and are summarized as follows.

Cask Body	Operating Condition	Water Density (g/cc)			k_{eff}+2σ
		TSC Interior	DFC Interior	TSC Exterior	
Transfer	--	0.0001	0.0001	0.0001	0.35333
Transfer	--	0.9982	0.9982	0.0001	0.87655
Transfer	--	0.9982	0.9982	0.9982	0.87636
Transfer	--	0.0001	0.9982	0.9982	0.91423
Transfer	--	0.0001	0.9982	0.0001	0.93014
Storage	Normal	0.0001	0.0001	0.0001	0.34222
Storage	Accident	0.0001	0.0001	0.9982	0.33691

The maximum reactivity was established for different baseline configurations, one in which the fuel retained its preirradiation configuration and one where damage occurred, resulting in the potential reconfiguration of fissile material.

Maximum reactivity of the system with fuel in an undamaged condition, i.e., fuel geometry is retained, was calculated to be one where system tolerances are combined to form a worst case, maximum reactivity geometry (also referred to as combined tolerance model). In this configuration, the following tolerances are applied:

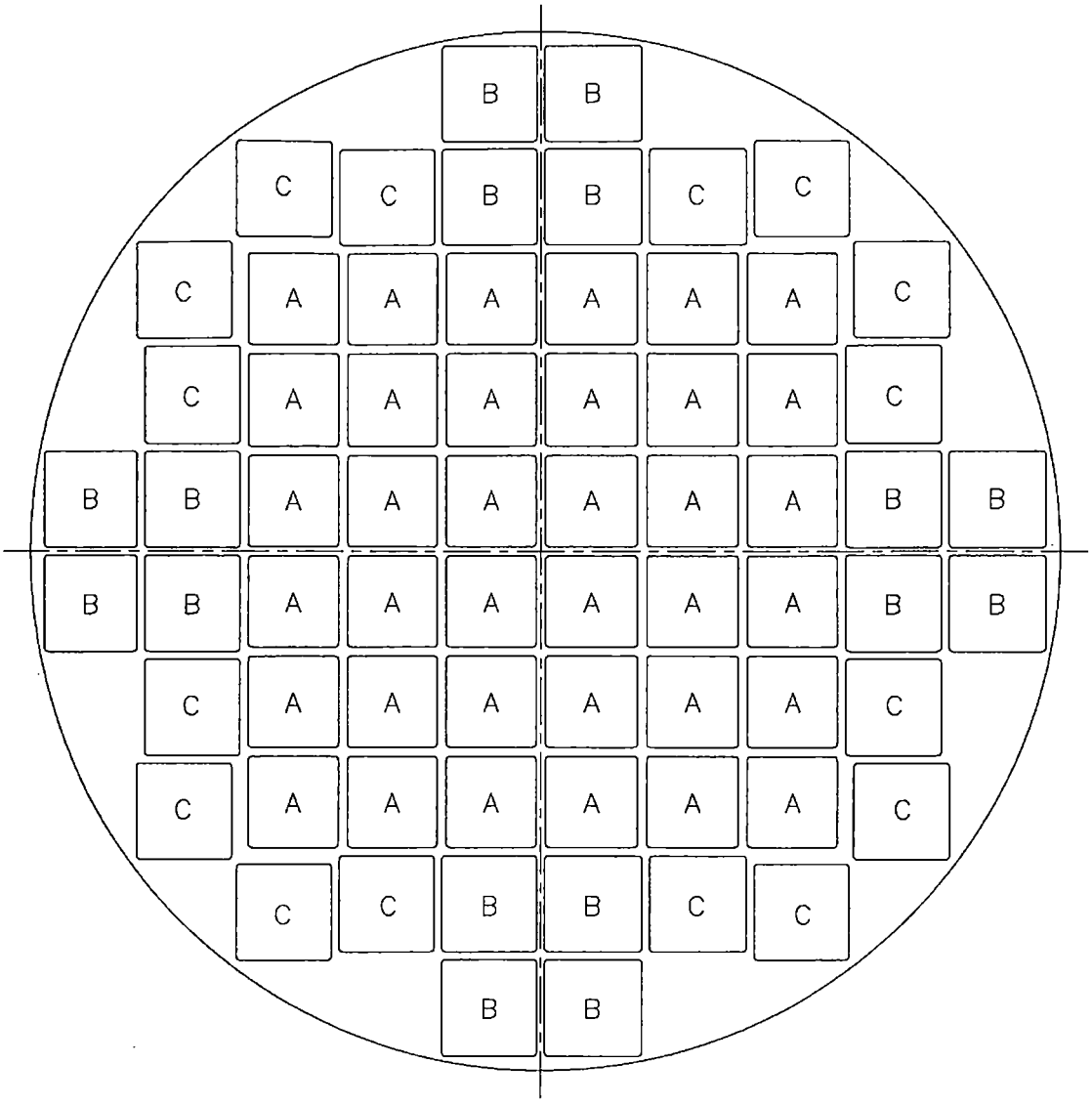
- Minimum absorber width and maximum absorber thickness
- Maximum width and minimum tube thickness
- Maximum size disk opening at the minimum radial location
- Minimum disk pitch at maximum thickness

Fuel assemblies and fuel tubes are moved radial to the center of the canister with fuel assembly clad to pellet gap flooded. This configuration results in a maximum k_{eff} of approximately 0.85.

Maximum system reactivity was achieved for the configuration in which damaged fuel is located in the exterior 32 locations of the basket as noted in Figure 6.A.1-1. In this configuration, undamaged Exxon fuel is located in the 36 interior locations. The maximum damaged fuel configuration is one where fuel clad, in addition to any other assembly steel hardware, is assumed to be removed from the DFC, and the fuel pellet stacks are assumed to be floating in the DFC at maximum square pitch available in the DFC opening. The DFCs are flooded with full density water to maximize neutron moderation, while the canister cavity is dry, reducing neutron absorber effectiveness. As there is no moderator in the canister cavity in the dry canister, preferential flood configuration, system manufacturing tolerances, such as disk thickness, tube thickness, and absorber size, do not affect system reactivity to any statistical extent. Storage casks are evaluated in an infinite array of casks by applying reflective boundary conditions, while transfer cask reactivities are based on a single cask model.

Analysis of moderator density in the canister shows a monotonic decrease in reactivity with decreasing moderator density for undamaged fuel. The full moderator density TSC interior condition bounds any off-normal or accident condition with the exception of the preferentially flooded DFC case. Analysis of moderator intrusion into the concrete cask heat transfer annulus with the dry TSC shows a slight decrease in reactivity from the completely dry condition.

Figure 6.A.1-1 Allowed Loading Configuration for LACBWR Fuel



Slot A: Undamaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Slot B: Undamaged or damaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Damaged Allis Chalmers fuel maximum enrichment 3.64 wt % ^{235}U.

Slot C: Undamaged or damaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Damaged Allis Chalmers fuel maximum enrichment 3.94 wt % ^{235}U.

Table 6.A.1-1 Bounding Fuel Assembly Loading Criteria

Fuel ID		AC	EX
Array		10×10	10×10
Number of Fuel Rods		100	96
Max. Active Length	[in]	83	83
Rod Pitch	[in]	0.565	0.557
Rod Diameter	[in]	0.396	0.394
Pellet Diameter	[in]	0.350	0.343
Clad Thickness	[in]	0.020	0.0220
Max. MTU(5)	[MTU]	0.1214	0.1119
Number of Inert Rods(1,2)		0	4
Listed Inert Rod OD	[in]	N/A	0.3940
Max. Enrichment	[wt.% ^{235}U]	3.64/3.94(4)	3.71(3)

Notes:

(1) Not required for fuel assemblies located in DFC.
(2) Inert rods comprised of stainless steel clad tube containing zirconium alloy slug.
(3) Planar average enrichment.
(4) Two AC fuel types, Type 1 at an enrichment of 3.64 wt % ^{235}U and Type 2 at 3.94 wt % ^{235}U.
(5) Damaged fuel cans are allowed to contain an additional 5% fissile material to account for loose pellets not necessarily associated with the as-built assembly.

General Note: All dimensions represent nominal, cold, unirradiated values.

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6.A.2 Spent Fuel Loading

There are two primary fuel types with distinct physical characteristics, Allis Chalmers (AC) and Exxon Nuclear Corporation (EX) fuel. AC fuel was constructed at two different enrichments while EX fuel contains a radial enrichment pattern. Relevant fuel characteristics are shown in Table 6.A.2-1.

Table 6.A.2-1 Fuel Assembly Characteristics

Fuel ID		AC	EX
Array		10×10	10×10
Number of Fuel Rods		100	96
Active Length	[in]	83.0	83.0
Rod Pitch	[in]	0.5650	0.5570
Rod Diameter	[in]	0.396	0.394
Pellet Diameter	[in]	0.3500	0.3430
Clad Thickness	[in]	0.0200	0.0220
Fuel Assembly Width	[in]	5.603	5.614
Fuel Assembly Height	[in]	102.34	102.45
Fuel Rod Height	[in]	87.820	88.03
Upper Nozzle Height	[in]	4.260	3.76
Top End-Cap Height	[in]	1.280	0.386
Upper Plenum Region Height	[in]	3.670	3.890
Lower Plenum Region Height	[in]	0.000	0.000
Bottom End-Cap Height	[in]	0.660	0.575
Gap Fuel Rod To Bottom Nozzle	[in]	0.0	0.0
Lower Nozzle Height	[in]	10.0	10.00
Number of Inert Rods		0	4
Listed Inert Rod OD	[in]	0.0000	0.3940
Listed Inert Rod Thickness	[in]	0.0000	0.0220
Upper Nozzle SS/Inconel Mass	[kg]	1.950	1.350
Lower Nozzle SS/Inconel Mass	[kg]	6.550	10.460
Enrichment	[wt% ^{235}U]	3.64,3.94[1]	3.71[2]
Uranium Loading	[kg]	120.5	108.3

[1] Represents Type I and Type II fuel.

[2] Represents the bounding planar average enrichment. Manufacturer input lists 12 rods at 3.12 wt % ^{235}U, 36 rods at 3.43 wt % ^{235}U, and 48 rods at 4.05 wt % ^{235}U.

6.A.3 Model Specification

6.A.3.1 Description of Calculation Model

The MCNP code is used to model the storage and transfer casks containing a full load of fuel assemblies. The system contains up to 68 fuel assemblies, with up to 32 assemblies being damaged. The MCNP code package uses combinatorial geometry, with the option to divide the model into self-contained Universes. The self-contained Universe structure can be used to separate canister, cask, and fuel into individual components that can be easily modified and checked.

The basic component of the geometry package is a set of general surfaces. To reduce the required user input MCNP includes simplified expressions for cylinders and planes perpendicular to system axes and "macrobodies" (cubes, finite cylinders, wedges, etc). Models are constructed by combining geometry components (surfaces) into cells. Cells may be embedded in individual Universes to simplify modeling. A given Universe may be included in different positions within the geometry by translation. Translation allows movement in the x, y, and z directions and rotation using direction cosines.

Finite cask/canister/basket/fuel models (termed cask model henceforth) are constructed for the storage and transfer system. The cask models are constructed in a set of distinct phases. In the first phase a fuel assembly is constructed from the basic components of the fuel assembly, i.e., fuel rod, inert rod (Exxon fuel), and nozzle (end-fitting). Next the basket structure is placed within the canister cavity. The basket structure is comprised of a set of stainless steel tubes and aluminum/B_4C (BORAL®) neutron absorber panels within a stacked set of stainless steel and aluminum disks. Fuel assemblies are placed into the canister cavity with the basket structure superimposed on the cavity surrounding the assemblies using the Universe structure. The canister shell and lid are placed around the loaded basket. The complete canister is then placed into either the transfer or storage cask overpack. For damaged fuel models an additional phase is the construction of the damaged fuel can (DFC) which surrounds the fuel material in the outer 32 fuel tubes.

Components within the fuel region are evaluated for manufacturing tolerance effects.

6.A.3.1.1 Fuel Assembly Models

Fuel assemblies are constructed of a top and bottom end-fitting, also referred to as top and bottom nozzles, inert rods (EX fuel only), and fuel rods that are held via grid spacers between the top and bottom nozzles. LACBWR assemblies do not contain channels.

The majority of fuel rods are not attached to either the top or bottom end-fitting. A limited number of fuel rods function as tie rods that connect the top and bottom end-fittings. Fuel rods may also be segmented. To simplify model construction all fuel rods are modeled as "floating" between the top and bottom end-fittings. All fuel rods are modeled at the full active fuel length. The number of fuel rods depends on the fuel design being evaluated. A fuel rod consists of: (1) a bottom end cap, (2) an active fuel region (including clad), (4) a top plenum, and (5) a top end cap. Spacing associated with the insulator disks is included in the end-cap definition. As stated in the assumptions, grid spacers are not modeled.

For each fuel assembly type selected a set of Universes is constructed. Assembly Universes are typically fuel rod, inert rod, tube/rod array, and the complete fuel assembly. Table 6.A.3-1 shows the geometry input summary sheet for the AC fuel type. Similar data is developed for the EX model with inert rods replacing four interior fuel rods.

Partial flooding evaluations are limited to cases with a void region above the active fuel region and canister cavity moderator from the top of the active fuel region to the canister bottom. This configuration allows a potential reactivity increase by neutron reflection from the steel lid, while minimizing neutron leakage in the moderated canister volume. As optimum moderator studies in Section 6.A.4 have demonstrated that the active fuel region achieves maximum system reactivity at the fully flooded (0.9982 g/cc) condition for the nonpreferentially flooded DFC and a void TSC (0.0001 g/cc) for the preferentially flooded DFC, moderator density changes as a function of elevation in the active fuel region are not required (i.e., decreasing moderator density in the active fuel region at any elevation will reduce reactivity, as the region has been demonstrated to be undermoderated).

6.A.3.1.2 Fuel Tube Model

The basket contains 68 fuel tubes, 36 standard size tubes and 32 DFC tubes. Each standard tube contains up to two absorber sheets, each held to a tube face by a stainless steel cover sheet. One standard size fuel tube is modeled for each absorber configuration which is then replicated using the MCNP "fill" option to fill the basket. DFCs contain either three or four absorbers. Similarly, one DFC tube is modeled for each required absorber configuration and duplicated using the "fill" option. A sketch of a fuel tube is shown in Figure 6.A.3-1.

Key dimensions for the fuel tube are shown in shown in Table 6.A.3-2. Manufacturing tolerances are applied within the calculated parameters.

6.A.3.1.3 DFC Model

The basket may contain up to 32 DFCs. Each DFC is comprised of a stainless steel rectangular box with a lid and bottom plate structure. The DFC is designed to freely drain and fill, thereby avoiding the potential of preferentially flooding the DFC. Key dimensions for the DFC are shown in Table 6.A.3-3.

DFC contents included in these evaluations are:

- Undamaged clad fuel assemblies with functional grids (i.e., fuel assemblies retaining clad and fuel rods in their as-designed configuration);
- A hypothetical fuel configuration, where the clad (stainless steel) is conservatively removed from the model and rods are allowed to achieve increased pitch; and
- A homogenized fuel/water mixture model.

For modeling the unclad array the fuel assembly input structure is repeated, this time with no clad or end-fitting. Homogenized fuel is modeled as a simple rectangular volume with the maximum mixture elevations set as a variable (compact fuel to full DFC cavity height). Material composition is then calculated based on the fuel mass within the DFC, DFC cross-section, and moderator density within the mixture volume.

6.A.3.1.4 Basket Model

Key dimensions for the basket are shown in shown in Table 6.A.3-4. A sketch of a support disk is shown in Figure 6.A.3-2. Manufacturing tolerances are applied within the calculated parameters. An MCNP Universe composed of the basket disks is constructed with no fuel or openings. Into this Universe the disk opening, tube, DFC (if required), and payload are inserted. Up to three fuel types may be implemented within the analysis, one for interior assemblies and up to two in the exterior DFC slots.

The fuel assemblies (or DFC payload) are placed into the basket at their respective radial and axial locations via the "fill" option. Fuel assembly location, DFC location, and disk opening locations and sizes may be adjusted to any desired manufacturing tolerance and shift direction.

6.A.3.1.5 Canister Model

Criticality evaluations for the storage and transfer configurations model the system with lid and port covers in place. A sketch of the canister model, composed of a canister cavity body, surrounded by lid, canister shell weldment and bottom plate, is shown in Figure 6.A.3-3. To simplify the geometry, the lid is modeled as a single cylinder with no penetrations. Parameters required in the canister model are listed in Table 6.A.3-5.

6.A.3.1.6 Transfer Cask Model

Model parameters for the transfer cask shown in Figure 6.A.3-4 are listed in Table 6.A.3-6. The cask body model is an arrangement of cylindrical shells. The origin of the transfer cask Universe (Universe 0) is the top of the shield door in the center of the cask, corresponding to the center bottom of the canister bottom plate. The canister filling the cask cavity must, therefore, be raised by the canister bottom thickness. The shield door is modeled by a combination of macro bodies (RHP and RPP). The retaining ring is not included in the model. Since the transfer cask is open to the cask exterior the cask exterior material is employed in the canister-to-cask gap.

6.A.3.1.7 Storage Cask Model

Model parameters for the storage cask shown in Figure 6.A.3-5 are listed in Table 6.A.3-7. The cask body model is an arrangement of a cylindrical carbon steel shell surrounded by concrete. Cask model complexity is associated with the pedestal stand and the air inlet and outlet structure. The cask body is composed of a lower section, housing the canister and air inlet structure, and an upper section composed of the cask lid and air outlet structure. The origin of the concrete cask Universe (Universe 0) is set to the top of the bottom weldment pedestal plate in the center of the cask, corresponding to the center bottom of the canister bottom plate. The canister filling the cask cavity must, therefore, be raised by the canister bottom thickness. Since the storage cask is open to the cask exterior the cask exterior material is employed in the canister-to-cask gap and air inlet and outlet structure.

6.A.3.1.8 Monte Carlo Sampling and Result Convergence

To assure proper spatial fission site distribution, 30 inactive generations (cycles) are tracked prior to starting the active cycles employed in the eigenvalue calculation. The standard deviation (σ) for all cases will be less than 0.002. Upon completion of the analysis, a reactivity comparison is made to the upper subcritical limit (USL). These comparisons are made using the reported "final estimated combined collision/absorption/track-length k_{eff}" identified in each output. Each output is checked for sampling of fissile material areas in the model and normal distribution of the k_{eff} values.

6.A.3.1.9 Sample Model Files

Sample input files for the transfer cask and storage cask models for undamaged and damaged fuel are provided in Section 6.A.7. The inputs provided represent the maximum reactivity configuration case and additional transfer and storage cases.

6.A.3.2 Model Assumptions

Key assumptions for the analytical models are as follows.

6.A.3.2.1 Fuel Modeling

a) All fuel assemblies are conservatively modeled at a fuel density of 96% theoretical. (0.96×10.96 g/cm^3 = 10.52 g/cm^3).

   Basis: Calculated fuel mass bounds LACBWR fuel assembly material mass.

b) Fuel assembly grid spacers are not included in the model.

   Basis: Removing material in the active fuel region raises reactivity by removing parasitic absorber material and increasing fuel assembly moderation in a typically under-moderated fuel assembly.

c) Stainless steel and inconel hardware are modeled as stainless steel.

   Basis: The total hardware mass is homogenized into end-fitting volumes. There is no neutronically significant difference in the materials. Furthermore, the components modeled are outside the active fuel region and therefore do not affect basket neutronics significantly.

d) The exact geometry of the top and bottom nozzles is unknown, therefore, they are modeled as solid boxes with the width of the fuel assembly.

   Basis: The material density in this region is adjusted to account for the volume of the box modeled. Since the material is outside the active fuel region, this simplifying assumption will not affect system reactivity significantly.

e) DFC fuel material is increased by 5% over that of an undamaged assembly.

   Basis: In-core clad failure leads to the potential of fuel releasing during assembly movement in the spent fuel pool. This could result in a limited quantity of loose pellets/fuel debris to transfer to the structure of another fuel assembly.

f) No fuel-related burnable absorbers are included in the fuel assembly.

   Basis: LACBWR fuel assemblies did not contain integral absorbers. Further, removing any fuel integral absorbers from the model increases fresh fuel reactivity.

6.A.3.2.2 Basket and Canister Modeling

a) Neutron absorber ^{10}B density is reduced to 75%.

   Basis: The Part 72 Standard Review Plan (NUREG-1536) indicates in Section IV.c that a 75% credit represents the standard accepted value.

b) To simplify modeling, the basket/fuel model ignores small steel masses in the basket such as nuts, washers and tie rods.

Basis: This modeling assumption does not have a statistically significant effect on subsequent analyses due to the small amount of material involved.

c) Basket components may not be listed with symmetric (i.e., ±x) tolerance bands. For component tolerances that are not symmetric the maximum tolerance is applied symmetrically.

Basis: Applying the largest band symmetrically will produce bounding results.

d) The basket structure, including neutron absorber panels and fuel assemblies, is assumed to rest at the lowest possible position in the basket cavity, which is at the bottom of the bottom weldment.

Basis: All storage and transfer cask operating conditions are vertical. There are no design basis tip-over events.

e) Aluminum sheet on DFC is not modeled.

Basis: The aluminum sheet is 0.075 inch of neutron transparent material that is facing the periphery of the basket.

f) Top weldment is modeled as a 0.625 inch plate with a 69.33-inch OD.

Basis: Due to structural concerns the top plate was increased to 1 inch thickness with a 69.35 inch OD. The top plate is outside the fissile material region in storage and transfer calculations. Difference in geometry in this region does not affect system reactivity significantly.

g) The canister lid location is modeled at 7 inches from the canister top.

Basis: Actual location is 6.97 inches from the top to assure that the lid is not below the shell wall. While potentially affecting transport calculations due to the change in calculated cavity length, and the corresponding component axial shift, there is no effect on storage calculations as fissile material is located at the bottom of the canister cavity.

h) The DFC canister lid bottom plate is modeled as 0.25 inch.

Basis: Actual thickness is 0.325 inch. The difference in plate thickness slightly decreases the cavity height inside the DFC from the modeled value. As various content locations and mixture heights are evaluated, a larger cavity height bounds the as-designed DFC.

6.A.3.2.3 Criticality Analysis

a) Code input will be in centimeters to four or five decimals.

Basis: Input dimensions are provided in a variety of significant figures and decimals down to $1/1000^{th}$ (0.001) inch. Based on reasonable engineering judgment, the affects of smaller dimensions cannot be resolved within the statistical uncertainties of the Monte Carlo analysis and do not have a significant effect on system reactivity.

b) Changes in reactivity are considered to be significant if the Δk_{eff} exceeds three times the standard deviation (3σ).

Basis: The 3σ level represents the 99% confidence band on a normally distributed result set. Exceeding this interval would therefore present a high likelihood that the result change is statistically significant.

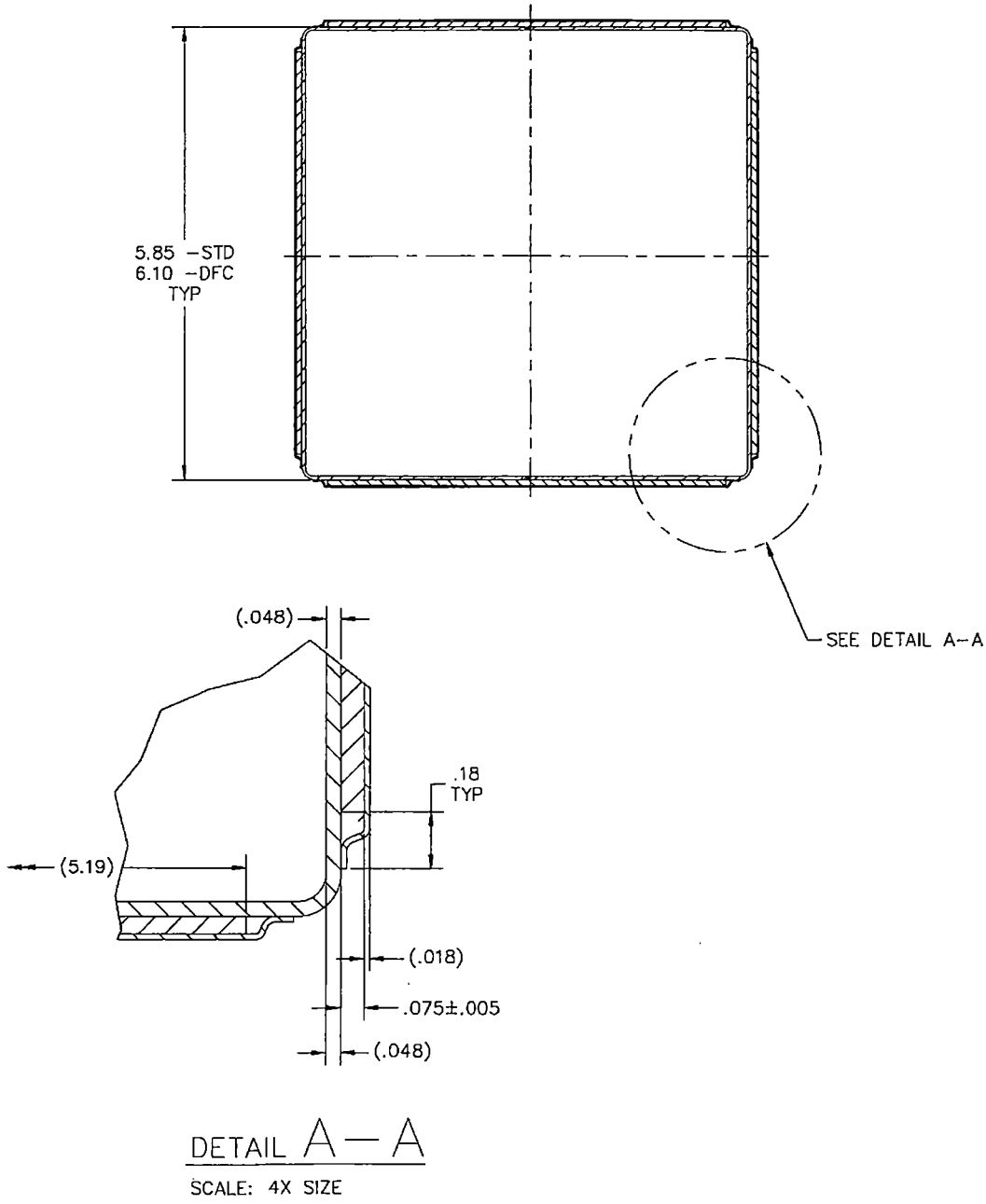
c) Base analyses are performed with DFC fuel material located axially lined up with the undamaged fuel.

Basis: Assembly nozzles are expected to provide axial offset for any loose fuel material within the DFCs. Fuel exposure analysis, neglecting assembly hardware, is included in the DFC studies to confirm the most reactivity axial DFC material configuration.

6.A.3.3 Cask Regional Densities

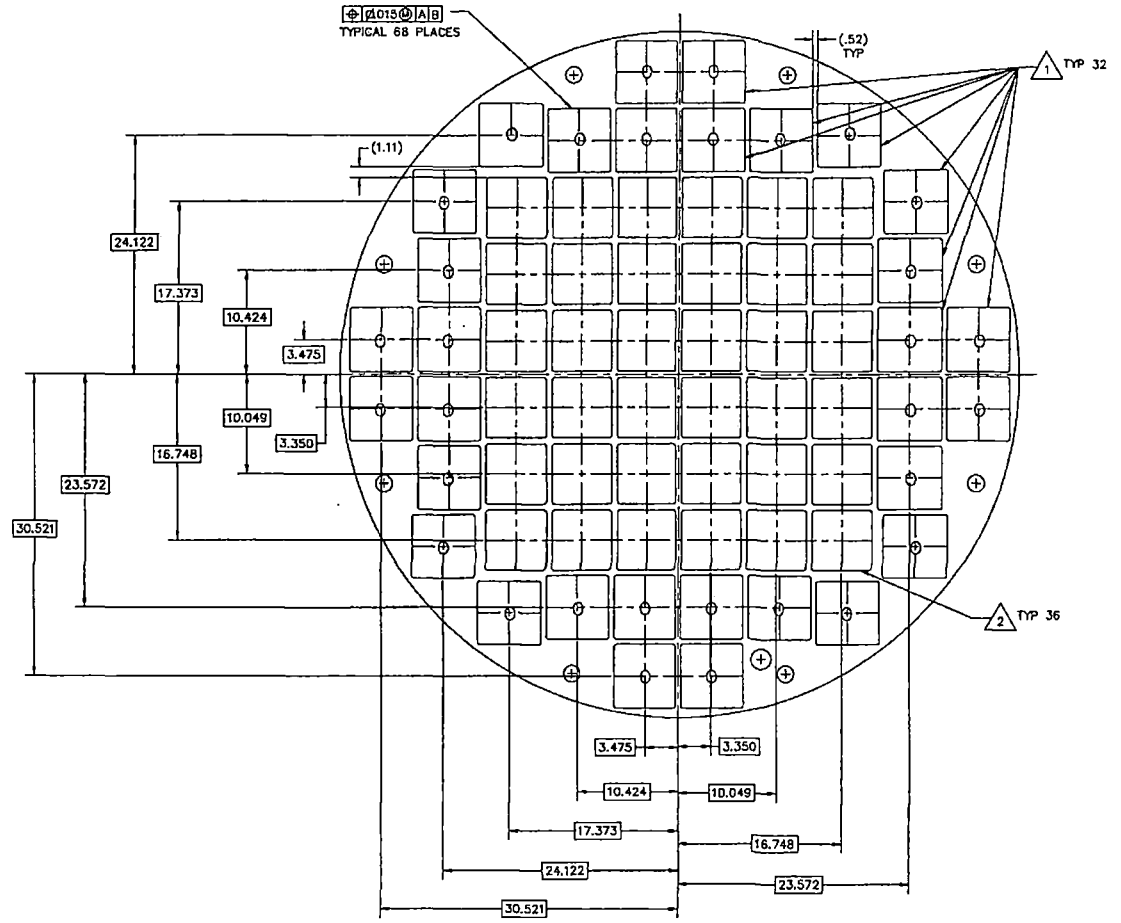
The densities used in the criticality analyses are primarily SCALE 4.3 default densities [A5]. NS-4-FR is a proprietary material and the listed information reflects values defined by the material information data sheet. Fuel assembly materials are listed in Table 6.A.3-8. Basket, TSC, and cask material definitions are shown in Table 6.A.3-9.

Figure 6.A.3-1 Fuel Tube Sketch



Note: Absorber number varies.

Figure 6.A.3-2 Support Disk Sketch

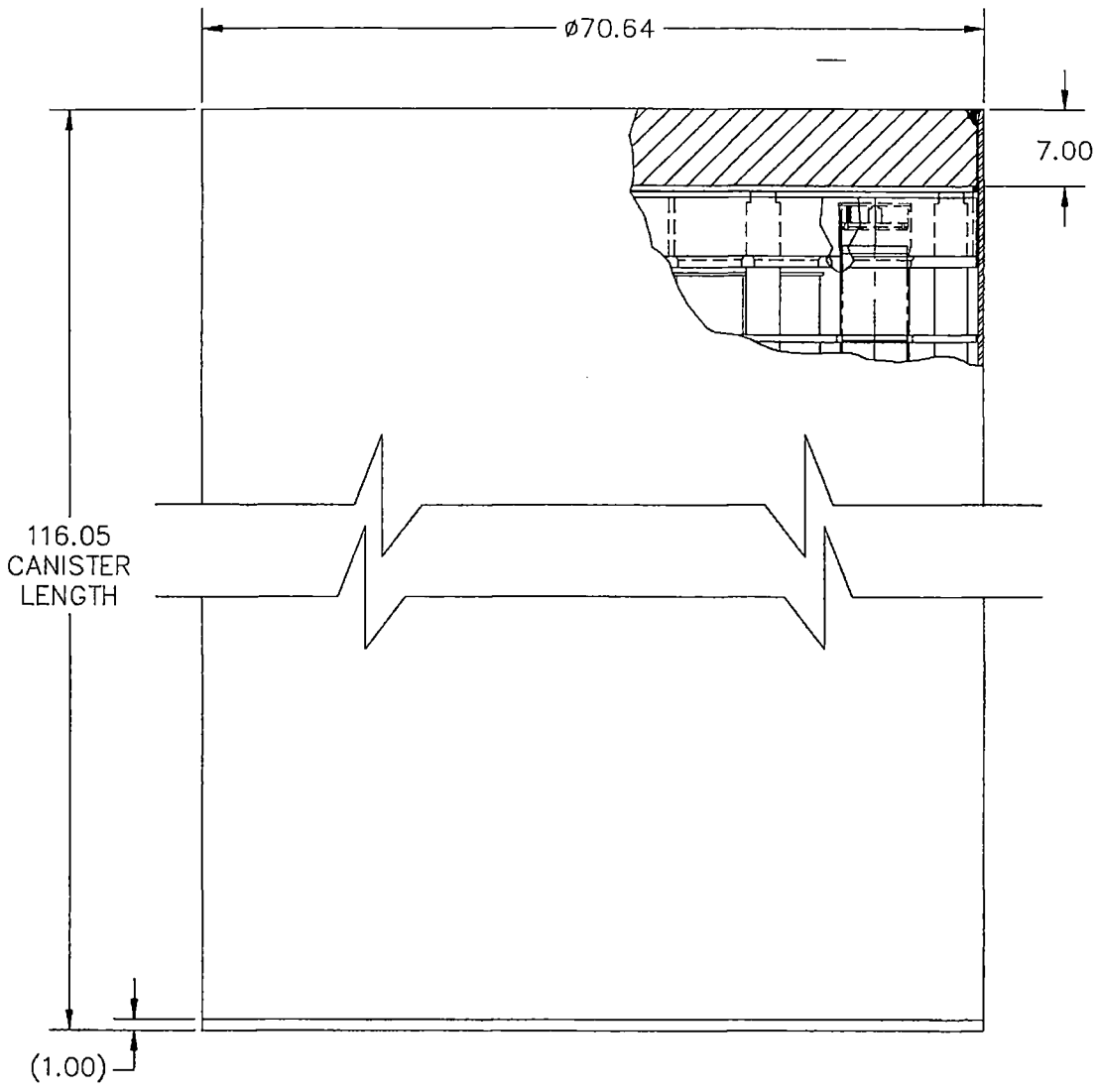


2 THIS OPENING SHALL BE 6.089±.015 X 6.089±.015.

1 THIS OPENING SHALL BE 6.433±.015 X 6.433±.015.

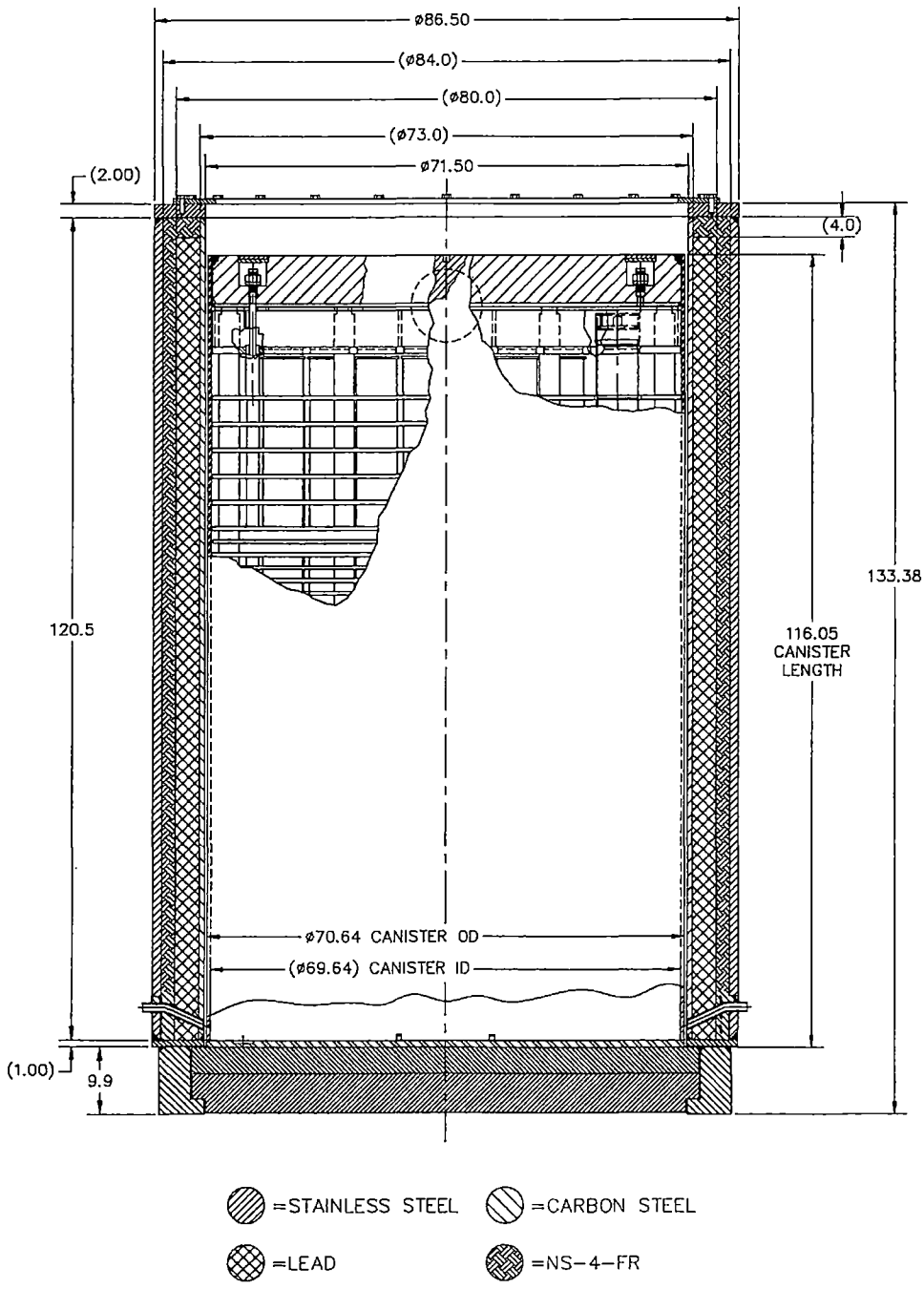
Note: Dimensions in inches

Figure 6.A.3-3 TSC Model Sketch



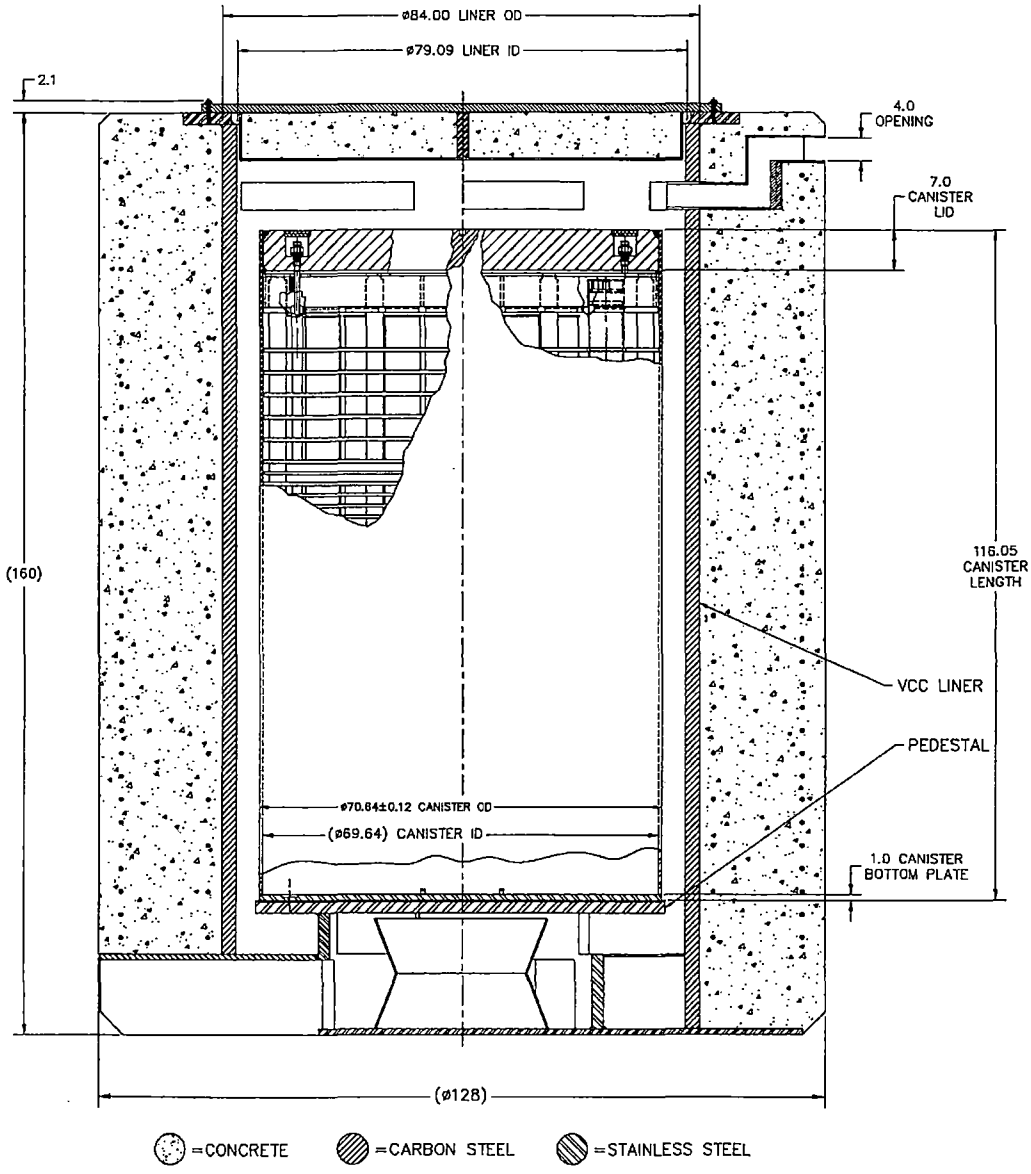
Note: Dimensions in inches

Figure 6.A.3-4 Transfer Cask Model Sketch



Note: Dimensions in inches

Figure 6.A.3-5 Storage Cask Model Sketch



Note: Dimensions in inches

Table 6.A.3-1 Fuel Assembly Configuration (AC)

Description	Value [in]
Fuel Rod Height	87.820
Top End-Cap Height	1.280
Bottom End-Cap Height	0.660
Upper Plenum Region Height	3.670
Active Length	83.000
Rod Diameter	0.3960
Clad Thickness	0.0200
Pellet Diameter	0.3500
Array	10
Pitch	0.5650
Fuel Assembly Height	102.340
Lower Nozzle Height	10.000
Upper Nozzle Height	4.260
Gap Fuel Rod to Bottom Nozzle	0.000
Number of Fuel Rods	100
Lower Nozzle SS/Inconel Mass (kg)	6.550
Upper Nozzle SS/Inconel Mass (kg)	1.950
Fuel Assembly Width	5.603
Number of Inert Rods	0
Inert Rod OD	N/A
Inert Rod Clad Thickness	N/A
Fuel Assembly Width	5.603

Table 6.A.3-2 Fuel Tube Model Parameters (Nominal Configuration)

Description	Dimension [in]
DFC tube outer width	6.10
DFC tube width tolerance	0.03
Standard tube outer width	5.85
Standard Tube outer width tolerance	0.02
Tube thickness	0.048
Tube thickness tolerance (+0.03, -0.01)	0.03
Absorber thickness	0.075
Tolerance on absorber thickness	0.005
Absorber width	5.19
Tolerance on absorber width	0.08
Minimum ^{10}B content (g/cm^2)	0.020
Cover sheet thickness	0.018
Fuel Tube height (min)	98.15
Absorber length (min)	95.88
Distance to bottom of absorber cover	0.8

Table 6.A.3-3 DFC Model Parameters

Description	Dimension [in]
Damaged fuel can opening width	5.750
Damaged fuel can wall thickness	0.048
Damaged fuel can bottom plate thickness	0.500
Damaged fuel can height	106.750
DFC lid handle height	1.500
DFC lid bottom plate thickness	0.250
DFC lid top plate thickness	0.375

Table 6.A.3-4 Basket Structure Model Parameters

Description	Dimension [in]	Description	Dimension [in]
Bottom weld. height	2.00	No. of structural disks	24
Bottom weld. OD	69.33	No. of structural B disks	1
Bottom weld. thick.	1.00	No. of structural C disks	1
Top weld. height	6.75	No. of aluminum disks	14
Top weld. OD	69.33	Split spacer height	1.60
Top weld. thick.	0.625	Split spacer tol.	0.02
Structural disk thick.	0.625	Spacer height	3.21
Structural thick. tol.	0.055	Spacer tol.	0.02
Structural disk OD	69.40	Spacer B height	1.31
Structural B disk thick..	1.250	Spacer B tol.	0.02
Structural B thick. tol.	0.055	Bottom spacer height	1.86
Structural C disk thick.	0.750	top spacer height	1.65
Structural C thick. tol.	0.055	Tube to Top Weldment gap	0.50
Std opening location 1	3.350	Basket height	107.40
Std opening location 2	10.049		
Std opening location 3	16.748		
Std opening location 4	23.572		
Dfc opening location 1	3.475		
Dfc opening location 2	10.424		
Dfc opening location 3	17.373		
Dfc opening location 4	24.122		
Dfc opening location 5	30.521		
Disk Op. location tol.	0.015		
Std opening width	6.089		
Std opening width tol.	0.015		
Dfc opening width	6.433		
Dfc opening width tol.	0.015		
Al. disk thick.	0.500		
Al. disk thick. tol.	0.027		
Aluminum disk OD	69.13		

Table 6.A.3-5 Canister Model Parameters

Description	Dimension [in]
Canister Outer Diameter	70.64
Canister Wall Thickness	0.50
Canister Length	116.05
Canister Lid Recess	7.00
Canister Bottom Plate	1.00
Canister Lid	7.00

T able 6.A.3-6 Transfer Cask Model Parameters

Description	Dimension [in]
Transfer cask OD	86.50
Bottom plate height	1.00
Inner shell height	120.50
Inner shell inner diameter	71.50
Inner shell thickness	0.75
Lead inner radius	36.5
Lead outer radius	40.0
Outer shell thickness	1.25
Top plate height	2.00
Shield door height	9.50
Shield door rail inner dimension	75.50
Shield door rail width	6.50
Shield door rail overlap	2.00
Shield door boundary total y-axis length	75.12
Shield door boundary base y-axis length	29.08
Shield door boundary x-axis length	45.38
Shield door boundary base x-axis length	17.39
Shield door overlap	4.00
Shield door trapezoidal angle (degree)	50.564
Lead shell thickness	3.500
Shield door boundary triangle y-axis length	23.020
Shield door boundary triangle x-axis length	27.990

Table 6.A.3-7 Key Storage Cask Model Parameters

Description	Dimension [in]
VCC shell height	158.9
VCC shell ID	79.0
VCC shell thickness	2.5
Top flange OD	97.9
Top flange ID	81.0
Top flange thickness	2.0
Bottom plate thickness	1.0
Baffle weldment height	19.0
Baffle weldment major diameter	30.0
Baffle weldment minor diameter	23.0
Baffle weldment plate thickness	0.25
Base weldment height without bottom plate	22.1
Air inlet vertical opening	12.0
Air inlet horizontal opening	12.0
Air inlet side plate thickness	0.375
Air inlet top plate thickness	1.0
Base plate thickness	2.0
Base plate outer diameter	72.0
Base plate cover thickness	0.25
Stand OD	50.0
Stand thickness	2.0
Stand cut dimension	20.2
VCC lid OD	91.5
VCC lid top thickness	1.5
VCC lid overall height	9.7
VCC lid concrete plate OD	78.0
VCC lid concrete plate thickness	0.375
Concrete OD	128.0

Table 6.A.3-8 Fuel Assembly Material Densities and Compositions

Material	Density g/cm^3	Element/ Isotope	Density atom/barn-cm
UO_2 (3.71 wt % ^{235}U) [1]	10.522	^{235}U	8.82E-03
96% theoretical density		^{238}U	2.26E-02
		O	4.69E-02
Water	0.9982	H	6.67E-02
Full Density		O	3.34E-02
Stainless Steel	7.94	Cr	1.75E-02
		Fe	5.95E-02
		Ni	7.74E-03
		Mn	1.74E-03

[1] System is evaluated at varying enrichment levels. Sample data is provided.

Table 6.A.3-9 Basket, TSC, and Cask Material Densities and Compositions

Material	Density g/cm^3	Element/ Isotope	Density atom/barn-cm
Carbon Steel	7.821	Fe	8.35E-02
		C	3.92E-03
Stainless Steel	7.94	Cr	1.75E-02
		Fe	5.95E-02
		Ni	7.74E-03
		Mn	1.74E-03
Aluminum	2.702	Al	6.03E-02
Lead	11.344	Pb	3.30E-02
NS-4-FR	1.632	H	5.8508E-02
		^{10}B	9.1385E-05
		^{11}B	3.3665E-04
		C	2.2600E-02
		N	1.3904E-03
		O	2.6107E-02
		Al	7.8003E-03
Concrete	2.322	H	1.3879E-02
(145 lb/ft^3)		O	4.6522E-02
		Na	1.7643E-03
		Al	1.7625E-03
		Si	1.6783E-02
		Ca	1.5356E-03
		Fe	3.5063E-04
Neutron Absorber	1.965	^{10}B	7.10E-03
(Core)	(75% of	^{11}B	3.01E-02
	Actual)	C	9.30E-03
		Al	2.48E-02

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6.A.4 Criticality Calculation

6.A.4.1 Calculation Method

System reactivity evaluations are performed with the MCNP5 three-dimensional Monte Carlo code and continuous neutron energy cross-sections [A3, A4]. The Monte Carlo code and neutron cross-section libraries are validated for use in fuel transport and storage cask applications through a series of calculations based on critical experiments. Validation detail is presented in Section 6.A.3.4. Validation and cask analysis apply a consistent cross-section set to ensure applicability of the experimental benchmark analysis to the cask analysis. Cross-sections used in both the benchmark and cask analysis are shown in the cask MCNP sample input file material descriptions in Section 6.A.7.

The criticality analysis of the system is performed in several steps.

- For Undamaged Fuel
  - Establish initial reactivities effects of gap conditions and fuel types for LACBWR fuel assemblies and justify the use of planar average versus heterogeneous enrichments.
  - Evaluate basket mechanical perturbations and basket geometric tolerances.
  - Construct optimum moderator density curve(s).
  - Based on the maximum reactivity configuration, demonstrate that the system reactivity remains below the USL.
- For Damaged Fuel
  - Establish maximum reactivity configuration for damaged fuel.
  - Evaluate optimum moderator density considering preferential flooding of DFC.
  - Justify that maximum reactivity configuration for undamaged fuel applies to the damaged fuel configuration.
  - Demonstrate that the reactivity for the maximum reactivity damaged fuel configuration remains below the USL.

6.A.4.2 Fuel Loading Optimization

The fuel loading is optimized in the criticality models using the following:

- Fresh fuel at 96% theoretical density
- Bounding fuel assembly characterization
- The most reactive cask configuration

The maximum reactivity cask configuration considers basket fabrication tolerances, component shifting, and moderator density evaluations. Each of these effects is evaluated individually and in combination to assure that the highest reactivity configuration is documented. Fabrication tolerances and shift effect are evaluated for each of the LACBWR fuel types.

Casks are evaluated at various interior and exterior flood conditions with reflective boundary conditions. Reflective boundary conditions are applied to an independently generated cylindrical body surrounding the cask body. This allows the modeling of infinite cask arrays at various cask spacings. Space between the cask surface and the reflecting body may be flooded at various moderator densities. Given the low neutron fluxes of either concrete or transfer cask bodies, no significant effect is observed from conditions outside the cask body.

The cask reactivity evaluation is divided into two primary sections. The first section details the determination of the maximum reactivity configuration for a payload of undamaged fuel assemblies. The maximum reactivity configuration is a function of the bounding parameters of the fuel, fuel location within the basket, manufacturing tolerances of the basket, and optimum moderator level. The second section details the extension of the analysis to consider damaged fuel cans (DFCs).

6.A.4.2.1 Undamaged Fuel

The maximum reactivity configuration is the result of fabrication tolerances, component shifting, and moderator density evaluations. Each of these effects is initially evaluated separately to determine the highest reactivity basket configuration. An evaluation combining tolerance and shift effects builds on the individual evaluations. These analyses are performed with the canister placed into the transfer cask. Fabrication tolerances and shift effects are evaluated using each of the primary fuel types.

Fuel Type and Enrichment Variation Study

LACBWR fuel is composed of two primary fuel types: Allis Chalmers (AC) fuel that was produced as Type I with a uniform enrichment of 3.64 wt% ^{235}U and as a Type II with a 3.94 wt% ^{235}U enrichment, and Exxon fuel with radial enrichment variations. Radial enrichments varied from 3.12 to 4.05 wt% ^{235}U, with an average enrichment of 3.70 wt% ^{235}U. A maximum planar average enrichment of 3.71 wt% ^{235}U is evaluated. Each of the fuel types is individually evaluated to determine their relative reactivity within the LACBWR cask system. Wet and dry pellet to clad gaps are evaluated to demonstrate the effect of minor clad failure on system reactivity. Radial enrichments were discretely modeled to allow a comparison to a homogenized enrichment.

Fabrication Tolerances

The basket is composed of a set of fuel tubes, held in place by disks which in turn are held in place by a set of tie rods, spacers and washers. Tube location in the basket is controlled by the disk opening cut-out in the structural disk (see Figure 6.A.3-2). Tolerances on the location and

size of the opening in the structural disk evaluated in Section 6.A.4.2.2 are included in.Figure 6.A.3-2. Moderator space between fuel tubes is controlled by a number of items including: fuel tube size, fuel tube thickness, absorber thickness and width, and locations of the disk opening and tube within the disk opening.

Component Shift

In addition to the component tolerances, a reactivity study on component shifts is required. Based on the tube in disk arrangement the radial shifts evaluated are the movement of the fuel assembly within the tubes, and the tubes within the disk opening. A sketch of the basket tube cross-section is included in Figure 6.A.3-1, with the structural disk shown in Figure 6.A.3-2.

Combined Basket Tolerances and Shift

In addition to the individual effect studies, the combination of the various basket tolerances with the maximum reactivity shift configuration (center shift) are considered in the results section of the chapter.

Moderator Density Study

Optimum moderator density is evaluated by considering TSC uniform water density variations ranging from void (0.0001 g/cm^3) to full density (0.9982 g/cm^3). More moderator density evaluations are performed with a void interior and various exterior water densities, and simultaneous variations in interior and exterior water densities, for the damaged fuel evaluations.

6.A.4.2.2 Damaged Fuel Evaluations

Starting with the most reactive basket configuration determined for undamaged fuel, various damaged fuel configurations are evaluated. Base evaluations for DFC designs are comprised of undamaged EX assemblies in the basket interior with EX or AC fuel assemblies in the DFCs. No AC assemblies are allowed in the non DFC basket locations.

To bound the potential of additional fissile material in the DFCs the total fissile mass in each DFC is increased by 5%. For mixture cases, the mass is increased by adjusting the fuel volume in the mixture. For pellet stack cases, the active fuel height is increased. As demonstrated in the various moderator density and rod pitch evaluations, the fuel rod lattice is under-moderated. Placing additional fissile material within the active fuel region displaces moderator and reduces reactivity. An increased active fuel height configuration was chosen.

Clad Rods – Grid Undamaged

DFC evaluations are initiated by placing undamaged fuel assemblies into the DFC to demonstrate the effect of the additional stainless steel shell. Table 6.A.4-8 demonstrates that starting from an all EX fuel payload, the DFC material results in a minor decrease in system

reactivity. Next, fuel rods are removed from the lattice to evaluate various "missing rod geometries." The missing rod pattern was chosen to increase potential reactivity by not removing adjacent fuel rods, i.e., not generating large moderator volumes that would result in exceeding the H/U peak and result in excess water neutron absorption; and by initially removing fuel rods near the center of the assembly, i.e., away from the neutron absorbers and in the area where increases in the moderator ratio are most likely to increase system reactivity.

Unclad Rods – Loose Pellet Stack

Damaged fuel is postulated to lose its cladding. As stainless steel presents a significant parasitic absorber within the fuel region, the removal of cladding from the array is evaluated. The next stage in the analysis is an increase in pitch for the unclad array. As the assembly array showed an increase in reactivity as a function of moderator density, increased rod pitches are also evaluated.

Fuel/Water Mixture

In addition to the heterogeneous (rod array) evaluations, a set of mixture analysis are run. Mixtures are designed to fill various fractions of the DFC canister and simulate small fuel rubble inside the canister.

The fuel mixture studies model fuel material at various material fractions, expressed as mixture height (i.e., fuel/water mixture height in DFC). At the low end fraction, the material is modeled as a solid mass at preirradiation density (10.522 g/cc or 96% theoretical), while at the high end, the fuel water mixture fills the DFC cavity. Per Table 6.A.4-10, a compacted mixture at full density occupies approximately 25% of the DFC. Therefore, the full height mixture will result in a fuel density approximately 25% of the initial case (i.e., 2.6 g/cc). This study is, therefore, an optimum moderator density study for the fuel/water mixture. Water within the mixture is full density in all cases.

Optimum Moderator

In the final stage of the maximum reactivity configurations analysis, moderator density variations are considered. Including the damaged fuel optimum moderator configuration studies, a preferential flooding of the damaged fuel cans is evaluated (i.e., DFCs may be flooded with a dry canister cavity and vice versa).

Maximum Reactivity Configuration Confirmation Studies

Maximum reactivity geometry for undamaged fuel was based on a fully flooded TSC. For preferentially flooded geometry, the fissile material shift and tolerance studies are repeated. Additional evaluations to assess the movement of the active fuel towards the top and bottom of the DFCs must also be included for damaged fuel contents.

6.A.4.2.3 Storage Cask Evaluations

Additional runs for the maximum reactivity assembly are performed for the single storage cask and array of casks under normal and accident conditions. These studies evaluate the effects of differences in reflector material on canister reactivity.

6.A.4.3 Criticality Results

The cask reactivity evaluation is divided into two primary sections. The first section details the results of undamaged fuel elevations with the second section detailing the extension of the analysis to consider damaged fuel cans (DFCs).

6.A.4.3.1 Undamaged Fuel Maximum Reactivity Basket Configuration

The maximum reactivity configuration is the result of fabrication tolerances, component shifting, and moderator density evaluations. Each of these effects is initially evaluated separately to determine the highest reactivity basket configuration. An evaluation combining tolerance and shift effects builds on the individual evaluations. As stated in the assumptions, these analyses are performed with the canister placed into the transfer cask.

Fabrication tolerances and shift effects are evaluated using each of the primary fuel types.

Fuel Type and Enrichment Variation Study

Each of the fuel types is individually evaluated to determine their relative reactivity within the LACBWR cask system. Radial enrichments were discretely modeled to allow a comparison to a homogenized enrichment. Results for the individual cases are shown in Table 6.A.4-1 and indicate a substantially higher reactivity for the AC fuel type. Wet and dry pellet to clad gaps are evaluated with a wet clad being bounding.

As shown in the result table, the radial and homogenized enrichment results are statistically identical. The variable enriched fuel may therefore be represented by the homogenized "average" enrichment description.

Fabrication Tolerances – Centered Components

The results of the tolerance evaluation for centered fuel assemblies and tubes are included in Table 6.A.4-2 and Table 6.A.4-3. As indicated in the tables, little statistically significant information is available from this study. Viewed independently, none of the fabrication related tolerance studies with the exception of fuel tube thickness produce significant reactivity increases across both fuel types. A combined model is therefore constructed based on theoretical maximum reactivity configuration. Maximum reactivity configuration is one that minimizes the amount of moderator and neutron absorber (BORAL and tube material) within the radial plane between disks (i.e., maximum tube opening, minimum tube wall thickness, minimum absorber

width and maximum absorber thickness). Disk thickness increase and decreased disk pitch increases the amount of parasitic absorber within the center (axial) fuel region while simultaneously decreasing water space between fuel tubes, thereby reducing the BORAL effectiveness. Structural disk thickness and pitch tolerances, therefore, invoke offsetting effects. A reduced flux trap (maximum disk thickness and minimum disk pitch) configuration is chosen for the maximum reactivity model. As shown in the tolerance study result tables, the combined tolerance model significantly increases system reactivity and produces the maximum reactivity configuration. Further evaluations of the component tolerance evaluation are performed in conjunction with the shifted component configuration.

Component Shift – Nominal Basket Configuration

The results of the shift evaluation are shown in Table 6.A.4-4 and Table 6.A.4-5 for Allis Chalmers (AC) and Exxon (EX) fuel and indicate that moving the fuel assembly and tube towards the basket center ("in" shift) clearly increases system reactivity.

Combined Basket Tolerances and Shift

Previous sections evaluated basket tolerances and fuel shifts as separate effects. This section evaluates the effect of combining various basket tolerances with the maximum reactivity shift configuration (center shift). The results for these evaluations are shown in Table 6.A.4-6 and Table 6.A.4-7. Similar to the results of the independent basket tolerance evaluations, applying fabrication tolerances to the basket components provides limited statistically significant change in system reactivity. A combined shifted/toleranced model is, therefore, constructed containing minimum absorber/flux trap space.

The maximum reactivity configuration is, therefore, based on:

a) Minimum absorber width and maximum absorber thickness
b) Maximum tube width and minimum tube thickness;
c) Maximum size disk openings at their minimum radial location;
d) Minimum disk pitch at maximum disk thickness

The minimum fuel assembly separation modeled in this configuration reduces the amount of moderation and the corresponding effectiveness of the absorber sheet, which depend on the ^{10}B neutron capture cross-section in the thermal energy range.

Moderator Density Study

The moderator density variation studies are limited to the AC (most reactive) fuel assembly type as it produces maximum system reactivity. The results of these analyses are shown in Figure 6.A.4-1. Maximum reactivity occurs at full density water inside the canister cavity. This analysis also demonstrates the low reactivity, $k_{eff}<0.4$, for the dry basket system.

More moderator density evaluations are performed with a void interior and various exterior water densities, and simultaneous variations in interior and exterior water densities, for the damaged fuel can evaluations.

6.A.4.3.2 Damaged Fuel Can (DFC) Evaluations

Starting with the most reactive basket configuration determined for undamaged fuel, various damaged fuel configurations are evaluated. Base evaluations for DFC designs are comprised of undamaged EX assemblies in the basket interior with EX or AC fuel assemblies in the DFCs. No AC assemblies are allowed in the non DFC basket locations.

Clad Rods – Grid Undamaged

Table 6.A.4-8 demonstrates that starting from an all EX fuel payload, the DFC material results in a minor decrease in system reactivity. Next, fuel rods are removed from the lattice to evaluate various "missing rod geometries." System reactivity for the AC and EX elements is not significantly affected by the removal of fuel rods.

Unclad Rods – Loose Pellet Stack

As listed in Table 6.A.4-9, system reactivity increases with rod pitch. A significant increase occurs for the midpoint pitch (midpoint between nominal assembly pitch and maximum pitch in the DFC) for both fuel types. Rod removal from the unclad rod maximum pitch array does not statistically affect or reduce system reactivity for either fuel type.

Fuel/Water Mixture

Shown in Table 6.A.4-10 are the results of the mixture analysis. Results for the homogenous mixture cases are lower than those of the rod array studies.

Optimum Moderator

In the final stage of the maximum reactivity configurations, analysis moderator density variations are considered for damaged fuel canisters. Similar to the undamaged fuel analysis, a uniform reduction in moderator density reduces reactivity. Maximum reactivity is achieved with maximum density moderator within the DFC and void (low density moderator) in the TSC cavity. This configuration reduces neutron absorber effectiveness by hardening the neutron spectrum. Moderator density cases are illustrated in Figure 6.A.4-2. Maximum reactivity plus two sigma for a 3.71 wt % ^{235}U Exxon interior loading and 3.94 wt % ^{235}U AC exterior DFC pattern is 0.9373, which is above the USL. To reduce system reactivity, the AC fuel is divided between 3.64 and 3.94 wt % ^{235}U enriched assemblies. The optimum moderator density study is repeated for a loading pattern of 16 high and 16 low enriched AC assemblies, with the lower enriched material restricted to the "on-axis" locations. The "off-axis" higher, 3.94 wt % ^{235}U

enriched AC loading bounds a payload of either 3.64 or 3.94 wt % ^{235}U AC fuel since the higher enrichment increases reactivity. Maximum reactivity ($k_{eff}+2\sigma$) of 0.92636 is below the USL and represents the allowed loading configuration as illustrated in Figure 6.A.4-3. Figure 6.A.4-4 illustrates the allowed loading configuration. Within the scope of the moderator density evaluations, a partial drain-down of the TSC is evaluated. Draining the cask to the top of the active fuel region changes the axial reflection from water to steel TSC lid. The reactivity change for this configuration is not statistically resolvable at Δk of 0.003 for the wet TSC case (k_{eff} 0.879) and -0.002 (k_{eff} 0.9250) for the dry TSC and wet DFC case. Drain down further than the top of the active fuel region decreases reactivity, as demonstrated by the optimum moderator density studies. Justification for loading Exxon fuel in the DFCs is included in the following section.

Maximum Reactivity Configuration Confirmation Studies

As maximum reactivity geometry was based on a fully flooded TSC, the fissile material shift and tolerance studies are repeated at the preferential flood configuration. Shift models contain two additional options. The additional options move DFC fissile material into close contact with each other. Results from studies, shown in Table 6.A.4-11, demonstrate that the shifted radial towards canister center ("in") pattern represents the most reactive fissile material configuration. Since the dry TSC removes the inter-assembly moderator, the minor geometry variations do not significantly affect system reactivity. Similarly, the small manufacturing tolerances on the system do not significantly affect system reactivity in the dry TSC cavity, see Table 6.A.4-12.

While all Exxon fuel is expected to be undamaged, the potential exists for Exxon assemblies to be characterized as damaged prior to placement in the TSC. Table 6.A.4-13 contains the reactivities for models containing Exxon fuel in some or all DFC locations. There is no increase in system reactivity when considering Exxon assemblies in DFCs.

All previous evaluations rely on models where the active fuel region in the DFCs is aligned with the active fuel region of the undamaged fuel in the basket interior locations. Evaluations to assess the movement of the active fuel towards the top and bottom of the DFCs are considered. These evaluations expose small amounts of fissile material outside the axial absorber coverage. As shown in Table 6.A.4-14, the effect of the fuel location within the DFC is minor for the dry TSC and insignificant for the wet TSC models. Maximum uncertainty adjusted (2σ) reactivity for the transfer cask is 0.93014. This model represents a partially flooded DFC with DFC fuel material arranged in an unclad pellet array at the bottom of the DFC.

6.A.4.3.3 Storage Cask Evaluations

Additional runs for the maximum reactivity assembly are performed for the single storage cask and array of casks under normal and accident conditions. Results of these evaluations are shown in Table 6.A.4-15. Results include a comparison to the single transfer cask evaluations. Both axially aligned fuel and DFC bottom models are evaluated for the storage cask. Transfer cask results are significantly higher than those of the storage cask at identical TSC configuration.

6.A.4.3.4 Allowed Fuel Specifications and Comparison to USL Range of Applicability

Fuel assembly characteristics evaluated for content within the MPC-LACBWR system are listed within Table 6.A.4-16. The variables are based on the maximum reactivity model for a preferentially flooded DFC with a maximum reactivity configuration payload. A comparison of the maximum reactivity case parameters to the MCNP range of applicability is shown in Table 6.A.4-17.

Figure 6.A.4-1 Undamaged Fuel Reactivity versus Water Density (AC Fuel, 3.94 wt % ^{235}U)

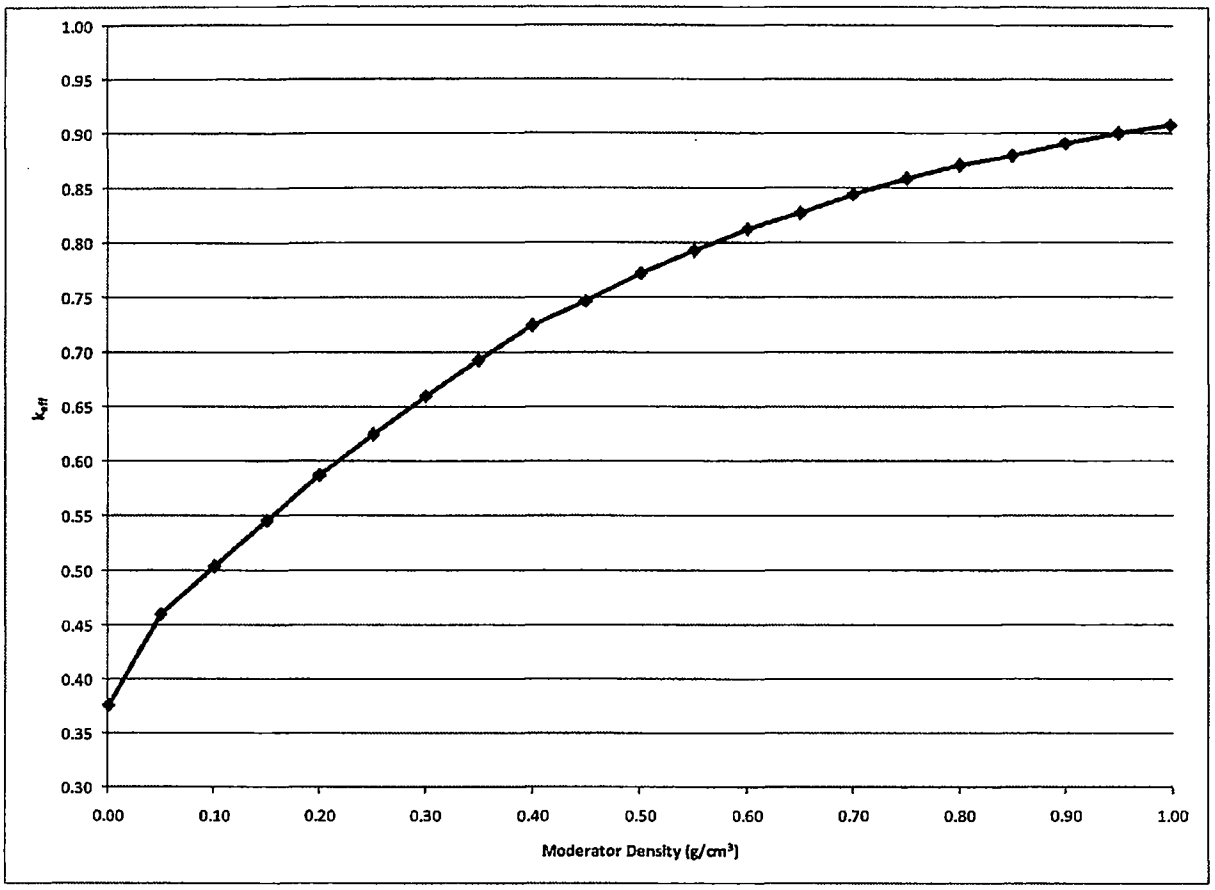


Figure 6.A.4-2 DFC Cask System Reactivity versus Water Density
(3.71 wt % EX Interior Locations, 3.94 wt % ^{235}U AC DFC Locations)

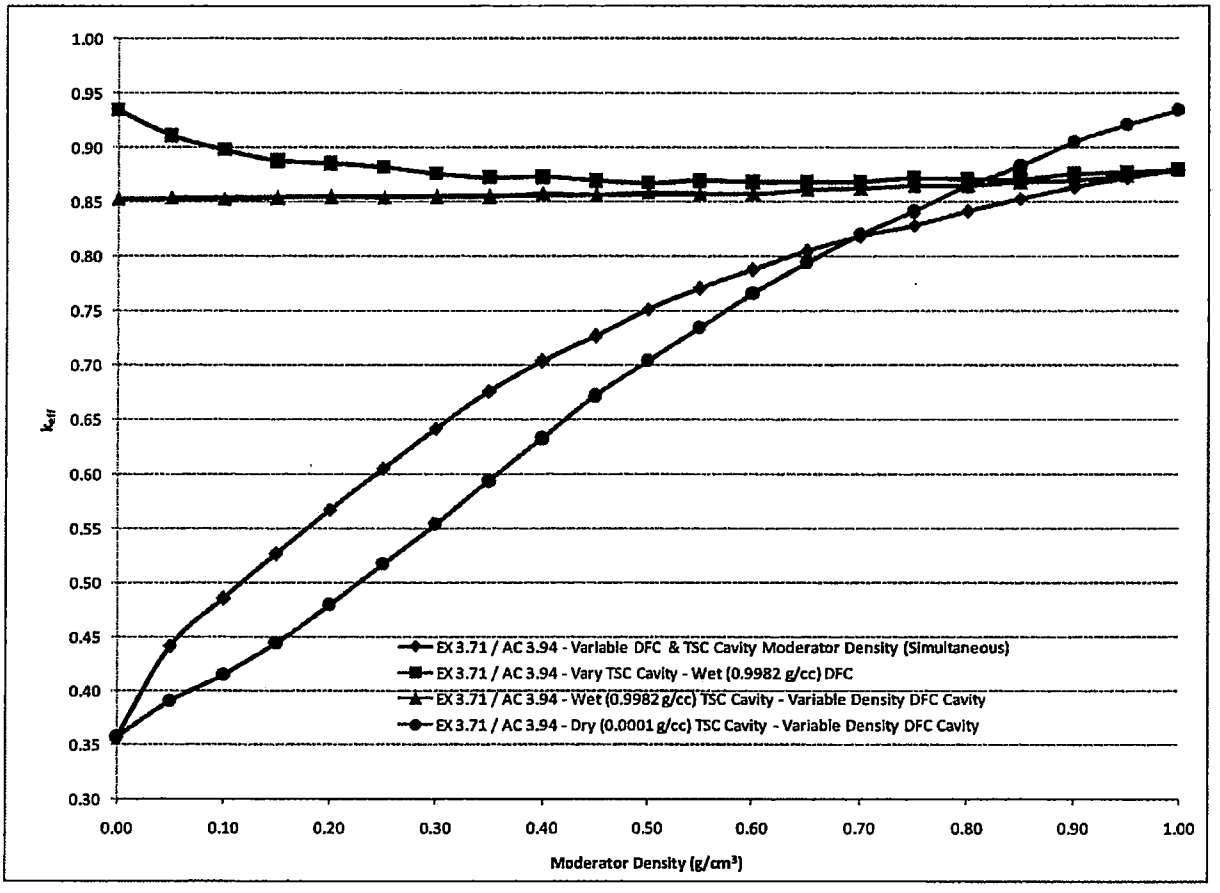


Figure 6.A.4-3 DFC Cask System Reactivity versus Water Density
(3.71 wt % EX Interior Locations, 3.94/3.64 wt % ^{235}U AC DFC Locations)

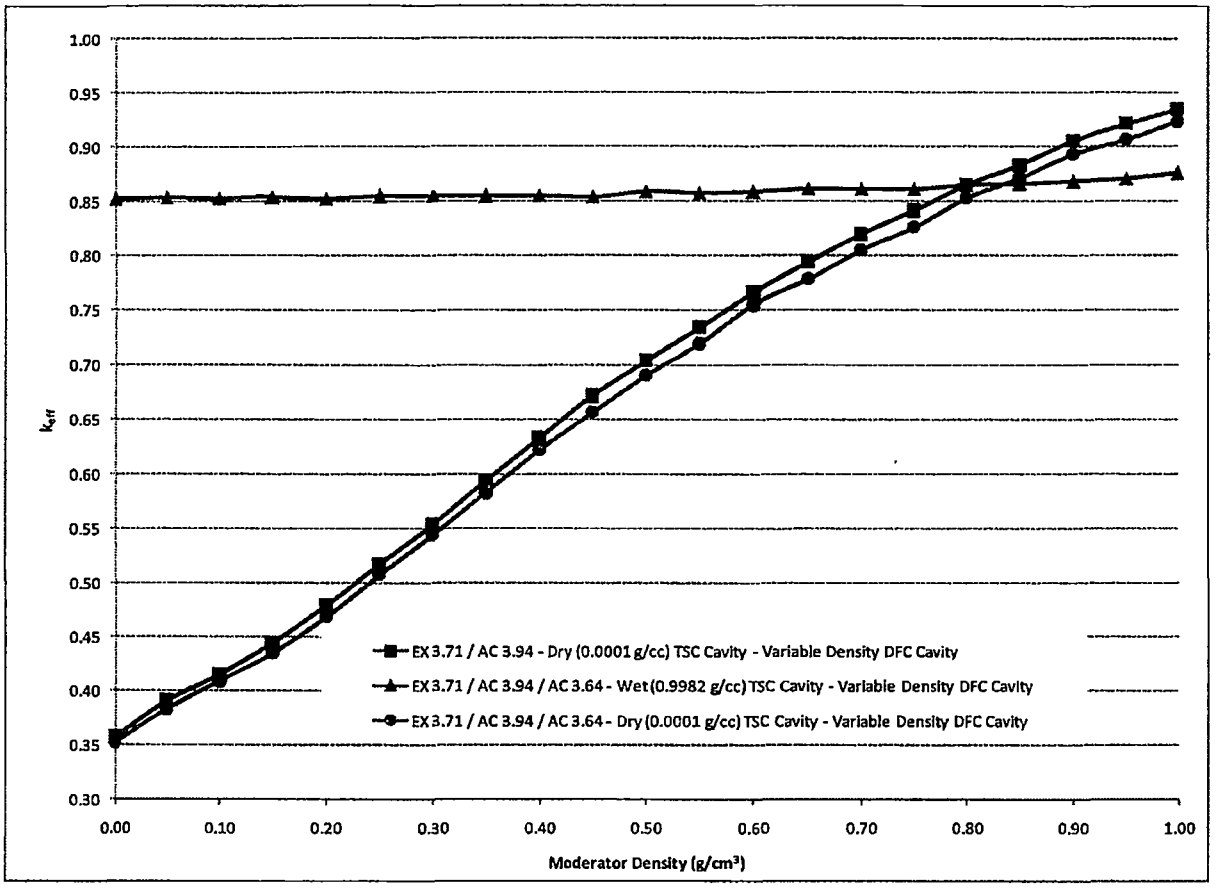
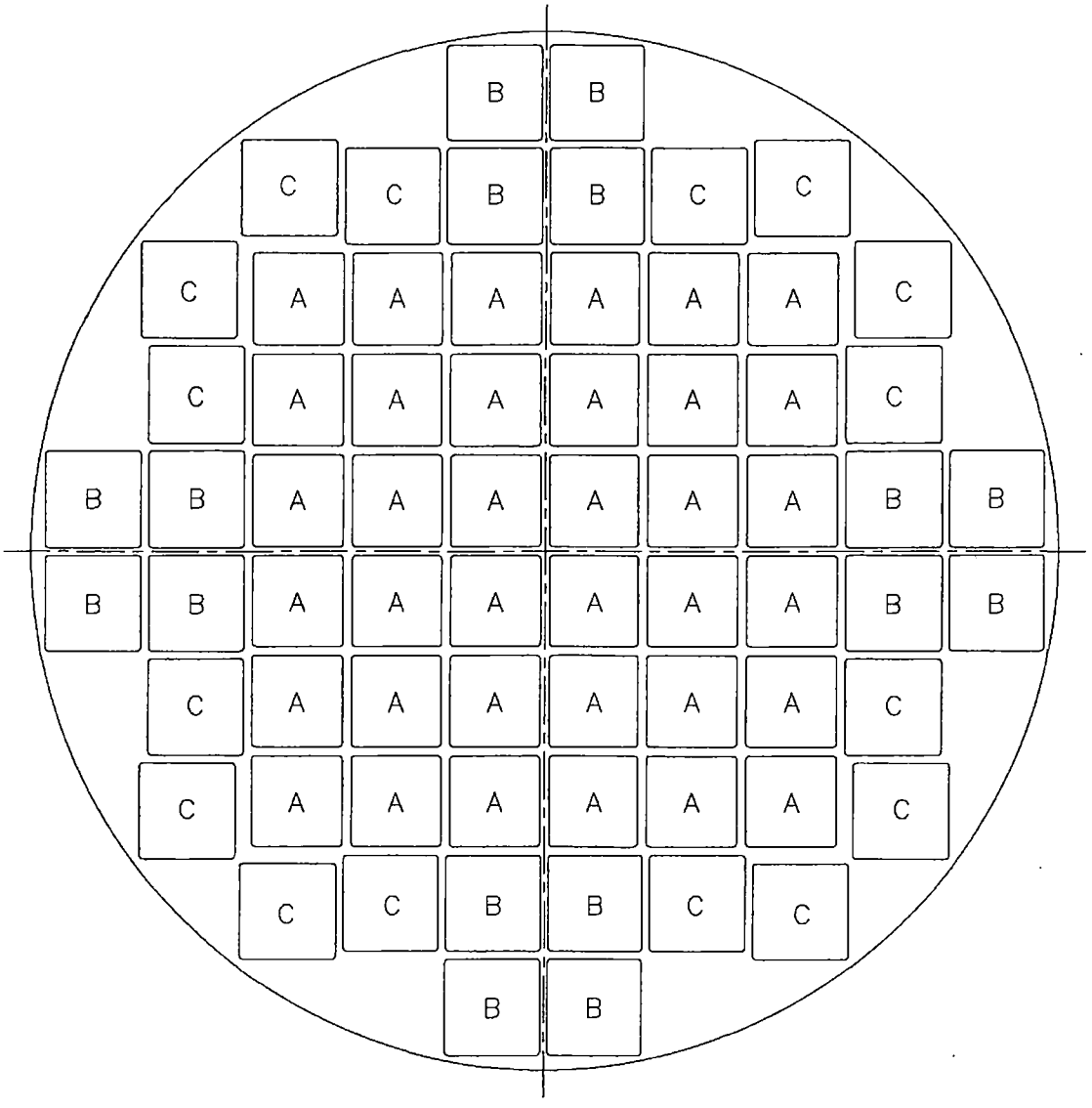


Figure 6.A.4-4 Allowed Loading Configuration for LACBWR Fuel



Slot A: Undamaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Slot B: Undamaged or damaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Damaged Allis Chalmers fuel maximum enrichment 3.64 wt % ^{235}U.

Slot C: Undamaged or damaged Exxon fuel maximum planar average enrichment 3.71 wt % ^{235}U.

Damaged Allis Chalmers fuel maximum enrichment 3.94 wt % ^{235}U.

Table 6.A.4-1 Baseline Reactivity Evaluation Results – Typical Tube and Disk Basket Maximum Reactivity Configuration

Fuel Type	Discrete Enrichment	Pellet / Clad Gap	Enrichment $\%^{235}U$	k_{eff}	Δk
AC	N/A	Dry	3.64	0.88298	--
AC	N/A	Dry	3.94	0.90521	--
EX	N/A	Dry	3.71	0.85525	--
EX	N/A	Dry	3.70	0.85365	--
EX	Yes	Dry	3.70	0.85313	-0.00052
AC	N/A	Wet	3.64	0.88704	--
AC	N/A	Wet	3.94	0.90794	--
EX	N/A	Wet	3.71	0.86033	--

Table 6.A.4-2 Component Tolerance Study – No Shift – Allis Chalmers Fuel (AC) at 3.94 wt % ^{235}U

Tube Tol.		Absorber Tol.		Disk Tol.						
Outer Width	Thickness	Width	Thickness	Op Width	Location	Thickness	Spacing	k_{eff}	Δk	Δk/σ
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.88983	--	--
Min	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.88980	-0.00003	0.0
Max	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.89144	0.00161	1.4
Nom	Min	Nom	Nom	Nom	Nom	Nom	Nom	0.89662	0.00679	6.0
Nom	Max	Nom	Nom	Nom	Nom	Nom	Nom	0.88524	-0.00459	-4.0
Nom	Nom	Min	Nom	Nom	Nom	Nom	Nom	0.89243	0.00260	2.3
Nom	Nom	Max	Nom	Nom	Nom	Nom	Nom	0.88889	-0.00094	-0.9
Nom	Nom	Nom	Min	Nom	Nom	Nom	Nom	0.89041	0.00058	0.5
Nom	Nom	Nom	Max	Nom	Nom	Nom	Nom	0.89027	0.00044	0.4
Nom	Nom	Nom	Nom	Min	Nom	Nom	Nom	0.88937	-0.00046	-0.4
Nom	Nom	Nom	Nom	Max	Nom	Nom	Nom	0.89041	0.00058	0.5
Nom	Nom	Nom	Nom	Nom	Min	Nom	Nom	0.88911	-0.00072	-0.6
Nom	Nom	Nom	Nom	Nom	Max	Nom	Nom	0.88988	0.00005	0.0
Nom	Nom	Nom	Nom	Nom	Nom	Min	Nom	0.88959	-0.00024	-0.2
Nom	Nom	Nom	Nom	Nom	Nom	Max	Nom	0.88931	-0.00052	-0.5
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Min	0.89031	0.00048	0.4
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Max	0.89061	0.00078	0.7
Max	Min	Min	Max	Max	Min	Max	Min	0.90051	0.01068	9.6

Table 6.A.4-3 Component Tolerance Study – No Shift – Exxon Fuel (EX) at 3.71 wt % ^{235}U

Tube Tol.		Absorber Tol.		Disk Tol.						
Outer Width	Thickness	Width	Thickness	Op_Width	Location	Thickness	Spacing	k_{eff}	Δk	Δk/σ
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.84195	--	--
Min	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.84009	-0.00186	-1.6
Max	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.84328	0.00133	1.2
Nom	Min	Nom	Nom	Nom	Nom	Nom	Nom	0.84800	0.00605	5.6
Nom	Max	Nom	Nom	Nom	Nom	Nom	Nom	0.83573	-0.00622	-5.5
Nom	Nom	Min	Nom	Nom	Nom	Nom	Nom	0.84201	0.00006	0.1
Nom	Nom	Max	Nom	Nom	Nom	Nom	Nom	0.83957	-0.00238	-2.1
Nom	Nom	Nom	Min	Nom	Nom	Nom	Nom	0.83924	-0.00271	-2.5
Nom	Nom	Nom	Max	Nom	Nom	Nom	Nom	0.84288	0.00093	0.8
Nom	Nom	Nom	Nom	Min	Nom	Nom	Nom	0.84140	-0.00055	-0.5
Nom	Nom	Nom	Nom	Max	Nom	Nom	Nom	0.84149	-0.00046	-0.4
Nom	Nom	Nom	Nom	Nom	Min	Nom	Nom	0.84094	-0.00101	-0.9
Nom	Nom	Nom	Nom	Nom	Max	Nom	Nom	0.84121	-0.00074	-0.6
Nom	Nom	Nom	Nom	Nom	Nom	Min	Nom	0.84150	-0.00045	-0.4
Nom	Nom	Nom	Nom	Nom	Nom	Max	Nom	0.84342	0.00147	1.3
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Min	0.84181	-0.00014	-0.1
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Max	0.84073	-0.00122	-1.1
Max	Min	Min	Max	Max	Min	Max	Min	0.85141	0.00946	8.4

Table 6.A.4-4 Component Shift Study – No Tolerance Applied – Allis Chalmers Fuel (AC) at 3.94 wt % ^{235}U

Comp. Radial Shift				
Fuel	**Tube**	k_{eff}	Δk	$\Delta k/\sigma$
Centered	Centered	0.88983	--	--
Centered	Top	0.88874	-0.00109	-1.0
Centered	Bottom	0.88951	-0.00032	-0.3
Centered	Right	0.88977	-0.00006	-0.1
Centered	Left	0.88928	-0.00055	-0.5
Centered	Corner	0.88995	0.00012	0.1
Centered	In	0.89618	0.00635	5.6
Centered	Out	0.88445	-0.00538	-4.8
Centered	Custom	0.88866	-0.00117	-1.0
Top	Centered	0.89067	0.00084	0.7
Top	Top	0.88932	-0.00051	-0.5
Bottom	Centered	0.89094	0.00111	1.0
Bottom	Bottom	0.88929	-0.00054	-0.5
Right	Centered	0.88994	0.00011	0.1
Right	Right	0.88984	0.00001	0.0
Left	Centered	0.89233	0.00250	2.2
Left	Left	0.88972	-0.00011	-0.1
Corner	Centered	0.88965	-0.00018	-0.2
Corner	Corner	0.89040	0.00057	0.5
In	Centered	0.89248	0.00265	2.3
In	In	0.89765	0.00782	6.9
Out	Centered	0.88705	-0.00278	-2.5
Out	Out	0.88181	-0.00802	-7.2

Table 6.A.4-5 Component Shift Study – No Tolerance Applied – Exxon Fuel (EX) at 3.71 wt % ^{235}U

Comp. Radial Shift				
Fuel	**Tube**	k_{eff}	Δk	$\Delta k/\sigma$
Centered	Centered	0.84195	--	--
Centered	Top	0.84142	-0.00053	-0.5
Centered	Bottom	0.84128	-0.00067	-0.6
Centered	Right	0.84094	-0.00101	-0.9
Centered	Left	0.84025	-0.00170	-1.5
Centered	Corner	0.84256	0.00061	0.6
Centered	In	0.84580	0.00385	3.5
Centered	Out	0.83437	-0.00758	-6.8
Centered	Custom	0.84188	-0.00007	-0.1
Top	Centered	0.84185	-0.00010	-0.1
Top	Top	0.84227	0.00032	0.3
Bottom	Centered	0.84096	-0.00099	-0.9
Bottom	Bottom	0.84099	-0.00096	-0.9
Right	Centered	0.84210	0.00015	0.1
Right	Right	0.83924	-0.00271	-2.4
Left	Centered	0.84188	-0.00007	-0.1
Left	Left	0.83911	-0.00284	-2.7
Corner	Centered	0.84070	-0.00125	-1.1
Corner	Corner	0.84220	0.00025	0.2
In	Centered	0.84182	-0.00013	-0.1
In	In	0.84753	0.00558	4.9
Out	Centered	0.84047	-0.00148	-1.3
Out	Out	0.83438	-0.00757	-6.9

Table 6.A.4-6 Component Tolerance Study – In Shift Allis Chalmers Fuel (AC) at 3.94 wt % ^{235}U

Tube Tol.		Absorber Tol.		Disk Tol.						
Outer Width	**Thickness**	**Width**	**Thickness**	**Op Width**	**Location**	**Thickness**	**Spacing**	k_{eff}	Δk	$\Delta k/\sigma$
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.89765	--	--
Min	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.89728	-0.00037	-0.3
Max	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.89960	0.00195	1.7
Nom	Min	Nom	Nom	Nom	Nom	Nom	Nom	0.90312	0.00547	4.8
Nom	Max	Nom	Nom	Nom	Nom	Nom	Nom	0.89114	-0.00651	-5.7
Nom	Nom	Min	Nom	Nom	Nom	Nom	Nom	0.89853	0.00088	0.8
Nom	Nom	Max	Nom	Nom	Nom	Nom	Nom	0.89477	-0.00288	-2.5
Nom	Nom	Nom	Min	Nom	Nom	Nom	Nom	0.89727	-0.00038	-0.3
Nom	Nom	Nom	Max	Nom	Nom	Nom	Nom	0.89679	-0.00086	-0.7
Nom	Nom	Nom	Nom	Min	Nom	Nom	Nom	0.89797	0.00032	0.3
Nom	Nom	Nom	Nom	Max	Nom	Nom	Nom	0.89666	-0.00099	-0.9
Nom	Nom	Nom	Nom	Nom	Min	Nom	Nom	0.89715	-0.00050	-0.5
Nom	Nom	Nom	Nom	Nom	Max	Nom	Nom	0.89735	-0.00030	-0.3
Nom	Nom	Nom	Nom	Nom	Nom	Min	Nom	0.89625	-0.00140	-1.3
Nom	Nom	Nom	Nom	Nom	Nom	Max	Nom	0.89615	-0.00150	-1.3
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Min	0.89713	-0.00052	-0.5
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Max	0.89683	-0.00082	-0.7
Max	Min	Min	Max	Max	Min	Max	Min	0.90794	0.01029	9.1

Table 6.A.4-7 Component Tolerance Study – In Shift Exxon Fuel (EX) at 3.71 wt % ^{235}U

Tube Tol.		Absorber Tol.		Disk Tol.						
Outer Width	Thickness	Width	Thickness	Op_Width	Location	Thickness	Spacing	k_{eff}	Δk	$\Delta k/\sigma$
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.84753	--	--
Min	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.84771	0.00018	0.2
Max	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.85028	0.00275	2.4
Nom	Min	Nom	Nom	Nom	Nom	Nom	Nom	0.85547	0.00794	6.9
Nom	Max	Nom	Nom	Nom	Nom	Nom	Nom	0.84325	-0.00428	-3.8
Nom	Nom	Min	Nom	Nom	Nom	Nom	Nom	0.84929	0.00176	1.6
Nom	Nom	Max	Nom	Nom	Nom	Nom	Nom	0.84789	0.00036	0.3
Nom	Nom	Nom	Min	Nom	Nom	Nom	Nom	0.84925	0.00172	1.5
Nom	Nom	Nom	Max	Nom	Nom	Nom	Nom	0.84800	0.00047	0.4
Nom	Nom	Nom	Nom	Min	Nom	Nom	Nom	0.84621	-0.00132	-1.2
Nom	Nom	Nom	Nom	Max	Nom	Nom	Nom	0.84798	0.00045	0.4
Nom	Nom	Nom	Nom	Nom	Min	Nom	Nom	0.84824	0.00071	0.6
Nom	Nom	Nom	Nom	Nom	Max	Nom	Nom	0.84717	-0.00036	-0.3
Nom	Nom	Nom	Nom	Nom	Nom	Min	Nom	0.84801	0.00048	0.4
Nom	Nom	Nom	Nom	Nom	Nom	Max	Nom	0.84796	0.00043	0.4
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Min	0.84936	0.00183	1.6
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Max	0.84810	0.00057	0.5
Max	Min	Min	Max	Max	Min	Max	Min	0.86033	0.01280	11.4

Table 6.A.4-8 DFC Undamaged Assembly and Missing Rod Study Results

Primary Fuel (Interior)		Secondary Fuel (Exterior)							
Type	Enrichment wt % ^{235}U	Type	Enrichment wt % ^{235}U	DFC Model	DFC Content	Missing Rods #	k_{eff}	Δk	$\Delta k/\sigma$
EX	3.71	N/A	N/A	No	N/A	N/A	0.86033	--	--
EX	3.71	N/A	N/A	Yes	IAA	N/A	0.85806	--	--
EX	3.71	N/A	N/A	Yes	IAA	1	0.86003	0.00197	1.8
EX	3.71	N/A	N/A	Yes	IAA	4	0.85946	0.00140	1.3
EX	3.71	N/A	N/A	Yes	IAA	8	0.85741	-0.00065	-0.6
EX	3.71	N/A	N/A	Yes	IAA	12	0.85886	0.00080	0.7
EX	3.71	N/A	N/A	Yes	IAA	16	0.85972	0.00166	1.5
EX	3.71	N/A	N/A	Yes	IAA	20	0.85883	0.00077	0.7
EX	3.71	N/A	N/A	Yes	IAA	30	0.85751	-0.00055	-0.5
EX	3.71	N/A	N/A	Yes	IAA	48	0.85433	-0.00373	-3.5
EX	3.71	AC	3.94	Yes	IAA	N/A	0.86144	--	--
EX	3.71	AC	3.94	Yes	IAA	1	0.86068	-0.00076	-0.7
EX	3.71	AC	3.94	Yes	IAA	4	0.86033	-0.00111	-1.0
EX	3.71	AC	3.94	Yes	IAA	8	0.86081	-0.00063	-0.6
EX	3.71	AC	3.94	Yes	IAA	12	0.86111	-0.00033	-0.3
EX	3.71	AC	3.94	Yes	IAA	16	0.86129	-0.00015	-0.1
EX	3.71	AC	3.94	Yes	IAA	20	0.86198	0.00054	0.5
EX	3.71	AC	3.94	Yes	IAA	32	0.86132	-0.00012	-0.1
EX	3.71	AC	3.94	Yes	IAA	50	0.85505	-0.00639	-5.8

Table 6.A.4-9 DFC Damaged Assembly – No Clad, Modified Pitch, Missing Rod Study Results

Primary Fuel		Secondary Fuel								
Type	Enrichment wt % ^{235}U	Type	Enrichment wt % ^{235}U	DFC Model	DFC Content	Pitch [in]	Missing Rods #	k_{eff}	Δk	$\Delta k/\sigma$
EX	3.71	AC	3.94	Yes	URA	--	N/A	0.87209	--	--
EX	3.71	AC	3.94	Yes	URA	0.5825	N/A	0.87595	0.00386	3.6
EX	3.71	AC	3.94	Yes	URA	0.5999	N/A	0.87930	0.00721	6.4
EX	3.71	AC	3.94	Yes	URA	0.5999	N/A	0.87930	--	--
EX	3.71	AC	3.94	Yes	URA	0.5999	1	0.88051	0.00121	1.1
EX	3.71	AC	3.94	Yes	URA	0.5999	4	0.87886	-0.00044	-0.4
EX	3.71	AC	3.94	Yes	URA	0.5999	8	0.87760	-0.00170	-1.5
EX	3.71	AC	3.94	Yes	URA	0.5999	12	0.87747	-0.00183	-1.6
EX	3.71	AC	3.94	Yes	URA	0.5999	16	0.87521	-0.00409	-3.7
EX	3.71	AC	3.94	Yes	URA	0.5999	20	0.87090	-0.00840	-7.2
EX	3.71	AC	3.94	Yes	URA	0.5999	32	0.86681	-0.01249	-10.8
EX	3.71	AC	3.94	Yes	URA	0.5999	50	0.86071	-0.01859	-16.7
EX	3.71	EX	3.71	Yes	URA	0.557	N/A	0.86752	--	--
EX	3.71	EX	3.71	Yes	URA	0.5789	N/A	0.87208	0.00456	4.2
EX	3.71	EX	3.71	Yes	URA	0.6007	N/A	0.87275	0.00523	4.6
EX	3.71	EX	3.71	Yes	URA	0.6007	N/A	0.87275	--	--
EX	3.71	EX	3.71	Yes	URA	0.6007	1	0.87319	0.00044	0.4
EX	3.71	EX	3.71	Yes	URA	0.6007	4	0.87174	-0.00101	-0.9
EX	3.71	EX	3.71	Yes	URA	0.6007	8	0.87075	-0.00200	-1.8
EX	3.71	EX	3.71	Yes	URA	0.6007	12	0.86867	-0.00408	-3.6
EX	3.71	EX	3.71	Yes	URA	0.6007	16	0.86906	-0.00369	-3.1
EX	3.71	EX	3.71	Yes	URA	0.6007	20	0.86673	-0.00602	-5.2
EX	3.71	EX	3.71	Yes	URA	0.6007	30	0.86065	-0.01210	-10.7
EX	3.71	EX	3.71	Yes	URA	0.6007	48	0.85479	-0.01796	-15.6

Table 6.A.4-10 DFC Damaged Assembly – Fuel Mixture Study Results

Primary Fuel		Secondary Fuel							
Type	Enrichment wt % ^{235}U	Type	Enrichment wt % ^{235}U	DFC Model	DFC Content	Mix. Height	k_{eff}	Δk	$\Delta k/\sigma$
EX	3.71	N/A	N/A	No	N/A	N/A	0.86033	--	--
EX	3.71	N/A	N/A	Yes	MIX	0.25	0.85102	-0.00931	-8.3
EX	3.71	N/A	N/A	Yes	MIX	0.3	0.85200	-0.00833	-7.8
EX	3.71	N/A	N/A	Yes	MIX	0.4	0.85778	-0.00255	-2.3
EX	3.71	N/A	N/A	Yes	MIX	0.5	0.85994	-0.00039	-0.3
EX	3.71	N/A	N/A	Yes	MIX	0.6	0.86369	0.00336	2.9
EX	3.71	N/A	N/A	Yes	MIX	0.7	0.86599	0.00566	5.1
EX	3.71	N/A	N/A	Yes	MIX	0.8	0.86621	0.00588	5.3
EX	3.71	N/A	N/A	Yes	MIX	0.9	0.86521	0.00488	4.2
EX	3.71	N/A	N/A	Yes	MIX	1	0.86485	0.00452	4.0
EX	3.71	AC	3.94	Yes	MIX	0.25	0.85118	-0.00915	-8.3
EX	3.71	AC	3.94	Yes	MIX	0.3	0.85096	-0.00937	-8.5
EX	3.71	AC	3.94	Yes	MIX	0.4	0.85511	-0.00522	-4.8
EX	3.71	AC	3.94	Yes	MIX	0.5	0.86074	0.00041	0.4
EX	3.71	AC	3.94	Yes	MIX	0.6	0.86393	0.00360	3.2
EX	3.71	AC	3.94	Yes	MIX	0.7	0.86783	0.00750	6.6
EX	3.71	AC	3.94	Yes	MIX	0.8	0.86864	0.00831	7.2
EX	3.71	AC	3.94	Yes	MIX	0.9	0.86780	0.00747	6.7
EX	3.71	AC	3.94	Yes	MIX	1	0.86659	0.00626	5.7

Table 6.A.4-11 Preferentially Flooded System Shift Study – (AC Fuel, 3.94/3.64 wt % ^{235}U DFC Locations, EX Fuel, 3.71 wt % ^{235}U Interior Locations)

Comp. Radial Shift				
Fuel	**Tube**	k_{eff}	Δk	$\Delta k/\sigma$
In	In	0.92286	--	--
DFC_Close_A	DFC_Close_A	0.92045	-0.00241	-1.0
DFC_Close_B	DFC_Close_B	0.92183	-0.00103	-0.4

Table 6.A.4-12 DFC Shift Study – Preferential Flood Tolerance Evaluations Based on DFC_Close_B Shift Pattern

Tube Tol.		Absorber Tol.		Disk Tol.						
Outer Width	**Thickness**	**Width**	**Thickness**	**Op_Width**	**Location**	**Thickness**	**Spacing**	k_{eff}	Δk	$\Delta k/\sigma$
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.92414	--	--
Min	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.92371	-0.00043	-0.2
Max	Nom	Nom	Nom	Nom	Nom	Nom	Nom	0.92117	-0.00297	-1.3
Nom	Min	Nom	Nom	Nom	Nom	Nom	Nom	0.91849	-0.00565	-2.5
Nom	Max	Nom	Nom	Nom	Nom	Nom	Nom	0.92373	-0.00041	-0.2
Nom	Nom	Min	Nom	Nom	Nom	Nom	Nom	0.92429	0.00015	0.1
Nom	Nom	Max	Nom	Nom	Nom	Nom	Nom	0.92288	-0.00126	-0.5
Nom	Nom	Nom	Min	Nom	Nom	Nom	Nom	0.92149	-0.00265	-1.2
Nom	Nom	Nom	Max	Nom	Nom	Nom	Nom	0.92201	-0.00213	-0.9
Nom	Nom	Nom	Nom	Min	Nom	Nom	Nom	0.92180	-0.00234	-1.0
Nom	Nom	Nom	Nom	Max	Nom	Nom	Nom	0.92311	-0.00103	-0.5
Nom	Nom	Nom	Nom	Nom	Min	Nom	Nom	0.92550	0.00136	0.6
Nom	Nom	Nom	Nom	Nom	Max	Nom	Nom	0.92160	-0.00254	-1.1
Nom	Nom	Nom	Nom	Nom	Nom	Min	Nom	0.92189	-0.00225	-1.0
Nom	Nom	Nom	Nom	Nom	Nom	Max	Nom	0.92253	-0.00161	-0.7
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Min	0.92638	0.00224	1.0
Nom	Nom	Nom	Nom	Nom	Nom	Nom	Max	0.92124	-0.00290	-1.3

Table 6.A.4-13 Exxon Placement in DFC

Primary Fuel		Secondary Fuel		Third Fuel				
Type	Enrichment wt % ^{235}U	Type	Enrichment wt % ^{235}U	Type	Enrichment wt % ^{235}U	k_{eff}	Δk	$\Delta k/\sigma$
EX	3.71	AC	3.94	AC	3.64	0.92286	--	--
EX	3.71	AC	3.94	EX	3.71	0.92175	-0.00123	-0.5
EX	3.71	EX	3.71	AC	3.64	0.90577	-0.01753	-7.5
EX	3.71	N/A	N/A	N/A	N/A	0.91357	-0.00977	-4.2

Table 6.A.4-14 Active Fuel Location Study for Wet TSC and Dry TSC

DFC Fuel Location	TSC	k_{eff}	Δk	$\Delta k/\sigma$
Active Fuel	Dry	0.92286	--	--
Bottom	Dry	0.92680	0.00394	1.6
Top	Dry	0.92502	0.00216	0.9
Active Fuel	Wet	0.87505	--	--
Bottom	Wet	0.87601	0.00096	0.8
Top	Wet	0.87254	-0.00251	-2.3

Table 6.A.4-15 Storage Cask Analyses Results

DFC Fuel Loc.Axial	Cask Model	Cask Array	Density (H_2O) Lattice	Exterior	DFC	k_{eff}	σ	$k_{eff}+2\sigma$	Δk
Active Fuel	Transfer	SC[1]	0.0001	0.0001	0.9982	0.92286	0.00175	0.92636	--
Active Fuel	Storage	SC	0.0001	0.0001	0.9982	0.90915	0.00161	0.91237	-0.01371
Active Fuel	Storage	SC	0.0001	0.0001	N/A	0.33965	0.00054	0.34073	-0.56950
Active Fuel	Storage	InfArray	0.9982	0.0001	N/A	0.87621	0.00083	0.87787	-0.04665
Active Fuel	Storage	InfArray	0.0001	0.0001	0.9982	0.91159	0.00163	0.91485	-0.01127
Active Fuel	Storage	InfArray	0.0001	0.0001	N/A	0.33869	0.00057	0.33983	-0.58417
Active Fuel	Storage	InfArray	0.0001	0.9982	N/A	0.33438	0.00069	0.33576	-0.58848
Active Fuel	Storage	InfArray	0.9982	0.9982	N/A	0.87447	0.00082	0.87611	-0.04839
Bottom	Transfer	SC	0.0001	0.0001	0.9982	0.92680	0.00167	0.93014	--
Bottom	Storage	SC	0.0001	0.0001	0.9982	0.91418	0.00170	0.91758	-0.01262
Bottom	Storage	SC	0.0001	0.0001	N/A	0.33994	0.00057	0.34108	-0.57424
Bottom	Storage	InfArray	0.9982	0.0001	N/A	0.87578	0.00082	0.87742	-0.05102
Bottom	Storage	InfArray	0.0001	0.0001	0.9982	0.91571	0.00164	0.91899	-0.01109
Bottom	Storage	InfArray	0.0001	0.0001	N/A	0.34100	0.00061	0.34222	-0.58580
Bottom	Storage	InfArray	0.0001	0.9982	N/A	0.33553	0.00069	0.33691	-0.59127
Bottom	Storage	InfArray	0.9982	0.9982	N/A	0.87363	0.00076	0.87515	-0.05317

[1] Single cask model.

Table 6.A.4-16 Fuel Assembly Limiting Characteristics

Fuel ID		AC	EX
Array		10×10	10×10
Number of Fuel Rods		100	96
Max. Active Length	[in]	83	83
Rod Pitch	[in]	0.565	0.557
Rod Diameter	[in]	0.396	0.394
Pellet Diameter	[in]	0.350	0.343
Clad Thickness	[in]	0.020	0.0220
Max. MTU(5)	[MTU]	0.1214	0.1119
Number of Inert Rods(1,2)		0	4
Listed Inert Rod OD	[in]	N/A	0.3940
Enrichment	[wt % ^{235}U]	3.64/3.94(4)	3.71(3)

Notes:

(1) Not required for fuel assemblies located in DFC.
(2) Inert rods comprised of stainless steel clad tube containing zirconium alloy slug.
(3) Planar average enrichment.
(4) Two AC fuel types, Type 1 at an enrichment of 3.64 wt % ^{235}U and Type 2 at 3.94 wt % ^{235}U.
(5) Damaged fuel cans are allowed to contain an additional 5% spent fuel rod material to account for loose pellets not necessarily associated with the as-built assembly.

Table 6.A.4-17 MCNP Validation – Range of Applicability

Parameter	Minimum	Maximum	MPC-LACBWR
Enrichment (wt % ^{235}U)	2.350%	4.738%	3.94%
Fuel rod pitch (cm)	1.30	2.54	1.524 (AC Loose Pellets)
Fuel pellet outer diameter (cm)	0.790	1.265	0.889 (AC Loose Pellets)
Fuel rod diameter (cm)	0.9400	1.4172	N/A
H/^{235}U atom ratio	72.7	403.9	195 (AC Loose Pellets)
Soluble boron (ppm by weight)	0	4986	0
Cluster Gap (cm)	1.206	13.750	1.2(1)
Boron (^{10}B) plate loading (g/cm^2)	0.0000	0.0670	0.020
EALCF (eV)	0.09781	0.77219	0.4215

Note: (1) Represents minimum flux trap between DFCs. Corner DFCs are separated by up to 2.8 cm. The maximum reactivity payload cluster gap is less than 1% lower than the range evaluated. This will not affect the USL applicability to the MPC-LACBWR basket.

6.A.5 Critical Benchmark Experiments

Criticality code validation is performed for the Monte Carlo evaluation code and neutron cross-section libraries. Criticality validation is required by the criticality safety standards ANSI/ANS-8.1 [A6].

6.A.5.1 Benchmark Experiments and Applicability

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. In Section 4, a guide for the determination of bias and subcritical safety limits is provided based on ANSI/ANS-8.17 [A7] 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 herein and is implemented for MCNP5 with continuous energy ENDF/B-VI cross-sections.

The NUREG/CR-6361 implements ANSI/ANS-8.17 criticality safety criterion as follows.

$$k_s \leq k_c - \Delta k_s - \Delta k_c - \Delta k_m \qquad \text{(Equation 1)}$$

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 the following.

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

Δk_c = margin for uncertainty in k_c, which includes allowance for the following.

- uncertainties in critical experiments
- statistical or convergence uncertainties, or both, in computation of k_c
- uncertainties resulting from extrapolation of k_c outside range of experimental data
- 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 shown.

$$k_s \leq 1 - \Delta k_m - \Delta k_s - (1 - k_c) - \Delta k_c \qquad \text{(Equation 2)}$$

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

$$k_s + \Delta k_s \leq 1 - \Delta k_m - \beta - \Delta\beta \qquad \text{(Equation 3)}$$

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 shown.

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

where:

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

This is the USL criterion as described in Section 4 of NUREG/CR-6361. Two methods are prescribed for the statistical determination of the USL. The "Confidence Band with Administrative Margin (USL-1)" approach is implemented here and is referred to generically as USL. A $\Delta k_m = 0.05$ and a lower confidence band are specified based on a linear regression of k_{eff} as a function of some system parameter. As recommended in NUREG/CR-6361, a simple

linear regression is performed on each system parameter, and the line with the greatest correlation is used to functionalize β.

Section 6.A.5.2 contains the extensive list of LWR critical benchmarks employed in the validation of MCNP with its continuous energy neutron cross-section libraries. The range of parameters included in the benchmarks is shown in Table 6.A.5-1.

Included in Section 6.A.5.2 are linear fits of reactivity (k_{eff}) to each of the system parameters. Experiments were chosen to reflect the fuel and basket geometry and materials, and the spent fuel cask criticality control mechanism. This includes the use of square pitched, low enriched uranium oxide fuel rods, a rectangular arrangement of assembles, light water moderation, and criticality control by spacing, borated moderator, and/or borated absorber panels and tubes. Trending in k_{eff} was evaluated for the following independent variables: wt % ^{235}U, rod pitch, H/U volume ratio, energy of the average neutron lethargy causing fission (EALCF), ^{10}B loading of the absorber sheet, and soluble boron loading. No statistically significant trends were found for any of the system parameters. USLs are, therefore, generated for each of the independent variables. A minimum USL covering the range of applicability of the benchmark set is determined as detailed in Section 6.A.5.2.

6.A.5.2 Results of Benchmark Calculations

To evaluate the relative importance of the trend analysis to the upper subcritical limits, correlation coefficients are required for all independent parameters. The linear correlation coefficient, R, is calculated by taking the square root of the R^2 value. In particular, the correlation coefficient, R, 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.

Table 6.A.5-2 contains the correlation coefficient, R, for each linear fit of k_{eff} versus experimental parameter. Linear fits and correlation constants are based on the 183 data-point evaluation sets plotted in Section 6.A.5-3. The cluster gap plot is limited to the 137 data points for experiments containing multiple fuel rod clusters. Single fuel rod cluster experiments documented in LEU-COMP-THERM sets 06, 14, 35 and 50, in addition to LEU-COMP-THERM experiments 01-01, 02-01 to -03, and 08-01 to -15, were therefore excluded from the cluster gap study. The 183 data points evaluated for the remaining parameters represent the complete set of experiments listed in Section 6.A.5-3 minus the three high energy lethargy experiments above 0.35 eV (Experiments LEU-COMP-THERM 14-05, -06 and -07). Addition of these points, while not resulting in a significant linear fit, produces a noticeable slope to the USL correlation not representative of the remaining data fits. As this increased slope results in a

higher USL, it is acceptable to discard these data points. The three higher energy points are removed from all independent variables for consistency.

As there is no significant correlation to any of the independent variables, the USL for each independent variable is calculated and shown with its range of applicability in Table 6.A.5-2. A sample output for EALCF is shown in Figure 6.A.5-1. Uncertainties included in the USLSTATS evaluation are the Monte Carlo uncertainty associated with the reactivity calculation and experimental uncertainty that was provided in the literature for each of the cases.

Based on all the independent variable correlations, a lower limit constant USL of 0.9376 may be applied. The range of applicability (area of applicability) of this limit may be extended to 5 wt % enriched fuel, as the correlation shows no significant trend with enrichment between 2.35 and 4.74 wt %, and that the limited trending observed increases the USL. Extending the range of applicability for the average neutron lethargy is based on a minimal, but positive, trend of the USL versus EALCF. Studies, including additional data points up to 0.7722 eV, indicate that the trending continues to the higher energy levels.

6.A.5.3 Critical Benchmarks

From the International Handbook of Evaluated Criticality Safety Benchmark Experiments [A8], 186 experiments are selected as basis of the MCNP benchmarking. Experiments were selected for compatibility of materials and geometry with the spent fuel casks. Of particular interest are benchmarks with rectangular arrays of low enriched uranium oxide fuel rods in which reactivity is controlled by soluble boron or borated plates (tubes).

MCNP benchmark cases represent a collection of files composed of inputs directly obtained from references (with cross-section sets adjusted to those used in the cask analysis), NAC modified input files representing unique geometries based on reference input files, and input files constructed from the experimental material and geometry information. All cases were reviewed on a "preparer/checker" principle for modeling consistency with the cask models and the choice of code options. Due to large variations in the benchmark complexities, not all options employed in the cask models are reflected in each of the benchmarks (e.g., UNIVERSE structure). A review of the criticality results did not indicate any result trend due to particular modeling choices (e.g., using the UNIVERSE structure versus a single universe, or employing KSRC versus SDEF sampling).

Key system parameters, the experimental uncertainty, and calculated k_{eff} and σ for each experiment are shown in Table 6.A.5-3. The case number listed in the table corresponds to the handbook LEU-COMP-THERM-XXX experiment identification (e.g., Case 1.07 corresponds to

LEU-COMP-THERM-001 Experiment 7). Stochastic Monte Carlo error is kept within ±0.2% and each output is checked to assure that the MCNP build-in statistical checks on the results are passed and that all fissile material is sampled.

Scatter plots of k_{eff} versus system parameters for 183 data point sets (full set minus three high lethargy points above 0.35 eV) are created (see Figure 6.A.5-2 through Figure 6.A.5-10). Included in these scatter plots are linear regression lines with a corresponding correlation coefficient (R^2) to statistically indicate any trend or lack thereof. Scatter plates are created for k_{eff} versus the following.

Enrichment in ^{235}U (wt % ^{235}U)
Fuel rod pitch (cm)
Fuel pellet outer diameter (cm)
Fuel rod outer diameter (cm)
Hydrogen/uranium (^{235}U) atom ratio
Soluble boron (ppm by weight)
Cluster gap spacing (spacing between assemblies in cm)
Boron (^{10}B) plate loading (g/cm^2)
Energy of average neutron lethargy causing fission (eV)

Figure 6.A.5-1 USLSTATS Output for EALCF

```
*****************************************************************************
                        Version 1.4, April 23, 2003
                      Oak Ridge National Laboratory
*****************************************************************************
 Input to statistical treatment from file:enrich-183.in
 Title: keff vs enrichment
 Proportion of the population = .995
 Confidence of fit            = .950
 Confidence on proportion     = .950
 Number of observations       =  183
 Minimum value of closed band =    0.00
 Maximum value of closed band =    0.00
 Administrative margin        =    0.05
```

independent variable - x	dependent variable - y	deviation in y	independent variable - x	dependent variable - y	deviation in y
2.35000E+00	9.94910E-01	3.42000E-03	2.35000E+00	9.95090E-01	3.46000E-03
2.35000E+00	9.92830E-01	3.38000E-03	2.35000E+00	9.92520E-01	3.47000E-03
2.35000E+00	9.98060E-01	3.38000E-03	2.35000E+00	9.95620E-01	3.50000E-03
2.35000E+00	9.96550E-01	3.42000E-03	2.35000E+00	9.93130E-01	3.55000E-03
2.35000E+00	9.89310E-01	3.44000E-03	2.35000E+00	9.98130E-01	3.58000E-03
2.35000E+00	9.95340E-01	3.41000E-03	2.35000E+00	9.96700E-01	3.56000E-03
2.35000E+00	9.93880E-01	3.44000E-03	2.35000E+00	9.93830E-01	3.55000E-03
2.35000E+00	9.89690E-01	3.36000E-03	2.35000E+00	9.92770E-01	3.47000E-03
4.30600E+00	9.95160E-01	2.79000E-03	2.35000E+00	9.92920E-01	3.50000E-03
4.30600E+00	9.93670E-01	2.54000E-03	2.35000E+00	9.96410E-01	3.46000E-03
4.30600E+00	9.96340E-01	2.76000E-03	2.35000E+00	9.93060E-01	3.49000E-03
4.30600E+00	9.93110E-01	2.64000E-03	2.35000E+00	9.96500E-01	3.45000E-03
4.30600E+00	9.93000E-01	2.49000E-03	2.35000E+00	9.94680E-01	3.50000E-03
2.59600E+00	9.92680E-01	2.10000E-03	2.35000E+00	9.93300E-01	3.47000E-03
2.59600E+00	9.93190E-01	2.14000E-03	2.35000E+00	9.91810E-01	3.46000E-03
2.59600E+00	9.92990E-01	2.13000E-03	2.35000E+00	9.93920E-01	3.47000E-03
2.59600E+00	9.94790E-01	2.13000E-03	2.35000E+00	9.95560E-01	3.55000E-03
2.59600E+00	9.93100E-01	2.12000E-03	2.35000E+00	9.94540E-01	3.51000E-03
2.59600E+00	9.93240E-01	2.12000E-03	2.35000E+00	9.94490E-01	3.47000E-03
2.59600E+00	9.91990E-01	2.12000E-03	2.35000E+00	9.91300E-01	3.52000E-03
2.59600E+00	9.93820E-01	2.12000E-03	2.35000E+00	9.94800E-01	3.47000E-03
2.59600E+00	9.94450E-01	2.12000E-03	2.35000E+00	9.93500E-01	3.60000E-03
2.59600E+00	9.95440E-01	2.13000E-03	2.35000E+00	9.94000E-01	3.45000E-03
2.59600E+00	9.94410E-01	2.12000E-03	2.35000E+00	9.96280E-01	3.53000E-03
2.59600E+00	9.93920E-01	2.15000E-03	2.35000E+00	9.92620E-01	3.45000E-03
2.59600E+00	9.95090E-01	2.14000E-03	2.35000E+00	9.94100E-01	3.53000E-03
2.59600E+00	9.93780E-01	2.12000E-03	2.35000E+00	9.96470E-01	3.52000E-03
2.59600E+00	9.95040E-01	2.14000E-03	2.35000E+00	9.93600E-01	3.47000E-03
2.59600E+00	9.94380E-01	2.11000E-03	2.35000E+00	9.97020E-01	3.49000E-03
2.59600E+00	9.95730E-01	2.12000E-03	2.35000E+00	9.94970E-01	3.50000E-03
2.59600E+00	9.94270E-01	2.14000E-03	2.35000E+00	9.91950E-01	3.55000E-03
2.45900E+00	9.98350E-01	1.34000E-03	2.59600E+00	9.93410E-01	1.93000E-03
2.45900E+00	9.96860E-01	1.36000E-03	2.59600E+00	9.91310E-01	2.05000E-03
2.45900E+00	9.99310E-01	1.24000E-03	4.73800E+00	9.95860E-01	4.36000E-03
2.45900E+00	9.97950E-01	1.36000E-03	4.73800E+00	9.93580E-01	4.53000E-03
2.45900E+00	9.97650E-01	1.38000E-03	4.73800E+00	9.95390E-01	4.58000E-03
2.45900E+00	9.96990E-01	1.35000E-03	4.73800E+00	9.92370E-01	4.54000E-03
2.45900E+00	9.97230E-01	1.37000E-03	4.73800E+00	9.91440E-01	4.62000E-03
2.45900E+00	9.96590E-01	1.40000E-03	4.73800E+00	9.98780E-01	4.82000E-03
2.45900E+00	9.95260E-01	1.40000E-03	4.73800E+00	9.94180E-01	4.94000E-03
2.45900E+00	9.97450E-01	1.36000E-03	4.73800E+00	9.92400E-01	4.90000E-03
2.45900E+00	9.97590E-01	1.38000E-03	4.73800E+00	9.96930E-01	4.98000E-03
2.45900E+00	9.97650E-01	1.36000E-03	4.73800E+00	9.91370E-01	5.05000E-03
2.45900E+00	9.98880E-01	1.39000E-03	2.35000E+00	9.92500E-01	2.34000E-03
2.45900E+00	9.97350E-01	1.37000E-03	2.35000E+00	9.95140E-01	2.43000E-03
2.45900E+00	9.97580E-01	1.39000E-03	2.35000E+00	9.92190E-01	2.33000E-03
2.45900E+00	9.97720E-01	1.39000E-03	2.35000E+00	9.94760E-01	2.40000E-03
2.45900E+00	9.96910E-01	1.35000E-03	2.35000E+00	9.94690E-01	3.67000E-03
4.30600E+00	9.95480E-01	2.84000E-03	2.35000E+00	9.94340E-01	2.49000E-03
4.30600E+00	9.93430E-01	2.78000E-03	2.35000E+00	9.93190E-01	2.39000E-03
4.30600E+00	9.93300E-01	2.81000E-03	4.73800E+00	9.93300E-01	1.28000E-03
4.30600E+00	9.93710E-01	2.85000E-03	4.73800E+00	9.93400E-01	1.23000E-03
4.30600E+00	9.95930E-01	2.73000E-03	4.73800E+00	9.94890E-01	1.25000E-03
4.30600E+00	9.92950E-01	2.85000E-03	4.73800E+00	9.93190E-01	1.25000E-03
4.30600E+00	9.96160E-01	2.89000E-03	4.73800E+00	9.93060E-01	1.28000E-03
4.30600E+00	9.93890E-01	2.73000E-03	2.45900E+00	9.91330E-01	2.03000E-03
4.30600E+00	9.95710E-01	2.96000E-03	2.45900E+00	9.95970E-01	2.43000E-03
4.30600E+00	9.93190E-01	2.60000E-03	2.45900E+00	9.95550E-01	2.42000E-03
4.30600E+00	9.93780E-01	2.75000E-03	2.45900E+00	9.94860E-01	2.42000E-03
4.30600E+00	9.92630E-01	2.84000E-03	2.45900E+00	9.95040E-01	2.42000E-03
4.30600E+00	9.95660E-01	2.75000E-03	2.45900E+00	9.95420E-01	2.42000E-03

Figure 6.A.5-1 USLSTATS Output for EALCF

```
4.30600E+00    9.94310E-01    2.82000E-03    2.45900E+00    9.95300E-01    2.42000E-03
4.30600E+00    9.96390E-01    2.95000E-03    2.45900E+00    9.95070E-01    2.42000E-03
4.30600E+00    9.96860E-01    2.79000E-03    2.45900E+00    9.93680E-01    1.93000E-03
4.30600E+00    9.97160E-01    2.68000E-03    2.45900E+00    9.92100E-01    1.93000E-03
4.30600E+00    9.92370E-01    2.86000E-03    2.45900E+00    9.94470E-01    1.93000E-03
4.30600E+00    9.97190E-01    2.81000E-03    2.45900E+00    9.90730E-01    1.93000E-03
4.30600E+00    9.94340E-01    2.76000E-03    2.45900E+00    9.86520E-01    2.23000E-03
4.30600E+00    9.96920E-01    2.79000E-03    2.45900E+00    9.86340E-01    1.93000E-03
4.30600E+00    9.96060E-01    2.83000E-03    2.45900E+00    9.90420E-01    2.42000E-03
4.30600E+00    9.97400E-01    2.94000E-03    2.45900E+00    9.89740E-01    2.03000E-03
4.30600E+00    9.92810E-01    2.69000E-03    2.45900E+00    9.91520E-01    2.72000E-03
4.30600E+00    9.92560E-01    2.88000E-03    2.45900E+00    9.90290E-01    2.13000E-03
4.30600E+00    9.93650E-01    2.88000E-03    2.45900E+00    9.89270E-01    1.93000E-03
4.30600E+00    9.94970E-01    2.85000E-03    2.60000E+00    9.95710E-01    1.42000E-03
2.45900E+00    9.94820E-01    3.21000E-03    2.60000E+00    9.96180E-01    1.42000E-03
2.45900E+00    9.94940E-01    3.21000E-03    2.60000E+00    9.95340E-01    1.52000E-03
2.45900E+00    9.95140E-01    3.21000E-03    2.60000E+00    9.95470E-01    1.52000E-03
2.45900E+00    9.95640E-01    3.21000E-03    2.60000E+00    9.96910E-01    1.42000E-03
2.45900E+00    9.95080E-01    3.21000E-03    2.60000E+00    9.96140E-01    1.42000E-03
2.45900E+00    9.95260E-01    3.21000E-03    2.60000E+00    9.95890E-01    1.42000E-03
2.45900E+00    9.95200E-01    3.21000E-03    2.60000E+00    9.96240E-01    1.62000E-03
4.30600E+00    9.94020E-01    1.92000E-03    2.60000E+00    9.96670E-01    1.52000E-03
4.30600E+00    9.94460E-01    1.91000E-03    2.60000E+00    9.96760E-01    1.62000E-03
4.30600E+00    9.93550E-01    1.91000E-03    2.60000E+00    9.96370E-01    1.62000E-03
4.30600E+00    9.94010E-01    1.91000E-03    2.60000E+00    9.96430E-01    1.72000E-03
4.30600E+00    9.92810E-01    3.27000E-03    2.60000E+00    9.97010E-01    1.62000E-03
4.30600E+00    9.94960E-01    1.91000E-03    2.60000E+00    9.96500E-01    1.62000E-03
4.30600E+00    9.93780E-01    1.90000E-03    2.60000E+00    9.96340E-01    1.62000E-03
4.30600E+00    9.96680E-01    1.95000E-03    2.60000E+00    9.96580E-01    1.71000E-03
4.30600E+00    9.85950E-01    7.71000E-03    2.60000E+00    9.96450E-01    1.62000E-03
2.35000E+00    9.94940E-01    3.54000E-03
chi =  2.5464 (upper bound = 9.49). The data tests normal.
      Output from statistical treatment
keff vs enrichment
 Number of data points (n)                          183
 Linear regression, k(X)                            0.9950 + (-1.5719E-04)*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                                 2.3500E+00
 Maximum value of X                                 4.7380E+00
 Average value of X                                 3.0597E+00
 Average value of k                                  0.99453
 Minimum value of k                                  0.98595
 Variance of fit, s(k,X)^2                          5.0408E-06
 Within variance, s(w)^2                            7.8633E-06
 Pooled variance, s(p)^2                            1.2904E-05
 Pooled std. deviation, s(p)                        3.5922E-03
 C(alpha,rho)*s(p)                                  1.5554E-02
 student-t @ (n-2,1-gamma)                          1.64500E+00
 Confidence band width, W                           5.9793E-03
 Minimum margin of subcriticality, C*s(p)-W         9.5746E-03

 Upper subcritical limits: (  2.3500     <= X <=   4.7380    )
 ***** *********** *******
 USL Method 1 (Confidence Band with
 Administrative Margin)              USL1 = 0.9390 + (-1.5719E-04)*X
 USL Method 2 (Single-Sided Uniform
 Width Closed Interval Approach)     USL2 = 0.9795 + (-1.5719E-04)*X
 USLs Evaluated Over Range of Parameter X:
 **** ********* **** ***** ** ********* **

 X:  2.35E+0  2.69E+0  3.03E+0  3.37E+0  3.71E+0  4.06E+0  4.40E+0  4.74E+0
     ---------------------------------------------------------------------
USL-1:   0.9387   0.9386   0.9386   0.9385   0.9385   0.9384   0.9383   0.9383
USL-2:   0.9791   0.9790   0.9790   0.9789   0.9789   0.9788   0.9788   0.9787
     ---------------------------------------------------------------------
```

Figure 6.A.5-2 k_{eff} versus Fuel Enrichment

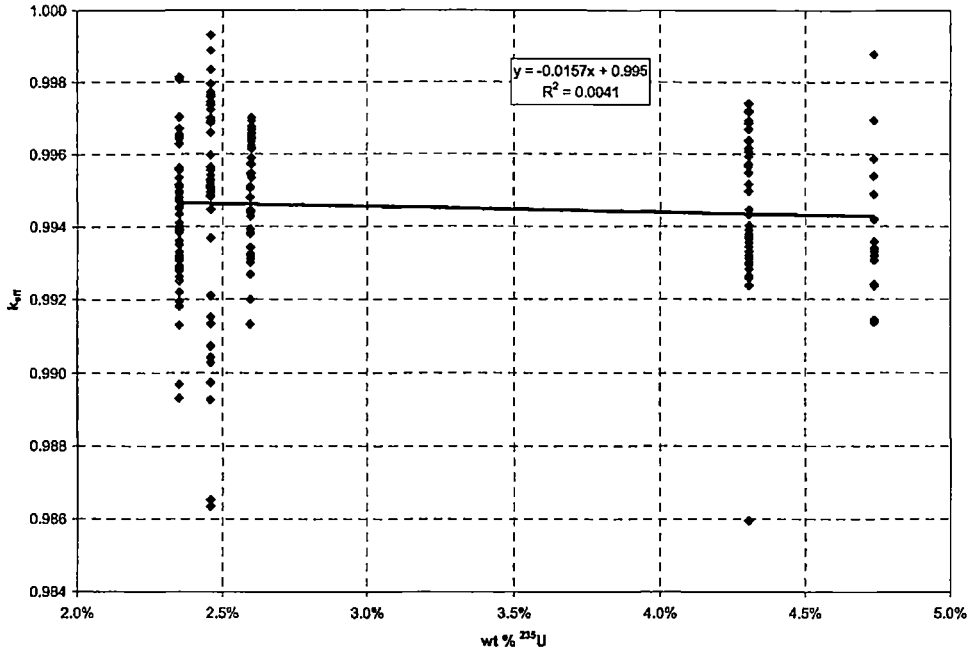


Figure 6.A.5-3 k_{eff} versus Rod Pitch

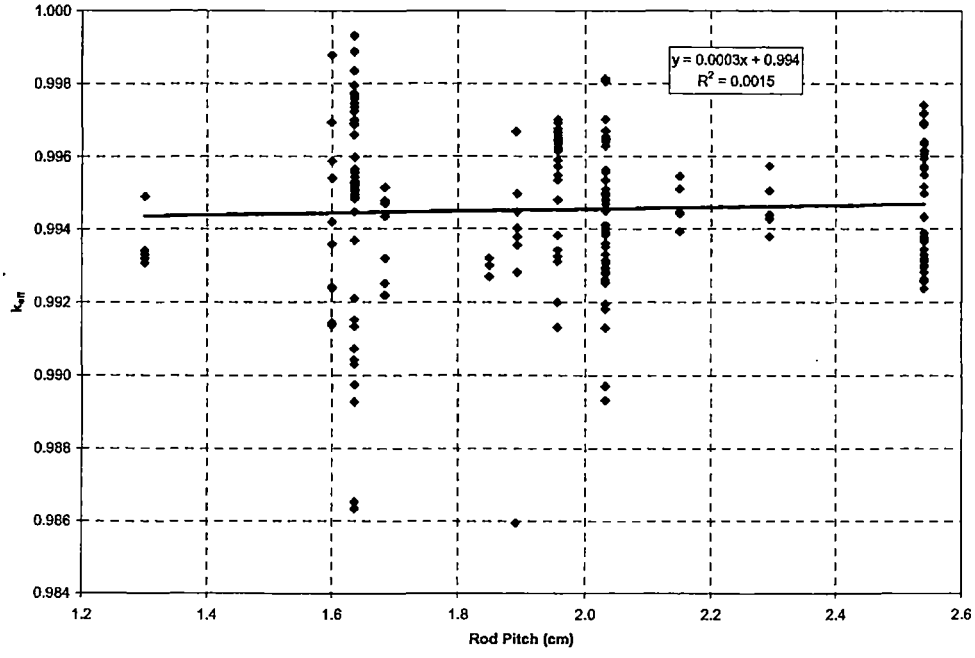


Figure 6.A.5-4 k_{eff} versus Fuel Pellet Diameter

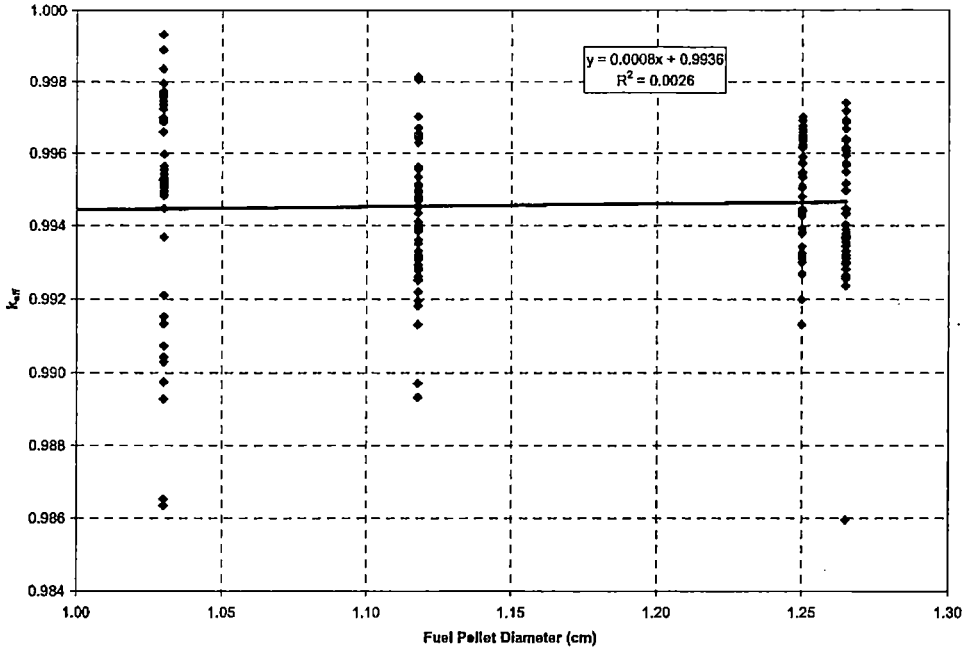


Figure 6.A.5-5 k_{eff} versus Fuel Rod Outside Diameter

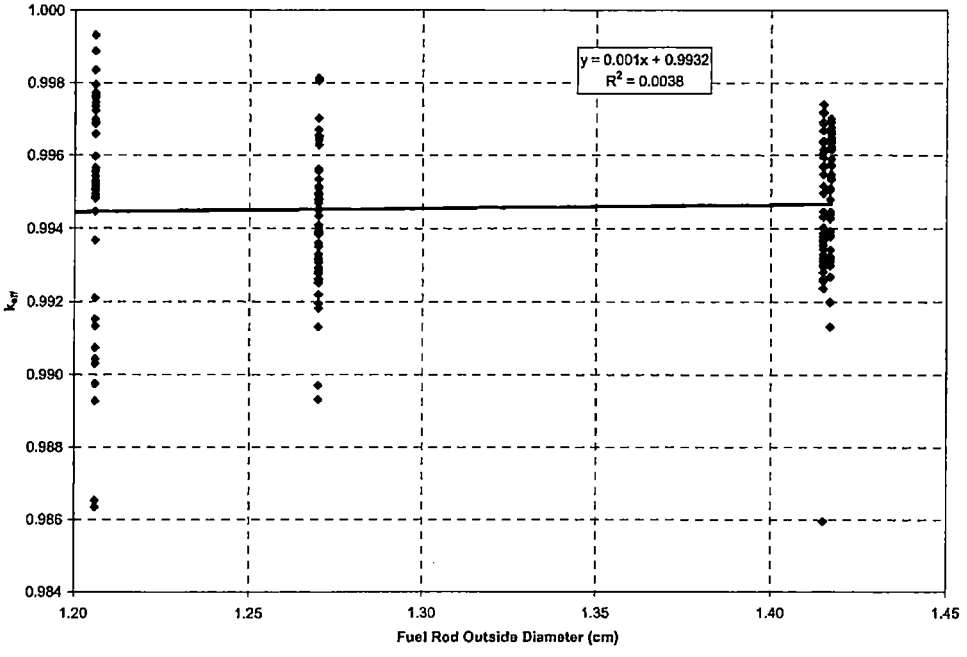


Figure 6.A.5-6 k_{eff} versus Hydrogen/^{235}U Atom Ratio

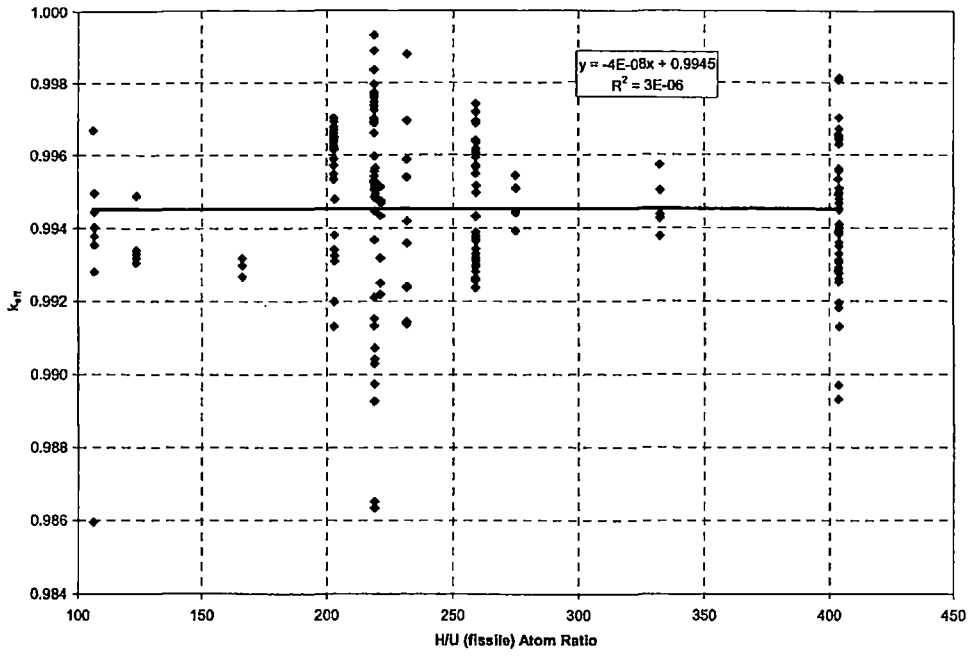


Figure 6.A.5-7 k_{eff} versus Soluble Boron Concentration

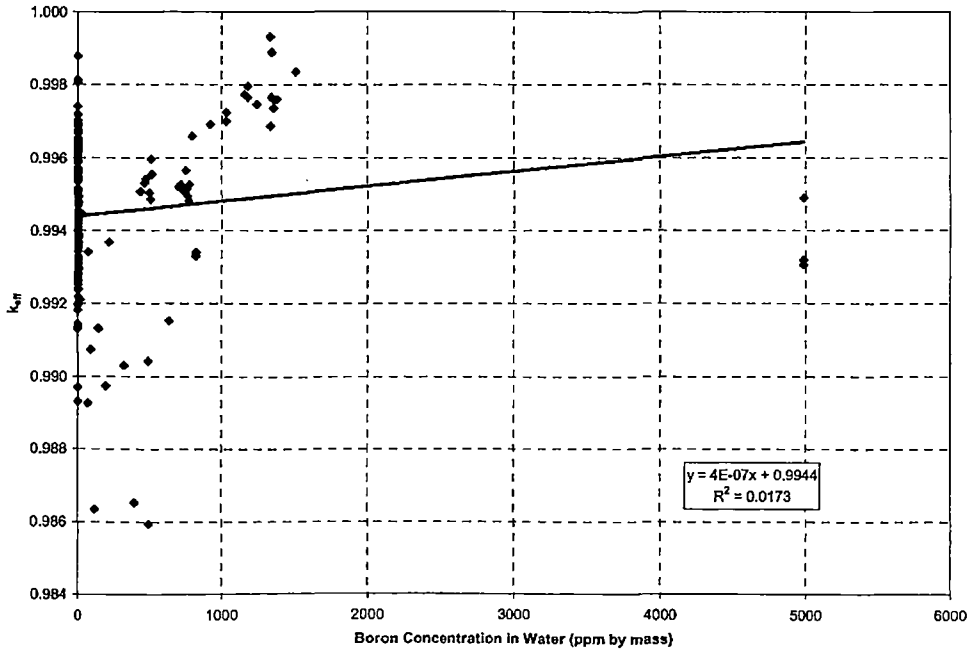


Figure 6.A.5-8 k_{eff} versus Cluster Gap Thickness

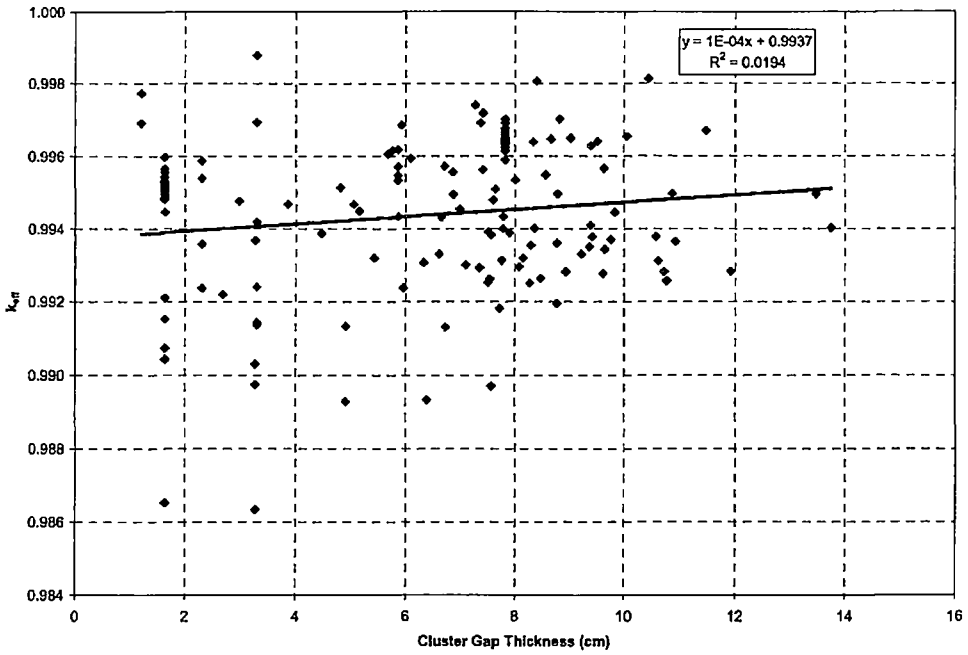


Figure 6.A.5-9 k_{eff} versus ^{10}B Plate Loading

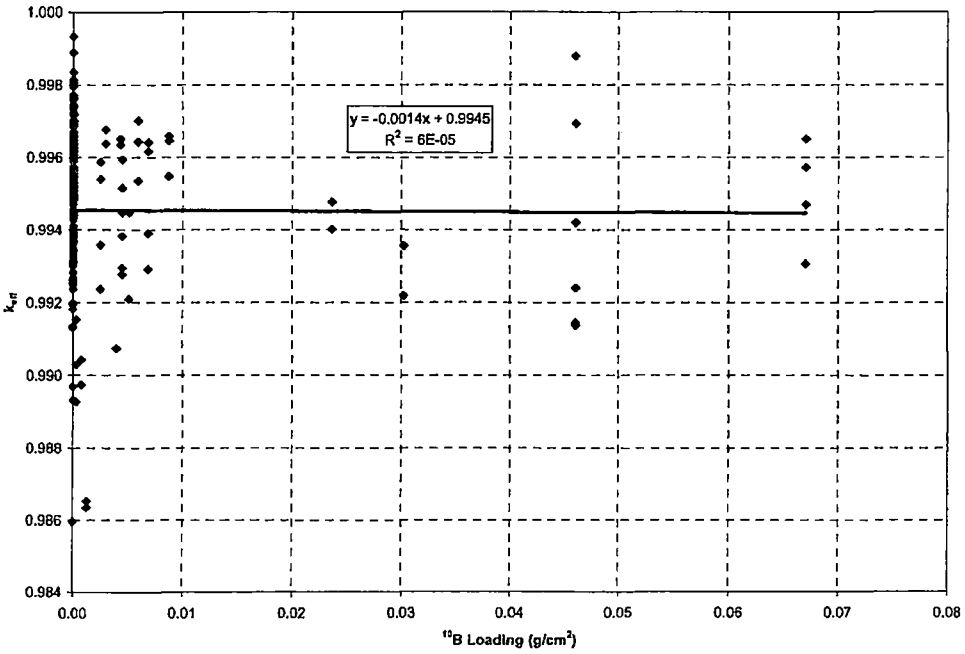


Figure 6.A.5-10 k_{eff} versus Energy of Average Neutron Lethargy Causing Fission

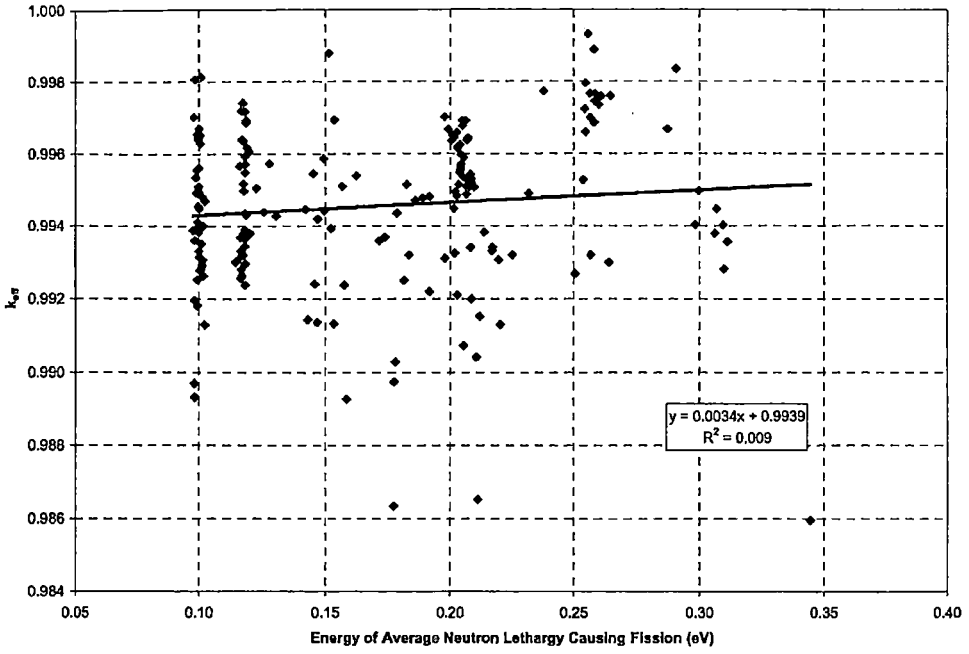


Table 6.A.5-1 Range of Applicability for Complete Set of 186 Benchmark Experiments

Parameter	Minimum	Maximum
Enrichment (wt % ^{235}U)	2.350%	4.738%
Fuel rod pitch (cm)	1.30	2.54
Fuel pellet outer diameter (cm)	0.790	1.265
Fuel rod diameter (cm)	0.9400	1.4172
$H/^{235}U$ atom ratio	72.7	403.9
Soluble boron (ppm by weight)	0	4986
Cluster Gap (cm)	1.206	13.750
Boron (^{10}B) plate loading (g/cm^2)	0.0000	0.0670
Energy of average neutron lethargy causing fission (eV)	0.09781	0.77219

Table 6.A.5-2 Correlation Coefficients and USLs for Benchmark Experiments

Variable	R^2	R	Range of Applicability	USLSTATS Correlation	USL Low	USL High
Enrichment (wt% ^{235}U)	0.00410	0.064	2.35<=X<=4.738	0.9390+-1.57E-04X	0.9382	0.9386
Fuel rod pitch (cm)	0.00150	0.039	1.3<=X<=2.54	0.9380+2.64E-04X	0.9383	0.9386
Fuel pellet outer diameter (cm)	0.00260	0.051	0.79<=X<=1.265	0.9376+8.25E-04X	0.9382	0.9386
Fuel rod diameter (cm)	0.00380	0.062	0.94<=X<=1.4172	0.9372+1.01E-03X	0.9381	0.9386
$H/^{235}U$ atom ratio	3.00E-06	0.002	106.2<=X<=403.9	0.9386-4.74E-08X	0.9385	0.9385
Soluble boron (ppm by weight)	0.01730	0.132	0<=X<=4986	0.9379+3.96E-07X	0.9379	0.9398
Cluster gap (cm)	0.01940	0.139	1.2<=X<=13.8	0.9375+9.82E-05X	0.9376	0.9388
Boron (^{10}B) plate loading (g/cm^2)	0.00006	0.008	0<=X<=0.067	0.9382-1.37E-03X	0.9381	0.9382
Energy of average neutron lethargy causing fission (eV)	0.00900	0.095	0.09781<=X<=0.3447	0.9379+3.45E-03X	0.9382	0.9390

Table 6.A.5-3 MCNP Validation Statistics

Case	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08
Clusters	1	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Mat'l	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-
Absorber Type	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	11.9	8.4	10.1	6.4	8.0	4.5	7.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-	-
EALCF (MeV)	9.916E-8	1.010E-7	9.838E-8	9.933E-8	9.837E-8	9.874E-8	9.781E-8	9.826E-8
Exp. σ	0.0030	0.0030	0.0030	0.0030	0.0030	0.0030	0.0031	0.0030
k_{eff}	0.99491	0.99283	0.99806	0.99655	0.98931	0.99534	0.99388	0.98969
σ	0.00165	0.00155	0.00155	0.00165	0.00169	0.00162	0.00150	0.00152

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	2.01	2.02	2.03	2.04	2.05
Clusters	1	1	1	3	3
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	2.540	2.540	2.540	2.540	2.540
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al
H/U (fissile)	259	259	259	259	259
Soluble B (ppm)	-	-	-	-	-
Absorber Type	-	-	-	-	-
Cluster Gap (cm)	-	-	-	10.6	7.1
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-
EALCF (MeV)	1.177E-7	1.164E-7	1.175E-7	1.161E-7	1.146E-7
Exp. σ	0.0020	0.0020	0.0020	0.0018	0.0019
k_{eff}	0.99516	0.99367	0.99634	0.99311	0.99300
σ	0.00195	0.00157	0.00190	0.00193	0.00161

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	6.01	6.02	6.03	6.04	6.05	6.06	6.07	6.08	6.09
Clusters	1	1	1	1	1	1	1	1	1
Enrichment (wt % ^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	1.849	1.849	1.849	1.956	1.956	1.956	1.956	1.956	2.150
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	166	166	166	203	203	203	203	203	275
Soluble B (ppm)	-	-	-	-	-	-	-	-	-
Absorber Type	-	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	-	-	-	-	-	-	-	-
EALCF (MeV)	2.506E-7	2.568E-7	2.642E-7	1.915E-7	1.978E-7	2.018E-7	2.085E-7	2.136E-7	1.422E-7
Exp. σ	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
k_{eff}	0.99268	0.99319	0.99299	0.99479	0.99310	0.99324	0.99199	0.99382	0.99445
σ	0.00065	0.00076	0.00074	0.00074	0.00069	0.00070	0.00071	0.00071	0.00069

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	6.10	6.11	6.12	6.13	6.14	6.15	6.16	6.17	6.18
Clusters	1	1	1	1	1	1	1	1	1
Enrichment (wt % ^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	2.150	2.150	2.150	2.150	2.293	2.293	2.293	2.293	2.293
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	275	275	275	275	332	332	332	332	332
Soluble B (ppm)	-	-	-	-	-	-	-	-	-
Absorber Type	-	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	-	-	-	-	-	-	-	-
EALCF (MeV)	1.453E-7	1.496E-7	1.523E-7	1.568E-7	1.202E-7	1.227E-7	1.257E-7	1.280E-7	1.306E-7
Exp. σ	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020	0.0020
k_{eff}	0.99544	0.99441	0.99392	0.99509	0.99378	0.99504	0.99438	0.99573	0.99427
σ	0.00073	0.00071	0.00078	0.00076	0.00070	0.00075	0.00067	0.00070	0.00076

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	8.01	8.02	8.03	8.04	8.05	8.06	8.07	8.08
Clusters	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3
Enrichment (wt % ^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219
Soluble B (ppm)	1511	1336	1336	1182	1182	1033	1033	794
Absorber Type	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-	-
EALCF (MeV)	2.907E-7	2.583E-7	2.559E-7	2.548E-7	2.566E-7	2.568E-7	2.544E-7	2.548E-7
Exp. σ	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
k_{eff}	0.99835	0.99686	0.99931	0.99795	0.99765	0.99699	0.99723	0.99659
σ	0.00060	0.00063	0.00032	0.00063	0.00069	0.00061	0.00066	0.00073

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	8.09	8.10	8.11	8.12	8.13	8.14	8.15	8.16	8.17
Clusters	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	3 x 3	5	5 x 5
Enrichment (wt % ^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	779	1245	1384	1348	1348	1363	1363	1158	921
Absorber Type	-	-	-	-	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-	-	-	1.2	1.2
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	-	-	-	-	-	-	-	-
EALCF (MeV)	2.538E-7	2.586E-7	2.647E-7	2.587E-7	2.582E-7	2.600E-7	2.609E-7	2.379E-7	2.063E-7
Exp. σ	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012	0.0012
k_{eff}	0.99526	0.99745	0.99759	0.99765	0.99888	0.99735	0.99758	0.99772	0.99691
σ	0.00072	0.00065	0.00068	0.00065	0.00070	0.00067	0.00071	0.00070	0.00062

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	9.01	9.02	9.03	9.04	9.05	9.06	9.07	9.08	9.09	9.10	9.11	9.12	9.13
Clusters	3	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment (wt % ^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	259	259	259	259	259	259	259	259	259	259	259	259	259
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (1.05% B)	304L SS (1.05% B)	304L SS (1.62% B)	304L SS (1.62% B)	Boral	Cu	Cu	Cu	Cu
Cluster Gap (cm)	8.6	9.7	9.2	9.8	6.1	8.1	5.8	7.9	6.7	8.2	9.4	8.5	9.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	0.00000	0.00000	0.00000	0.00000	0.00455	0.00455	0.00690	0.00690	0.06704	-	-	-	-
EALCF(MeV)	1.183E-7	1.181E-7	1.168E-7	1.179E-7	1.182E-7	1.182E-7	1.191E-7	1.182E-7	1.183E-7	1.173E-7	1.176E-7	1.169E-7	1.163E-7
Exp. σ	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
k_{eff}	0.99548	0.99343	0.99330	0.99371	0.99593	0.99295	0.99616	0.99389	0.99571	0.99319	0.99378	0.99263	0.99566
σ	0.00191	0.00182	0.00187	0.00192	0.00174	0.00193	0.00198	0.00175	0.00209	0.00153	0.00178	0.00191	0.00177

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	9.14	9.15	9.16	9.17	9.18	9.19	9.20	9.21	9.22	9.23	9.24	9.25	9.26	9.27
Clusters	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment (wt % ^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540	2.540
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	259	259	259	259	259	259	259	259	259	259	259	259	259	259
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	Cu (0.989 wt % Cd)	Cu (0.989 wt % Cd)	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Cd	Al (no B)	Al (no B)	Zircaloy-4	Zircaloy-4
Cluster Gap (cm)	6.7	8.4	5.9	7.4	6.0	7.4	5.9	7.4	5.7	7.3	10.7	10.8	10.9	10.9
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	-	-	-	-	-	-	-	-	-	0.00000	0.00000	-	-
EALCF(MeV)	1.186E-7	1.171E-7	1.186E-7	1.183E-7	1.183E-7	1.168E-7	1.182E-7	1.187E-7	1.199E-7	1.173E-7	1.167E-7	1.165E-7	1.181E-7	1.177E-7
Exp. σ	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021	0.0021
k_{eff}	0.99431	0.99639	0.99686	0.99716	0.99237	0.99719	0.99434	0.99692	0.99606	0.99740	0.99281	0.99256	0.99365	0.99497
σ	0.00188	0.00207	0.00183	0.00166	0.00194	0.00187	0.00179	0.00183	0.00189	0.00206	0.00168	0.00197	0.00197	0.00193

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	11.03	11.04	11.05	11.06	11.07	11.08	11.09
Clusters	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219
Soluble B (ppm)	769	764	762	753	739	721	702
Absorber Type	-	-	-	-	-	-	-
Cluster Gap (cm)	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-	-	-
EALCF [MeV]	2.027E-7	2.020E-7	2.035E-7	2.044E-7	2.065E-7	2.068E-7	2.085E-7
Exp. σ	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032
k_{eff}	0.99482	0.99494	0.99514	0.99564	0.99508	0.99526	0.99520
σ	0.00031	0.00030	0.00030	0.00030	0.00031	0.00030	0.00031

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	13.01	13.02	13.03	13.04	13.05	13.06	13.07
Clusters	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	1.892	1.892	1.892	1.892	1.892	1.892	1.892
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	107	107	107	107	107	107	107
Soluble B (ppm)	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (1.05% B)	Boral B	Boroflex	Cd	Cu	Cu (0.989 wt % Cd)
Cluster Gap (cm)	13.8	9.8	8.3	8.4	8.9	13.5	10.6
Reflector	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Plate Loading ($g^{10}B/cm^2$)	0.00000	0.00455	0.03022	0.02361	-	-	-
EALCF (MeV)	2.982E-7	3.068E-7	3.111E-7	3.094E-7	3.097E-7	2.998E-7	3.061E-7
Exp. σ	0.0018	0.0018	0.0018	0.0018	0.0032	0.0018	0.0018
k_{eff}	0.99402	0.99446	0.99355	0.99401	0.99281	0.99496	0.99378
σ	0.00068	0.00064	0.00064	0.00064	0.00066	0.00063	0.00062

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	14.01	14.02	14.05	14.06	14.07
Clusters	1	1	1	1	1
Enrichment (wt %^{235}U)	4.31%	4.31%	4.31%	4.31%	4.31%
Pitch (cm)	1.890	1.890	1.890	1.715	1.715
Fuel OD (cm)	1.265	1.265	1.265	1.265	1.265
Clad OD (cm)	1.415	1.415	1.415	1.415	1.415
Clad Material	Al	Al	Al	Al	Al
H/U (fissile)	106	106	106	73	73
Soluble B (ppm)	0	491	2539	0	1030
Absorber Type	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-
EALCF (MeV)	2.873E-7	3.447E-7	6.003E-7	5.175E-7	7.722E-7
Exp. σ	0.0019	0.0077	0.0069	0.0033	0.0051
k_{eff}	0.99668	0.98595	1.00221	1.00245	0.99973
σ	0.00044	0.00045	0.00043	0.00045	0.00044

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	16.01	16.02	16.03	16.04	16.05	16.06	16.07	16.08	16.09	16.10
Clusters	3	3	3	3	3	3	3	3	3	3
Enrichment [wt % ^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (no B)	304L SS (1.05% B)	304L SS (1.05% B)	304L SS (1.62% B)
Cluster Gap (cm)	6.9	7.6	7.5	7.4	7.8	10.4	11.5	7.6	9.6	7.4
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00455	0.00455	0.00690
EALCF (MeV)	1.000E-7	9.983E-8	9.947E-8	1.001E-7	1.002E-7	1.009E-7	1.001E-7	9.993E-8	1.004E-7	1.012E-7
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031
k_{eff}	0.99494	0.99509	0.99252	0.99562	0.99313	0.99813	0.99670	0.99383	0.99277	0.99292
σ	0.00171	0.00153	0.00157	0.00162	0.00173	0.00179	0.00175	0.00172	0.00157	0.00162

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	16.11	16.12	16.13	16.14	16.15	16.16	16.17	16.18	16.19	16.20	16.21	16.22
Clusters	3	3	3	3	3	3	3	3	3	3	3	3
Enrichment [wt % ^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch(cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (1.62% B)	Boral	Boral	Boral	Cu	Cu	Cu	Cu	Cu	Cu (0.989 wt % Cd)	Cd	Cd
Cluster Gap (cm)	9.5	6.3	9.0	5.1	6.6	7.7	7.5	6.9	7.0	5.2	6.7	7.6
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	0.00690	0.06704	0.06704	0.06704	-	-	-	-	-	-	-	-
EALCF (MeV)	9.962E-8	1.016E-7	1.006E-7	1.025E-7	1.000E-7	9.944E-8	9.904E-8	9.919E-8	9.971E-8	1.001E-7	1.024E-7	1.014E-7
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031
k_{eff}	0.99641	0.99306	0.99650	0.99468	0.99330	0.99181	0.99392	0.99556	0.99454	0.99449	0.99130	0.99480
σ	0.00154	0.00161	0.00152	0.00162	0.00157	0.00153	0.00155	0.00172	0.00165	0.00155	0.00166	0.00157

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	16.23	16.24	16.25	16.26	16.27	16.28	16.29	16.30	16.31	16.32
Clusters	3	3	3	3	3	3	3	3	3	3
Enrichment [wt % ^{235}U]	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch(cm)	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032	2.032
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	404	404	404	404	404	404	404	404	404	404
Soluble B (ppm)	-	-	-	-	-	-	-	-	-	-
Absorber Type	Cd	Cd	Cd	Cd	Cd	Al (no B)	Al (no B)	Al (no B)	Zircaloy-4	Zircaloy-4
Cluster Gap cm)	9.4	7.8	9.4	7.5	9.4	8.7	8.8	8.8	8.8	8.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	-	-	-	-	0.00000	0.00000	0.00000	-	-
EALCF (MeV)	1.010E-7	1.018E-7	1.006E-7	1.019E-7	9.948E-8	9.991E-8	9.843E-8	9.807E-8	9.964E-8	9.834E-8
Exp. σ	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031	0.0031
k_{eff}	0.99350	0.99400	0.99628	0.99262	0.99410	0.99647	0.99360	0.99702	0.99497	0.99195
σ	0.00184	0.00152	0.00169	0.00151	0.00168	0.00166	0.00157	0.00160	0.00163	0.00172

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	35.01	35.02	40.01	40.02	40.03	40.04	40.05	40.06	40.07	40.08	40.09	40.10
Clusters	1	1	4	4	4	4	4	4	4	4	4	4
Enrichment (wt % ^{235}U)	2.60%	2.60%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%	4.74%
Pitch (cm)	1.956	1.956	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600	1.600
Fuel OD (cm)	1.250	1.250	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790	0.790
Clad OD (cm)	1.417	1.417	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940	0.940
Clad Material	Al	Al	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy
H/U (fissile)	203	203	231	231	231	231	231	231	231	231	231	231
Soluble B (ppm)	70	148	-	-	-	-	-	-	-	-	-	-
Absorber Type	-	-	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Z2 CN18/10 SS (1.10% B)	Boral	Boral	Boral	Boral	Boral	Boral
Cluster Gap (cm)	-	-	2.3	2.3	2.3	2.3	3.3	3.3	3.3	3.3	3.3	3.3
Reflector	H_2O	H_2O	H_2O	Lead	Lead	Lead	H_2O	Lead	Lead	Lead	Steel	Steel
Plate Loading ($g^{10}B/cm^2$)	-	-	0.00252	0.00252	0.00252	0.00252	0.04608	0.04608	0.04608	0.04608	0.04608	0.04608
EALCF (MeV)	2.170E-7	2.202E-7	1.493E-7	1.717E-7	1.625E-7	1.576E-7	1.432E-7	1.515E-7	1.470E-7	1.459E-7	1.537E-7	1.469E-7
Exp. σ	0.0018	0.0019	0.0039	0.0041	0.0041	0.0041	0.0042	0.0044	0.0044	0.0044	0.0046	0.0046
k_{eff}	0.99341	0.99131	0.99586	0.99358	0.99539	0.99237	0.99144	0.99878	0.99418	0.99240	0.99693	0.99137
σ	0.00070	0.00078	0.00195	0.00192	0.00203	0.00194	0.00193	0.00196	0.00224	0.00216	0.00190	0.00208

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	42.01	42.02	42.03	42.04	42.05	42.06	42.07
Clusters	3	3	3	3	3	3	3
Enrichment (wt %^{235}U)	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%	2.35%
Pitch (cm)	1.684	1.684	1.684	1.684	1.684	1.684	1.684
Fuel OD (cm)	1.118	1.118	1.118	1.118	1.118	1.118	1.118
Clad OD (cm)	1.270	1.270	1.270	1.270	1.270	1.270	1.270
Clad Materiall	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	221	221	221	221	221	221	221
Soluble B (ppm)	-	-	-	-	-	-	-
Absorber Type	304L SS (no B)	304L SS (1.05% B)	Boral B	Boroflex	Cd	Cu	Cu-Cd
Cluster Gap (cm)	8.3	4.8	2.7	3.0	3.9	7.8	5.4
Reflector	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Plate Loading (g^{10}B /cm^2)	0.00000	0.00455	0.03022	0.02361	-	-	-
EALCF (MeV)	1.813E-7	1.824E-7	1.915E-7	1.887E-7	1.857E-7	1.786E-7	1.833E-7
Exp. σ	0.0016	0.0016	0.0016	0.0017	0.0033	0.0016	0.0018
k_{eff}	0.99250	0.99514	0.99219	0.99476	0.99469	0.99434	0.99319
σ	0.00171	0.00183	0.00169	0.00169	0.00161	0.00191	0.00157

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	50.03	50.03	50.03	50.03	50.03
Clusters	1	1	1	1	1
Enrichment (wt %^{235}U)	4.74%	4.74%	4.74%	4.74%	4.74%
Pitch (cm)	1.300	1.300	1.300	1.300	1.300
Fuel OD (cm)	0.790	0.790	0.790	0.790	0.790
Clad OD (cm)	0.940	0.940	0.940	0.940	0.940
Clad Material	Al alloy	Al alloy	Al alloy	Al alloy	Al alloy
H/U (fissile)	124	124	124	124	124
Soluble B (ppm)	821	821	4986	4986	4986
Absorber Type	-	-	-	-	-
Cluster Gap (cm)	-	-	-	-	-
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading (g^{10}B /cm^2)	-	-	-	-	-
EALCF (MeV)	2.170E-7	2.083E-7	2.318E-7	2.252E-7	2.195E-7
Exp. σ	0.0010	0.0010	0.0010	0.0010	0.0010
k_{eff}	0.99330	0.99340	0.99489	0.99319	0.99306
σ	0.00080	0.00071	0.00075	0.00075	0.00080

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	51.01	51.02	51.03	51.04	51.05	51.06	51.07	51.08	51.09
Clusters	9	9	9	9	9	9	9	9	9
Enrichment (wt %^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	143	510	514	501	493	474	462	432	217
Absorber Type	none	SS	SS	SS	SS	SS	SS	SS	SS
Cluster Gap (cm)	4.9	1.6	1.6	1.6	1.6	1.6	1.6	1.6	3.3
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading (g^{10}B /cm^2)	0.00000	-	-	-	-	-	-	-	-
EALCF (MeV)	1.535E-7	2.045E-7	2.043E-7	2.067E-7	2.074E-7	2.083E-7	2.085E-7	2.098E-7	1.737E-7
Exp. σ	0.0020	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0024	0.0019
k_{eff}	0.99133	0.99597	0.99555	0.99486	0.99504	0.99542	0.99530	0.99507	0.99368
σ	0.00033	0.00035	0.00033	0.00034	0.00034	0.00034	0.00034	0.00034	0.00033

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	51.10	51.11	51.12	51.13	51.14	51.15	51.16	51.17	51.18	51.19
Clusters	9	9	9	9	9	9	9	9	9	9
Enrichment (wt %^{235}U)	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%	2.46%
Pitch (cm)	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636	1.636
Fuel OD (cm)	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030	1.030
Clad OD (cm)	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206	1.206
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	219	219	219	219	219	219	219	219	219	219
Soluble B (ppm)	15	28	92	395	121	487	197	634	320	72
Absorber Type	B/Al Set 5	B/Al Set 5A	B/Al Set 4	B/Al Set 3	B/Al Set 3	B/Al Set 2	B/Al Set 2	B/Al Set 1	B/Al Set 1	B/Al Set 1
Cluster Gap (cm)	1.6	1.6	1.6	1.6	3.3	1.6	3.3	1.6	3.3	4.9
Reflector	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O	Borated H_2O
Plate Loading (g^{10}B /cm^2)	0.00517	0.00519	0.00403	0.00128	0.00128	0.00078	0.00078	0.00032	0.00032	0.00032
EALCF (MeV)	2.029E-7	2.015E-7	2.056E-7	2.112E-7	1.773E-7	2.106E-7	1.775E-7	2.119E-7	1.780E-7	1.587E-7
p. σ	0.0019	0.0019	0.0019	0.0022	0.0019	0.0024	0.0020	0.0027	0.0021	0.0019
keff	0.99210	0.99447	0.99073	0.98652	0.98634	0.99042	0.98974	0.99152	0.99029	0.98927
σ	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034	0.00035	0.00035

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	65.01	65.02	65.03	65.04	65.05	65.06	65.07	65.08
Clusters	2	2	2	2	2	2	2	2
Enrichment (wt % ^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	203	203	203	203	203	203	203	203
Soluble B (ppm)	-	-	-	-	-	-	-	-
Absorber Type	none	304L SS (No B)	304L SS (0.67% B)	304L SS (0.98% B)	none	304L SS (No B)	304L SS (No B)	304L SS (No B)
Cluster Gap (cm)	5.9	5.9	5.9	5.9	7.8	7.8	7.8	7.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading ($g^{10}B/cm^2$)	-	0.00000	0.00599	0.00875	-	0.00000	0.00000	0.00000
EALCF [MeV]	2.045E-7	2.030E-7	2.054E-7	2.038E-7	2.049E-7	2.030E-7	2.055E-7	2.040E-7
Exp. σ	0.0014	0.0014	0.0015	0.0015	0.0014	0.0014	0.0014	0.0016
k_{eff}	0.99571	0.99618	0.99534	0.99547	0.99691	0.99614	0.99589	0.99624
σ	0.00023	0.00022	0.00023	0.00023	0.00023	0.00023	0.00023	0.00023

Table 6.A.5-3 MCNP Validation Statistics (continued)

Case	65.09	65.10	65.11	65.12	65.13	65.14	65.15	65.16	65.17
Clusters	2	2	2	2	2	2	2	2	2
Enrichment (wt % ^{235}U)	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%	2.60%
Pitch (cm)	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956	1.956
Fuel OD (cm)	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250	1.250
Clad OD (cm)	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417	1.417
Clad Material	Al	Al	Al	Al	Al	Al	Al	Al	Al
H/U (fissile)	203	203	203	203	203	203	203	203	203
Soluble B (ppm)	-	-	-	-	-	-	-	-	-
Absorber Type	304L SS (No B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.67% B)	304L SS (0.98% B)	304L SS (0.98% B)	304L SS (0.98% B)	304L SS (0.98% B)
Cluster Gap (cm)	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Reflector	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O	H_2O
Plate Loading (g^{10}B /cm^2)	0.00000	0.00299	0.00299	0.00599	0.00599	0.00438	0.00438	0.00875	0.00875
EALCF [MeV]	1.993E-7	2.050E-7	2.069E-7	2.072E-7	1.977E-7	2.010E-7	2.004E-7	2.027E-7	2.017E-7
Exp. σ	0.0015	0.0016	0.0016	0.0017	0.0016	0.0016	0.0016	0.0017	0.0016
k_{eff}	0.99667	0.99676	0.99637	0.99643	0.99701	0.99650	0.99634	0.99658	0.99645
σ	0.00022	0.00022	0.00023	0.00023	0.00022	0.00023	0.00023	0.00022	0.00023

6.A.6 References

[A1] 10 CFR 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste and Reactor-Related Greater Than Class C Waste," Code of Federal Regulations, US Government, Washington, DC.

[A2] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," US Nuclear Regulatory Commission, Washington, DC, January 1997.

[A3] "MCNP – A General Monte Carlo N-Particle Transport Code, Version 5," X-5 Monte Carlo Team, Los Alamos National Laboratory, Los Alamos, NM, April 24, 2003.

[A4] CC-710/MCNP: Data Libraries for MCNP5, "MCNP5 DATA: Standard Neutron, Photoatomic, Photonuclear, and Electron Data Libraries for MCNP5," February 2003.

[A5] CCC-545-NUREG/CR-0200, "Standard Composition Library," Petrie, L.M., et al., Rev. 6, Volume 3 Section M8, September 1998.

[A6] ANSI/ANS - 8.1-1983, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," American Nuclear Society, La Grange Park, IL.

[A7] ANSI/ANS - 8.17-1984, "Criticality Safety Criteria for the Handling, Storage, and of LWR Fuel Outside Reactors," American Nuclear Society, La Grange Park, IL.

[A8] International Handbook of Evaluated Criticality Safety Benchmark Experiments, NEA/NSC/DOC(95)03, September 2003.

[A9] NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages," US Nuclear Regulatory Commission, Washington, DC, March 1997.

6.A.7 Sample Inputs

This section contains sample input files for the MCNP model. Included are sample input files for undamaged and damaged LACBWR fuel in the MPC-LACBWR transfer cask and damaged LACBWR fuel in the MPC-LACBWR storage cask.

6.A.7.1 Transfer Cask

Input files are presented for undamaged AC 3.94 wt % enriched material at the maximum reactivity configuration. Also included is the maximum reactivity preferentially flooded input case for damaged fuel.

Figure 6.A.7-1 AC Undamaged Fuel Transfer Cask Sample Input

```
LACBWR Transfer Cask Model -  Fuel Assembly Type: AC - BWR_10x10_0 WR
c
c Model Revision 3.4
c
c Single Cask Model
c
c Partial Flood: No
c
c Damaged Fuel Can Option:  No
c
c
c
c
c Primary Fuel Tye Enrichment:  3.94 wt%
c
c Secondary Fuel Type:  None
c Seondary Fuel Enrichment:  None
c
c Thrid Fuel Type:  None
c Seondary Fuel Enrichment:  None
c
c Density (H2O) (g/cc)
c               Lattice DFC Exterior
c               0.9982  N/A 0.0001
c
c Tube
c      Outer_Width Thickness
c      Max         Min
c
c Absorber
c          Width Thickness
c          Min   Max
c
c Disk
c      Op_Width Location Thickness Spacing
c      Max      Min      Max       Min
c
c Shift Patterns
c  Rad Fuel Rad Tube Axial Fuel Axial Basket
c  In       In       Bottom     Bottom
c Cells - Fuel Rod - AC - BWR_10x10_0 WR
10 1 -10.522 -10     u=22 $ Fuel
11 3 -0.9982 -11 +10    u=22 $ Plenum + Fuel to Clad Gap
12 2 -7.94 -12 +11    u=22 $ Clad + End Plugs
13 3 -0.9982 +12     u=22 $ Outside Fuel Rod
c Array_10x10_0
40 3 -0.9982 -40 +41 -42 +43
      trcl=(0.71755 0.71755 25.4)   lat=1 u=21 fill=-5:4 -5:4 0:0
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
      22 22 22 22 22 22 22 22 22 22
c Cells - Fuel Assembly Array Inserted Into Assembly - cellAssy
50 3 -0.9982 -50    fill=21 u=20 $ Array
51 3 -0.9982 -51 +50 -50.6 -50.5  u=20 $ Gap to Fuel Envelope
52 6 -2.0929 -51  +50.6   u=20 $ Lower Nozzle
53 7 -1.7632 -51   +50.5  u=20 $ Upper Nozzle
54 3 -0.9982 +51     u=20 $ Remaining Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,PY)
```

```
330 3 -0.9982 -311       u=18 $ Space in Tube
331 8 -7.940 -312 +311     u=18 $ FuelTube
332 15 -1.965 -313       u=18 $ Absorber +Y
333 9 -2.702 -314 +313     u=18 $ Absorber Clad  +Y
334 3 -0.9982 -315 +314     u=18 $ Absorber Cover Opening+Y
335 8 -7.940 -316 +315     u=18 $ Absorber Cover  +Y
336 15 -1.965 -317       u=18 $ Absorber +X
337 9 -2.702 -318 +317     u=18 $ Absorber Clad  +X
338 3 -0.9982 -319 +318     u=18 $ Absorber Cover Opening+X
339 8 -7.940 -320 +319     u=18 $ Absorber Cover  +X
340 3 -0.9982 +311 +312 +316 +320      u=18 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,PY)
341 3 -0.9982 -311       u=17 $ Space in Tube
342 8 -7.940 -312 +311     u=17 $ FuelTube
343 15 -1.965 -313       u=17 $ Absorber +Y
344 9 -2.702 -314 +313     u=17 $ Absorber Clad  +Y
345 3 -0.9982 -315 +314     u=17 $ Absorber Cover Opening+Y
346 8 -7.940 -316 +315     u=17 $ Absorber Cover  +Y
347 15 -1.965 -325       u=17 $ Absorber -X
348 9 -2.702 -326 +325     u=17 $ Absorber Clad  -X
349 3 -0.9982 -327 +326     u=17 $ Absorber Cover Opening-X
350 8 -7.940 -328 +327     u=17 $ Absorber Cover  -X
351 3 -0.9982 +311 +312 +316 +328      u=17 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,MY)
352 3 -0.9982 -311       u=16 $ Space in Tube
353 8 -7.940 -312 +311     u=16 $ FuelTube
354 15 -1.965 -321       u=16 $ Absorber -Y
355 9 -2.702 -322 +321     u=16 $ Absorber Clad  -Y
356 3 -0.9982 -323 +322     u=16 $ Absorber Cover Opening-Y
357 8 -7.940 -324 +323     u=16 $ Absorber Cover  -Y
358 15 -1.965 -325       u=16 $ Absorber -X
359 9 -2.702 -326 +325     u=16 $ Absorber Clad  -X
360 3 -0.9982 -327 +326     u=16 $ Absorber Cover Opening-X
361 8 -7.940 -328 +327     u=16 $ Absorber Cover  -X
362 3 -0.9982 +311 +312 +324 +328      u=16 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,MY)
363 3 -0.9982 -311       u=15 $ Space in Tube
364 8 -7.940 -312 +311     u=15 $ FuelTube
365 15 -1.965 -321       u=15 $ Absorber -Y
366 9 -2.702 -322 +321     u=15 $ Absorber Clad  -Y
367 3 -0.9982 -323 +322     u=15 $ Absorber Cover Opening-Y
368 8 -7.940 -324 +323     u=15 $ Absorber Cover  -Y
369 15 -1.965 -317       u=15 $ Absorber +X
370 9 -2.702 -318 +317     u=15 $ Absorber Clad  +X
371 3 -0.9982 -319 +318     u=15 $ Absorber Cover Opening+X
372 8 -7.940 -320 +319     u=15 $ Absorber Cover  +X
373 3 -0.9982 +311 +312 +320 +324      u=15 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX)
374 3 -0.9982 -311       u=14 $ Space in Tube
375 8 -7.940 -312 +311     u=14 $ FuelTube
376 15 -1.965 -317       u=14 $ Absorber +X
377 9 -2.702 -318 +317     u=14 $ Absorber Clad  +X
378 3 -0.9982 -319 +318     u=14 $ Absorber Cover Opening+X
379 8 -7.940 -320 +319     u=14 $ Absorber Cover  +X
380 3 -0.9982 +311 +312 +320      u=14 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX)
381 3 -0.9982 -311       u=13 $ Space in Tube
382 8 -7.940 -312 +311     u=13 $ FuelTube
383 15 -1.965 -325       u=13 $ Absorber -X
384 9 -2.702 -326 +325     u=13 $ Absorber Clad  -X
385 3 -0.9982 -327 +326     u=13 $ Absorber Cover Opening-X
386 8 -7.940 -328 +327     u=13 $ Absorber Cover  -X
387 3 -0.9982 +311 +312 +328      u=13 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PY)
388 3 -0.9982 -311       u=12 $ Space in Tube
389 8 -7.940 -312 +311     u=12 $ FuelTube
390 15 -1.965 -313       u=12 $ Absorber +Y
391 9 -2.702 -314 +313     u=12 $ Absorber Clad  +Y
392 3 -0.9982 -315 +314     u=12 $ Absorber Cover Opening+Y
393 8 -7.940 -316 +315     u=12 $ Absorber Cover  +Y
```

```
394 3 -0.9982 +311 +312 +316      u=12 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MY)
395 3 -0.9982 -311      u=11 $ Space in Tube
396 8 -7.940 -312 +311     u=11 $ FuelTube
397 15 -1.965 -321      u=11 $ Absorber -Y
398 9 -2.702 -322 +321     u=11 $ Absorber Clad  -Y
399 3 -0.9982 -323 +322     u=11 $ Absorber Cover Opening-Y
400 8 -7.940 -324 +323     u=11 $ Absorber Cover  -Y
401 3 -0.9982 +311 +312 +324      u=11 $ Exterior Space
c Cell Cards - Standard Tube
402 3 -0.9982 -311      u=10 $ Space in Tube
403 8 -7.940 -312 +311     u=10 $ FuelTube
404 3 -0.9982 +311 +312      u=10 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 4 BORAL
411 3 -0.9982 -411      u=8 $ Space in Tube
412 8 -7.940 -412 +411     u=8 $ FuelTube
413 15 -1.965 -413      u=8 $ Absorber +Y
414 9 -2.702 -414 +413     u=8 $ Absorber Clad  +Y
415 3 -0.9982 -415 +414     u=8 $ Absorber Cover Opening+Y
416 8 -7.940 -416 +415     u=8 $ Absorber Cover  +Y
417 15 -1.965 -417      u=8 $ Absorber +X
418 8 -7.940 -418 +417     u=8 $ Absorber Clad  +X
419 3 -0.9982 -419 +418     u=8 $ Absorber Cover Opening+X
420 8 -7.940 -420 +419     u=8 $ Absorber Cover  +X
421 15 -1.965 -421      u=8 $ Absorber -Y
422 9 -2.702 -422 +421     u=8 $ Absorber Clad  -Y
423 3 -0.9982 -423 +422     u=8 $ Absorber Cover Opening-Y
424 8 -7.940 -424 +423     u=8 $ Absorber Cover  -Y
425 15 -1.965 -425      u=8 $ Absorber -X
426 8 -7.940 -426 +425     u=8 $ Absorber Clad  -X
427 3 -0.9982 -427 +426     u=8 $ Absorber Cover Opening-X
428 8 -7.940 -428 +427     u=8 $ Absorber Cover  -X
429 3 -0.9982 +411 +412 +416 +420 +424 +428      u=8 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X. PY
430 3 -0.9982 -411      u=7 $ Space in Tube
431 8 -7.940 -412 +411     u=7 $ FuelTube
432 15 -1.965 -413      u=7 $ Absorber +Y
433 9 -2.702 -414 +413     u=7 $ Absorber Clad  +Y
434 3 -0.9982 -415 +414     u=7 $ Absorber Cover Opening+Y
435 8 -7.940 -416 +415     u=7 $ Absorber Cover  +Y
436 15 -1.965 -417      u=7 $ Absorber +X
437 8 -7.940 -418 +417     u=7 $ Absorber Clad  +X
438 3 -0.9982 -419 +418     u=7 $ Absorber Cover Opening+X
439 8 -7.940 -420 +419     u=7 $ Absorber Cover  +X
440 15 -1.965 -425      u=7 $ Absorber -X
441 8 -7.940 -426 +425     u=7 $ Absorber Clad  -X
442 3 -0.9982 -427 +426     u=7 $ Absorber Cover Opening-X
443 8 -7.940 -428 +427     u=7 $ Absorber Cover  -X
444 3 -0.9982 +411 +412 +416 +420 +428      u=7 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X, MY
445 3 -0.9982 -411      u=6 $ Space in Tube
446 8 -7.940 -412 +411     u=6 $ FuelTube
447 15 -1.965 -417      u=6 $ Absorber +X
448 8 -7.940 -418 +417     u=6 $ Absorber Clad  +X
449 3 -0.9982 -419 +418     u=6 $ Absorber Cover Opening+X
450 8 -7.940 -420 +419     u=6 $ Absorber Cover  +X
451 15 -1.965 -421      u=6 $ Absorber -Y
452 9 -2.702 -422 +421     u=6 $ Absorber Clad  -Y
453 3 -0.9982 -423 +422     u=6 $ Absorber Cover Opening-Y
454 8 -7.940 -424 +423     u=6 $ Absorber Cover  -Y
455 15 -1.965 -425      u=6 $ Absorber -X
456 8 -7.940 -426 +425     u=6 $ Absorber Clad  -X
457 3 -0.9982 -427 +426     u=6 $ Absorber Cover Opening-X
458 8 -7.940 -428 +427     u=6 $ Absorber Cover  -X
459 3 -0.9982 +411 +412 +420 +424 +428      u=6 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer-PX, 2Y
460 3 -0.9982 -411      u=5 $ Space in Tube
461 8 -7.940 -412 +411     u=5 $ FuelTube
462 15 -1.965 -413      u=5 $ Absorber +Y
463 9 -2.702 -414 +413     u=5 $ Absorber Clad  +Y
```

```
464 3 -0.9982 -415 +414      u=5 $ Absorber Cover Opening+Y
465 8 -7.940 -416 +415      u=5 $ Absorber Cover  +Y
466 15 -1.965 -417       u=5 $ Absorber +X
467 8 -7.940 -418 +417      u=5 $ Absorber Clad  +X
468 3 -0.9982 -419 +418      u=5 $ Absorber Cover Opening+X
469 8 -7.940 -420 +419      u=5 $ Absorber Cover  +X
470 15 -1.965 -421       u=5 $ Absorber -Y
471 9 -2.702 -422 +421      u=5 $ Absorber Clad  -Y
472 3 -0.9982 -423 +422      u=5 $ Absorber Cover Opening-Y
473 8 -7.940 -424 +423      u=5 $ Absorber Cover  -Y
474 3 -0.9982 +411 +412 +416 +420 +424       u=5 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- MX, 2Y
475 3 -0.9982 -411       u=4 $ Space in Tube
476 8 -7.940 -412 +411      u=4 $ FuelTube
477 15 -1.965 -413       u=4 $ Absorber +Y
478 9 -2.702 -414 +413      u=4 $ Absorber Clad  +Y
479 3 -0.9982 -415 +414      u=4 $ Absorber Cover Opening+Y
480 8 -7.940 -416 +415      u=4 $ Absorber Cover  +Y
481 15 -1.965 -421       u=4 $ Absorber -Y
482 9 -2.702 -422 +421      u=4 $ Absorber Clad  -Y
483 3 -0.9982 -423 +422      u=4 $ Absorber Cover Opening-Y
484 8 -7.940 -424 +423      u=4 $ Absorber Cover  -Y
485 15 -1.965 -425       u=4 $ Absorber -X
486 8 -7.940 -426 +425      u=4 $ Absorber Clad  -X
487 3 -0.9982 -427 +426      u=4 $ Absorber Cover Opening-X
488 8 -7.940 -428 +427      u=4 $ Absorber Cover  -X
489 3 -0.9982 +411 +412 +416 +424 +428       u=4 $ Exterior Space
c Cell Cards - Disk Stack
601 8 -7.94 -606 *trcl=( 0.0000 0.0000 2.5400 )     u=3 $ Bottom weldment disk
602 8 -7.94 -603 *trcl=( 0.0000 0.0000 9.8044 )     u=3 $ Support disk 1 (Thick Disk)
603 8 -7.94 -601 *trcl=( 0.0000 0.0000 15.1257 )     u=3 $ Support disk 2
604 like 603 but    *trcl=( 0.0000 0.0000 24.9555 )     u=3 $ Support disk 3
605 like 603 but    *trcl=( 0.0000 0.0000 34.7853 )     u=3 $ Support disk 4
606 like 603 but    *trcl=( 0.0000 0.0000 44.6151 )     u=3 $ Support disk 5
607 like 603 but    *trcl=( 0.0000 0.0000 54.4449 )     u=3 $ Support disk 6
608 9 -2.70 -604 *trcl=( 0.0000 0.0000 59.5160 )     u=3 $ Heat transfer disk 1
609 like 603 but    *trcl=( 0.0000 0.0000 64.1985 )     u=3 $ Support disk 7
610 like 608 but    *trcl=( 0.0000 0.0000 69.2696 )     u=3 $ Heat transfer disk 2
611 like 603 but    *trcl=( 0.0000 0.0000 73.9521 )     u=3 $ Support disk 8
612 like 608 but    *trcl=( 0.0000 0.0000 79.0232 )     u=3 $ Heat transfer disk 3
613 like 603 but    *trcl=( 0.0000 0.0000 83.7057 )     u=3 $ Support disk 9
614 like 608 but    *trcl=( 0.0000 0.0000 88.7768 )     u=3 $ Heat transfer disk 4
615 like 603 but    *trcl=( 0.0000 0.0000 93.4593 )     u=3 $ Support disk 10
616 like 608 but    *trcl=( 0.0000 0.0000 98.5304 )     u=3 $ Heat transfer disk 5
617 like 603 but    *trcl=( 0.0000 0.0000 103.2129 )     u=3 $ Support disk 11
618 like 608 but    *trcl=( 0.0000 0.0000 108.2840 )     u=3 $ Heat transfer disk 6
619 like 603 but    *trcl=( 0.0000 0.0000 112.9665 )     u=3 $ Support disk 12
620 like 608 but    *trcl=( 0.0000 0.0000 118.0376 )     u=3 $ Heat transfer disk 7
621 like 603 but    *trcl=( 0.0000 0.0000 122.7201 )     u=3 $ Support disk 13
622 like 608 but    *trcl=( 0.0000 0.0000 127.7912 )     u=3 $ Heat transfer disk 8
623 like 603 but    *trcl=( 0.0000 0.0000 132.4737 )     u=3 $ Support disk 14
624 like 608 but    *trcl=( 0.0000 0.0000 137.5448 )     u=3 $ Heat transfer disk 9
625 like 603 but    *trcl=( 0.0000 0.0000 142.2273 )     u=3 $ Support disk 15
626 like 608 but    *trcl=( 0.0000 0.0000 147.2984 )     u=3 $ Heat transfer disk 10
627 like 603 but    *trcl=( 0.0000 0.0000 151.9809 )     u=3 $ Support disk 16
628 like 608 but    *trcl=( 0.0000 0.0000 157.0520 )     u=3 $ Heat transfer disk 11
629 like 603 but    *trcl=( 0.0000 0.0000 161.7345 )     u=3 $ Support disk 17
630 like 608 but    *trcl=( 0.0000 0.0000 166.8056 )     u=3 $ Heat transfer disk 12
631 like 603 but    *trcl=( 0.0000 0.0000 171.4881 )     u=3 $ Support disk 18
632 like 608 but    *trcl=( 0.0000 0.0000 176.5592 )     u=3 $ Heat transfer disk 13
633 like 603 but    *trcl=( 0.0000 0.0000 181.2417 )     u=3 $ Support disk 19
634 like 608 but    *trcl=( 0.0000 0.0000 186.3128 )     u=3 $ Heat transfer disk 14
635 like 603 but    *trcl=( 0.0000 0.0000 190.9953 )     u=3 $ Support disk 20
636 like 603 but    *trcl=( 0.0000 0.0000 200.8251 )     u=3 $ Support disk 21
637 like 603 but    *trcl=( 0.0000 0.0000 210.6549 )     u=3 $ Support disk 22
638 like 603 but    *trcl=( 0.0000 0.0000 220.4847 )     u=3 $ Support disk 23
639 like 603 but    *trcl=( 0.0000 0.0000 230.3145 )     u=3 $ Support disk 24
640 like 603 but    *trcl=( 0.0000 0.0000 240.1443 )     u=3 $ Support disk 25
641 8 -7.94 -602 *trcl=( 0.0000 0.0000 248.3231 )     u=3 $ Support disk 26 (Thick Disk)
642 8 -7.94 -605 *trcl=( 0.0000 0.0000 255.8288 )     u=3 $ Top weldment disk
```

```
643 3 -0.9982        $ Outside Disks
      #601 #602 #603 #604 #605 #606 #607 #608 #609 #610
      #611 #612 #613 #614 #615 #616 #617 #618 #619 #620
      #621 #622 #623 #624 #625 #626 #627 #628 #629 #630
      #631 #632 #633 #634 #635 #636 #637 #638 #639 #640
      #641 #642         u=3
c Cell Cards - Basket
701 3 -0.9982 -702  #702  fill=6 ( -8.6463 77.3430 0.0000 )     $ Tube/Disk 1
            *trcl=( -8.7884 77.4852 0.0000 )    u=2
702 3 -0.9982 -51   fill=20 *trcl=( -8.0826 76.7793 0.0000 )    u=2 $ Assembly 1
703 3 -0.9982 -702  #704  fill=6 ( 8.6463 77.3430 0.0000 )     $ Tube/Disk 2
            *trcl=( 8.7884 77.4852 0.0000 )    u=2
704 3 -0.9982 -51   fill=20 *trcl=( 8.0826 76.7793 0.0000 )    u=2 $ Assembly 2
705 3 -0.9982 -702  #706  fill=6 ( -43.9472 61.0896 0.0000 )     $ Tube/Disk 3
            *trcl=( -44.0893 61.2318 0.0000 )    u=2
706 3 -0.9982 -51   fill=20 *trcl=( -43.3835 60.5259 0.0000 )    u=2 $ Assembly 3
707 3 -0.9982 -702  #708  fill=8 ( -26.2968 59.6927 0.0000 )     $ Tube/Disk 4
            *trcl=( -26.4389 59.8348 0.0000 )    u=2
708 3 -0.9982 -51   fill=20 *trcl=( -25.7331 59.1290 0.0000 )    u=2 $ Assembly 4
709 3 -0.9982 -702  #710  fill=8 ( -8.6463 59.6927 0.0000 )     $ Tube/Disk 5
            *trcl=( -8.7884 59.8348 0.0000 )    u=2
710 3 -0.9982 -51   fill=20 *trcl=( -8.0826 59.1290 0.0000 )    u=2 $ Assembly 5
711 3 -0.9982 -702  #712  fill=8 ( 8.6463 59.6927 0.0000 )     $ Tube/Disk 6
            *trcl=( 8.7884 59.8348 0.0000 )    u=2
712 3 -0.9982 -51   fill=20 *trcl=( 8.0826 59.1290 0.0000 )    u=2 $ Assembly 6
713 3 -0.9982 -702  #714  fill=8 ( 26.2968 59.6927 0.0000 )     $ Tube/Disk 7
            *trcl=( 26.4389 59.8348 0.0000 )    u=2
714 3 -0.9982 -51   fill=20 *trcl=( 25.7331 59.1290 0.0000 )    u=2 $ Assembly 7
715 3 -0.9982 -702  #716  fill=6 ( 43.9472 61.0896 0.0000 )     $ Tube/Disk 8
            *trcl=( 44.0893 61.2318 0.0000 )    u=2
716 3 -0.9982 -51   fill=20 *trcl=( 43.3835 60.5259 0.0000 )    u=2 $ Assembly 8
717 3 -0.9982 -702  #718  fill=5 ( -61.0896 43.9472 0.0000 )     $ Tube/Disk 9
            *trcl=( -61.2318 44.0893 0.0000 )    u=2
718 3 -0.9982 -51   fill=20 *trcl=( -60.5259 43.3835 0.0000 )    u=2 $ Assembly 9
719 3 -0.9982 -701  #720  fill=15 ( -42.4663 42.4663 0.0000 )     $ Tube/Disk 10
            *trcl=( -42.5018 42.5018 0.0000 )    u=2
720 3 -0.9982 -51   fill=20 *trcl=( -42.2328 42.2328 0.0000 )    u=2 $ Assembly 10
721 3 -0.9982 -701  #722  fill=15 ( -25.4509 42.4663 0.0000 )     $ Tube/Disk 11
            *trcl=( -25.4864 42.5018 0.0000 )    u=2
722 3 -0.9982 -51   fill=20 *trcl=( -25.2174 42.2328 0.0000 )    u=2 $ Assembly 11
723 3 -0.9982 -701  #724  fill=15 ( -8.4354 42.4663 0.0000 )     $ Tube/Disk 12
            *trcl=( -8.4709 42.5018 0.0000 )    u=2
724 3 -0.9982 -51   fill=20 *trcl=( -8.2019 42.2328 0.0000 )    u=2 $ Assembly 12
725 3 -0.9982 -701  #726  fill=11 ( 8.1739 42.4663 0.0000 )     $ Tube/Disk 13
            *trcl=( 8.4709 42.5018 0.0000 )    u=2
726 3 -0.9982 -51   fill=20 *trcl=( 7.9404 42.2328 0.0000 )    u=2 $ Assembly 13
727 3 -0.9982 -701  #728  fill=16 ( 25.4509 42.4663 0.0000 )     $ Tube/Disk 14
            *trcl=( 25.4864 42.5018 0.0000 )    u=2
728 3 -0.9982 -51   fill=20 *trcl=( 25.2174 42.2328 0.0000 )    u=2 $ Assembly 14
729 3 -0.9982 -701  #730  fill=16 ( 42.4663 42.4663 0.0000 )     $ Tube/Disk 15
            *trcl=( 42.5018 42.5018 0.0000 )    u=2
730 3 -0.9982 -51   fill=20 *trcl=( 42.2328 42.2328 0.0000 )    u=2 $ Assembly 15
731 3 -0.9982 -702  #732  fill=4 ( 61.0896 43.9472 0.0000 )     $ Tube/Disk 16
            *trcl=( 61.2318 44.0893 0.0000 )    u=2
732 3 -0.9982 -51   fill=20 *trcl=( 60.5259 43.3835 0.0000 )    u=2 $ Assembly 16
733 3 -0.9982 -702  #734  fill=8 ( -59.6927 26.2968 0.0000 )     $ Tube/Disk 17
            *trcl=( -59.8348 26.4389 0.0000 )    u=2
734 3 -0.9982 -51   fill=20 *trcl=( -59.1290 25.7331 0.0000 )    u=2 $ Assembly 17
735 3 -0.9982 -701  #736  fill=15 ( -42.4663 25.4509 0.0000 )     $ Tube/Disk 18
            *trcl=( -42.5018 25.4864 0.0000 )    u=2
736 3 -0.9982 -51   fill=20 *trcl=( -42.2328 25.2174 0.0000 )    u=2 $ Assembly 18
737 3 -0.9982 -701  #738  fill=15 ( -25.4509 25.4509 0.0000 )     $ Tube/Disk 19
            *trcl=( -25.4864 25.4864 0.0000 )    u=2
738 3 -0.9982 -51   fill=20 *trcl=( -25.2174 25.2174 0.0000 )    u=2 $ Assembly 19
739 3 -0.9982 -701  #740  fill=15 ( -8.4354 25.4509 0.0000 )     $ Tube/Disk 20
            *trcl=( -8.4709 25.4864 0.0000 )    u=2
740 3 -0.9982 -51   fill=20 *trcl=( -8.2019 25.2174 0.0000 )    u=2 $ Assembly 20
741 3 -0.9982 -701  #742  fill=11 ( 8.1739 25.4509 0.0000 )     $ Tube/Disk 21
            *trcl=( 8.4709 25.4864 0.0000 )    u=2
742 3 -0.9982 -51   fill=20 *trcl=( 7.9404 25.2174 0.0000 )    u=2 $ Assembly 21
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743 3 -0.9982 -701  #744  fill=16 ( 25.4509 25.4509 0.0000 )     $ Tube/Disk 22
            *trcl=( 25.4864 25.4864 0.0000 )    u=2
744 3 -0.9982 -51   fill=20 *trcl=( 25.2174 25.2174 0.0000 )    u=2 $ Assembly 22
745 3 -0.9982 -701  #746  fill=16 ( 42.4663 25.4509 0.0000 )     $ Tube/Disk 23
            *trcl=( 42.5018 25.4864 0.0000 )    u=2
746 3 -0.9982 -51   fill=20 *trcl=( 42.2328 25.2174 0.0000 )    u=2 $ Assembly 23
747 3 -0.9982 -702  #748  fill=8 ( 59.6927 26.2968 0.0000 )     $ Tube/Disk 24
            *trcl=( 59.8348 26.4389 0.0000 )    u=2
748 3 -0.9982 -51   fill=20 *trcl=( 59.1290 25.7331 0.0000 )    u=2 $ Assembly 24
749 3 -0.9982 -702  #750  fill=5 ( -77.3430 8.6463 0.0000 )     $ Tube/Disk 25
            *trcl=( -77.4852 8.7884 0.0000 )    u=2
750 3 -0.9982 -51   fill=20 *trcl=( -76.7793 8.0826 0.0000 )    u=2 $ Assembly 25
751 3 -0.9982 -702  #752  fill=8 ( -59.6927 8.6463 0.0000 )     $ Tube/Disk 26
            *trcl=( -59.8348 8.7884 0.0000 )    u=2
752 3 -0.9982 -51   fill=20 *trcl=( -59.1290 8.0826 0.0000 )    u=2 $ Assembly 26
753 3 -0.9982 -701  #754  fill=15 ( -42.4663 8.4354 0.0000 )     $ Tube/Disk 27
            *trcl=( -42.5018 8.4709 0.0000 )    u=2
754 3 -0.9982 -51   fill=20 *trcl=( -42.2328 8.2019 0.0000 )    u=2 $ Assembly 27
755 3 -0.9982 -701  #756  fill=15 ( -25.4509 8.4354 0.0000 )     $ Tube/Disk 28
            *trcl=( -25.4864 8.4709 0.0000 )    u=2
756 3 -0.9982 -51   fill=20 *trcl=( -25.2174 8.2019 0.0000 )    u=2 $ Assembly 28
757 3 -0.9982 -701  #758  fill=15 ( -8.4354 8.4354 0.0000 )     $ Tube/Disk 29
            *trcl=( -8.4709 8.4709 0.0000 )    u=2
758 3 -0.9982 -51   fill=20 *trcl=( -8.2019 8.2019 0.0000 )    u=2 $ Assembly 29
759 3 -0.9982 -701  #760  fill=10 ( 8.1739 8.1739 0.0000 )     $ Tube/Disk 30
            *trcl=( 8.4709 8.4709 0.0000 )    u=2
760 3 -0.9982 -51   fill=20 *trcl=( 7.9404 7.9404 0.0000 )    u=2 $ Assembly 30
761 3 -0.9982 -701  #762  fill=13 ( 25.4509 8.1739 0.0000 )     $ Tube/Disk 31
            *trcl=( 25.4864 8.4709 0.0000 )    u=2
762 3 -0.9982 -51   fill=20 *trcl=( 25.2174 7.9404 0.0000 )    u=2 $ Assembly 31
763 3 -0.9982 -701  #764  fill=13 ( 42.4663 8.1739 0.0000 )     $ Tube/Disk 32
            *trcl=( 42.5018 8.4709 0.0000 )    u=2
764 3 -0.9982 -51   fill=20 *trcl=( 42.2328 7.9404 0.0000 )    u=2 $ Assembly 32
765 3 -0.9982 -702  #766  fill=8 ( 59.6927 8.6463 0.0000 )     $ Tube/Disk 33
            *trcl=( 59.8348 8.7884 0.0000 )    u=2
766 3 -0.9982 -51   fill=20 *trcl=( 59.1290 8.0826 0.0000 )    u=2 $ Assembly 33
767 3 -0.9982 -702  #768  fill=4 ( 77.3430 8.6463 0.0000 )     $ Tube/Disk 34
            *trcl=( 77.4852 8.7884 0.0000 )    u=2
768 3 -0.9982 -51   fill=20 *trcl=( 76.7793 8.0826 0.0000 )    u=2 $ Assembly 34
769 3 -0.9982 -702  #770  fill=5 ( -77.3430 -8.6463 0.0000 )     $ Tube/Disk 35
            *trcl=( -77.4852 -8.7884 0.0000 )    u=2
770 3 -0.9982 -51   fill=20 *trcl=( -76.7793 -8.0826 0.0000 )    u=2 $ Assembly 35
771 3 -0.9982 -702  #772  fill=8 ( -59.6927 -8.6463 0.0000 )     $ Tube/Disk 36
            *trcl=( -59.8348 -8.7884 0.0000 )    u=2
772 3 -0.9982 -51   fill=20 *trcl=( -59.1290 -8.0826 0.0000 )    u=2 $ Assembly 36
773 3 -0.9982 -701  #774  fill=14 ( -42.4663 -8.1739 0.0000 )     $ Tube/Disk 37
            *trcl=( -42.5018 -8.4709 0.0000 )    u=2
774 3 -0.9982 -51   fill=20 *trcl=( -42.2328 -7.9404 0.0000 )    u=2 $ Assembly 37
775 3 -0.9982 -701  #776  fill=14 ( -25.4509 -8.1739 0.0000 )     $ Tube/Disk 38
            *trcl=( -25.4864 -8.4709 0.0000 )    u=2
776 3 -0.9982 -51   fill=20 *trcl=( -25.2174 -7.9404 0.0000 )    u=2 $ Assembly 38
777 3 -0.9982 -701  #778  fill=10 ( -8.1739 -8.1739 0.0000 )     $ Tube/Disk 39
            *trcl=( -8.4709 -8.4709 0.0000 )    u=2
778 3 -0.9982 -51   fill=20 *trcl=( -7.9404 -7.9404 0.0000 )    u=2 $ Assembly 39
779 3 -0.9982 -701  #780  fill=17 ( 8.4354 -8.4354 0.0000 )     $ Tube/Disk 40
            *trcl=( 8.4709 -8.4709 0.0000 )    u=2
780 3 -0.9982 -51   fill=20 *trcl=( 8.2019 -8.2019 0.0000 )    u=2 $ Assembly 40
781 3 -0.9982 -701  #782  fill=17 ( 25.4509 -8.4354 0.0000 )     $ Tube/Disk 41
            *trcl=( 25.4864 -8.4709 0.0000 )    u=2
782 3 -0.9982 -51   fill=20 *trcl=( 25.2174 -8.2019 0.0000 )    u=2 $ Assembly 41
783 3 -0.9982 -701  #784  fill=17 ( 42.4663 -8.4354 0.0000 )     $ Tube/Disk 42
            *trcl=( 42.5018 -8.4709 0.0000 )    u=2
784 3 -0.9982 -51   fill=20 *trcl=( 42.2328 -8.2019 0.0000 )    u=2 $ Assembly 42
785 3 -0.9982 -702  #786  fill=8 ( 59.6927 -8.6463 0.0000 )     $ Tube/Disk 43
            *trcl=( 59.8348 -8.7884 0.0000 )    u=2
786 3 -0.9982 -51   fill=20 *trcl=( 59.1290 -8.0826 0.0000 )    u=2 $ Assembly 43
787 3 -0.9982 -702  #788  fill=4 ( 77.3430 -8.6463 0.0000 )     $ Tube/Disk 44
            *trcl=( 77.4852 -8.7884 0.0000 )    u=2
788 3 -0.9982 -51   fill=20 *trcl=( 76.7793 -8.0826 0.0000 )    u=2 $ Assembly 44
789 3 -0.9982 -702  #790  fill=8 ( -59.6927 -26.2968 0.0000 )     $ Tube/Disk 45
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            *trcl=( -59.8348 -26.4389 0.0000 )    u=2
790 3 -0.9982 -51   fill=20 *trcl=( -59.1290 -25.7331 0.0000 )    u=2 $ Assembly 45
791 3 -0.9982 -701  #792  fill=18 ( -42.4663 -25.4509 0.0000 )     $ Tube/Disk 46
            *trcl=( -42.5018 -25.4864 0.0000 )    u=2
792 3 -0.9982 -51   fill=20 *trcl=( -42.2328 -25.2174 0.0000 )    u=2 $ Assembly 46
793 3 -0.9982 -701  #794  fill=18 ( -25.4509 -25.4509 0.0000 )     $ Tube/Disk 47
            *trcl=( -25.4864 -25.4864 0.0000 )    u=2
794 3 -0.9982 -51   fill=20 *trcl=( -25.2174 -25.2174 0.0000 )    u=2 $ Assembly 47
795 3 -0.9982 -701  #796  fill=12 ( -8.1739 -25.4509 0.0000 )     $ Tube/Disk 48
            *trcl=( -8.4709 -25.4864 0.0000 )    u=2
796 3 -0.9982 -51   fill=20 *trcl=( -7.9404 -25.2174 0.0000 )    u=2 $ Assembly 48
797 3 -0.9982 -701  #798  fill=17 ( 8.4354 -25.4509 0.0000 )     $ Tube/Disk 49
            *trcl=( 8.4709 -25.4864 0.0000 )    u=2
798 3 -0.9982 -51   fill=20 *trcl=( 8.2019 -25.2174 0.0000 )    u=2 $ Assembly 49
799 3 -0.9982 -701  #800  fill=17 ( 25.4509 -25.4509 0.0000 )     $ Tube/Disk 50
            *trcl=( 25.4864 -25.4864 0.0000 )    u=2
800 3 -0.9982 -51   fill=20 *trcl=( 25.2174 -25.2174 0.0000 )    u=2 $ Assembly 50
801 3 -0.9982 -701  #802  fill=17 ( 42.4663 -25.4509 0.0000 )     $ Tube/Disk 51
            *trcl=( 42.5018 -25.4864 0.0000 )    u=2
802 3 -0.9982 -51   fill=20 *trcl=( 42.2328 -25.2174 0.0000 )    u=2 $ Assembly 51
803 3 -0.9982 -702  #804  fill=8 ( 59.6927 -26.2968 0.0000 )     $ Tube/Disk 52
            *trcl=( 59.8348 -26.4389 0.0000 )    u=2
804 3 -0.9982 -51   fill=20 *trcl=( 59.1290 -25.7331 0.0000 )    u=2 $ Assembly 52
805 3 -0.9982 -702  #806  fill=5 ( -61.0896 -43.9472 0.0000 )     $ Tube/Disk 53
            *trcl=( -61.2318 -44.0893 0.0000 )    u=2
806 3 -0.9982 -51   fill=20 *trcl=( -60.5259 -43.3835 0.0000 )    u=2 $ Assembly 53
807 3 -0.9982 -701  #808  fill=18 ( -42.4663 -42.4663 0.0000 )     $ Tube/Disk 54
            *trcl=( -42.5018 -42.5018 0.0000 )    u=2
808 3 -0.9982 -51   fill=20 *trcl=( -42.2328 -42.2328 0.0000 )    u=2 $ Assembly 54
809 3 -0.9982 -701  #810  fill=18 ( -25.4509 -42.4663 0.0000 )     $ Tube/Disk 55
            *trcl=( -25.4864 -42.5018 0.0000 )    u=2
810 3 -0.9982 -51   fill=20 *trcl=( -25.2174 -42.2328 0.0000 )    u=2 $ Assembly 55
811 3 -0.9982 -701  #812  fill=12 ( -8.1739 -42.4663 0.0000 )     $ Tube/Disk 56
            *trcl=( -8.4709 -42.5018 0.0000 )    u=2
812 3 -0.9982 -51   fill=20 *trcl=( -7.9404 -42.2328 0.0000 )    u=2 $ Assembly 56
813 3 -0.9982 -701  #814  fill=17 ( 8.4354 -42.4663 0.0000 )     $ Tube/Disk 57
            *trcl=( 8.4709 -42.5018 0.0000 )    u=2
814 3 -0.9982 -51   fill=20 *trcl=( 8.2019 -42.2328 0.0000 )    u=2 $ Assembly 57
815 3 -0.9982 -701  #816  fill=17 ( 25.4509 -42.4663 0.0000 )     $ Tube/Disk 58
            *trcl=( 25.4864 -42.5018 0.0000 )    u=2
816 3 -0.9982 -51   fill=20 *trcl=( 25.2174 -42.2328 0.0000 )    u=2 $ Assembly 58
817 3 -0.9982 -701  #818  fill=17 ( 42.4663 -42.4663 0.0000 )     $ Tube/Disk 59
            *trcl=( 42.5018 -42.5018 0.0000 )    u=2
818 3 -0.9982 -51   fill=20 *trcl=( 42.2328 -42.2328 0.0000 )    u=2 $ Assembly 59
819 3 -0.9982 -702  #820  fill=4 ( 61.0896 -43.9472 0.0000 )     $ Tube/Disk 60
            *trcl=( 61.2318 -44.0893 0.0000 )    u=2
820 3 -0.9982 -51   fill=20 *trcl=( 60.5259 -43.3835 0.0000 )    u=2 $ Assembly 60
821 3 -0.9982 -702  #822  fill=7 ( -43.9472 -61.0896 0.0000 )     $ Tube/Disk 61
            *trcl=( -44.0893 -61.2318 0.0000 )    u=2
822 3 -0.9982 -51   fill=20 *trcl=( -43.3835 -60.5259 0.0000 )    u=2 $ Assembly 61
823 3 -0.9982 -702  #824  fill=8 ( -26.2968 -59.6927 0.0000 )     $ Tube/Disk 62
            *trcl=( -26.4389 -59.8348 0.0000 )    u=2
824 3 -0.9982 -51   fill=20 *trcl=( -25.7331 -59.1290 0.0000 )    u=2 $ Assembly 62
825 3 -0.9982 -702  #826  fill=8 ( -8.6463 -59.6927 0.0000 )     $ Tube/Disk 63
            *trcl=( -8.7884 -59.8348 0.0000 )    u=2
826 3 -0.9982 -51   fill=20 *trcl=( -8.0826 -59.1290 0.0000 )    u=2 $ Assembly 63
827 3 -0.9982 -702  #828  fill=8 ( 8.6463 -59.6927 0.0000 )     $ Tube/Disk 64
            *trcl=( 8.7884 -59.8348 0.0000 )    u=2
828 3 -0.9982 -51   fill=20 *trcl=( 8.0826 -59.1290 0.0000 )    u=2 $ Assembly 64
829 3 -0.9982 -702  #830  fill=8 ( 26.2968 -59.6927 0.0000 )     $ Tube/Disk 65
            *trcl=( 26.4389 -59.8348 0.0000 )    u=2
830 3 -0.9982 -51   fill=20 *trcl=( 25.7331 -59.1290 0.0000 )    u=2 $ Assembly 65
831 3 -0.9982 -702  #832  fill=7 ( 43.9472 -61.0896 0.0000 )     $ Tube/Disk 66
            *trcl=( 44.0893 -61.2318 0.0000 )    u=2
832 3 -0.9982 -51   fill=20 *trcl=( 43.3835 -60.5259 0.0000 )    u=2 $ Assembly 66
833 3 -0.9982 -702  #834  fill=7 ( -8.6463 -77.3430 0.0000 )     $ Tube/Disk 67
            *trcl=( -8.7884 -77.4852 0.0000 )    u=2
834 3 -0.9982 -51   fill=20 *trcl=( -8.0826 -76.7793 0.0000 )    u=2 $ Assembly 67
835 3 -0.9982 -702  #836  fill=7 ( 8.6463 -77.3430 0.0000 )     $ Tube/Disk 68
            *trcl=( 8.7884 -77.4852 0.0000 )    u=2
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836 3 -0.9982 -51   fill=20 *trcl=( 8.0826 -76.7793 0.0000 )    u=2 $ Assembly 68
837 3 -0.9982 +703 +704        $ Canister Cavity Q1
      #703 #711 #713 #715 #725 #727 #729 #731 #741
      #704 #712 #714 #716 #726 #728 #730 #732 #742
      #743 #745 #747 #759 #761 #763 #765 #767
      #744 #746 #748 #760 #762 #764 #766 #768
          fill=3      u=2
838 3 -0.9982 +703 -704        $ Canister Cavity Q2
      #701 #705 #707 #709 #717 #719 #721 #723 #733
      #702 #706 #708 #710 #718 #720 #722 #724 #734
      #735 #737 #739 #749 #751 #753 #755 #757
      #736 #738 #740 #750 #752 #754 #756 #758
          fill=3      u=2
839 3 -0.9982 -703 -704        $ Canister Cavity Q3
      #769 #771 #773 #775 #777 #789 #791 #793 #795
      #770 #772 #774 #776 #778 #790 #792 #794 #796
      #805 #807 #809 #811 #821 #823 #825 #833
      #806 #808 #810 #812 #822 #824 #826 #834
          fill=3      u=2
840 3 -0.9982 -703 704        $ Canister Cavity Q4
      #779 #781 #783 #785 #787 #797 #799 #801 #803
      #780 #782 #784 #786 #788 #798 #800 #802 #804
      #813 #815 #817 #819 #827 #829 #831 #835
      #814 #816 #818 #820 #828 #830 #832 #836
          fill=3      u=2
c Cell Cards - Canister
901 3 -0.9982 -901 #902     fill=2 u=1 $ Cavity
902 9 -2.702 -902      u=1 $ Spacer
903 8 -7.940 -903 +901     u=1 $ Canister Shell / Lid / Bottom
904 14 -0.0001 +903      u=1 $ Remaining Space
c Cell Cards - Transfer Cask Geometry
911 14 -0.0001 -911 -912  fill=1 ( 0.0000 0.0000 2.5400 )   $ Cask cavity
912 10 -7.821 -911 +912 -916     $ Bottom plate
913 10 -7.821 -913 +912 +916 -918    $ Inner shell
914 11 -11.344 -914 +913 +916 -917    $ Lead shell
915 12 -1.632 -914 +913 +917 -918    $ NS-4-FR (above lead)
916 12 -1.632 -915 +914 +916 -918    $ NS-4-FR
917 10 -7.821 -911 +915 +916 -918    $ Outer shell
918 10 -7.821 -911 +912 +918     $ Top plate
919 10 -7.821 -919 +920  -925    $ Door rail
920 10 -7.821 -919 -921  -925    $ Door rail
921 10 -7.821 -924 -922 +923 -925    $ Door steel
922 14 -0.0001 -925 +911 #919 #920 #921      $ Exterior space to Reflector
923 0         +925       $ Exterior space

c Surfaces - Fuel Rod - AC - BWR_10x10_0 WR
10 RCC 0.0000 0.0000 1.6764 0.0000 0.0000 210.8200 0.4445 $ Fuel pellet stack
11 RCC 0.0000 0.0000 1.6764 0.0000 0.0000 218.1352 0.4521 $ Annulus + Plenum
12 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 223.0628 0.5029 $ Clad + End-Caps
c Surfaces - Pitch - AC - BWR_10x10_0 WR
40 PX 0.7176       $ Lattice Cell Boundaries
41 PX -0.7176
42 PY 0.7176
43 PY -0.7176
c Surfaces - Fuel Assembly Array Inserted Into Assembly - AC - BWR_10x10_0 WR
50 RPP -6.9608 6.9608 -6.9608 6.9608 25.4000 249.1232  $ Array
51 RPP -7.1755 7.1755 -7.1755 7.1755 0.0000 259.9436  $ Assembly Outer Dims
c Surface Cards - Standard Tube, Absorber and Retainer
311 RPP -7.4092 7.4092 -7.4092 7.4092 0.0000 274.4470 $  Space inside tube - cavity extent
312 RPP -7.4549 7.4549 -7.4549 7.4549 5.0800 254.5588 $  Fuel tube body
313 RPP -6.4897 6.4897 7.4930 7.6200 7.1120 250.6472 $ Absorber +Y
314 RPP -6.4897 6.4897 7.4549 7.6581 7.1120 250.6472 $ Absorber Clad  +Y
315 RPP -6.7374 6.7374 7.4549 7.6581 7.1120 250.6472 $ Absorber Cover Opening +Y
316 RPP -6.7958 6.7958 7.4549 7.7164 7.0536 250.6472 $ Absorber Cover  +Y
317 RPP 7.4930 7.6200 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
318 RPP 7.4549 7.6581 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
319 RPP 7.4549 7.6581 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
320 RPP 7.4549 7.7164 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
321 RPP -6.4897 6.4897 -7.6200 -7.4930 7.1120 250.6472 $ Absorber -Y
322 RPP -6.4897 6.4897 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Clad  -Y
```

```
323 RPP -6.7374 6.7374 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Cover Opening -Y
324 RPP -6.7958 6.7958 -7.7164 -7.4549 7.0536 250.6472 $ Absorber Cover  -Y
325 RPP -7.6200 -7.4930 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
326 RPP -7.6581 -7.4549 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
327 RPP -7.6581 -7.4549 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
328 RPP -7.7164 -7.4549 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - DFC Tube, Absorber and Retainer
411 RPP -7.7394 7.7394 -7.7394 7.7394 0.0000 274.4470 $  Space inside tube - cavity extent
412 RPP -7.7851 7.7851 -7.7851 7.7851 5.0800 254.5588 $  Fuel tube body
413 RPP -6.4897 6.4897 7.8232 7.9502 7.1120 250.6472 $ Absorber +Y
414 RPP -6.4897 6.4897 7.7851 7.9883 7.1120 250.6472 $ Absorber Clad  +Y
415 RPP -6.7374 6.7374 7.7851 7.9883 7.1120 250.6472 $ Absorber Cover Opening +Y
416 RPP -6.7958 6.7958 7.7851 8.0466 7.0536 250.6472 $ Absorber Cover  +Y
417 RPP 7.8232 7.9502 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
418 RPP 7.7851 7.9883 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
419 RPP 7.7851 7.9883 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
420 RPP 7.7851 8.0466 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
421 RPP -6.4897 6.4897 -7.9502 -7.8232 7.1120 250.6472 $ Absorber -Y
422 RPP -6.4897 6.4897 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Clad  -Y
423 RPP -6.7374 6.7374 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Cover Opening -Y
424 RPP -6.7958 6.7958 -8.0466 -7.7851 7.0536 250.6472 $ Absorber Cover  -Y
425 RPP -7.9502 -7.8232 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
426 RPP -7.9883 -7.7851 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
427 RPP -7.9883 -7.7851 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
428 RPP -8.0466 -7.7851 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - Disk Stack
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.7272 88.1380 $ Structural disk
602 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 3.3147 88.1380 $ Structural top disk
603 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.0447 88.1380 $ Structural bottom disk
604 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.3386 87.7951 $ Heat transfer disk
605 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.0491 $ Top weldment disk
606 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Bottom weldment disk
c Surface Cards - Basket
701 RPP -7.7521 7.7521 -7.7521 7.7521 0.0000 274.4470  $ Std opening
702 RPP -8.1890 8.1890 -8.1890 8.1890 0.0000 274.4470  $ DFC opening
703 PY 0.0000        $ Cut plane
704 PX 0.0000        $ Cut plane
c Surface Cards - Canister
901 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470  88.4428 $ Canister cavity
902 RPP -48.6410 48.6410 -48.6410 48.6410 264.2870 274.4469   $ Canister spacer
903 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670  89.7128 $ Canister
c Surface Cards - Transfer Cask Geometry
911 RCC 0.000 0.000 0.000 0.000 0.000 313.6900 109.8550  $ Cask Cylindrical Section
912 CZ 90.8050        $ Cask cavity radius
913 CZ 92.7100        $ Inner shell OR
914 CZ 101.6000        $ Lead shell OR
915 CZ 106.6800        $ Outer shell IR
916 PZ 2.5400        $ Top of bottom plate
917 PZ 298.4500        $ Top of lead shield
918 PZ 308.6100        $ Bottom of top plate
919 RPP -110.1852 110.1852 -107.3150 107.3150 -24.1300 0.0000   $ Door Enclosing Shape
920 PY 95.8850        $ Inside rail surface
921 PY -95.8850        $ Inside rail surface
922 PY 95.4024        $ Door surface
923 PY -95.4024        $ Door surface
924 RHP 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300
          89.9681 0.0000 0.0000 54.42077 -66.1670 0.0000
          -54.4208 -66.1670 0.0000      $ Door prism
925 RCC 0.000 0.000 -44.130 0.000 0.000 370.2000 129.8550  $ Cylinder to Reflect

c
c Materials List
c
c Fuel Pellet Material   3.94%  Weight UO2 [amu]  269.93
m1    92235.66c -3.473E-02 92238.66c -8.467E-01  8016.62c -1.185E-01
c SS348 Clad
m2
      24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
```

```
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Water
m3     1001.62c -1.119E-01  8016.62c -8.881E-01
mt3  lwtr.01t
c Lower Nozzle Material
m6
       1001.62c -4.496E-02  8016.62c -3.568E-01
      24050.62c -4.750E-03 26054.62c -2.349E-02 28058.62c -3.819E-02
      24052.62c -9.514E-02 26056.62c -3.821E-01 28060.62c -1.522E-02
      24053.62c -1.099E-02 26057.62c -8.987E-03 28061.62c -6.726E-04
      24054.62c -2.783E-03 26058.62c -1.208E-03 28062.62c -2.177E-03
                                                28064.62c -5.757E-04
      25055.62c -1.197E-02
mt6  lwtr.01t
c Upper Nozzle Material
m7
       1001.62c -5.637E-02  8016.62c -4.474E-01
      24050.62c -3.940E-03 26054.62c -1.949E-02 28058.62c -3.168E-02
      24052.62c -7.892E-02 26056.62c -3.170E-01 28060.62c -1.262E-02
      24053.62c -9.120E-03 26057.62c -7.455E-03 28061.62c -5.580E-04
      24054.62c -2.308E-03 26058.62c -1.002E-03 28062.62c -1.806E-03
                                                28064.62c -4.776E-04
      25055.62c -9.925E-03
mt7  lwtr.01t
c SS304
m8    24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Aluminum
m9    13027.62c -1.000E+00
c Carbon Steel
m10   26054.62c -5.594E-02  6000.66c -1.000E-02
      26056.62c -9.098E-01
      26057.62c -2.140E-02
      26058.62c -2.876E-03
c Lead
m11   82206.66c -2.534E-01
      82207.66c -2.207E-01
      82208.66c -5.259E-01
c NS-F-FR
m12    5010.66c -9.313E-04  7014.62c -1.974E-02  8016.62c -4.250E-01
       5011.66c -3.772E-03  7015.66c -7.852E-05
      13027.62c -2.142E-01  1001.62c -6.001E-02  6000.66c -2.763E-01
c Concrete
m13   26054.62c -7.911E-04 14000.60c -3.370E-01
      26056.62c -1.287E-02
      26057.62c -3.026E-04
      26058.62c -4.067E-05
       1001.62c -1.000E-02 13027.62c -3.400E-02 20000.62c -4.400E-02
       8016.62c -5.320E-01 11023.62c -2.900E-02
c Water Exterior
m14    1001.62c 2.0
       8016.62c 1.0
mt14  lwtr.01t
c Borated Aluminum (Absorber Core / Sheet)
m15    5010.66c -6.011E-02 13027.62c -5.656E-01  6000.66c -9.430E-02
       5011.66c -2.799E-01
c Zirc Alloy
m17   26054.62c -7.063E-05 24050.62c -4.179E-05  7014.62c -4.980E-04
      26056.62c -1.149E-03 24052.62c -8.370E-04  7015.66c -1.981E-06
      26057.62c -2.702E-05 24053.62c -9.673E-05
      26058.62c -3.631E-06 24054.62c -2.448E-05
      40000.66c -9.823E-01 50000.42c -1.500E-02
c SS304/Cu Heat Fin
m18   24050.62c -4.537E-03 26054.62c -2.244E-02 28058.62c -3.648E-02
```

```
      24052.62c -9.088E-02 26056.62c -3.650E-01 28060.62c -1.453E-02
      24053.62c -1.050E-02 26057.62c -8.584E-03 28061.62c -6.425E-04
      24054.62c -2.658E-03 26058.62c -1.154E-03 28062.62c -2.079E-03
                                                28064.62c -5.499E-04
      25055.62c -1.143E-02
      29000 -0.4286
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m19   92235.66c -2.683E-02 92238.66c -6.540E-01  8016.62c -9.156E-02
       1001.62c -2.547E-02  8016.62c -2.021E-01
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m20   92235.66c -2.683E-02 92238.66c -6.540E-01  8016.62c -9.156E-02
       1001.62c -2.547E-02  8016.62c -2.021E-01
c
c Rotation Matrix
*TR1 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0  $ z-rotation 45 degrees
*TR2 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0  $ z-rotation 135 degrees
*TR3 0.0 0.0 0.0 15 105 90 -75 15 90 90 90 0  $ z-rotation 15 degrees
*TR4 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0  $ z-rotation 30 degrees
*TR5 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0  $ z-rotation 60 degrees
*TR6 0.0 0.0 0.0 75 165 90 -15 75 90 90 90 0  $ z-rotation 75 degrees
*TR7 0.0 0.0 0.0 8 98 90 -82 8 90 90 90 0  $ z-rotation 8 degrees
*TR8 0.0 0.0 0.0 102 192 90 12 102 90 90 90 0  $ z-rotation 102 degrees
*TR9 0.0 0.0 0.0 156 246 90 66 156 90 90 90 0  $ z-rotation 156 degrees
*TR10 0.0 0.0 0.0 78 168 90 -12 78 90 90 90 0  $ z-rotation 78 degrees
*TR11 0.0 0.0 0.0 24 114 90 -66 24 90 90 90 0  $ z-rotation 24 degrees
c
c Cell Importances
c
mode n
imp:n 1 362r 0
c
c
c Criticality Controls
c
kcode 2000 1.00 30 430
c Ones source point in each of the fuel assemblies
ksrc
      -5.2124 79.6495 100.00
      10.9528 79.6495 100.00
      -40.5133 63.3961 100.00
      -22.8629 61.9992 100.00
      -5.2124 61.9992 100.00
      10.9528 61.9992 100.00
      28.6033 61.9992 100.00
      46.2537 63.3961 100.00
      -57.6557 46.2537 100.00
      -39.3626 45.1030 100.00
      -22.3472 45.1030 100.00
      -5.3317 45.1030 100.00
      10.8106 45.1030 100.00
      28.0876 45.1030 100.00
      45.1030 45.1030 100.00
      63.3961 46.2537 100.00
      -56.2588 28.6033 100.00
      -39.3626 28.0876 100.00
      -22.3472 28.0876 100.00
      -5.3317 28.0876 100.00
      10.8106 28.0876 100.00
      28.0876 28.0876 100.00
      45.1030 28.0876 100.00
      61.9992 28.6033 100.00
      -73.9091 10.9528 100.00
      -56.2588 10.9528 100.00
      -39.3626 11.0721 100.00
      -22.3472 11.0721 100.00
      -5.3317 11.0721 100.00
      10.8106 10.8106 100.00
      28.0876 10.8106 100.00
      45.1030 10.8106 100.00
      61.9992 10.9528 100.00
```

```
      79.6495 10.9528 100.00
      -73.9091 -5.2124 100.00
      -56.2588 -5.2124 100.00
      -39.3626 -5.0702 100.00
      -22.3472 -5.0702 100.00
      -5.0702 -5.0702 100.00
      11.0721 -5.3317 100.00
      28.0876 -5.3317 100.00
      45.1030 -5.3317 100.00
      61.9992 -5.2124 100.00
      79.6495 -5.2124 100.00
      -56.2588 -22.8629 100.00
      -39.3626 -22.3472 100.00
      -22.3472 -22.3472 100.00
      -5.0702 -22.3472 100.00
      11.0721 -22.3472 100.00
      28.0876 -22.3472 100.00
      45.1030 -22.3472 100.00
      61.9992 -22.8629 100.00
      -57.6557 -40.5133 100.00
      -39.3626 -39.3626 100.00
      -22.3472 -39.3626 100.00
      -5.0702 -39.3626 100.00
      11.0721 -39.3626 100.00
      28.0876 -39.3626 100.00
      45.1030 -39.3626 100.00
      63.3961 -40.5133 100.00
      -40.5133 -57.6557 100.00
      -22.8629 -56.2588 100.00
      -5.2124 -56.2588 100.00
      10.9528 -56.2588 100.00
      28.6033 -56.2588 100.00
      46.2537 -57.6557 100.00
      -5.2124 -73.9091 100.00
      10.9528 -73.9091 100.00
c
c
c Random Number Generator Controls
c
RAND GEN=2 SEED=19073486328127
c
c
c Print Control
c
PRINT
c
```

Figure 6.A.7-2 Damaged Fuel Transfer Cask Sample Input

```
LACBWR Transfer Cask Model -  Fuel Assembly Type: EX - BWR_10x10_4 WR
c
c Model Revision 3.4
c
c Single Cask Model
c
c Partial Flood: No
c
c Damaged Fuel Can Option:  Yes
c DFC Content: Unclad Rod Array
c
c DFC Content Active Fuel Location: Bottom
c
c Primary Fuel Tye Enrichment:  3.71 wt%
c
c Secondary Fuel Type:  AC - BWR_10x10_0 WR
c Seondary Fuel Enrichment:  3.94 wt%
c
c Thrid Fuel Type:  AC - BWR_10x10_0 WR
c Seondary Fuel Enrichment:  3.64 wt%
c
c Density (H2O) (g/cc)
c               Lattice DFC Exterior
c               0.0001  0.9982 0.0001
c
c Tube
c      Outer_Width Thickness
c      Max         Min
c
c Absorber
c          Width Thickness
c          Min   Max
c
c Disk
c      Op_Width Location Thickness Spacing
c      Max      Min      Max       Min
c
c Shift Patterns
c  Rad Fuel Rad Tube Axial Fuel Axial Basket
c  In       In       Bottom     Bottom
c Cells - Fuel Rod - EX - BWR_10x10_4 WR
10 1 -10.522 -10     u=30 $ Fuel
11 3 -0.0001 -11 +10    u=30 $ Plenum + Fuel to Clad Gap
12 2 -7.94 -12 +11    u=30 $ Clad + End Plugs
13 3 -0.0001 +12     u=30 $ Outside Fuel Rod
c Cells - Inert Rods - EX - BWR_10x10_4 WR
30 17 -6.56 -30     u=29 $ Inside Inert Rod
31 2 -7.94 -31 +30    u=29 $ Inert Rod Clad and Plugs
32 3 -0.0001 +31     u=29 $ Outside Inert Rod
c Array_10x10_4
40 3 -0.0001 -40 +41 -42 +43
      trcl=(0.7074 0.7074 25.4)   lat=1 u=28 fill=-5:4 -5:4 0:0
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 29 29 30 30 30 30
      30 30 30 30 29 29 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
c Cells - Fuel Assembly Array Inserted Into Assembly - cellAssy
50 3 -0.0001 -50    fill=28 u=27 $ Array
51 3 -0.0001 -51 +50 -50.6 -50.5  u=27 $ Gap to Fuel Envelope
```

```
52 6 -2.0254 -51  +50.6   u=27 $ Lower Nozzle
53 7 -0.6953 -51   +50.5  u=27 $ Upper Nozzle
54 3 -0.0001 +51     u=27 $ Remaining Space
c Cells - DFC Content
261 4 -10.522 -261     u=26  $ Pellet Stack
262 3 -0.9982 +261     u=26  $ Exterior
c Cells - DFC Content
265 3 -0.9982 -265 +266 -267 +268
      trcl=(0.76185 0.76185 0)   lat=1 u=25 fill=-5:4 -5:4 0:0
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
c Cells - Fuel Assembly Array Inserted Into Assembly - cellDFCAssy
270 3 -0.0001 -270  fill=25   ( 0.0000 0.0000 0.0000 ) u=24 $ Array
271 3 -0.0001 +270      u=24 $ Remaining Space
c Cells - DFC Content
281 5 -10.522 -281     u=23  $ Pellet Stack
282 3 -0.9982 +281     u=23  $ Exterior
c Cells - DFC Content
285 3 -0.9982 -285 +286 -287 +288
      trcl=(0.76185 0.76185 0)   lat=1 u=22 fill=-5:4 -5:4 0:0
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
c Cells - Fuel Assembly Array Inserted Into Assembly - cellDFCAssyAxis
290 3 -0.0001 -290  fill=22   ( 0.0000 0.0000 0.0000 ) u=21 $ Array
291 3 -0.0001 +290      u=21 $ Remaining Space
c Cell Cards -DFC
301 3 -0.0001 -301 -305 +303    u=20 $ DFC Cavity
302 8 -7.940 -302  -303    u=20 $ DFC Bottom Plate
303 8 -7.940 -302 +301 +303    u=20 $ DFC Body
304 8 -7.940 -301 +305 -304    u=20 $ DFC Lid Plates
305 3 -0.0001 -301 +304     u=20 $ Area above lid
306 3 -0.0001 +302      u=20 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,PY)
330 3 -0.0001 -311      u=18 $ Space in Tube
331 8 -7.940 -312 +311     u=18 $ FuelTube
332 15 -1.965 -313      u=18 $ Absorber +Y
333 9 -2.702 -314 +313     u=18 $ Absorber Clad  +Y
334 3 -0.0001 -315 +314     u=18 $ Absorber Cover Opening+Y
335 8 -7.940 -316 +315     u=18 $ Absorber Cover  +Y
336 15 -1.965 -317      u=18 $ Absorber +X
337 9 -2.702 -318 +317     u=18 $ Absorber Clad  +X
338 3 -0.0001 -319 +318     u=18 $ Absorber Cover Opening+X
339 8 -7.940 -320 +319     u=18 $ Absorber Cover  +X
340 3 -0.0001 +311 +312 +316 +320      u=18 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,PY)
341 3 -0.0001 -311      u=17 $ Space in Tube
342 8 -7.940 -312 +311     u=17 $ FuelTube
343 15 -1.965 -313      u=17 $ Absorber +Y
344 9 -2.702 -314 +313     u=17 $ Absorber Clad  +Y
345 3 -0.0001 -315 +314     u=17 $ Absorber Cover Opening+Y
346 8 -7.940 -316 +315     u=17 $ Absorber Cover  +Y
347 15 -1.965 -325      u=17 $ Absorber -X
348 9 -2.702 -326 +325     u=17 $ Absorber Clad  -X
349 3 -0.0001 -327 +326     u=17 $ Absorber Cover Opening-X
```

```
350 8 -7.940 -328 +327      u=17 $ Absorber Cover  -X
351 3 -0.0001 +311 +312 +316 +328      u=17 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,MY)
352 3 -0.0001 -311      u=16 $ Space in Tube
353 8 -7.940 -312 +311      u=16 $ FuelTube
354 15 -1.965 -321      u=16 $ Absorber -Y
355 9 -2.702 -322 +321      u=16 $ Absorber Clad  -Y
356 3 -0.0001 -323 +322      u=16 $ Absorber Cover Opening-Y
357 8 -7.940 -324 +323      u=16 $ Absorber Cover  -Y
358 15 -1.965 -325      u=16 $ Absorber -X
359 9 -2.702 -326 +325      u=16 $ Absorber Clad  -X
360 3 -0.0001 -327 +326      u=16 $ Absorber Cover Opening-X
361 8 -7.940 -328 +327      u=16 $ Absorber Cover  -X
362 3 -0.0001 +311 +312 +324 +328      u=16 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,MY)
363 3 -0.0001 -311      u=15 $ Space in Tube
364 8 -7.940 -312 +311      u=15 $ FuelTube
365 15 -1.965 -321      u=15 $ Absorber -Y
366 9 -2.702 -322 +321      u=15 $ Absorber Clad  -Y
367 3 -0.0001 -323 +322      u=15 $ Absorber Cover Opening-Y
368 8 -7.940 -324 +323      u=15 $ Absorber Cover  -Y
369 15 -1.965 -317      u=15 $ Absorber +X
370 9 -2.702 -318 +317      u=15 $ Absorber Clad  +X
371 3 -0.0001 -319 +318      u=15 $ Absorber Cover Opening+X
372 8 -7.940 -320 +319      u=15 $ Absorber Cover  +X
373 3 -0.0001 +311 +312 +320 +324      u=15 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX)
374 3 -0.0001 -311      u=14 $ Space in Tube
375 8 -7.940 -312 +311      u=14 $ FuelTube
376 15 -1.965 -317      u=14 $ Absorber +X
377 9 -2.702 -318 +317      u=14 $ Absorber Clad  +X
378 3 -0.0001 -319 +318      u=14 $ Absorber Cover Opening+X
379 8 -7.940 -320 +319      u=14 $ Absorber Cover  +X
380 3 -0.0001 +311 +312 +320      u=14 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX)
381 3 -0.0001 -311      u=13 $ Space in Tube
382 8 -7.940 -312 +311      u=13 $ FuelTube
383 15 -1.965 -325      u=13 $ Absorber -X
384 9 -2.702 -326 +325      u=13 $ Absorber Clad  -X
385 3 -0.0001 -327 +326      u=13 $ Absorber Cover Opening-X
386 8 -7.940 -328 +327      u=13 $ Absorber Cover  -X
387 3 -0.0001 +311 +312 +328      u=13 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PY)
388 3 -0.0001 -311      u=12 $ Space in Tube
389 8 -7.940 -312 +311      u=12 $ FuelTube
390 15 -1.965 -313      u=12 $ Absorber +Y
391 9 -2.702 -314 +313      u=12 $ Absorber Clad  +Y
392 3 -0.0001 -315 +314      u=12 $ Absorber Cover Opening+Y
393 8 -7.940 -316 +315      u=12 $ Absorber Cover  +Y
394 3 -0.0001 +311 +312 +316      u=12 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MY)
395 3 -0.0001 -311      u=11 $ Space in Tube
396 8 -7.940 -312 +311      u=11 $ FuelTube
397 15 -1.965 -321      u=11 $ Absorber -Y
398 9 -2.702 -322 +321      u=11 $ Absorber Clad  -Y
399 3 -0.0001 -323 +322      u=11 $ Absorber Cover Opening-Y
400 8 -7.940 -324 +323      u=11 $ Absorber Cover  -Y
401 3 -0.0001 +311 +312 +324      u=11 $ Exterior Space
c Cell Cards - Standard Tube
402 3 -0.0001 -311      u=10 $ Space in Tube
403 8 -7.940 -312 +311      u=10 $ FuelTube
404 3 -0.0001 +311 +312      u=10 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 4 BORAL
411 3 -0.0001 -411      u=8 $ Space in Tube
412 8 -7.940 -412 +411      u=8 $ FuelTube
413 15 -1.965 -413      u=8 $ Absorber +Y
414 9 -2.702 -414 +413      u=8 $ Absorber Clad  +Y
415 3 -0.0001 -415 +414      u=8 $ Absorber Cover Opening+Y
416 8 -7.940 -416 +415      u=8 $ Absorber Cover  +Y
417 15 -1.965 -417      u=8 $ Absorber +X
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418 8 -7.940 -418 +417      u=8 $ Absorber Clad  +X
419 3 -0.0001 -419 +418      u=8 $ Absorber Cover Opening+X
420 8 -7.940 -420 +419      u=8 $ Absorber Cover  +X
421 15 -1.965 -421       u=8 $ Absorber -Y
422 9 -2.702 -422 +421      u=8 $ Absorber Clad  -Y
423 3 -0.0001 -423 +422      u=8 $ Absorber Cover Opening-Y
424 8 -7.940 -424 +423      u=8 $ Absorber Cover  -Y
425 15 -1.965 -425       u=8 $ Absorber -X
426 8 -7.940 -426 +425      u=8 $ Absorber Clad  -X
427 3 -0.0001 -427 +426      u=8 $ Absorber Cover Opening-X
428 8 -7.940 -428 +427      u=8 $ Absorber Cover  -X
429 3 -0.0001 +411 +412 +416 +420 +424 +428      u=8 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X. PY
430 3 -0.0001 -411       u=7 $ Space in Tube
431 8 -7.940 -412 +411      u=7 $ FuelTube
432 15 -1.965 -413       u=7 $ Absorber +Y
433 9 -2.702 -414 +413      u=7 $ Absorber Clad  +Y
434 3 -0.0001 -415 +414      u=7 $ Absorber Cover Opening+Y
435 8 -7.940 -416 +415      u=7 $ Absorber Cover  +Y
436 15 -1.965 -417       u=7 $ Absorber +X
437 8 -7.940 -418 +417      u=7 $ Absorber Clad  +X
438 3 -0.0001 -419 +418      u=7 $ Absorber Cover Opening+X
439 8 -7.940 -420 +419      u=7 $ Absorber Cover  +X
440 15 -1.965 -425       u=7 $ Absorber -X
441 8 -7.940 -426 +425      u=7 $ Absorber Clad  -X
442 3 -0.0001 -427 +426      u=7 $ Absorber Cover Opening-X
443 8 -7.940 -428 +427      u=7 $ Absorber Cover  -X
444 3 -0.0001 +411 +412 +416 +420 +428      u=7 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X, MY
445 3 -0.0001 -411       u=6 $ Space in Tube
446 8 -7.940 -412 +411      u=6 $ FuelTube
447 15 -1.965 -417       u=6 $ Absorber +X
448 8 -7.940 -418 +417      u=6 $ Absorber Clad  +X
449 3 -0.0001 -419 +418      u=6 $ Absorber Cover Opening+X
450 8 -7.940 -420 +419      u=6 $ Absorber Cover  +X
451 15 -1.965 -421       u=6 $ Absorber -Y
452 9 -2.702 -422 +421      u=6 $ Absorber Clad  -Y
453 3 -0.0001 -423 +422      u=6 $ Absorber Cover Opening-Y
454 8 -7.940 -424 +423      u=6 $ Absorber Cover  -Y
455 15 -1.965 -425       u=6 $ Absorber -X
456 8 -7.940 -426 +425      u=6 $ Absorber Clad  -X
457 3 -0.0001 -427 +426      u=6 $ Absorber Cover Opening-X
458 8 -7.940 -428 +427      u=6 $ Absorber Cover  -X
459 3 -0.0001 +411 +412 +420 +424 +428      u=6 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer-PX, 2Y
460 3 -0.0001 -411       u=5 $ Space in Tube
461 8 -7.940 -412 +411      u=5 $ FuelTube
462 15 -1.965 -413       u=5 $ Absorber +Y
463 9 -2.702 -414 +413      u=5 $ Absorber Clad  +Y
464 3 -0.0001 -415 +414      u=5 $ Absorber Cover Opening+Y
465 8 -7.940 -416 +415      u=5 $ Absorber Cover  +Y
466 15 -1.965 -417       u=5 $ Absorber +X
467 8 -7.940 -418 +417      u=5 $ Absorber Clad  +X
468 3 -0.0001 -419 +418      u=5 $ Absorber Cover Opening+X
469 8 -7.940 -420 +419      u=5 $ Absorber Cover  +X
470 15 -1.965 -421       u=5 $ Absorber -Y
471 9 -2.702 -422 +421      u=5 $ Absorber Clad  -Y
472 3 -0.0001 -423 +422      u=5 $ Absorber Cover Opening-Y
473 8 -7.940 -424 +423      u=5 $ Absorber Cover  -Y
474 3 -0.0001 +411 +412 +416 +420 +424      u=5 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- MX, 2Y
475 3 -0.0001 -411       u=4 $ Space in Tube
476 8 -7.940 -412 +411      u=4 $ FuelTube
477 15 -1.965 -413       u=4 $ Absorber +Y
478 9 -2.702 -414 +413      u=4 $ Absorber Clad  +Y
479 3 -0.0001 -415 +414      u=4 $ Absorber Cover Opening+Y
480 8 -7.940 -416 +415      u=4 $ Absorber Cover  +Y
481 15 -1.965 -421       u=4 $ Absorber -Y
482 9 -2.702 -422 +421      u=4 $ Absorber Clad  -Y
483 3 -0.0001 -423 +422      u=4 $ Absorber Cover Opening-Y
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484 8 -7.940 -424 +423      u=4 $ Absorber Cover  -Y
485 15 -1.965 -425       u=4 $ Absorber -X
486 8 -7.940 -426 +425      u=4 $ Absorber Clad  -X
487 3 -0.0001 -427 +426      u=4 $ Absorber Cover Opening-X
488 8 -7.940 -428 +427      u=4 $ Absorber Cover  -X
489 3 -0.0001 +411 +412 +416 +424 +428       u=4 $ Exterior Space
c Cell Cards - Disk Stack
601 8 -7.94 -606 *trcl=( 0.0000 0.0000 2.5400 )     u=3 $ Bottom weldment disk
602 8 -7.94 -603 *trcl=( 0.0000 0.0000 9.8044 )     u=3 $ Support disk 1 (Thick Disk)
603 8 -7.94 -601 *trcl=( 0.0000 0.0000 15.1257 )     u=3 $ Support disk 2
604 like 603 but   *trcl=( 0.0000 0.0000 24.9555 )     u=3 $ Support disk 3
605 like 603 but   *trcl=( 0.0000 0.0000 34.7853 )     u=3 $ Support disk 4
606 like 603 but   *trcl=( 0.0000 0.0000 44.6151 )     u=3 $ Support disk 5
607 like 603 but   *trcl=( 0.0000 0.0000 54.4449 )     u=3 $ Support disk 6
608 9 -2.70 -604 *trcl=( 0.0000 0.0000 59.5160 )     u=3 $ Heat transfer disk 1
609 like 603 but   *trcl=( 0.0000 0.0000 64.1985 )     u=3 $ Support disk 7
610 like 608 but   *trcl=( 0.0000 0.0000 69.2696 )     u=3 $ Heat transfer disk 2
611 like 603 but   *trcl=( 0.0000 0.0000 73.9521 )     u=3 $ Support disk 8
612 like 608 but   *trcl=( 0.0000 0.0000 79.0232 )     u=3 $ Heat transfer disk 3
613 like 603 but   *trcl=( 0.0000 0.0000 83.7057 )     u=3 $ Support disk 9
614 like 608 but   *trcl=( 0.0000 0.0000 88.7768 )     u=3 $ Heat transfer disk 4
615 like 603 but   *trcl=( 0.0000 0.0000 93.4593 )     u=3 $ Support disk 10
616 like 608 but   *trcl=( 0.0000 0.0000 98.5304 )     u=3 $ Heat transfer disk 5
617 like 603 but   *trcl=( 0.0000 0.0000 103.2129 )     u=3 $ Support disk 11
618 like 608 but   *trcl=( 0.0000 0.0000 108.2840 )     u=3 $ Heat transfer disk 6
619 like 603 but   *trcl=( 0.0000 0.0000 112.9665 )     u=3 $ Support disk 12
620 like 608 but   *trcl=( 0.0000 0.0000 118.0376 )     u=3 $ Heat transfer disk 7
621 like 603 but   *trcl=( 0.0000 0.0000 122.7201 )     u=3 $ Support disk 13
622 like 608 but   *trcl=( 0.0000 0.0000 127.7912 )     u=3 $ Heat transfer disk 8
623 like 603 but   *trcl=( 0.0000 0.0000 132.4737 )     u=3 $ Support disk 14
624 like 608 but   *trcl=( 0.0000 0.0000 137.5448 )     u=3 $ Heat transfer disk 9
625 like 603 but   *trcl=( 0.0000 0.0000 142.2273 )     u=3 $ Support disk 15
626 like 608 but   *trcl=( 0.0000 0.0000 147.2984 )     u=3 $ Heat transfer disk 10
627 like 603 but   *trcl=( 0.0000 0.0000 151.9809 )     u=3 $ Support disk 16
628 like 608 but   *trcl=( 0.0000 0.0000 157.0520 )     u=3 $ Heat transfer disk 11
629 like 603 but   *trcl=( 0.0000 0.0000 161.7345 )     u=3 $ Support disk 17
630 like 608 but   *trcl=( 0.0000 0.0000 166.8056 )     u=3 $ Heat transfer disk 12
631 like 603 but   *trcl=( 0.0000 0.0000 171.4881 )     u=3 $ Support disk 18
632 like 608 but   *trcl=( 0.0000 0.0000 176.5592 )     u=3 $ Heat transfer disk 13
633 like 603 but   *trcl=( 0.0000 0.0000 181.2417 )     u=3 $ Support disk 19
634 like 608 but   *trcl=( 0.0000 0.0000 186.3128 )     u=3 $ Heat transfer disk 14
635 like 603 but   *trcl=( 0.0000 0.0000 190.9953 )     u=3 $ Support disk 20
636 like 603 but   *trcl=( 0.0000 0.0000 200.8251 )     u=3 $ Support disk 21
637 like 603 but   *trcl=( 0.0000 0.0000 210.6549 )     u=3 $ Support disk 22
638 like 603 but   *trcl=( 0.0000 0.0000 220.4847 )     u=3 $ Support disk 23
639 like 603 but   *trcl=( 0.0000 0.0000 230.3145 )     u=3 $ Support disk 24
640 like 603 but   *trcl=( 0.0000 0.0000 240.1443 )     u=3 $ Support disk 25
641 8 -7.94 -602 *trcl=( 0.0000 0.0000 248.3231 )     u=3 $ Support disk 26 (Thick Disk)
642 8 -7.94 -605 *trcl=( 0.0000 0.0000 255.8288 )     u=3 $ Top weldment disk
643 3 -0.0001       $ Outside Disks
      #601 #602 #603 #604 #605 #606 #607 #608 #609 #610
      #611 #612 #613 #614 #615 #616 #617 #618 #619 #620
      #621 #622 #623 #624 #625 #626 #627 #628 #629 #630
      #631 #632 #633 #634 #635 #636 #637 #638 #639 #640
      #641 #642        u=3
c Cell Cards - Basket
701 3 -0.0001 -702 #702  #703  fill=6 ( -8.6463 77.3430 0.0000 )      $ Tube/Disk 1
            *trcl=( -8.7884 77.4852 0.0000 )     u=2
702 3 -0.0001 -302 #703   fill=20 *trcl=( -8.3315 77.0282 0.0000 )     u=2 $DFC
703 3 -0.0001 -290   fill=21 *trcl=( -8.3303 77.0270 1.2700 )     u=2 $ Assembly 1
704 3 -0.0001 -702 #705  #706  fill=6 ( 8.6463 77.3430 0.0000 )      $ Tube/Disk 2
            *trcl=( 8.7884 77.4852 0.0000 )     u=2
705 3 -0.0001 -302 #706   fill=20 *trcl=( 8.3315 77.0282 0.0000 )     u=2 $DFC
706 3 -0.0001 -290   fill=21 *trcl=( 8.3303 77.0270 1.2700 )     u=2 $ Assembly 2
707 3 -0.0001 -702 #708  #709  fill=6 ( -43.9472 61.0896 0.0000 )      $ Tube/Disk 3
            *trcl=( -44.0893 61.2318 0.0000 )     u=2
708 3 -0.0001 -302 #709   fill=20 *trcl=( -43.6324 60.7748 0.0000 )     u=2 $DFC
709 3 -0.0001 -270   fill=24 *trcl=( -43.6312 60.7736 1.2700 )     u=2 $ Assembly 3
710 3 -0.0001 -702 #711  #712  fill=8 ( -26.2968 59.6927 0.0000 )      $ Tube/Disk 4
            *trcl=( -26.4389 59.8348 0.0000 )     u=2
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711 3 -0.0001 -302 #712   fill=20 *trcl=( -25.9820 59.3779 0.0000 )    u=2 $DFC
712 3 -0.0001 -270   fill=24 *trcl=( -25.9808 59.3767 1.2700 )    u=2 $ Assembly 4
713 3 -0.0001 -702 #714  #715  fill=8 ( -8.6463 59.6927 0.0000 )     $ Tube/Disk 5
            *trcl=( -8.7884 59.8348 0.0000 )    u=2
714 3 -0.0001 -302 #715   fill=20 *trcl=( -8.3315 59.3779 0.0000 )    u=2 $DFC
715 3 -0.0001 -290   fill=21 *trcl=( -8.3303 59.3767 1.2700 )    u=2 $ Assembly 5
716 3 -0.0001 -702 #717  #718  fill=8 ( 8.6463 59.6927 0.0000 )     $ Tube/Disk 6
            *trcl=( 8.7884 59.8348 0.0000 )    u=2
717 3 -0.0001 -302 #718   fill=20 *trcl=( 8.3315 59.3779 0.0000 )    u=2 $DFC
718 3 -0.0001 -290   fill=21 *trcl=( 8.3303 59.3767 1.2700 )    u=2 $ Assembly 6
719 3 -0.0001 -702 #720  #721  fill=8 ( 26.2968 59.6927 0.0000 )     $ Tube/Disk 7
            *trcl=( 26.4389 59.8348 0.0000 )    u=2
720 3 -0.0001 -302 #721   fill=20 *trcl=( 25.9820 59.3779 0.0000 )    u=2 $DFC
721 3 -0.0001 -270   fill=24 *trcl=( 25.9808 59.3767 1.2700 )    u=2 $ Assembly 7
722 3 -0.0001 -702 #723  #724  fill=6 ( 43.9472 61.0896 0.0000 )     $ Tube/Disk 8
            *trcl=( 44.0893 61.2318 0.0000 )    u=2
723 3 -0.0001 -302 #724   fill=20 *trcl=( 43.6324 60.7748 0.0000 )    u=2 $DFC
724 3 -0.0001 -270   fill=24 *trcl=( 43.6312 60.7736 1.2700 )    u=2 $ Assembly 8
725 3 -0.0001 -702 #726  #727  fill=5 ( -61.0896 43.9472 0.0000 )     $ Tube/Disk 9
            *trcl=( -61.2318 44.0893 0.0000 )    u=2
726 3 -0.0001 -302 #727   fill=20 *trcl=( -60.7748 43.6324 0.0000 )    u=2 $DFC
727 3 -0.0001 -270   fill=24 *trcl=( -60.7736 43.6312 1.2700 )    u=2 $ Assembly 9
728 3 -0.0001 -701  #729  fill=15 ( -42.4663 42.4663 0.0000 )     $ Tube/Disk 10
            *trcl=( -42.5018 42.5018 0.0000 )    u=2
729 3 -0.0001 -51   fill=27 *trcl=( -42.1871 42.1871 1.2700 )    u=2 $ Assembly 10
730 3 -0.0001 -701  #731  fill=15 ( -25.4509 42.4663 0.0000 )     $ Tube/Disk 11
            *trcl=( -25.4864 42.5018 0.0000 )    u=2
731 3 -0.0001 -51   fill=27 *trcl=( -25.1717 42.1871 1.2700 )    u=2 $ Assembly 11
732 3 -0.0001 -701  #733  fill=15 ( -8.4354 42.4663 0.0000 )     $ Tube/Disk 12
            *trcl=( -8.4709 42.5018 0.0000 )    u=2
733 3 -0.0001 -51   fill=27 *trcl=( -8.1562 42.1871 1.2700 )    u=2 $ Assembly 12
734 3 -0.0001 -701  #735  fill=11 ( 8.1739 42.4663 0.0000 )     $ Tube/Disk 13
            *trcl=( 8.4709 42.5018 0.0000 )    u=2
735 3 -0.0001 -51   fill=27 *trcl=( 7.8947 42.1871 1.2700 )    u=2 $ Assembly 13
736 3 -0.0001 -701  #737  fill=16 ( 25.4509 42.4663 0.0000 )     $ Tube/Disk 14
            *trcl=( 25.4864 42.5018 0.0000 )    u=2
737 3 -0.0001 -51   fill=27 *trcl=( 25.1717 42.1871 1.2700 )    u=2 $ Assembly 14
738 3 -0.0001 -701  #739  fill=16 ( 42.4663 42.4663 0.0000 )     $ Tube/Disk 15
            *trcl=( 42.5018 42.5018 0.0000 )    u=2
739 3 -0.0001 -51   fill=27 *trcl=( 42.1871 42.1871 1.2700 )    u=2 $ Assembly 15
740 3 -0.0001 -702 #741  #742  fill=4 ( 61.0896 43.9472 0.0000 )     $ Tube/Disk 16
            *trcl=( 61.2318 44.0893 0.0000 )    u=2
741 3 -0.0001 -302 #742   fill=20 *trcl=( 60.7748 43.6324 0.0000 )    u=2 $DFC
742 3 -0.0001 -270   fill=24 *trcl=( 60.7736 43.6312 1.2700 )    u=2 $ Assembly 16
743 3 -0.0001 -702 #744  #745  fill=8 ( -59.6927 26.2968 0.0000 )     $ Tube/Disk 17
            *trcl=( -59.8348 26.4389 0.0000 )    u=2
744 3 -0.0001 -302 #745   fill=20 *trcl=( -59.3779 25.9820 0.0000 )    u=2 $DFC
745 3 -0.0001 -270   fill=24 *trcl=( -59.3767 25.9808 1.2700 )    u=2 $ Assembly 17
746 3 -0.0001 -701  #747  fill=15 ( -42.4663 25.4509 0.0000 )     $ Tube/Disk 18
            *trcl=( -42.5018 25.4864 0.0000 )    u=2
747 3 -0.0001 -51   fill=27 *trcl=( -42.1871 25.1717 1.2700 )    u=2 $ Assembly 18
748 3 -0.0001 -701  #749  fill=15 ( -25.4509 25.4509 0.0000 )     $ Tube/Disk 19
            *trcl=( -25.4864 25.4864 0.0000 )    u=2
749 3 -0.0001 -51   fill=27 *trcl=( -25.1717 25.1717 1.2700 )    u=2 $ Assembly 19
750 3 -0.0001 -701  #751  fill=15 ( -8.4354 25.4509 0.0000 )     $ Tube/Disk 20
            *trcl=( -8.4709 25.4864 0.0000 )    u=2
751 3 -0.0001 -51   fill=27 *trcl=( -8.1562 25.1717 1.2700 )    u=2 $ Assembly 20
752 3 -0.0001 -701  #753  fill=11 ( 8.1739 25.4509 0.0000 )     $ Tube/Disk 21
            *trcl=( 8.4709 25.4864 0.0000 )    u=2
753 3 -0.0001 -51   fill=27 *trcl=( 7.8947 25.1717 1.2700 )    u=2 $ Assembly 21
754 3 -0.0001 -701  #755  fill=16 ( 25.4509 25.4509 0.0000 )     $ Tube/Disk 22
            *trcl=( 25.4864 25.4864 0.0000 )    u=2
755 3 -0.0001 -51   fill=27 *trcl=( 25.1717 25.1717 1.2700 )    u=2 $ Assembly 22
756 3 -0.0001 -701  #757  fill=16 ( 42.4663 25.4509 0.0000 )     $ Tube/Disk 23
            *trcl=( 42.5018 25.4864 0.0000 )    u=2
757 3 -0.0001 -51   fill=27 *trcl=( 42.1871 25.1717 1.2700 )    u=2 $ Assembly 23
758 3 -0.0001 -702 #759  #760  fill=8 ( 59.6927 26.2968 0.0000 )     $ Tube/Disk 24
            *trcl=( 59.8348 26.4389 0.0000 )    u=2
759 3 -0.0001 -302 #760   fill=20 *trcl=( 59.3779 25.9820 0.0000 )    u=2 $DFC
760 3 -0.0001 -270   fill=24 *trcl=( 59.3767 25.9808 1.2700 )    u=2 $ Assembly 24
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761 3 -0.0001 -702 #762  #763  fill=5 ( -77.3430 8.6463 0.0000 )     $ Tube/Disk 25
            *trcl=( -77.4852 8.7884 0.0000 )    u=2
762 3 -0.0001 -302 #763   fill=20 *trcl=( -77.0282 8.3315 0.0000 )    u=2 $DFC
763 3 -0.0001 -290   fill=21 *trcl=( -77.0270 8.3303 1.2700 )    u=2 $ Assembly 25
764 3 -0.0001 -702 #765  #766  fill=8 ( -59.6927 8.6463 0.0000 )     $ Tube/Disk 26
            *trcl=( -59.8348 8.7884 0.0000 )    u=2
765 3 -0.0001 -302 #766   fill=20 *trcl=( -59.3779 8.3315 0.0000 )    u=2 $DFC
766 3 -0.0001 -290   fill=21 *trcl=( -59.3767 8.3303 1.2700 )    u=2 $ Assembly 26
767 3 -0.0001 -701  #768  fill=15 ( -42.4663 8.4354 0.0000 )     $ Tube/Disk 27
            *trcl=( -42.5018 8.4709 0.0000 )    u=2
768 3 -0.0001 -51   fill=27 *trcl=( -42.1871 8.1562 1.2700 )    u=2 $ Assembly 27
769 3 -0.0001 -701  #770  fill=15 ( -25.4509 8.4354 0.0000 )     $ Tube/Disk 28
            *trcl=( -25.4864 8.4709 0.0000 )    u=2
770 3 -0.0001 -51   fill=27 *trcl=( -25.1717 8.1562 1.2700 )    u=2 $ Assembly 28
771 3 -0.0001 -701  #772  fill=15 ( -8.4354 8.4354 0.0000 )     $ Tube/Disk 29
            *trcl=( -8.4709 8.4709 0.0000 )    u=2
772 3 -0.0001 -51   fill=27 *trcl=( -8.1562 8.1562 1.2700 )    u=2 $ Assembly 29
773 3 -0.0001 -701  #774  fill=10 ( 8.1739 8.1739 0.0000 )     $ Tube/Disk 30
            *trcl=( 8.4709 8.4709 0.0000 )    u=2
774 3 -0.0001 -51   fill=27 *trcl=( 7.8947 7.8947 1.2700 )    u=2 $ Assembly 30
775 3 -0.0001 -701  #776  fill=13 ( 25.4509 8.1739 0.0000 )     $ Tube/Disk 31
            *trcl=( 25.4864 8.4709 0.0000 )    u=2
776 3 -0.0001 -51   fill=27 *trcl=( 25.1717 7.8947 1.2700 )    u=2 $ Assembly 31
777 3 -0.0001 -701  #778  fill=13 ( 42.4663 8.1739 0.0000 )     $ Tube/Disk 32
            *trcl=( 42.5018 8.4709 0.0000 )    u=2
778 3 -0.0001 -51   fill=27 *trcl=( 42.1871 7.8947 1.2700 )    u=2 $ Assembly 32
779 3 -0.0001 -702 #780  #781  fill=8 ( 59.6927 8.6463 0.0000 )     $ Tube/Disk 33
            *trcl=( 59.8348 8.7884 0.0000 )    u=2
780 3 -0.0001 -302 #781   fill=20 *trcl=( 59.3779 8.3315 0.0000 )    u=2 $DFC
781 3 -0.0001 -290   fill=21 *trcl=( 59.3767 8.3303 1.2700 )    u=2 $ Assembly 33
782 3 -0.0001 -702 #783  #784  fill=4 ( 77.3430 8.6463 0.0000 )     $ Tube/Disk 34
            *trcl=( 77.4852 8.7884 0.0000 )    u=2
783 3 -0.0001 -302 #784   fill=20 *trcl=( 77.0282 8.3315 0.0000 )    u=2 $DFC
784 3 -0.0001 -290   fill=21 *trcl=( 77.0270 8.3303 1.2700 )    u=2 $ Assembly 34
785 3 -0.0001 -702 #786  #787  fill=5 ( -77.3430 -8.6463 0.0000 )     $ Tube/Disk 35
            *trcl=( -77.4852 -8.7884 0.0000 )    u=2
786 3 -0.0001 -302 #787   fill=20 *trcl=( -77.0282 -8.3315 0.0000 )    u=2 $DFC
787 3 -0.0001 -290   fill=21 *trcl=( -77.0270 -8.3303 1.2700 )    u=2 $ Assembly 35
788 3 -0.0001 -702 #789  #790  fill=8 ( -59.6927 -8.6463 0.0000 )     $ Tube/Disk 36
            *trcl=( -59.8348 -8.7884 0.0000 )    u=2
789 3 -0.0001 -302 #790   fill=20 *trcl=( -59.3779 -8.3315 0.0000 )    u=2 $DFC
790 3 -0.0001 -290   fill=21 *trcl=( -59.3767 -8.3303 1.2700 )    u=2 $ Assembly 36
791 3 -0.0001 -701  #792  fill=14 ( -42.4663 -8.1739 0.0000 )     $ Tube/Disk 37
            *trcl=( -42.5018 -8.4709 0.0000 )    u=2
792 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -7.8947 1.2700 )    u=2 $ Assembly 37
793 3 -0.0001 -701  #794  fill=14 ( -25.4509 -8.1739 0.0000 )     $ Tube/Disk 38
            *trcl=( -25.4864 -8.4709 0.0000 )    u=2
794 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -7.8947 1.2700 )    u=2 $ Assembly 38
795 3 -0.0001 -701  #796  fill=10 ( -8.1739 -8.1739 0.0000 )     $ Tube/Disk 39
            *trcl=( -8.4709 -8.4709 0.0000 )    u=2
796 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -7.8947 1.2700 )    u=2 $ Assembly 39
797 3 -0.0001 -701  #798  fill=17 ( 8.4354 -8.4354 0.0000 )     $ Tube/Disk 40
            *trcl=( 8.4709 -8.4709 0.0000 )    u=2
798 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -8.1562 1.2700 )    u=2 $ Assembly 40
799 3 -0.0001 -701  #800  fill=17 ( 25.4509 -8.4354 0.0000 )     $ Tube/Disk 41
            *trcl=( 25.4864 -8.4709 0.0000 )    u=2
800 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -8.1562 1.2700 )    u=2 $ Assembly 41
801 3 -0.0001 -701  #802  fill=17 ( 42.4663 -8.4354 0.0000 )     $ Tube/Disk 42
            *trcl=( 42.5018 -8.4709 0.0000 )    u=2
802 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -8.1562 1.2700 )    u=2 $ Assembly 42
803 3 -0.0001 -702 #804  #805  fill=8 ( 59.6927 -8.6463 0.0000 )     $ Tube/Disk 43
            *trcl=( 59.8348 -8.7884 0.0000 )    u=2
804 3 -0.0001 -302 #805   fill=20 *trcl=( 59.3779 -8.3315 0.0000 )    u=2 $DFC
805 3 -0.0001 -290   fill=21 *trcl=( 59.3767 -8.3303 1.2700 )    u=2 $ Assembly 43
806 3 -0.0001 -702 #807  #808  fill=4 ( 77.3430 -8.6463 0.0000 )     $ Tube/Disk 44
            *trcl=( 77.4852 -8.7884 0.0000 )    u=2
807 3 -0.0001 -302 #808   fill=20 *trcl=( 77.0282 -8.3315 0.0000 )    u=2 $DFC
808 3 -0.0001 -290   fill=21 *trcl=( 77.0270 -8.3303 1.2700 )    u=2 $ Assembly 44
809 3 -0.0001 -702 #810  #811  fill=8 ( -59.6927 -26.2968 0.0000 )     $ Tube/Disk 45
            *trcl=( -59.8348 -26.4389 0.0000 )    u=2
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810 3 -0.0001 -302 #811   fill=20 *trcl=( -59.3779 -25.9820 0.0000 )    u=2 $DFC
811 3 -0.0001 -270   fill=24 *trcl=( -59.3767 -25.9808 1.2700 )    u=2 $ Assembly 45
812 3 -0.0001 -701  #813  fill=18 ( -42.4663 -25.4509 0.0000 )     $ Tube/Disk 46
            *trcl=( -42.5018 -25.4864 0.0000 )    u=2
813 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -25.1717 1.2700 )    u=2 $ Assembly 46
814 3 -0.0001 -701  #815  fill=18 ( -25.4509 -25.4509 0.0000 )     $ Tube/Disk 47
            *trcl=( -25.4864 -25.4864 0.0000 )    u=2
815 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -25.1717 1.2700 )    u=2 $ Assembly 47
816 3 -0.0001 -701  #817  fill=12 ( -8.1739 -25.4509 0.0000 )     $ Tube/Disk 48
            *trcl=( -8.4709 -25.4864 0.0000 )    u=2
817 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -25.1717 1.2700 )    u=2 $ Assembly 48
818 3 -0.0001 -701  #819  fill=17 ( 8.4354 -25.4509 0.0000 )     $ Tube/Disk 49
            *trcl=( 8.4709 -25.4864 0.0000 )    u=2
819 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -25.1717 1.2700 )    u=2 $ Assembly 49
820 3 -0.0001 -701  #821  fill=17 ( 25.4509 -25.4509 0.0000 )     $ Tube/Disk 50
            *trcl=( 25.4864 -25.4864 0.0000 )    u=2
821 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -25.1717 1.2700 )    u=2 $ Assembly 50
822 3 -0.0001 -701  #823  fill=17 ( 42.4663 -25.4509 0.0000 )     $ Tube/Disk 51
            *trcl=( 42.5018 -25.4864 0.0000 )    u=2
823 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -25.1717 1.2700 )    u=2 $ Assembly 51
824 3 -0.0001 -702 #825  #826  fill=8 ( 59.6927 -26.2968 0.0000 )     $ Tube/Disk 52
            *trcl=( 59.8348 -26.4389 0.0000 )    u=2
825 3 -0.0001 -302 #826   fill=20 *trcl=( 59.3779 -25.9820 0.0000 )    u=2 $DFC
826 3 -0.0001 -270   fill=24 *trcl=( 59.3767 -25.9808 1.2700 )    u=2 $ Assembly 52
827 3 -0.0001 -702 #828  #829  fill=5 ( -61.0896 -43.9472 0.0000 )     $ Tube/Disk 53
            *trcl=( -61.2318 -44.0893 0.0000 )    u=2
828 3 -0.0001 -302 #829   fill=20 *trcl=( -60.7748 -43.6324 0.0000 )    u=2 $DFC
829 3 -0.0001 -270   fill=24 *trcl=( -60.7736 -43.6312 1.2700 )    u=2 $ Assembly 53
830 3 -0.0001 -701  #831  fill=18 ( -42.4663 -42.4663 0.0000 )     $ Tube/Disk 54
            *trcl=( -42.5018 -42.5018 0.0000 )    u=2
831 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -42.1871 1.2700 )    u=2 $ Assembly 54
832 3 -0.0001 -701  #833  fill=18 ( -25.4509 -42.4663 0.0000 )     $ Tube/Disk 55
            *trcl=( -25.4864 -42.5018 0.0000 )    u=2
833 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -42.1871 1.2700 )    u=2 $ Assembly 55
834 3 -0.0001 -701  #835  fill=12 ( -8.1739 -42.4663 0.0000 )     $ Tube/Disk 56
            *trcl=( -8.4709 -42.5018 0.0000 )    u=2
835 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -42.1871 1.2700 )    u=2 $ Assembly 56
836 3 -0.0001 -701  #837  fill=17 ( 8.4354 -42.4663 0.0000 )     $ Tube/Disk 57
            *trcl=( 8.4709 -42.5018 0.0000 )    u=2
837 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -42.1871 1.2700 )    u=2 $ Assembly 57
838 3 -0.0001 -701  #839  fill=17 ( 25.4509 -42.4663 0.0000 )     $ Tube/Disk 58
            *trcl=( 25.4864 -42.5018 0.0000 )    u=2
839 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -42.1871 1.2700 )    u=2 $ Assembly 58
840 3 -0.0001 -701  #841  fill=17 ( 42.4663 -42.4663 0.0000 )     $ Tube/Disk 59
            *trcl=( 42.5018 -42.5018 0.0000 )    u=2
841 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -42.1871 1.2700 )    u=2 $ Assembly 59
842 3 -0.0001 -702 #843  #844  fill=4 ( 61.0896 -43.9472 0.0000 )     $ Tube/Disk 60
            *trcl=( 61.2318 -44.0893 0.0000 )    u=2
843 3 -0.0001 -302 #844   fill=20 *trcl=( 60.7748 -43.6324 0.0000 )    u=2 $DFC
844 3 -0.0001 -270   fill=24 *trcl=( 60.7736 -43.6312 1.2700 )    u=2 $ Assembly 60
845 3 -0.0001 -702 #846  #847  fill=7 ( -43.9472 -61.0896 0.0000 )     $ Tube/Disk 61
            *trcl=( -44.0893 -61.2318 0.0000 )    u=2
846 3 -0.0001 -302 #847   fill=20 *trcl=( -43.6324 -60.7748 0.0000 )    u=2 $DFC
847 3 -0.0001 -270   fill=24 *trcl=( -43.6312 -60.7736 1.2700 )    u=2 $ Assembly 61
848 3 -0.0001 -702 #849  #850  fill=8 ( -26.2968 -59.6927 0.0000 )     $ Tube/Disk 62
            *trcl=( -26.4389 -59.8348 0.0000 )    u=2
849 3 -0.0001 -302 #850   fill=20 *trcl=( -25.9820 -59.3779 0.0000 )    u=2 $DFC
850 3 -0.0001 -270   fill=24 *trcl=( -25.9808 -59.3767 1.2700 )    u=2 $ Assembly 62
851 3 -0.0001 -702 #852  #853  fill=8 ( -8.6463 -59.6927 0.0000 )     $ Tube/Disk 63
            *trcl=( -8.7884 -59.8348 0.0000 )    u=2
852 3 -0.0001 -302 #853   fill=20 *trcl=( -8.3315 -59.3779 0.0000 )    u=2 $DFC
853 3 -0.0001 -290   fill=21 *trcl=( -8.3303 -59.3767 1.2700 )    u=2 $ Assembly 63
854 3 -0.0001 -702 #855  #856  fill=8 ( 8.6463 -59.6927 0.0000 )     $ Tube/Disk 64
            *trcl=( 8.7884 -59.8348 0.0000 )    u=2
855 3 -0.0001 -302 #856   fill=20 *trcl=( 8.3315 -59.3779 0.0000 )    u=2 $DFC
856 3 -0.0001 -290   fill=21 *trcl=( 8.3303 -59.3767 1.2700 )    u=2 $ Assembly 64
857 3 -0.0001 -702 #858  #859  fill=8 ( 26.2968 -59.6927 0.0000 )     $ Tube/Disk 65
            *trcl=( 26.4389 -59.8348 0.0000 )    u=2
858 3 -0.0001 -302 #859   fill=20 *trcl=( 25.9820 -59.3779 0.0000 )    u=2 $DFC
859 3 -0.0001 -270   fill=24 *trcl=( 25.9808 -59.3767 1.2700 )    u=2 $ Assembly 65
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860 3 -0.0001 -702 #861  #862  fill=7 ( 43.9472 -61.0896 0.0000 )     $ Tube/Disk 66
            *trcl=( 44.0893 -61.2318 0.0000 )    u=2
861 3 -0.0001 -302 #862   fill=20 *trcl=( 43.6324 -60.7748 0.0000 )    u=2 $DFC
862 3 -0.0001 -270   fill=24 *trcl=( 43.6312 -60.7736 1.2700 )    u=2 $ Assembly 66
863 3 -0.0001 -702 #864  #865  fill=7 ( -8.6463 -77.3430 0.0000 )     $ Tube/Disk 67
            *trcl=( -8.7884 -77.4852 0.0000 )    u=2
864 3 -0.0001 -302 #865   fill=20 *trcl=( -8.3315 -77.0282 0.0000 )    u=2 $DFC
865 3 -0.0001 -290   fill=21 *trcl=( -8.3303 -77.0270 1.2700 )    u=2 $ Assembly 67
866 3 -0.0001 -702 #867  #868  fill=7 ( 8.6463 -77.3430 0.0000 )     $ Tube/Disk 68
            *trcl=( 8.7884 -77.4852 0.0000 )    u=2
867 3 -0.0001 -302 #868   fill=20 *trcl=( 8.3315 -77.0282 0.0000 )    u=2 $DFC
868 3 -0.0001 -290   fill=21 *trcl=( 8.3303 -77.0270 1.2700 )    u=2 $ Assembly 68
869 3 -0.0001 +703 +704        $ Canister Cavity Q1
      #704 #716 #719 #722 #734 #736 #738 #740 #752
      #706 #718 #721 #724 #735 #737 #739 #742 #753
      #754 #756 #758 #773 #775 #777 #779 #782
      #755 #757 #760 #774 #776 #778 #781 #784
      #705 #717 #720 #723 #741 #759 #780 #783
          fill=3      u=2
870 3 -0.0001 +703 -704        $ Canister Cavity Q2
      #701 #707 #710 #713 #725 #728 #730 #732 #743
      #703 #709 #712 #715 #727 #729 #731 #733 #745
      #746 #748 #750 #761 #764 #767 #769 #771
      #747 #749 #751 #763 #766 #768 #770 #772
      #702 #708 #711 #714 #726 #744 #762 #765
          fill=3      u=2
871 3 -0.0001 -703 -704        $ Canister Cavity Q3
      #785 #788 #791 #793 #795 #809 #812 #814 #816
      #787 #790 #792 #794 #796 #811 #813 #815 #817
      #827 #830 #832 #834 #845 #848 #851 #863
      #829 #831 #833 #835 #847 #850 #853 #865
      #786 #789 #810 #828 #846 #849 #852 #864
          fill=3      u=2
872 3 -0.0001 -703 704        $ Canister Cavity Q4
      #797 #799 #801 #803 #806 #818 #820 #822 #824
      #798 #800 #802 #805 #808 #819 #821 #823 #826
      #836 #838 #840 #842 #854 #857 #860 #866
      #837 #839 #841 #844 #856 #859 #862 #868
      #804 #807 #825 #843 #855 #858 #861 #867
          fill=3      u=2
c Cell Cards - Canister
901 3 -0.0001 -901 #902     fill=2 u=1 $ Cavity
902 9 -2.702 -902      u=1 $ Spacer
903 8 -7.940 -903 +901     u=1 $ Canister Shell / Lid / Bottom
904 14 -0.0001 +903      u=1 $ Remaining Space
c Cell Cards - Transfer Cask Geometry
911 14 -0.0001 -911 -912  fill=1 ( 0.0000 0.0000 2.5400 )   $ Cask cavity
912 10 -7.821 -911 +912 -916     $ Bottom plate
913 10 -7.821 -913 +912 +916 -918    $ Inner shell
914 11 -11.344 -914 +913 +916 -917    $ Lead shell
915 12 -1.632 -914 +913 +917 -918    $ NS-4-FR (above lead)
916 12 -1.632 -915 +914 +916 -918    $ NS-4-FR
917 10 -7.821 -911 +915 +916 -918    $ Outer shell
918 10 -7.821 -911 +912 +918     $ Top plate
919 10 -7.821 -919 +920  -925    $ Door rail
920 10 -7.821 -919 -921  -925    $ Door rail
921 10 -7.821 -924 -922 +923 -925    $ Door steel
922 14 -0.0001 -925 +911 #919 #920 #921      $ Exterior space to Reflector
923 0         +925       $ Exterior space

c Surfaces - Fuel Rod - EX - BWR_10x10_4 WR
10 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 210.8200 0.4356 $ Fuel pellet stack
11 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 221.1553 0.4445 $ Annulus + Plenum
12 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 223.5962 0.5004 $ Clad + End-Caps
c Surfaces - Inert Rods - EX - BWR_10x10_4 WR
30 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 210.8200 0.4356 $ Zirc filler stack
31 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 223.5962 0.5004 $ Clad + End-Caps
c Surfaces - Pitch - EX - BWR_10x10_4 WR
40 PX 0.7074       $ Lattice Cell Boundaries
41 PX -0.7074
```

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42 PY 0.7074
43 PY -0.7074
c Surfaces - Fuel Assembly Array Inserted Into Assembly - EX - BWR_10x10_4 WR
50 RPP -6.8669 6.8669 -6.8669 6.8669 25.4000 250.6726  $ Array
51 RPP -7.1298 7.1298 -7.1298 7.1298 0.0000 260.2230  $ Assembly Outer Dims
c Surfaces - DFC Content - Fuel Pellet Stack
261 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 221.3610 0.4445 $ Fuel pellet stack
c Surfaces - DFC Content - Array
265 PX 0.7619       $ Lattice Cell Boundaries
266 PX -0.7619
267 PY 0.7619
268 PY -0.7619
c Surfaces - DFC Content - Envelope of Array
270 RPP -7.3011 7.3011 -7.3011 7.3011 0.0000 221.361  $ Array
c Surfaces - Axis DFC Content - Fuel Pellet Stack
281 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 221.3610 0.4445 $ Fuel pellet stack
c Surfaces - Axis DFC Content - Array
285 PX 0.7619       $ Lattice Cell Boundaries
286 PX -0.7619
287 PY 0.7619
288 PY -0.7619
c Surfaces - Axis DFC Content - Envelope of Array
290 RPP -7.3011 7.3011 -7.3011 7.3011 0.0000 221.361  $ Array
c Surface Cards - DFC
301 RPP -7.3025 7.3025 -7.3025 7.3025 0.0000 265.7475 $  Space inside DFC Shell
302 RPP -7.4244 7.4244 -7.4244 7.4244 0.0000 271.1450 $  DFC body
303 PZ 1.2700      $ Bottom plate top
304 PZ 267.3350      $ Top of lid
305 PZ 265.748      $ Bottom of lid
c Surface Cards - Standard Tube, Absorber and Retainer
311 RPP -7.4092 7.4092 -7.4092 7.4092 0.0000 274.4470 $  Space inside tube - cavity extent
312 RPP -7.4549 7.4549 -7.4549 7.4549 5.0800 254.5588 $  Fuel tube body
313 RPP -6.4897 6.4897 7.4930 7.6200 7.1120 250.6472 $ Absorber +Y
314 RPP -6.4897 6.4897 7.4549 7.6581 7.1120 250.6472 $ Absorber Clad  +Y
315 RPP -6.7374 6.7374 7.4549 7.6581 7.1120 250.6472 $ Absorber Cover Opening +Y
316 RPP -6.7958 6.7958 7.4549 7.7164 7.0536 250.6472 $ Absorber Cover  +Y
317 RPP 7.4930 7.6200 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
318 RPP 7.4549 7.6581 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
319 RPP 7.4549 7.6581 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
320 RPP 7.4549 7.7164 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
321 RPP -6.4897 6.4897 -7.6200 -7.4930 7.1120 250.6472 $ Absorber -Y
322 RPP -6.4897 6.4897 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Clad  -Y
323 RPP -6.7374 6.7374 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Cover Opening -Y
324 RPP -6.7958 6.7958 -7.7164 -7.4549 7.0536 250.6472 $ Absorber Cover  -Y
325 RPP -7.6200 -7.4930 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
326 RPP -7.6581 -7.4549 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
327 RPP -7.6581 -7.4549 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
328 RPP -7.7164 -7.4549 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - DFC Tube, Absorber and Retainer
411 RPP -7.7394 7.7394 -7.7394 7.7394 0.0000 274.4470 $  Space inside tube - cavity extent
412 RPP -7.7851 7.7851 -7.7851 7.7851 5.0800 254.5588 $  Fuel tube body
413 RPP -6.4897 6.4897 7.8232 7.9502 7.1120 250.6472 $ Absorber +Y
414 RPP -6.4897 6.4897 7.7851 7.9883 7.1120 250.6472 $ Absorber Clad  +Y
415 RPP -6.7374 6.7374 7.7851 7.9883 7.1120 250.6472 $ Absorber Cover Opening +Y
416 RPP -6.7958 6.7958 7.7851 8.0466 7.0536 250.6472 $ Absorber Cover  +Y
417 RPP 7.8232 7.9502 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
418 RPP 7.7851 7.9883 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
419 RPP 7.7851 7.9883 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
420 RPP 7.7851 8.0466 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
421 RPP -6.4897 6.4897 -7.9502 -7.8232 7.1120 250.6472 $ Absorber -Y
422 RPP -6.4897 6.4897 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Clad  -Y
423 RPP -6.7374 6.7374 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Cover Opening -Y
424 RPP -6.7958 6.7958 -8.0466 -7.7851 7.0536 250.6472 $ Absorber Cover  -Y
425 RPP -7.9502 -7.8232 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
426 RPP -7.9883 -7.7851 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
427 RPP -7.9883 -7.7851 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
428 RPP -8.0466 -7.7851 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - Disk Stack
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.7272 88.1380 $ Structural disk
602 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 3.3147 88.1380 $ Structural top disk
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603 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.0447 88.1380 $ Structural bottom disk
604 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.3386 87.7951 $ Heat transfer disk
605 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.0491 $ Top weldment disk
606 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Bottom weldment disk
c Surface Cards - Basket
701 RPP -7.7521 7.7521 -7.7521 7.7521 0.0000 274.4470  $ Std opening
702 RPP -8.1890 8.1890 -8.1890 8.1890 0.0000 274.4470  $ DFC opening
703 PY 0.0000        $ Cut plane
704 PX 0.0000        $ Cut plane
c Surface Cards - Canister
901 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470  88.4428 $ Canister cavity
902 RPP -48.6410 48.6410 -48.6410 48.6410 264.2870 274.4469   $ Canister spacer
903 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670  89.7128 $ Canister
c Surface Cards - Transfer Cask Geometry
911 RCC 0.000 0.000 0.000 0.000 0.000 313.6900 109.8550  $ Cask Cylindrical Section
912 CZ 90.8050        $ Cask cavity radius
913 CZ 92.7100        $ Inner shell OR
914 CZ 101.6000        $ Lead shell OR
915 CZ 106.6800        $ Outer shell IR
916 PZ 2.5400        $ Top of bottom plate
917 PZ 298.4500        $ Top of lead shield
918 PZ 308.6100        $ Bottom of top plate
919 RPP -110.1852 110.1852 -107.3150 107.3150 -24.1300 0.0000   $ Door Enclosing Shape
920 PY 95.8850        $ Inside rail surface
921 PY -95.8850        $ Inside rail surface
922 PY 95.4024        $ Door surface
923 PY -95.4024        $ Door surface
924 RHP 0.0000 0.0000 -24.1300 0.0000 0.0000 24.1300
          89.9681 0.0000 0.0000 54.42077 -66.1670 0.0000
          -54.4208 -66.1670 0.0000      $ Door prism
925 RCC 0.000 0.000 -44.130 0.000 0.000 370.2000 129.8550  $ Cylinder to Reflect

c
c Materials List
c
c Fuel Pellet Material   3.71%  Weight UO2 [amu]  269.94
m1    92235.66c -3.270E-02 92238.66c -8.488E-01  8016.62c -1.185E-01
c SS348 Clad
m2
      24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Water
m3     1001.62c -1.119E-01  8016.62c -8.881E-01
mt3  lwtr.01t
c Sec. Fuel - 45 Degree Axis - Exterior   3.94%  Weight UO2 [amu]  269.93
m4    92235.66c -3.473E-02 92238.66c -8.467E-01  8016.62c -1.185E-01
c Third Fuel -Coord. Axis - Exterior   3.64%  Weight UO2 [amu]  269.94
m5    92235.66c -3.209E-02 92238.66c -8.494E-01  8016.62c -1.185E-01
c Lower Nozzle Material
m6
       1001.62c -4.116E-06  8016.62c -3.266E-05
      24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.651E-03 26058.62c -2.019E-03 28062.62c -3.638E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
mt6  lwtr.01t
c Upper Nozzle Material
m7
       1001.62c -1.469E-05  8016.62c -1.165E-04
      24050.62c -7.938E-03 26054.62c -3.927E-02 28058.62c -6.383E-02
      24052.62c -1.590E-01 26056.62c -6.386E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.651E-03 26058.62c -2.019E-03 28062.62c -3.638E-03
                                                28064.62c -9.622E-04
```

```
      25055.62c -2.000E-02
mt7  lwtr.01t
c SS304
m8    24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Aluminum
m9    13027.62c -1.000E+00
c Carbon Steel
m10   26054.62c -5.594E-02  6000.66c -1.000E-02
      26056.62c -9.098E-01
      26057.62c -2.140E-02
      26058.62c -2.876E-03
c Lead
m11   82206.66c -2.534E-01
      82207.66c -2.207E-01
      82208.66c -5.259E-01
c NS-F-FR
m12    5010.66c -9.313E-04  7014.62c -1.974E-02  8016.62c -4.250E-01
       5011.66c -3.772E-03  7015.66c -7.852E-05
      13027.62c -2.142E-01  1001.62c -6.001E-02  6000.66c -2.763E-01
c Concrete
m13   26054.62c -7.911E-04 14000.60c -3.370E-01
      26056.62c -1.287E-02
      26057.62c -3.026E-04
      26058.62c -4.067E-05
       1001.62c -1.000E-02 13027.62c -3.400E-02 20000.62c -4.400E-02
       8016.62c -5.320E-01 11023.62c -2.900E-02
c Water Exterior
m14    1001.62c 2.0
       8016.62c 1.0
mt14  lwtr.01t
c Borated Aluminum (Absorber Core / Sheet)
m15    5010.66c -6.011E-02 13027.62c -5.656E-01  6000.66c -9.430E-02
       5011.66c -2.799E-01
c Zirc Alloy
m17   26054.62c -7.063E-05 24050.62c -4.179E-05  7014.62c -4.980E-04
      26056.62c -1.149E-03 24052.62c -8.370E-04  7015.66c -1.981E-06
      26057.62c -2.702E-05 24053.62c -9.673E-05
      26058.62c -3.631E-06 24054.62c -2.448E-05
      40000.66c -9.823E-01 50000.42c -1.500E-02
c SS304/Cu Heat Fin
m18   24050.62c -4.537E-03 26054.62c -2.244E-02 28058.62c -3.648E-02
      24052.62c -9.088E-02 26056.62c -3.650E-01 28060.62c -1.453E-02
      24053.62c -1.050E-02 26057.62c -8.584E-03 28061.62c -6.425E-04
      24054.62c -2.658E-03 26058.62c -1.154E-03 28062.62c -2.079E-03
                                                28064.62c -5.499E-04
      25055.62c -1.143E-02
      29000 -0.4286
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m19   92235.66c -2.683E-02 92238.66c -6.540E-01  8016.62c -9.156E-02
       1001.62c -2.547E-02  8016.62c -2.021E-01
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m20   92235.66c -2.478E-02 92238.66c -6.561E-01  8016.62c -9.156E-02
       1001.62c -2.547E-02  8016.62c -2.021E-01
c
c Rotation Matrix
*TR1 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0  $ z-rotation 45 degrees
*TR2 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0  $ z-rotation 135 degrees
*TR3 0.0 0.0 0.0 15 105 90 -75 15 90 90 90 0  $ z-rotation 15 degrees
*TR4 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0  $ z-rotation 30 degrees
*TR5 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0  $ z-rotation 60 degrees
*TR6 0.0 0.0 0.0 75 165 90 -15 75 90 90 90 0  $ z-rotation 75 degrees
*TR7 0.0 0.0 0.0 8 98 90 -82 8 90 90 90 0  $ z-rotation 8 degrees
*TR8 0.0 0.0 0.0 102 192 90 12 102 90 90 90 0  $ z-rotation 102 degrees
*TR9 0.0 0.0 0.0 156 246 90 66 156 90 90 90 0  $ z-rotation 156 degrees
*TR10 0.0 0.0 0.0 78 168 90 -12 78 90 90 90 0  $ z-rotation 78 degrees
```

```
*TR11 0.0 0.0 0.0 24 114 90 -66 24 90 90 90 0  $ z-rotation 24 degrees
c
c Cell Importances
c
mode n
imp:n 1 413r 0
c
c
c Criticality Controls
c
kcode 500 1.00 30 430
c Ones source point in each of the fuel assemblies
ksrc
      -5.5007 79.8566 100.00
      11.1599 79.8566 100.00
      -40.8016 63.6032 100.00
      -23.1512 62.2063 100.00
      -5.5007 62.2063 100.00
      11.1599 62.2063 100.00
      28.8104 62.2063 100.00
      46.4608 63.6032 100.00
      -57.9440 46.4608 100.00
      -39.3575 45.0167 100.00
      -22.3421 45.0167 100.00
      -5.3266 45.0167 100.00
      10.7243 45.0167 100.00
      28.0013 45.0167 100.00
      45.0167 45.0167 100.00
      63.6032 46.4608 100.00
      -56.5471 28.8104 100.00
      -39.3575 28.0013 100.00
      -22.3421 28.0013 100.00
      -5.3266 28.0013 100.00
      10.7243 28.0013 100.00
      28.0013 28.0013 100.00
      45.0167 28.0013 100.00
      62.2063 28.8104 100.00
      -74.1974 11.1599 100.00
      -56.5471 11.1599 100.00
      -39.3575 10.9858 100.00
      -22.3421 10.9858 100.00
      -5.3266 10.9858 100.00
      10.7243 10.7243 100.00
      28.0013 10.7243 100.00
      45.0167 10.7243 100.00
      62.2063 11.1599 100.00
      79.8566 11.1599 100.00
      -74.1974 -5.5007 100.00
      -56.5471 -5.5007 100.00
      -39.3575 -5.0651 100.00
      -22.3421 -5.0651 100.00
      -5.0651 -5.0651 100.00
      10.9858 -5.3266 100.00
      28.0013 -5.3266 100.00
      45.0167 -5.3266 100.00
      62.2063 -5.5007 100.00
      79.8566 -5.5007 100.00
      -56.5471 -23.1512 100.00
      -39.3575 -22.3421 100.00
      -22.3421 -22.3421 100.00
      -5.0651 -22.3421 100.00
      10.9858 -22.3421 100.00
      28.0013 -22.3421 100.00
      45.0167 -22.3421 100.00
      62.2063 -23.1512 100.00
      -57.9440 -40.8016 100.00
      -39.3575 -39.3575 100.00
      -22.3421 -39.3575 100.00
      -5.0651 -39.3575 100.00
      10.9858 -39.3575 100.00
```

```
      28.0013 -39.3575 100.00
      45.0167 -39.3575 100.00
      63.6032 -40.8016 100.00
      -40.8016 -57.9440 100.00
      -23.1512 -56.5471 100.00
      -5.5007 -56.5471 100.00
      11.1599 -56.5471 100.00
      28.8104 -56.5471 100.00
      46.4608 -57.9440 100.00
      -5.5007 -74.1974 100.00
      11.1599 -74.1974 100.00
c
c
c Random Number Generator Controls
c
RAND GEN=2 SEED=19073486328127
c
c
c Print Control
c
PRINT
c
```

6.A.7.2 Concrete Cask

The only difference between the transfer and concrete cask inputs is the cask body geometry. Storage casks are evaluated as single casks and infinite cask arrays. A sample infinite cask array is provided for this case.

Figure 6.A.7-3 Storage Cask Sample Input

```
LACBWR Storage Cask Model -  Fuel Assembly Type: EX - BWR_10x10_4 WR
c
c Model Revision 3.4
c
c Infinite Cask Array Model
c
c Partial Flood: No
c
c Damaged Fuel Can Option:  Yes
c DFC Content: Unclad Rod Array
c
c DFC Content Active Fuel Location: Bottom
c
c Primary Fuel Tye Enrichment:  3.71 wt%
c
c Secondary Fuel Type:  AC - BWR_10x10_0 WR
c Seondary Fuel Enrichment:  3.94 wt%
c
c Thrid Fuel Type:  AC - BWR_10x10_0 WR
c Seondary Fuel Enrichment:  3.64 wt%
c
c Density (H2O) (g/cc)
c               Lattice DFC Exterior
c               0.0001  N/A 0.9982
c
c Tube
c      Outer_Width Thickness
c      Max         Min
c
c Absorber
c          Width Thickness
c          Min   Max
c
c Disk
c      Op_Width Location Thickness Spacing
c      Max      Min      Max       Min
c
c Shift Patterns
c  Rad Fuel Rad Tube Axial Fuel Axial Basket
c  In       In       Bottom     Bottom
c Cells - Fuel Rod - EX - BWR_10x10_4 WR
10 1 -10.522 -10     u=30 $ Fuel
11 3 -0.0001 -11 +10    u=30 $ Plenum + Fuel to Clad Gap
12 2 -7.94 -12 +11    u=30 $ Clad + End Plugs
13 3 -0.0001 +12     u=30 $ Outside Fuel Rod
c Cells - Inert Rods - EX - BWR_10x10_4 WR
30 17 -6.56 -30     u=29 $ Inside Inert Rod
31 2 -7.94 -31 +30    u=29 $ Inert Rod Clad and Plugs
32 3 -0.0001 +31     u=29 $ Outside Inert Rod
c Array_10x10_4
40 3 -0.0001 -40 +41 -42 +43
      trcl=(0.7074 0.7074 25.4)   lat=1 u=28 fill=-5:4 -5:4 0:0
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 29 29 30 30 30 30
      30 30 30 30 29 29 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
      30 30 30 30 30 30 30 30 30 30
c Cells - Fuel Assembly Array Inserted Into Assembly - cellAssy
50 3 -0.0001 -50    fill=28 u=27 $ Array
51 3 -0.0001 -51 +50 -50.6 -50.5  u=27 $ Gap to Fuel Envelope
```

```
52 6 -2.0254 -51  +50.6   u=27 $ Lower Nozzle
53 7 -0.6953 -51   +50.5  u=27 $ Upper Nozzle
54 3 -0.0001 +51     u=27 $ Remaining Space
c Cells - DFC Content
261 4 -10.522 -261     u=26  $ Pellet Stack
262 3 -0.0001 +261     u=26  $ Exterior
c Cells - DFC Content
265 3 -0.0001 -265 +266 -267 +268
      trcl=(0.76185 0.76185 0)   lat=1 u=25 fill=-5:4 -5:4 0:0
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
      26 26 26 26 26 26 26 26 26 26
c Cells - Fuel Assembly Array Inserted Into Assembly - cellDFCAssy
270 3 -0.0001 -270  fill=25   ( 0.0000 0.0000 0.0000 ) u=24 $ Array
271 3 -0.0001 +270      u=24 $ Remaining Space
c Cells - DFC Content
281 5 -10.522 -281     u=23  $ Pellet Stack
282 3 -0.0001 +281     u=23  $ Exterior
c Cells - DFC Content
285 3 -0.0001 -285 +286 -287 +288
      trcl=(0.76185 0.76185 0)   lat=1 u=22 fill=-5:4 -5:4 0:0
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
      23 23 23 23 23 23 23 23 23 23
c Cells - Fuel Assembly Array Inserted Into Assembly - cellDFCAssyAxis
290 3 -0.0001 -290  fill=22   ( 0.0000 0.0000 0.0000 ) u=21 $ Array
291 3 -0.0001 +290      u=21 $ Remaining Space
c Cell Cards -DFC
301 3 -0.0001 -301 -305 +303    u=20 $ DFC Cavity
302 8 -7.940 -302  -303    u=20 $ DFC Bottom Plate
303 8 -7.940 -302 +301 +303    u=20 $ DFC Body
304 8 -7.940 -301 +305 -304    u=20 $ DFC Lid Plates
305 3 -0.0001 -301 +304     u=20 $ Area above lid
306 3 -0.0001 +302      u=20 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,PY)
330 3 -0.0001 -311      u=18 $ Space in Tube
331 8 -7.940 -312 +311     u=18 $ FuelTube
332 15 -1.965 -313      u=18 $ Absorber +Y
333 9 -2.702 -314 +313     u=18 $ Absorber Clad  +Y
334 3 -0.0001 -315 +314     u=18 $ Absorber Cover Opening+Y
335 8 -7.940 -316 +315     u=18 $ Absorber Cover  +Y
336 15 -1.965 -317      u=18 $ Absorber +X
337 9 -2.702 -318 +317     u=18 $ Absorber Clad  +X
338 3 -0.0001 -319 +318     u=18 $ Absorber Cover Opening+X
339 8 -7.940 -320 +319     u=18 $ Absorber Cover  +X
340 3 -0.0001 +311 +312 +316 +320      u=18 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,PY)
341 3 -0.0001 -311      u=17 $ Space in Tube
342 8 -7.940 -312 +311     u=17 $ FuelTube
343 15 -1.965 -313      u=17 $ Absorber +Y
344 9 -2.702 -314 +313     u=17 $ Absorber Clad  +Y
345 3 -0.0001 -315 +314     u=17 $ Absorber Cover Opening+Y
346 8 -7.940 -316 +315     u=17 $ Absorber Cover  +Y
347 15 -1.965 -325      u=17 $ Absorber -X
348 9 -2.702 -326 +325     u=17 $ Absorber Clad  -X
349 3 -0.0001 -327 +326     u=17 $ Absorber Cover Opening-X
```

```
350 8 -7.940 -328 +327      u=17 $ Absorber Cover  -X
351 3 -0.0001 +311 +312 +316 +328      u=17 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX,MY)
352 3 -0.0001 -311      u=16 $ Space in Tube
353 8 -7.940 -312 +311      u=16 $ FuelTube
354 15 -1.965 -321      u=16 $ Absorber -Y
355 9 -2.702 -322 +321      u=16 $ Absorber Clad  -Y
356 3 -0.0001 -323 +322      u=16 $ Absorber Cover Opening-Y
357 8 -7.940 -324 +323      u=16 $ Absorber Cover  -Y
358 15 -1.965 -325      u=16 $ Absorber -X
359 9 -2.702 -326 +325      u=16 $ Absorber Clad  -X
360 3 -0.0001 -327 +326      u=16 $ Absorber Cover Opening-X
361 8 -7.940 -328 +327      u=16 $ Absorber Cover  -X
362 3 -0.0001 +311 +312 +324 +328      u=16 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX,MY)
363 3 -0.0001 -311      u=15 $ Space in Tube
364 8 -7.940 -312 +311      u=15 $ FuelTube
365 15 -1.965 -321      u=15 $ Absorber -Y
366 9 -2.702 -322 +321      u=15 $ Absorber Clad  -Y
367 3 -0.0001 -323 +322      u=15 $ Absorber Cover Opening-Y
368 8 -7.940 -324 +323      u=15 $ Absorber Cover  -Y
369 15 -1.965 -317      u=15 $ Absorber +X
370 9 -2.702 -318 +317      u=15 $ Absorber Clad  +X
371 3 -0.0001 -319 +318      u=15 $ Absorber Cover Opening+X
372 8 -7.940 -320 +319      u=15 $ Absorber Cover  +X
373 3 -0.0001 +311 +312 +320 +324      u=15 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PX)
374 3 -0.0001 -311      u=14 $ Space in Tube
375 8 -7.940 -312 +311      u=14 $ FuelTube
376 15 -1.965 -317      u=14 $ Absorber +X
377 9 -2.702 -318 +317      u=14 $ Absorber Clad  +X
378 3 -0.0001 -319 +318      u=14 $ Absorber Cover Opening+X
379 8 -7.940 -320 +319      u=14 $ Absorber Cover  +X
380 3 -0.0001 +311 +312 +320      u=14 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MX)
381 3 -0.0001 -311      u=13 $ Space in Tube
382 8 -7.940 -312 +311      u=13 $ FuelTube
383 15 -1.965 -325      u=13 $ Absorber -X
384 9 -2.702 -326 +325      u=13 $ Absorber Clad  -X
385 3 -0.0001 -327 +326      u=13 $ Absorber Cover Opening-X
386 8 -7.940 -328 +327      u=13 $ Absorber Cover  -X
387 3 -0.0001 +311 +312 +328      u=13 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (PY)
388 3 -0.0001 -311      u=12 $ Space in Tube
389 8 -7.940 -312 +311      u=12 $ FuelTube
390 15 -1.965 -313      u=12 $ Absorber +Y
391 9 -2.702 -314 +313      u=12 $ Absorber Clad  +Y
392 3 -0.0001 -315 +314      u=12 $ Absorber Cover Opening+Y
393 8 -7.940 -316 +315      u=12 $ Absorber Cover  +Y
394 3 -0.0001 +311 +312 +316      u=12 $ Exterior Space
c Cell Cards - Standard Tube, Absorber and Retainer (MY)
395 3 -0.0001 -311      u=11 $ Space in Tube
396 8 -7.940 -312 +311      u=11 $ FuelTube
397 15 -1.965 -321      u=11 $ Absorber -Y
398 9 -2.702 -322 +321      u=11 $ Absorber Clad  -Y
399 3 -0.0001 -323 +322      u=11 $ Absorber Cover Opening-Y
400 8 -7.940 -324 +323      u=11 $ Absorber Cover  -Y
401 3 -0.0001 +311 +312 +324      u=11 $ Exterior Space
c Cell Cards - Standard Tube
402 3 -0.0001 -311      u=10 $ Space in Tube
403 8 -7.940 -312 +311      u=10 $ FuelTube
404 3 -0.0001 +311 +312      u=10 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 4 BORAL
411 3 -0.0001 -411      u=8 $ Space in Tube
412 8 -7.940 -412 +411      u=8 $ FuelTube
413 15 -1.965 -413      u=8 $ Absorber +Y
414 9 -2.702 -414 +413      u=8 $ Absorber Clad  +Y
415 3 -0.0001 -415 +414      u=8 $ Absorber Cover Opening+Y
416 8 -7.940 -416 +415      u=8 $ Absorber Cover  +Y
417 15 -1.965 -417      u=8 $ Absorber +X
```

```
418 8 -7.940 -418 +417      u=8 $ Absorber Clad  +X
419 3 -0.0001 -419 +418      u=8 $ Absorber Cover Opening+X
420 8 -7.940 -420 +419      u=8 $ Absorber Cover  +X
421 15 -1.965 -421       u=8 $ Absorber -Y
422 9 -2.702 -422 +421      u=8 $ Absorber Clad  -Y
423 3 -0.0001 -423 +422      u=8 $ Absorber Cover Opening-Y
424 8 -7.940 -424 +423      u=8 $ Absorber Cover  -Y
425 15 -1.965 -425       u=8 $ Absorber -X
426 8 -7.940 -426 +425      u=8 $ Absorber Clad  -X
427 3 -0.0001 -427 +426      u=8 $ Absorber Cover Opening-X
428 8 -7.940 -428 +427      u=8 $ Absorber Cover  -X
429 3 -0.0001 +411 +412 +416 +420 +424 +428      u=8 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X. PY
430 3 -0.0001 -411       u=7 $ Space in Tube
431 8 -7.940 -412 +411      u=7 $ FuelTube
432 15 -1.965 -413       u=7 $ Absorber +Y
433 9 -2.702 -414 +413      u=7 $ Absorber Clad  +Y
434 3 -0.0001 -415 +414      u=7 $ Absorber Cover Opening+Y
435 8 -7.940 -416 +415      u=7 $ Absorber Cover  +Y
436 15 -1.965 -417       u=7 $ Absorber +X
437 8 -7.940 -418 +417      u=7 $ Absorber Clad  +X
438 3 -0.0001 -419 +418      u=7 $ Absorber Cover Opening+X
439 8 -7.940 -420 +419      u=7 $ Absorber Cover  +X
440 15 -1.965 -425       u=7 $ Absorber -X
441 8 -7.940 -426 +425      u=7 $ Absorber Clad  -X
442 3 -0.0001 -427 +426      u=7 $ Absorber Cover Opening-X
443 8 -7.940 -428 +427      u=7 $ Absorber Cover  -X
444 3 -0.0001 +411 +412 +416 +420 +428      u=7 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- 2X, MY
445 3 -0.0001 -411       u=6 $ Space in Tube
446 8 -7.940 -412 +411      u=6 $ FuelTube
447 15 -1.965 -417       u=6 $ Absorber +X
448 8 -7.940 -418 +417      u=6 $ Absorber Clad  +X
449 3 -0.0001 -419 +418      u=6 $ Absorber Cover Opening+X
450 8 -7.940 -420 +419      u=6 $ Absorber Cover  +X
451 15 -1.965 -421       u=6 $ Absorber -Y
452 9 -2.702 -422 +421      u=6 $ Absorber Clad  -Y
453 3 -0.0001 -423 +422      u=6 $ Absorber Cover Opening-Y
454 8 -7.940 -424 +423      u=6 $ Absorber Cover  -Y
455 15 -1.965 -425       u=6 $ Absorber -X
456 8 -7.940 -426 +425      u=6 $ Absorber Clad  -X
457 3 -0.0001 -427 +426      u=6 $ Absorber Cover Opening-X
458 8 -7.940 -428 +427      u=6 $ Absorber Cover  -X
459 3 -0.0001 +411 +412 +420 +424 +428      u=6 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer-PX, 2Y
460 3 -0.0001 -411       u=5 $ Space in Tube
461 8 -7.940 -412 +411      u=5 $ FuelTube
462 15 -1.965 -413       u=5 $ Absorber +Y
463 9 -2.702 -414 +413      u=5 $ Absorber Clad  +Y
464 3 -0.0001 -415 +414      u=5 $ Absorber Cover Opening+Y
465 8 -7.940 -416 +415      u=5 $ Absorber Cover  +Y
466 15 -1.965 -417       u=5 $ Absorber +X
467 8 -7.940 -418 +417      u=5 $ Absorber Clad  +X
468 3 -0.0001 -419 +418      u=5 $ Absorber Cover Opening+X
469 8 -7.940 -420 +419      u=5 $ Absorber Cover  +X
470 15 -1.965 -421       u=5 $ Absorber -Y
471 9 -2.702 -422 +421      u=5 $ Absorber Clad  -Y
472 3 -0.0001 -423 +422      u=5 $ Absorber Cover Opening-Y
473 8 -7.940 -424 +423      u=5 $ Absorber Cover  -Y
474 3 -0.0001 +411 +412 +416 +420 +424      u=5 $ Exterior Space
c Cell Cards - DFC Tube, Absorber and Retainer- MX, 2Y
475 3 -0.0001 -411       u=4 $ Space in Tube
476 8 -7.940 -412 +411      u=4 $ FuelTube
477 15 -1.965 -413       u=4 $ Absorber +Y
478 9 -2.702 -414 +413      u=4 $ Absorber Clad  +Y
479 3 -0.0001 -415 +414      u=4 $ Absorber Cover Opening+Y
480 8 -7.940 -416 +415      u=4 $ Absorber Cover  +Y
481 15 -1.965 -421       u=4 $ Absorber -Y
482 9 -2.702 -422 +421      u=4 $ Absorber Clad  -Y
483 3 -0.0001 -423 +422      u=4 $ Absorber Cover Opening-Y
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484 8 -7.940 -424 +423     u=4 $ Absorber Cover  -Y
485 15 -1.965 -425      u=4 $ Absorber -X
486 8 -7.940 -426 +425     u=4 $ Absorber Clad  -X
487 3 -0.0001 -427 +426     u=4 $ Absorber Cover Opening-X
488 8 -7.940 -428 +427     u=4 $ Absorber Cover  -X
489 3 -0.0001 +411 +412 +416 +424 +428      u=4 $ Exterior Space
c Cell Cards - Disk Stack
601 8 -7.94 -606 *trcl=( 0.0000 0.0000 2.5400 )    u=3 $ Bottom weldment disk
602 8 -7.94 -603 *trcl=( 0.0000 0.0000 9.8044 )    u=3 $ Support disk 1 (Thick Disk)
603 8 -7.94 -601 *trcl=( 0.0000 0.0000 15.1257 )    u=3 $ Support disk 2
604 like 603 but   *trcl=( 0.0000 0.0000 24.9555 )    u=3 $ Support disk 3
605 like 603 but   *trcl=( 0.0000 0.0000 34.7853 )    u=3 $ Support disk 4
606 like 603 but   *trcl=( 0.0000 0.0000 44.6151 )    u=3 $ Support disk 5
607 like 603 but   *trcl=( 0.0000 0.0000 54.4449 )    u=3 $ Support disk 6
608 9 -2.70 -604 *trcl=( 0.0000 0.0000 59.5160 )    u=3 $ Heat transfer disk 1
609 like 603 but   *trcl=( 0.0000 0.0000 64.1985 )    u=3 $ Support disk 7
610 like 608 but   *trcl=( 0.0000 0.0000 69.2696 )    u=3 $ Heat transfer disk 2
611 like 603 but   *trcl=( 0.0000 0.0000 73.9521 )    u=3 $ Support disk 8
612 like 608 but   *trcl=( 0.0000 0.0000 79.0232 )    u=3 $ Heat transfer disk 3
613 like 603 but   *trcl=( 0.0000 0.0000 83.7057 )    u=3 $ Support disk 9
614 like 608 but   *trcl=( 0.0000 0.0000 88.7768 )    u=3 $ Heat transfer disk 4
615 like 603 but   *trcl=( 0.0000 0.0000 93.4593 )    u=3 $ Support disk 10
616 like 608 but   *trcl=( 0.0000 0.0000 98.5304 )    u=3 $ Heat transfer disk 5
617 like 603 but   *trcl=( 0.0000 0.0000 103.2129 )    u=3 $ Support disk 11
618 like 608 but   *trcl=( 0.0000 0.0000 108.2840 )    u=3 $ Heat transfer disk 6
619 like 603 but   *trcl=( 0.0000 0.0000 112.9665 )    u=3 $ Support disk 12
620 like 608 but   *trcl=( 0.0000 0.0000 118.0376 )    u=3 $ Heat transfer disk 7
621 like 603 but   *trcl=( 0.0000 0.0000 122.7201 )    u=3 $ Support disk 13
622 like 608 but   *trcl=( 0.0000 0.0000 127.7912 )    u=3 $ Heat transfer disk 8
623 like 603 but   *trcl=( 0.0000 0.0000 132.4737 )    u=3 $ Support disk 14
624 like 608 but   *trcl=( 0.0000 0.0000 137.5448 )    u=3 $ Heat transfer disk 9
625 like 603 but   *trcl=( 0.0000 0.0000 142.2273 )    u=3 $ Support disk 15
626 like 608 but   *trcl=( 0.0000 0.0000 147.2984 )    u=3 $ Heat transfer disk 10
627 like 603 but   *trcl=( 0.0000 0.0000 151.9809 )    u=3 $ Support disk 16
628 like 608 but   *trcl=( 0.0000 0.0000 157.0520 )    u=3 $ Heat transfer disk 11
629 like 603 but   *trcl=( 0.0000 0.0000 161.7345 )    u=3 $ Support disk 17
630 like 608 but   *trcl=( 0.0000 0.0000 166.8056 )    u=3 $ Heat transfer disk 12
631 like 603 but   *trcl=( 0.0000 0.0000 171.4881 )    u=3 $ Support disk 18
632 like 608 but   *trcl=( 0.0000 0.0000 176.5592 )    u=3 $ Heat transfer disk 13
633 like 603 but   *trcl=( 0.0000 0.0000 181.2417 )    u=3 $ Support disk 19
634 like 608 but   *trcl=( 0.0000 0.0000 186.3128 )    u=3 $ Heat transfer disk 14
635 like 603 but   *trcl=( 0.0000 0.0000 190.9953 )    u=3 $ Support disk 20
636 like 603 but   *trcl=( 0.0000 0.0000 200.8251 )    u=3 $ Support disk 21
637 like 603 but   *trcl=( 0.0000 0.0000 210.6549 )    u=3 $ Support disk 22
638 like 603 but   *trcl=( 0.0000 0.0000 220.4847 )    u=3 $ Support disk 23
639 like 603 but   *trcl=( 0.0000 0.0000 230.3145 )    u=3 $ Support disk 24
640 like 603 but   *trcl=( 0.0000 0.0000 240.1443 )    u=3 $ Support disk 25
641 8 -7.94 -602 *trcl=( 0.0000 0.0000 248.3231 )    u=3 $ Support disk 26 (Thick Disk)
642 8 -7.94 -605 *trcl=( 0.0000 0.0000 255.8288 )    u=3 $ Top weldment disk
643 3 -0.0001       $ Outside Disks
      #601 #602 #603 #604 #605 #606 #607 #608 #609 #610
      #611 #612 #613 #614 #615 #616 #617 #618 #619 #620
      #621 #622 #623 #624 #625 #626 #627 #628 #629 #630
      #631 #632 #633 #634 #635 #636 #637 #638 #639 #640
      #641 #642        u=3
c Cell Cards - Basket
701 3 -0.0001 -702 #702  #703  fill=6 ( -8.6463 77.3430 0.0000 )     $ Tube/Disk 1
            *trcl=( -8.7884 77.4852 0.0000 )    u=2
702 3 -0.0001 -302 #703   fill=20 *trcl=( -8.3315 77.0282 0.0000 )    u=2 $DFC
703 3 -0.0001 -290   fill=21 *trcl=( -8.3303 77.0270 1.2700 )    u=2 $ Assembly 1
704 3 -0.0001 -702 #705  #706  fill=6 ( 8.6463 77.3430 0.0000 )     $ Tube/Disk 2
            *trcl=( 8.7884 77.4852 0.0000 )    u=2
705 3 -0.0001 -302 #706   fill=20 *trcl=( 8.3315 77.0282 0.0000 )    u=2 $DFC
706 3 -0.0001 -290   fill=21 *trcl=( 8.3303 77.0270 1.2700 )    u=2 $ Assembly 2
707 3 -0.0001 -702 #708  #709  fill=6 ( -43.9472 61.0896 0.0000 )     $ Tube/Disk 3
            *trcl=( -44.0893 61.2318 0.0000 )    u=2
708 3 -0.0001 -302 #709   fill=20 *trcl=( -43.6324 60.7748 0.0000 )    u=2 $DFC
709 3 -0.0001 -270   fill=24 *trcl=( -43.6312 60.7736 1.2700 )    u=2 $ Assembly 3
710 3 -0.0001 -702 #711  #712  fill=8 ( -26.2968 59.6927 0.0000 )     $ Tube/Disk 4
            *trcl=( -26.4389 59.8348 0.0000 )    u=2
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711 3 -0.0001 -302 #712   fill=20 *trcl=( -25.9820 59.3779 0.0000 )    u=2 $DFC
712 3 -0.0001 -270   fill=24 *trcl=( -25.9808 59.3767 1.2700 )    u=2 $ Assembly 4
713 3 -0.0001 -702 #714  #715  fill=8 ( -8.6463 59.6927 0.0000 )     $ Tube/Disk 5
            *trcl=( -8.7884 59.8348 0.0000 )    u=2
714 3 -0.0001 -302 #715   fill=20 *trcl=( -8.3315 59.3779 0.0000 )    u=2 $DFC
715 3 -0.0001 -290   fill=21 *trcl=( -8.3303 59.3767 1.2700 )    u=2 $ Assembly 5
716 3 -0.0001 -702 #717  #718  fill=8 ( 8.6463 59.6927 0.0000 )     $ Tube/Disk 6
            *trcl=( 8.7884 59.8348 0.0000 )    u=2
717 3 -0.0001 -302 #718   fill=20 *trcl=( 8.3315 59.3779 0.0000 )    u=2 $DFC
718 3 -0.0001 -290   fill=21 *trcl=( 8.3303 59.3767 1.2700 )    u=2 $ Assembly 6
719 3 -0.0001 -702 #720  #721  fill=8 ( 26.2968 59.6927 0.0000 )     $ Tube/Disk 7
            *trcl=( 26.4389 59.8348 0.0000 )    u=2
720 3 -0.0001 -302 #721   fill=20 *trcl=( 25.9820 59.3779 0.0000 )    u=2 $DFC
721 3 -0.0001 -270   fill=24 *trcl=( 25.9808 59.3767 1.2700 )    u=2 $ Assembly 7
722 3 -0.0001 -702 #723  #724  fill=6 ( 43.9472 61.0896 0.0000 )     $ Tube/Disk 8
            *trcl=( 44.0893 61.2318 0.0000 )    u=2
723 3 -0.0001 -302 #724   fill=20 *trcl=( 43.6324 60.7748 0.0000 )    u=2 $DFC
724 3 -0.0001 -270   fill=24 *trcl=( 43.6312 60.7736 1.2700 )    u=2 $ Assembly 8
725 3 -0.0001 -702 #726  #727  fill=5 ( -61.0896 43.9472 0.0000 )     $ Tube/Disk 9
            *trcl=( -61.2318 44.0893 0.0000 )    u=2
726 3 -0.0001 -302 #727   fill=20 *trcl=( -60.7748 43.6324 0.0000 )    u=2 $DFC
727 3 -0.0001 -270   fill=24 *trcl=( -60.7736 43.6312 1.2700 )    u=2 $ Assembly 9
728 3 -0.0001 -701  #729  fill=15 ( -42.4663 42.4663 0.0000 )     $ Tube/Disk 10
            *trcl=( -42.5018 42.5018 0.0000 )    u=2
729 3 -0.0001 -51   fill=27 *trcl=( -42.1871 42.1871 1.2700 )    u=2 $ Assembly 10
730 3 -0.0001 -701  #731  fill=15 ( -25.4509 42.4663 0.0000 )     $ Tube/Disk 11
            *trcl=( -25.4864 42.5018 0.0000 )    u=2
731 3 -0.0001 -51   fill=27 *trcl=( -25.1717 42.1871 1.2700 )    u=2 $ Assembly 11
732 3 -0.0001 -701  #733  fill=15 ( -8.4354 42.4663 0.0000 )     $ Tube/Disk 12
            *trcl=( -8.4709 42.5018 0.0000 )    u=2
733 3 -0.0001 -51   fill=27 *trcl=( -8.1562 42.1871 1.2700 )    u=2 $ Assembly 12
734 3 -0.0001 -701  #735  fill=11 ( 8.1739 42.4663 0.0000 )     $ Tube/Disk 13
            *trcl=( 8.4709 42.5018 0.0000 )    u=2
735 3 -0.0001 -51   fill=27 *trcl=( 7.8947 42.1871 1.2700 )    u=2 $ Assembly 13
736 3 -0.0001 -701  #737  fill=16 ( 25.4509 42.4663 0.0000 )     $ Tube/Disk 14
            *trcl=( 25.4864 42.5018 0.0000 )    u=2
737 3 -0.0001 -51   fill=27 *trcl=( 25.1717 42.1871 1.2700 )    u=2 $ Assembly 14
738 3 -0.0001 -701  #739  fill=16 ( 42.4663 42.4663 0.0000 )     $ Tube/Disk 15
            *trcl=( 42.5018 42.5018 0.0000 )    u=2
739 3 -0.0001 -51   fill=27 *trcl=( 42.1871 42.1871 1.2700 )    u=2 $ Assembly 15
740 3 -0.0001 -702 #741  #742  fill=4 ( 61.0896 43.9472 0.0000 )     $ Tube/Disk 16
            *trcl=( 61.2318 44.0893 0.0000 )    u=2
741 3 -0.0001 -302 #742   fill=20 *trcl=( 60.7748 43.6324 0.0000 )    u=2 $DFC
742 3 -0.0001 -270   fill=24 *trcl=( 60.7736 43.6312 1.2700 )    u=2 $ Assembly 16
743 3 -0.0001 -702 #744  #745  fill=8 ( -59.6927 26.2968 0.0000 )     $ Tube/Disk 17
            *trcl=( -59.8348 26.4389 0.0000 )    u=2
744 3 -0.0001 -302 #745   fill=20 *trcl=( -59.3779 25.9820 0.0000 )    u=2 $DFC
745 3 -0.0001 -270   fill=24 *trcl=( -59.3767 25.9808 1.2700 )    u=2 $ Assembly 17
746 3 -0.0001 -701  #747  fill=15 ( -42.4663 25.4509 0.0000 )     $ Tube/Disk 18
            *trcl=( -42.5018 25.4864 0.0000 )    u=2
747 3 -0.0001 -51   fill=27 *trcl=( -42.1871 25.1717 1.2700 )    u=2 $ Assembly 18
748 3 -0.0001 -701  #749  fill=15 ( -25.4509 25.4509 0.0000 )     $ Tube/Disk 19
            *trcl=( -25.4864 25.4864 0.0000 )    u=2
749 3 -0.0001 -51   fill=27 *trcl=( -25.1717 25.1717 1.2700 )    u=2 $ Assembly 19
750 3 -0.0001 -701  #751  fill=15 ( -8.4354 25.4509 0.0000 )     $ Tube/Disk 20
            *trcl=( -8.4709 25.4864 0.0000 )    u=2
751 3 -0.0001 -51   fill=27 *trcl=( -8.1562 25.1717 1.2700 )    u=2 $ Assembly 20
752 3 -0.0001 -701  #753  fill=11 ( 8.1739 25.4509 0.0000 )     $ Tube/Disk 21
            *trcl=( 8.4709 25.4864 0.0000 )    u=2
753 3 -0.0001 -51   fill=27 *trcl=( 7.8947 25.1717 1.2700 )    u=2 $ Assembly 21
754 3 -0.0001 -701  #755  fill=16 ( 25.4509 25.4509 0.0000 )     $ Tube/Disk 22
            *trcl=( 25.4864 25.4864 0.0000 )    u=2
755 3 -0.0001 -51   fill=27 *trcl=( 25.1717 25.1717 1.2700 )    u=2 $ Assembly 22
756 3 -0.0001 -701  #757  fill=16 ( 42.4663 25.4509 0.0000 )     $ Tube/Disk 23
            *trcl=( 42.5018 25.4864 0.0000 )    u=2
757 3 -0.0001 -51   fill=27 *trcl=( 42.1871 25.1717 1.2700 )    u=2 $ Assembly 23
758 3 -0.0001 -702 #759  #760  fill=8 ( 59.6927 26.2968 0.0000 )     $ Tube/Disk 24
            *trcl=( 59.8348 26.4389 0.0000 )    u=2
759 3 -0.0001 -302 #760   fill=20 *trcl=( 59.3779 25.9820 0.0000 )    u=2 $DFC
760 3 -0.0001 -270   fill=24 *trcl=( 59.3767 25.9808 1.2700 )    u=2 $ Assembly 24
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761 3 -0.0001 -702 #762  #763  fill=5 ( -77.3430 8.6463 0.0000 )     $ Tube/Disk 25
            *trcl=( -77.4852 8.7884 0.0000 )    u=2
762 3 -0.0001 -302 #763   fill=20 *trcl=( -77.0282 8.3315 0.0000 )    u=2 $DFC
763 3 -0.0001 -290   fill=21 *trcl=( -77.0270 8.3303 1.2700 )    u=2 $ Assembly 25
764 3 -0.0001 -702 #765  #766  fill=8 ( -59.6927 8.6463 0.0000 )     $ Tube/Disk 26
            *trcl=( -59.8348 8.7884 0.0000 )    u=2
765 3 -0.0001 -302 #766   fill=20 *trcl=( -59.3779 8.3315 0.0000 )    u=2 $DFC
766 3 -0.0001 -290   fill=21 *trcl=( -59.3767 8.3303 1.2700 )    u=2 $ Assembly 26
767 3 -0.0001 -701  #768  fill=15 ( -42.4663 8.4354 0.0000 )     $ Tube/Disk 27
            *trcl=( -42.5018 8.4709 0.0000 )    u=2
768 3 -0.0001 -51   fill=27 *trcl=( -42.1871 8.1562 1.2700 )    u=2 $ Assembly 27
769 3 -0.0001 -701  #770  fill=15 ( -25.4509 8.4354 0.0000 )     $ Tube/Disk 28
            *trcl=( -25.4864 8.4709 0.0000 )    u=2
770 3 -0.0001 -51   fill=27 *trcl=( -25.1717 8.1562 1.2700 )    u=2 $ Assembly 28
771 3 -0.0001 -701  #772  fill=15 ( -8.4354 8.4354 0.0000 )     $ Tube/Disk 29
            *trcl=( -8.4709 8.4709 0.0000 )    u=2
772 3 -0.0001 -51   fill=27 *trcl=( -8.1562 8.1562 1.2700 )    u=2 $ Assembly 29
773 3 -0.0001 -701  #774  fill=10 ( 8.1739 8.1739 0.0000 )     $ Tube/Disk 30
            *trcl=( 8.4709 8.4709 0.0000 )    u=2
774 3 -0.0001 -51   fill=27 *trcl=( 7.8947 7.8947 1.2700 )    u=2 $ Assembly 30
775 3 -0.0001 -701  #776  fill=13 ( 25.4509 8.1739 0.0000 )     $ Tube/Disk 31
            *trcl=( 25.4864 8.4709 0.0000 )    u=2
776 3 -0.0001 -51   fill=27 *trcl=( 25.1717 7.8947 1.2700 )    u=2 $ Assembly 31
777 3 -0.0001 -701  #778  fill=13 ( 42.4663 8.1739 0.0000 )     $ Tube/Disk 32
            *trcl=( 42.5018 8.4709 0.0000 )    u=2
778 3 -0.0001 -51   fill=27 *trcl=( 42.1871 7.8947 1.2700 )    u=2 $ Assembly 32
779 3 -0.0001 -702 #780  #781  fill=8 ( 59.6927 8.6463 0.0000 )     $ Tube/Disk 33
            *trcl=( 59.8348 8.7884 0.0000 )    u=2
780 3 -0.0001 -302 #781   fill=20 *trcl=( 59.3779 8.3315 0.0000 )    u=2 $DFC
781 3 -0.0001 -290   fill=21 *trcl=( 59.3767 8.3303 1.2700 )    u=2 $ Assembly 33
782 3 -0.0001 -702 #783  #784  fill=4 ( 77.3430 8.6463 0.0000 )     $ Tube/Disk 34
            *trcl=( 77.4852 8.7884 0.0000 )    u=2
783 3 -0.0001 -302 #784   fill=20 *trcl=( 77.0282 8.3315 0.0000 )    u=2 $DFC
784 3 -0.0001 -290   fill=21 *trcl=( 77.0270 8.3303 1.2700 )    u=2 $ Assembly 34
785 3 -0.0001 -702 #786  #787  fill=5 ( -77.3430 -8.6463 0.0000 )     $ Tube/Disk 35
            *trcl=( -77.4852 -8.7884 0.0000 )    u=2
786 3 -0.0001 -302 #787   fill=20 *trcl=( -77.0282 -8.3315 0.0000 )    u=2 $DFC
787 3 -0.0001 -290   fill=21 *trcl=( -77.0270 -8.3303 1.2700 )    u=2 $ Assembly 35
788 3 -0.0001 -702 #789  #790  fill=8 ( -59.6927 -8.6463 0.0000 )     $ Tube/Disk 36
            *trcl=( -59.8348 -8.7884 0.0000 )    u=2
789 3 -0.0001 -302 #790   fill=20 *trcl=( -59.3779 -8.3315 0.0000 )    u=2 $DFC
790 3 -0.0001 -290   fill=21 *trcl=( -59.3767 -8.3303 1.2700 )    u=2 $ Assembly 36
791 3 -0.0001 -701  #792  fill=14 ( -42.4663 -8.1739 0.0000 )     $ Tube/Disk 37
            *trcl=( -42.5018 -8.4709 0.0000 )    u=2
792 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -7.8947 1.2700 )    u=2 $ Assembly 37
793 3 -0.0001 -701  #794  fill=14 ( -25.4509 -8.1739 0.0000 )     $ Tube/Disk 38
            *trcl=( -25.4864 -8.4709 0.0000 )    u=2
794 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -7.8947 1.2700 )    u=2 $ Assembly 38
795 3 -0.0001 -701  #796  fill=10 ( -8.1739 -8.1739 0.0000 )     $ Tube/Disk 39
            *trcl=( -8.4709 -8.4709 0.0000 )    u=2
796 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -7.8947 1.2700 )    u=2 $ Assembly 39
797 3 -0.0001 -701  #798  fill=17 ( 8.4354 -8.4354 0.0000 )     $ Tube/Disk 40
            *trcl=( 8.4709 -8.4709 0.0000 )    u=2
798 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -8.1562 1.2700 )    u=2 $ Assembly 40
799 3 -0.0001 -701  #800  fill=17 ( 25.4509 -8.4354 0.0000 )     $ Tube/Disk 41
            *trcl=( 25.4864 -8.4709 0.0000 )    u=2
800 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -8.1562 1.2700 )    u=2 $ Assembly 41
801 3 -0.0001 -701  #802  fill=17 ( 42.4663 -8.4354 0.0000 )     $ Tube/Disk 42
            *trcl=( 42.5018 -8.4709 0.0000 )    u=2
802 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -8.1562 1.2700 )    u=2 $ Assembly 42
803 3 -0.0001 -702 #804  #805  fill=8 ( 59.6927 -8.6463 0.0000 )     $ Tube/Disk 43
            *trcl=( 59.8348 -8.7884 0.0000 )    u=2
804 3 -0.0001 -302 #805   fill=20 *trcl=( 59.3779 -8.3315 0.0000 )    u=2 $DFC
805 3 -0.0001 -290   fill=21 *trcl=( 59.3767 -8.3303 1.2700 )    u=2 $ Assembly 43
806 3 -0.0001 -702 #807  #808  fill=4 ( 77.3430 -8.6463 0.0000 )     $ Tube/Disk 44
            *trcl=( 77.4852 -8.7884 0.0000 )    u=2
807 3 -0.0001 -302 #808   fill=20 *trcl=( 77.0282 -8.3315 0.0000 )    u=2 $DFC
808 3 -0.0001 -290   fill=21 *trcl=( 77.0270 -8.3303 1.2700 )    u=2 $ Assembly 44
809 3 -0.0001 -702 #810  #811  fill=8 ( -59.6927 -26.2968 0.0000 )     $ Tube/Disk 45
            *trcl=( -59.8348 -26.4389 0.0000 )    u=2
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810 3 -0.0001 -302 #811   fill=20 *trcl=( -59.3779 -25.9820 0.0000 )    u=2 $DFC
811 3 -0.0001 -270   fill=24 *trcl=( -59.3767 -25.9808 1.2700 )    u=2 $ Assembly 45
812 3 -0.0001 -701  #813  fill=18 ( -42.4663 -25.4509 0.0000 )     $ Tube/Disk 46
            *trcl=( -42.5018 -25.4864 0.0000 )    u=2
813 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -25.1717 1.2700 )    u=2 $ Assembly 46
814 3 -0.0001 -701  #815  fill=18 ( -25.4509 -25.4509 0.0000 )     $ Tube/Disk 47
            *trcl=( -25.4864 -25.4864 0.0000 )    u=2
815 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -25.1717 1.2700 )    u=2 $ Assembly 47
816 3 -0.0001 -701  #817  fill=12 ( -8.1739 -25.4509 0.0000 )     $ Tube/Disk 48
            *trcl=( -8.4709 -25.4864 0.0000 )    u=2
817 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -25.1717 1.2700 )    u=2 $ Assembly 48
818 3 -0.0001 -701  #819  fill=17 ( 8.4354 -25.4509 0.0000 )     $ Tube/Disk 49
            *trcl=( 8.4709 -25.4864 0.0000 )    u=2
819 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -25.1717 1.2700 )    u=2 $ Assembly 49
820 3 -0.0001 -701  #821  fill=17 ( 25.4509 -25.4509 0.0000 )     $ Tube/Disk 50
            *trcl=( 25.4864 -25.4864 0.0000 )    u=2
821 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -25.1717 1.2700 )    u=2 $ Assembly 50
822 3 -0.0001 -701  #823  fill=17 ( 42.4663 -25.4509 0.0000 )     $ Tube/Disk 51
            *trcl=( 42.5018 -25.4864 0.0000 )    u=2
823 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -25.1717 1.2700 )    u=2 $ Assembly 51
824 3 -0.0001 -702 #825  #826  fill=8 ( 59.6927 -26.2968 0.0000 )     $ Tube/Disk 52
            *trcl=( 59.8348 -26.4389 0.0000 )    u=2
825 3 -0.0001 -302 #826   fill=20 *trcl=( 59.3779 -25.9820 0.0000 )    u=2 $DFC
826 3 -0.0001 -270   fill=24 *trcl=( 59.3767 -25.9808 1.2700 )    u=2 $ Assembly 52
827 3 -0.0001 -702 #828  #829  fill=5 ( -61.0896 -43.9472 0.0000 )     $ Tube/Disk 53
            *trcl=( -61.2318 -44.0893 0.0000 )    u=2
828 3 -0.0001 -302 #829   fill=20 *trcl=( -60.7748 -43.6324 0.0000 )    u=2 $DFC
829 3 -0.0001 -270   fill=24 *trcl=( -60.7736 -43.6312 1.2700 )    u=2 $ Assembly 53
830 3 -0.0001 -701  #831  fill=18 ( -42.4663 -42.4663 0.0000 )     $ Tube/Disk 54
            *trcl=( -42.5018 -42.5018 0.0000 )    u=2
831 3 -0.0001 -51   fill=27 *trcl=( -42.1871 -42.1871 1.2700 )    u=2 $ Assembly 54
832 3 -0.0001 -701  #833  fill=18 ( -25.4509 -42.4663 0.0000 )     $ Tube/Disk 55
            *trcl=( -25.4864 -42.5018 0.0000 )    u=2
833 3 -0.0001 -51   fill=27 *trcl=( -25.1717 -42.1871 1.2700 )    u=2 $ Assembly 55
834 3 -0.0001 -701  #835  fill=12 ( -8.1739 -42.4663 0.0000 )     $ Tube/Disk 56
            *trcl=( -8.4709 -42.5018 0.0000 )    u=2
835 3 -0.0001 -51   fill=27 *trcl=( -7.8947 -42.1871 1.2700 )    u=2 $ Assembly 56
836 3 -0.0001 -701  #837  fill=17 ( 8.4354 -42.4663 0.0000 )     $ Tube/Disk 57
            *trcl=( 8.4709 -42.5018 0.0000 )    u=2
837 3 -0.0001 -51   fill=27 *trcl=( 8.1562 -42.1871 1.2700 )    u=2 $ Assembly 57
838 3 -0.0001 -701  #839  fill=17 ( 25.4509 -42.4663 0.0000 )     $ Tube/Disk 58
            *trcl=( 25.4864 -42.5018 0.0000 )    u=2
839 3 -0.0001 -51   fill=27 *trcl=( 25.1717 -42.1871 1.2700 )    u=2 $ Assembly 58
840 3 -0.0001 -701  #841  fill=17 ( 42.4663 -42.4663 0.0000 )     $ Tube/Disk 59
            *trcl=( 42.5018 -42.5018 0.0000 )    u=2
841 3 -0.0001 -51   fill=27 *trcl=( 42.1871 -42.1871 1.2700 )    u=2 $ Assembly 59
842 3 -0.0001 -702 #843  #844  fill=4 ( 61.0896 -43.9472 0.0000 )     $ Tube/Disk 60
            *trcl=( 61.2318 -44.0893 0.0000 )    u=2
843 3 -0.0001 -302 #844   fill=20 *trcl=( 60.7748 -43.6324 0.0000 )    u=2 $DFC
844 3 -0.0001 -270   fill=24 *trcl=( 60.7736 -43.6312 1.2700 )    u=2 $ Assembly 60
845 3 -0.0001 -702 #846  #847  fill=7 ( -43.9472 -61.0896 0.0000 )     $ Tube/Disk 61
            *trcl=( -44.0893 -61.2318 0.0000 )    u=2
846 3 -0.0001 -302 #847   fill=20 *trcl=( -43.6324 -60.7748 0.0000 )    u=2 $DFC
847 3 -0.0001 -270   fill=24 *trcl=( -43.6312 -60.7736 1.2700 )    u=2 $ Assembly 61
848 3 -0.0001 -702 #849  #850  fill=8 ( -26.2968 -59.6927 0.0000 )     $ Tube/Disk 62
            *trcl=( -26.4389 -59.8348 0.0000 )    u=2
849 3 -0.0001 -302 #850   fill=20 *trcl=( -25.9820 -59.3779 0.0000 )    u=2 $DFC
850 3 -0.0001 -270   fill=24 *trcl=( -25.9808 -59.3767 1.2700 )    u=2 $ Assembly 62
851 3 -0.0001 -702 #852  #853  fill=8 ( -8.6463 -59.6927 0.0000 )     $ Tube/Disk 63
            *trcl=( -8.7884 -59.8348 0.0000 )    u=2
852 3 -0.0001 -302 #853   fill=20 *trcl=( -8.3315 -59.3779 0.0000 )    u=2 $DFC
853 3 -0.0001 -290   fill=21 *trcl=( -8.3303 -59.3767 1.2700 )    u=2 $ Assembly 63
854 3 -0.0001 -702 #855  #856  fill=8 ( 8.6463 -59.6927 0.0000 )     $ Tube/Disk 64
            *trcl=( 8.7884 -59.8348 0.0000 )    u=2
855 3 -0.0001 -302 #856   fill=20 *trcl=( 8.3315 -59.3779 0.0000 )    u=2 $DFC
856 3 -0.0001 -290   fill=21 *trcl=( 8.3303 -59.3767 1.2700 )    u=2 $ Assembly 64
857 3 -0.0001 -702 #858  #859  fill=8 ( 26.2968 -59.6927 0.0000 )     $ Tube/Disk 65
            *trcl=( 26.4389 -59.8348 0.0000 )    u=2
858 3 -0.0001 -302 #859   fill=20 *trcl=( 25.9820 -59.3779 0.0000 )    u=2 $DFC
859 3 -0.0001 -270   fill=24 *trcl=( 25.9808 -59.3767 1.2700 )    u=2 $ Assembly 65
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860 3 -0.0001 -702 #861  #862  fill=7 ( 43.9472 -61.0896 0.0000 )     $ Tube/Disk 66
            *trcl=( 44.0893 -61.2318 0.0000 )    u=2
861 3 -0.0001 -302 #862   fill=20 *trcl=( 43.6324 -60.7748 0.0000 )    u=2 $DFC
862 3 -0.0001 -270   fill=24 *trcl=( 43.6312 -60.7736 1.2700 )    u=2 $ Assembly 66
863 3 -0.0001 -702 #864  #865  fill=7 ( -8.6463 -77.3430 0.0000 )     $ Tube/Disk 67
            *trcl=( -8.7884 -77.4852 0.0000 )    u=2
864 3 -0.0001 -302 #865   fill=20 *trcl=( -8.3315 -77.0282 0.0000 )    u=2 $DFC
865 3 -0.0001 -290   fill=21 *trcl=( -8.3303 -77.0270 1.2700 )    u=2 $ Assembly 67
866 3 -0.0001 -702 #867  #868  fill=7 ( 8.6463 -77.3430 0.0000 )     $ Tube/Disk 68
            *trcl=( 8.7884 -77.4852 0.0000 )    u=2
867 3 -0.0001 -302 #868   fill=20 *trcl=( 8.3315 -77.0282 0.0000 )    u=2 $DFC
868 3 -0.0001 -290   fill=21 *trcl=( 8.3303 -77.0270 1.2700 )    u=2 $ Assembly 68
869 3 -0.0001 +703 +704        $ Canister Cavity Q1
      #704 #716 #719 #722 #734 #736 #738 #740 #752
      #706 #718 #721 #724 #735 #737 #739 #742 #753
      #754 #756 #758 #773 #775 #777 #779 #782
      #755 #757 #760 #774 #776 #778 #781 #784
      #705 #717 #720 #723 #741 #759 #780 #783
          fill=3      u=2
870 3 -0.0001 +703 -704        $ Canister Cavity Q2
      #701 #707 #710 #713 #725 #728 #730 #732 #743
      #703 #709 #712 #715 #727 #729 #731 #733 #745
      #746 #748 #750 #761 #764 #767 #769 #771
      #747 #749 #751 #763 #766 #768 #770 #772
      #702 #708 #711 #714 #726 #744 #762 #765
          fill=3      u=2
871 3 -0.0001 -703 -704        $ Canister Cavity Q3
      #785 #788 #791 #793 #795 #809 #812 #814 #816
      #787 #790 #792 #794 #796 #811 #813 #815 #817
      #827 #830 #832 #834 #845 #848 #851 #863
      #829 #831 #833 #835 #847 #850 #853 #865
      #786 #789 #810 #828 #846 #849 #852 #864
          fill=3      u=2
872 3 -0.0001 -703 704        $ Canister Cavity Q4
      #797 #799 #801 #803 #806 #818 #820 #822 #824
      #798 #800 #802 #805 #808 #819 #821 #823 #826
      #836 #838 #840 #842 #854 #857 #860 #866
      #837 #839 #841 #844 #856 #859 #862 #868
      #804 #807 #825 #843 #855 #858 #861 #867
          fill=3      u=2
c Cell Cards - Canister
901 3 -0.0001 -901 #902     fill=2 u=1 $ Cavity
902 9 -2.702 -902      u=1 $ Spacer
903 8 -7.940 -903 +901     u=1 $ Canister Shell / Lid / Bottom
904 14 -0.9982 +903      u=1 $ Remaining Space
c Cell Cards - Storage Cask Geometry
911 10 -7.8212 -915         $ Base Plate
912 14 -0.9982 (-924 +922 -911):         $ Air Inlet Channel Void
                                  (-924 +923 -922 +928)
913 10 -7.8212 -925 +924 +922 -911      $ Air Inlet Channel Mat
914 14 -0.9982 (-926 +922 -911):         $ Air Inlet Channel Void
                                  (-926 +923 -922 +928)
915 10 -7.8212 -927 +926 +922 -911      $ Air Inlet Channel Mat
916 14 -0.9982 -929 -922 +923       $ Stand Cut-Out Top
917 like 916 but *trcl = (0.0 0.0 0.0 90 180 90 0 90 90 90 90 0)       $ Stand Cut-Out Top
918 10 -7.8212 -911 -922 +923 +928 +915 +924 +926 #916 #917   $ Stand Material
919 10 -7.8212 (-911 -922 -928) : (-911 +922 -928 +925 +927)         $ Bottom Plate
920 10 -7.8212 (-916 +917 +928 -920) : (-918 +919 +920 -921)         $ Baffle Cone Mat
921 14 -0.9982 (-917 +928 -920) : (-919 +920 -921)         $ Baffle Cone Int. Void
922 14 -0.9982 -923 +928 -921 +916 +918     $ Void inside stand - A
923 14 -0.9982 -911 -923 +921 +915      $ Void inside stand - B
924 14 -0.9982 -911 -913 +922 +928 +915 +925 +927   $ Void stand to liner
925 10 -7.8212 -911 -914 +913 +928 +925 +927    $ Liner
926 13 -2.3220 -911 +914 +928 +925 +927     $ Concrete
927 10 -7.8212 -930         $ VCC Lid
928 10 -7.8212 -931 +932        $ TopFlange
929 14 -0.9982 -931 -932 +913 +933      $ Void Cavity to Flange
930 13 -2.3220 -934         $ Lid Concrete
931 10 -7.8212 -933 +934        $ Lid Cover
932 13 -2.3220 (-936 +914) : (-937 -912 +938)         $ Concrete - Outlet Box
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933 14 -0.9982 (-939 +940 +914) : (-941 +939 -912)         $ Air Outlet Void
934 10 -7.8212 -935 -912 +914 #932 #933       $ Air Outlet Steel
935 13 -2.3220 (-943 +914) : (-944 -912 +945)         $ Concrete - Outlet Box
936 14 -0.9982 (-946 +947 +914) : (-948 +946 -912)         $ Air Outlet Void
937 10 -7.8212 -942 -912 +914 #935 #936       $ Air Outlet Steel
938 13 -2.3220 -912 +914 +931 #932 #933 #934 #935 #936 #937       $ Concrete
939 14 -0.9982 (-949 -951 +913) : (-950 -914 +951)         $ Air Outlet Liner Void
940 like 939 but *trcl = (0.0 0.0 0.0 90 180 90 0 90 90 90 90 0)       $ Air Outlet Liner Void
941 10 -7.8212 -912 -914 +913 +931 #939 #940      $ Liner Minus Voids
942 14 -0.9982 -912 -913 +933  fill=1 ( 0.0000 0.0000 2.5400 )    $ Cavity
943 14 -0.9982 -952 +911 +912 +930  #912 #913 #914 #915     $ Exterior space to Reflector
944 0         +952         $ Exterior space

c Surfaces - Fuel Rod - EX - BWR_10x10_4 WR
10 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 210.8200 0.4356 $ Fuel pellet stack
11 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 221.1553 0.4445 $ Annulus + Plenum
12 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 223.5962 0.5004 $ Clad + End-Caps
c Surfaces - Inert Rods - EX - BWR_10x10_4 WR
30 RCC 0.0000 0.0000 1.4605 0.0000 0.0000 210.8200 0.4356 $ Zirc filler stack
31 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 223.5962 0.5004 $ Clad + End-Caps
c Surfaces - Pitch - EX - BWR_10x10_4 WR
40 PX 0.7074       $ Lattice Cell Boundaries
41 PX -0.7074
42 PY 0.7074
43 PY -0.7074
c Surfaces - Fuel Assembly Array Inserted Into Assembly - EX - BWR_10x10_4 WR
50 RPP -6.8669 6.8669 -6.8669 6.8669 25.4000 250.6726  $ Array
51 RPP -7.1298 7.1298 -7.1298 7.1298 0.0000 260.2230  $ Assembly Outer Dims
c Surfaces - DFC Content - Fuel Pellet Stack
261 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 221.3610 0.4445 $ Fuel pellet stack
c Surfaces - DFC Content - Array
265 PX 0.7619       $ Lattice Cell Boundaries
266 PX -0.7619
267 PY 0.7619
268 PY -0.7619
c`Surfaces - DFC Content - Envelope of Array
270 RPP -7.3011 7.3011 -7.3011 7.3011 0.0000 221.361  $ Array
c Surfaces - Axis DFC Content - Fuel Pellet Stack
281 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 221.3610 0.4445 $ Fuel pellet stack
c Surfaces - Axis DFC Content - Array
285 PX 0.7619       $ Lattice Cell Boundaries
286 PX -0.7619
287 PY 0.7619
288 PY -0.7619
c Surfaces - Axis DFC Content - Envelope of Array
290 RPP -7.3011 7.3011 -7.3011 7.3011 0.0000 221.361  $ Array
c Surface Cards - DFC
301 RPP -7.3025 7.3025 -7.3025 7.3025 0.0000 265.7475 $  Space inside DFC Shell
302 RPP -7.4244 7.4244 -7.4244 7.4244 0.0000 271.1450 $  DFC body
303 PZ 1.2700      $ Bottom plate top
304 PZ 267.3350      $ Top of lid
305 PZ 265.748      $ Bottom of lid
c Surface Cards - Standard Tube, Absorber and Retainer
311 RPP -7.4092 7.4092 -7.4092 7.4092 0.0000 274.4470 $  Space inside tube - cavity extent
312 RPP -7.4549 7.4549 -7.4549 7.4549 5.0800 254.5588 $  Fuel tube body
313 RPP -6.4897 6.4897 7.4930 7.6200 7.1120 250.6472 $ Absorber +Y
314 RPP -6.4897 6.4897 7.4549 7.6581 7.1120 250.6472 $ Absorber Clad  +Y
315 RPP -6.7374 6.7374 7.4549 7.6581 7.1120 250.6472 $ Absorber Cover Opening +Y
316 RPP -6.7958 6.7958 7.4549 7.7164 7.0536 250.6472 $ Absorber Cover  +Y
317 RPP 7.4930 7.6200 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
318 RPP 7.4549 7.6581 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
319 RPP 7.4549 7.6581 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
320 RPP 7.4549 7.7164 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
321 RPP -6.4897 6.4897 -7.6200 -7.4930 7.1120 250.6472 $ Absorber -Y
322 RPP -6.4897 6.4897 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Clad  -Y
323 RPP -6.7374 6.7374 -7.6581 -7.4549 7.1120 250.6472 $ Absorber Cover Opening -Y
324 RPP -6.7958 6.7958 -7.7164 -7.4549 7.0536 250.6472 $ Absorber Cover  -Y
325 RPP -7.6200 -7.4930 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
326 RPP -7.6581 -7.4549 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
327 RPP -7.6581 -7.4549 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
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328 RPP -7.7164 -7.4549 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - DFC Tube, Absorber and Retainer
411 RPP -7.7394 7.7394 -7.7394 7.7394 0.0000 274.4470 $  Space inside tube - cavity extent
412 RPP -7.7851 7.7851 -7.7851 7.7851 5.0800 254.5588 $  Fuel tube body
413 RPP -6.4897 6.4897 7.8232 7.9502 7.1120 250.6472 $ Absorber +Y
414 RPP -6.4897 6.4897 7.7851 7.9883 7.1120 250.6472 $ Absorber Clad  +Y
415 RPP -6.7374 6.7374 7.7851 7.9883 7.1120 250.6472 $ Absorber Cover Opening +Y
416 RPP -6.7958 6.7958 7.7851 8.0466 7.0536 250.6472 $ Absorber Cover  +Y
417 RPP 7.8232 7.9502 -6.4897 6.4897 7.1120 250.6472 $ Absorber +X
418 RPP 7.7851 7.9883 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  +X
419 RPP 7.7851 7.9883 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening +X
420 RPP 7.7851 8.0466 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  +X
421 RPP -6.4897 6.4897 -7.9502 -7.8232 7.1120 250.6472 $ Absorber -Y
422 RPP -6.4897 6.4897 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Clad  -Y
423 RPP -6.7374 6.7374 -7.9883 -7.7851 7.1120 250.6472 $ Absorber Cover Opening -Y
424 RPP -6.7958 6.7958 -8.0466 -7.7851 7.0536 250.6472 $ Absorber Cover  -Y
425 RPP -7.9502 -7.8232 -6.4897 6.4897 7.1120 250.6472 $ Absorber -X
426 RPP -7.9883 -7.7851 -6.4897 6.4897 7.1120 250.6472 $ Absorber Clad  -X
427 RPP -7.9883 -7.7851 -6.7374 6.7374 7.1120 250.6472 $ Absorber Cover Opening -X
428 RPP -8.0466 -7.7851 -6.7958 6.7958 7.0536 250.6472 $ Absorber Cover  -X
c Surface Cards - Disk Stack
601 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.7272 88.1380 $ Structural disk
602 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 3.3147 88.1380 $ Structural top disk
603 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.0447 88.1380 $ Structural bottom disk
604 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.3386 87.7951 $ Heat transfer disk
605 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 1.5875 88.0491 $ Top weldment disk
606 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 2.5400 88.0491 $ Bottom weldment disk
c Surface Cards - Basket
701 RPP -7.7521 7.7521 -7.7521 7.7521 0.0000 274.4470  $ Std opening
702 RPP -8.1890 8.1890 -8.1890 8.1890 0.0000 274.4470  $ DFC opening
703 PY 0.0000       $ Cut plane
704 PX 0.0000       $ Cut plane
c Surface Cards - Canister
901 RCC 0.0000 0.0000 0.0000 0.0000 0.0000 274.4470  88.4428 $ Canister cavity
902 RPP -48.6410 48.6410 -48.6410 48.6410 264.2870 274.4469   $ Canister spacer
903 RCC 0.0000 0.0000 -2.5400 0.0000 0.0000 294.7670  89.7128 $ Canister
c Surface Cards - Storage Cask Geometry
911  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 -58.6740 162.5600 $ Bottom Section Container
912  RCC 0.0000 0.0000 0.0000 0.0000 0.0000 352.5520 162.5600 $ Top Section Container (Not VCC
Lid)
913  CZ 100.3300       $ VCC liner inner
914  CZ 106.6800       $ VCC liner outer
915  RCC 0.0000 0.0000 -5.7150 0.0000 0.0000 5.7150 91.4400 $ Base plate/cover
916  KZ 47.2803 0.1357 -1     $ Baffle weldment bot
917  KZ 45.4435 0.1357 -1     $ Baffle weldment bot void
918  KZ -111.2883 0.1357 1     $ Baffle weldment top
919  KZ -109.4515 0.1357 1     $ Baffle weldment top void
920  PZ -32.0040       $ Baffle middle cut surface
921  PZ -7.8740       $ Baffle top cut surface
922  CZ 63.5000       $ Stand outer
923  CZ 58.4200       $ Stand inner
924 1 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
925 1 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
926 2 RPP -162.5600 162.5600 -15.2400 15.2400 -58.6740 -25.6540  $ Air inlet void
927 2 RPP -162.5600 162.5600 -16.1925 16.1925 -58.6740 -23.1140  $ Air inlet channel
928  PZ -56.1340       $ Bottom plate height
929  RPP -25.6540 25.6540 -63.5001 63.5001 -25.6540 -5.7150  $ Stand top cut box
930  RCC 0.0000 0.0000 352.5520 0.0000 0.0000 3.8100 116.2050 $ VCC lid
931  RCC 0.0000 0.0000 347.4720 0.0000 0.0000 5.0800 124.3330 $ Top flange cylinder
932  CZ 102.8700       $ Top flange inner cut cylinder
933  RCC 0.0000 0.0000 331.7240 0.0000 0.0000 20.8280 99.0600 $ Lid concrete enclosure
934  RCC 0.0000 0.0000 332.6765 0.0000 0.0000 19.8755 98.1075 $ Lid concrete
935  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 336.8040  $ Box for outlet structure
(outside liner)
936  RPP -54.2290 54.2290 -127.0635 127.0635 315.7220 336.8040  $ Upper portion concrete
937  RPP -54.2290 54.2290 -162.5600 162.5600 303.6570 324.7390  $ Lower portion concrete
938  RPP -54.2290 54.2290 -143.2560 143.2560 303.6570 324.7390  $ Lower portion concrete cut
surface
939  RPP -53.2765 53.2765 -138.1760 138.1760 304.6095 335.8515  $ Lower/middle outlet void
940  RPP -53.2765 53.2765 -128.0160 128.0160 314.7695 335.8515  $ Cut box for lower/middle void
```

```
941  RPP -53.2765 53.2765 -162.5600 162.5600 325.6915 335.8515  $ Upper void
942  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 336.8040  $ Box for outlet structure
(outside liner)
943  RPP -127.0635 127.0635 -54.2290 54.2290 315.7220 336.8040  $ Upper portion concrete
944  RPP -162.5600 162.5600 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete
945  RPP -143.2560 143.2560 -54.2290 54.2290 303.6570 324.7390  $ Lower portion concrete cut
surface
946  RPP -138.1760 138.1760 -53.2765 53.2765 304.6095 335.8515  $ Lower/middle outlet void
947  RPP -128.0160 128.0160 -53.2765 53.2765 314.7695 335.8515  $ Cut box for lower/middle void
948  RPP -162.5600 162.5600 -53.2765 53.2765 325.6915 335.8515  $ Upper void
949  RPP -54.2290 54.2290 -106.6800 106.6800 303.6570 315.7220  $ Outlet cut in liner
950  RPP -53.2765 53.2765 -106.6800 106.6800 304.6095 314.7695  $ Portion of outlet in liner
951  CZ 104.1400        $ Air outlet inner radius
*952  RCC 0.0000 0.0000 -78.6740 0.0000 0.0000 455.0360 182.5600 $ Cylinde to reflect

c
c Materials List
c
c Fuel Pellet Material   3.71%  Weight UO2 [amu]  269.94
m1    92235.66c -3.270E-02 92238.66c -8.488E-01  8016.62c -1.185E-01
c SS348 Clad
m2
      24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Water
m3     1001.62c -1.119E-01  8016.62c -8.881E-01
mt3  lwtr.01t
c Sec. Fuel - 45 Degree Axis - Exterior   3.94%  Weight UO2 [amu]  269.93
m4    92235.66c -3.473E-02 92238.66c -8.467E-01  8016.62c -1.185E-01
c Third Fuel -Coord. Axis - Exterior   3.64%  Weight UO2 [amu]  269.94
m5    92235.66c -3.209E-02 92238.66c -8.494E-01  8016.62c -1.185E-01
c Lower Nozzle Material
m6
       1001.62c -4.116E-06  8016.62c -3.266E-05
      24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.651E-03 26058.62c -2.019E-03 28062.62c -3.638E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
mt6  lwtr.01t
c Upper Nozzle Material
m7
       1001.62c -1.469E-05  8016.62c -1.165E-04
      24050.62c -7.938E-03 26054.62c -3.927E-02 28058.62c -6.383E-02
      24052.62c -1.590E-01 26056.62c -6.386E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.651E-03 26058.62c -2.019E-03 28062.62c -3.638E-03
                                                28064.62c -9.622E-04
      25055.62c -2.000E-02
mt7  lwtr.01t
c SS304
m8    24050.62c -7.939E-03 26054.62c -3.927E-02 28058.62c -6.384E-02
      24052.62c -1.590E-01 26056.62c -6.387E-01 28060.62c -2.543E-02
      24053.62c -1.838E-02 26057.62c -1.502E-02 28061.62c -1.124E-03
      24054.62c -4.652E-03 26058.62c -2.019E-03 28062.62c -3.639E-03
                                                28064.62c -9.623E-04
      25055.62c -2.000E-02
c Aluminum
m9    13027.62c -1.000E+00
c Carbon Steel
m10   26054.62c -5.594E-02  6000.66c -1.000E-02
      26056.62c -9.098E-01
      26057.62c -2.140E-02
      26058.62c -2.876E-03
c Lead
```

```
m11    82206.66c -2.534E-01
       82207.66c -2.207E-01
       82208.66c -5.259E-01
c NS-F-FR
m12     5010.66c -9.313E-04  7014.62c -1.974E-02  8016.62c -4.250E-01
        5011.66c -3.772E-03  7015.66c -7.852E-05
       13027.62c -2.142E-01  1001.62c -6.001E-02  6000.66c -2.763E-01
c Concrete
m13    26054.62c -7.911E-04 14000.60c -3.370E-01
       26056.62c -1.287E-02
       26057.62c -3.026E-04
       26058.62c -4.067E-05
        1001.62c -1.000E-02 13027.62c -3.400E-02 20000.62c -4.400E-02
        8016.62c -5.320E-01 11023.62c -2.900E-02
c Water Exterior
m14     1001.62c 2.0
        8016.62c 1.0
mt14  lwtr.01t
c Borated Aluminum (Absorber Core / Sheet)
m15     5010.66c -6.011E-02 13027.62c -5.656E-01  6000.66c -9.430E-02
        5011.66c -2.799E-01
c Zirc Alloy
m17    26054.62c -7.063E-05 24050.62c -4.179E-05  7014.62c -4.980E-04
       26056.62c -1.149E-03 24052.62c -8.370E-04  7015.66c -1.981E-06
       26057.62c -2.702E-05 24053.62c -9.673E-05
       26058.62c -3.631E-06 24054.62c -2.448E-05
       40000.66c -9.823E-01 50000.42c -1.500E-02
c SS304/Cu Heat Fin
m18    24050.62c -4.537E-03 26054.62c -2.244E-02 28058.62c -3.648E-02
       24052.62c -9.088E-02 26056.62c -3.650E-01 28060.62c -1.453E-02
       24053.62c -1.050E-02 26057.62c -8.584E-03 28061.62c -6.425E-04
       24054.62c -2.658E-03 26058.62c -1.154E-03 28062.62c -2.079E-03
                                                 28064.62c -5.499E-04
       25055.62c -1.143E-02
       29000 -0.4286
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m19    92235.66c -3.473E-02 92238.66c -8.467E-01  8016.62c -1.185E-01
        1001.62c -3.303E-06  8016.62c -2.621E-05
c DFC fuel mixture material (if applicable)   Mix Height=264.5in
m20    92235.66c -3.208E-02 92238.66c -8.493E-01  8016.62c -1.185E-01
        1001.62c -3.303E-06  8016.62c -2.621E-05
c
c Rotation Matrix
*TR1 0.0 0.0 0.0 45 135 90 -45 45 90 90 90 0  $ z-rotation 45 degrees
*TR2 0.0 0.0 0.0 135 225 90 45 135 90 90 90 0  $ z-rotation 135 degrees
*TR3 0.0 0.0 0.0 15 105 90 -75 15 90 90 90 0  $ z-rotation 15 degrees
*TR4 0.0 0.0 0.0 30 120 90 -60 30 90 90 90 0  $ z-rotation 30 degrees
*TR5 0.0 0.0 0.0 60 150 90 -30 60 90 90 90 0  $ z-rotation 60 degrees
*TR6 0.0 0.0 0.0 75 165 90 -15 75 90 90 90 0  $ z-rotation 75 degrees
*TR7 0.0 0.0 0.0 8 98 90 -82 8 90 90 90 0  $ z-rotation 8 degrees
*TR8 0.0 0.0 0.0 102 192 90 12 102 90 90 90 0  $ z-rotation 102 degrees
*TR9 0.0 0.0 0.0 156 246 90 66 156 90 90 90 0  $ z-rotation 156 degrees
*TR10 0.0 0.0 0.0 78 168 90 -12 78 90 90 90 0  $ z-rotation 78 degrees
*TR11 0.0 0.0 0.0 24 114 90 -66 24 90 90 90 0  $ z-rotation 24 degrees
c
c Cell Importances
c
mode n
imp:n 1 434r 0
c
c
c Criticality Controls
c
kcode 500 1.00 30 430
c Ones source point in each of the fuel assemblies
ksrc
       -5.5007 79.8566 100.00
       11.1599 79.8566 100.00
       -40.8016 63.6032 100.00
       -23.1512 62.2063 100.00
```

```
      -5.5007 62.2063 100.00
      11.1599 62.2063 100.00
      28.8104 62.2063 100.00
      46.4608 63.6032 100.00
      -57.9440 46.4608 100.00
      -39.3575 45.0167 100.00
      -22.3421 45.0167 100.00
      -5.3266 45.0167 100.00
      10.7243 45.0167 100.00
      28.0013 45.0167 100.00
      45.0167 45.0167 100.00
      63.6032 46.4608 100.00
      -56.5471 28.8104 100.00
      -39.3575 28.0013 100.00
      -22.3421 28.0013 100.00
      -5.3266 28.0013 100.00
      10.7243 28.0013 100.00
      28.0013 28.0013 100.00
      45.0167 28.0013 100.00
      62.2063 28.8104 100.00
      -74.1974 11.1599 100.00
      -56.5471 11.1599 100.00
      -39.3575 10.9858 100.00
      -22.3421 10.9858 100.00
      -5.3266 10.9858 100.00
      10.7243 10.7243 100.00
      28.0013 10.7243 100.00
      45.0167 10.7243 100.00
      62.2063 11.1599 100.00
      79.8566 11.1599 100.00
      -74.1974 -5.5007 100.00
      -56.5471 -5.5007 100.00
      -39.3575 -5.0651 100.00
      -22.3421 -5.0651 100.00
      -5.0651 -5.0651 100.00
      10.9858 -5.3266 100.00
      28.0013 -5.3266 100.00
      45.0167 -5.3266 100.00
      62.2063 -5.5007 100.00
      79.8566 -5.5007 100.00
      -56.5471 -23.1512 100.00
      -39.3575 -22.3421 100.00
      -22.3421 -22.3421 100.00
      -5.0651 -22.3421 100.00
      10.9858 -22.3421 100.00
      28.0013 -22.3421 100.00
      45.0167 -22.3421 100.00
      62.2063 -23.1512 100.00
      -57.9440 -40.8016 100.00
      -39.3575 -39.3575 100.00
      -22.3421 -39.3575 100.00
      -5.0651 -39.3575 100.00
      10.9858 -39.3575 100.00
      28.0013 -39.3575 100.00
      45.0167 -39.3575 100.00
      63.6032 -40.8016 100.00
      -40.8016 -57.9440 100.00
      -23.1512 -56.5471 100.00
      -5.5007 -56.5471 100.00
      11.1599 -56.5471 100.00
      28.8104 -56.5471 100.00
      46.4608 -57.9440 100.00
      -5.5007 -74.1974 100.00
      11.1599 -74.1974 100.00
c
c
c Random Number Generator Controls
c
RAND GEN=2 SEED=19073486328127
c
```

```
c
c Print Control
c
PRINT
c
```

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MPC STORAGE SYSTEM FOR DAIRYLAND POWER
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7.0 CONFINEMENT

The NAC-MPC storage system is provided in three configurations. The Yankee-MPC provides storage for up to 36 intact Yankee Class spent fuel assemblies and reconfigured fuel assemblies (RFA). The CY-MPC holds up to 26 Connecticut Yankee spent fuel assemblies, reconfigured fuel assemblies or damaged fuel cans. The MPC-LACBWR provides storage for up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor spent fuel assemblies with 32 damaged fuel cans. These three configurations of the NAC-MPC have similar components and operating features, but have different physical dimensions, weights and storage capacities. Confinement features for the Yankee-MPC and CY-MPC systems are addressed in the main body of this chapter. Appendix 7.A has been added to address the MPC-LACBWR system.

The Transportable Storage Canister (canister) provides long-term storage confinement of the Yankee Class and Connecticut Yankee spent fuel. The canister confinement boundary is closed by welding, which presents a leaktight barrier to the release of contents in all of the evaluated normal, off-normal and accident conditions. The method of closing the confinement boundary is the same for both NAC-MPC configurations.

The NAC-MPC canister contains an inert gas (helium). The confinement boundary retains the helium and also prevents the entry of outside air into the NAC-MPC. The exclusion of air precludes degradation of the fuel rod cladding over time, due to cladding oxidation failures.

The NAC-MPC canister confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material, and 10 CFR 72.122 for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The helium purity level of at least 99.9% maintains the quantity of oxidizing contaminant to less than one mole per canister for all loading conditions. Based on the calculations presented in Sections 4.4.5 and 4.5.5, respectively, the free gas volume of the empty Yankee-MPC or CY-MPC canister is less than 300 moles. Conservatively assuming that all of the impurities in 99.9% pure helium are oxidents, a maximum of 0.3 moles of oxidants could exist in the NAC-MPC canister during storage. By limiting the amount of oxidants to less than one mole, the recommended limits for preventing cladding degradation found in the Pacific Northwest Laboratory, "Evaluation of Cover Gas Impurities and Their Effects on the Dry Storage of LWR Spent Fuel," PNL-6365 are satisfied.

7.1 Confinement Boundary

Confinement of the contents in long-term storage is provided by the transportable storage canister. The welded canister forms the confinement vessel.

The primary confinement boundary of the canister consists of the canister shell, bottom closure plate, shield lid, the two (2) port covers, and the welds that join these components. There are no bolted closures or mechanical seals in the primary confinement boundary. The confinement boundary welds are described in Table 7.1-1.

7.1.1 Confinement Vessel

The NAC-MPC transportable storage canister provides the confinement vessel for the radioactive contents.

7.1.1.1 Confinement Vessel - Canister

The canister consists of three (3) principal components: the canister shell, the shield lid, and the structural lid. The nominal dimensions for these components are provided below. The canister shell is a right circular cylinder constructed of rolled Type 304L stainless steel plate. The edges of the rolled plate are joined using full penetration welds. It is closed at the bottom end by a circular plate joined to the shell by a full penetration weld. The Yankee-MPC canister shell is 5/8-inch thick and the bottom circular plate is 1-inch thick. The inside and outside diameter of the Yankee-MPC canister are 69.39 inches and 70.64 inches, respectively, and the inside length is 121.5 inches. The overall external length of the Yankee-MPC canister is 122.5 inches. The CY-MPC canister shell is 5/8-inch thick and the bottom circular plate is 1.75-inch thick. The inside and outside diameter of the canister are 69.39 inches and 70.64 inches, respectively, with the inside length being 150 inches. The overall external length of the canister is 151.75 inches. The canister is fabricated in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, except for the top end weld closures and their nondestructive ultrasonic or progressive dye penetrant examinations. The list of Code alternatives for the NAC-MPC system is provided in Table B3-1 of the Certificate of Compliance.

After loading, the canister is closed at the top by a shield lid and a structural lid. The shield lid is a 5-inch-thick Type 304 stainless steel plate. It is joined to the canister shell using a field installed bevel weld. The shield lid contains the drain and fill penetrations and provides gamma

radiation protection to the operators during the draining, drying and inerting operations. After the shield lid is welded in place, the canister is pressure tested and leak tested to ensure leaktightness. Following draining, drying and inerting operations, the penetrations are closed with Type 304 stainless steel port covers that are welded in place with bevel welds. The operating procedures describing the handling steps to close the canister are presented in Chapter 8. The pressure and leak test procedures are described in Chapter 9.

A secondary, or redundant, confinement boundary closure is provided at the top of the canister by a structural lid, which is placed over the shield lid. The structural lid is a 3-inch thick Type 304L stainless steel plate. The structural lid provides the attachment points for lifting the loaded canister. The structural lid is welded to the shell using a field installed bevel weld. The weld specifications and weld inspection and acceptance criteria are presented in Sections 7.1.3.2 and 7.1.3.3, respectively.

The confinement boundaries are shown in Figures 7.1-1 and 7.1-2. As illustrated in Figure 7.1-2, the secondary, or redundant, confinement boundary includes: the structural lid, the upper 3.5 inches of the canister shell and the joining weld. This boundary provides additional assurance of the leaktightness of the canister during its service life.

7.1.1.2 Design Documents, Codes, and Standards

The canister is constructed in accordance with the license drawings presented in Section 1.7. The principal Codes and Standards that apply to the design, fabrication and assembly are described in Sections 7.1.1 and 7.1.3 and are shown on the licensing drawings. Other Codes and Standards are applied as appropriate in the design or specification of the canister.

7.1.1.3 Technical Requirements for the Canister

The Yankee-MPC canister confines up to 36 intact or reconfigured Yankee Class fuel assemblies. The total number of rods in reconfigured assemblies is limited to 64. The CY-MPC canister confines up to 26 Connecticut Yankee fuel assemblies, damaged fuel cans or reconfigured fuel assemblies. Up to 100 fuel rods may be installed in a CY-MPC reconfigured fuel assembly. Over its 50-year design life, the canister precludes the release of radioactive contents and precludes the entry of air that could potentially damage the cladding of the stored spent fuel. The design of the canister to the requirements of ASME Code Section III, Subsection

NB, ensures that the canister maintains confinement in all of the evaluated normal, off-normal, and accident conditions.

The design of the canister allows the recovery of stored spent fuel, should that become necessary.

The canister has no exposed penetrations, no mechanical closures, and does not employ seals to maintain confinement. There is no requirement for continuous monitoring.

The design basis parameters for the Yankee Class and Connecticut Yankee fuel are presented in Sections 1.3.1 and 1.3.2, respectively. The design parameters that apply to the two canister configurations, as an element of the NAC-MPC dry storage system, are presented in Table 1.2-1.

7.1.1.4 Release Rate

A stainless steel plate, joined to the canister shell by welding, forms the primary confinement boundary. The welds are visually inspected, nondestructively examined, pressure tested, and leak tested to confirm integrity. There is no maximum allowable leak rate specified for the NAC-MPC canister, as leakage to any degree up to the level of sensitivity of the leak test, is not acceptable. To demonstrate leaktightness of the shield lid weld, a leak test is performed based on the leaktight condition of $1x10^{-7}$ ref cm^3/sec, as defined by the American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, ANSI N14.5-1997, issued by the American National Standards Institute in December 1997.

Based on the leaktight configuration, the calculation of radionuclide inventories is not required.

7.1.2 Confinement Penetrations

Two penetrations (with quick disconnect fittings) are provided in the canister shield lid for operator use. One penetration is used for draining residual water from the canister. It connects to a drain tube that extends to the bottom of the canister. The other penetration extends only to the underside of the shield lid. It is used to introduce gas into the top of the canister. Once draining is completed, either penetration (or both) may be used for vacuum drying and backfilling with helium. Following backfilling, both penetrations are closed with port covers that are welded to the shield lid. When the port covers are in place, the penetrations are not accessible. These port covers are subsequently enclosed and covered by the structural lid, which is also welded in place. The structural lid and the remainder of the canister have no penetrations.

7.1.3 Seals and Welds

This section describes the process used to properly assemble the confinement vessel. Weld specification, examination and acceptance criteria are described in Sections 7.1.3.2 and 7.1.3.3. There are no elastomer or metallic seals used in the confinement boundary of the canister.

7.1.3.1 Fabrication

All cutting, machining, welding, and forming is in accordance with Section III, Article NB-4000 of the ASME Code, unless otherwise specified in the approved fabrication drawings and specifications consistent with the alternatives to the Code described in Section 7.1.1.1 and in Table B3-1 of the Certificate of Compliance. License drawings are provided in Section 1.7. ASME Code stamping of the canister is not required.

7.1.3.2 Welding Specifications

The canister body is assembled using longitudinal welded joints in the shell and circumferential welded joints at the bottom plate/shell juncture. The canister body may also require a circumferential weld, depending on the overall length of the canister shell.

These welds are performed in accordance with ASME Code Section III, NB-4000. The full penetration longitudinal weld and the circumferential weld (if used), joining the canister shell are radiographed in accordance with ASME Code Section V, Article 2. The weld joining the bottom plate to the canister shell is ultrasonically inspected in accordance with ASME Code Section V, Article 5. The acceptance criteria for these welds is as specified in ASME Code Section III, NB-5320 and NB-5330, respectively. The finished surface of each weld is liquid penetrant examined in accordance with ASME Code Section V, Article 6, and accepted in accordance with Section III, NB-5350.

After loading, the canister is closed by a shield lid and a structural lid using field installed bevel welds.

After the shield lid is welded in place, the canister is pnuematically (air over water) pressure tested. Following draining, drying and inerting operations, the vent and drain ports are closed with port covers that are welded in place with bevel welds. The shield lid and port cover welds

are liquid penetrant examined at the root and final passes in accordance with ASME Code Section V, Article 6. Acceptance is in accordance with ASME Code Section III, NB-5350. The shield lid to canister shell weld is liquid penetrant examined at the root and final passes in accordance with ASME Code Section V, Article 6, and is pressure and leak tested to ensure leaktightness. The operating procedures describing the handling steps to seal the canister are presented in Chapter 8. The pressure and leak test procedures are described in Chapter 9.

A secondary, or redundant, confinement boundary is provided at the top end of the canister by the structural lid, which is installed over the shield lid. The structural lid is welded to the canister shell using a field-installed bevel weld. The structural lid to canister shell weld is either: 1) ultrasonically examined (UT) in accordance with ASME Code Section V, Article 5, with the final weld surface liquid penetrant (PT) examined in accordance with ASME Code Section V, Article 6, or 2) progressive liquid penetrant examined in accordance with ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, Subsections NB-5330 (UT) and NB-5350 (PT).

All welding procedures are written and qualified in accordance with Section IX of the ASME Code. Each welder and welding equipment operator must be qualified in accordance with Section IX of the ASME Code.

The results of all weld examinations are recorded.

7.1.3.3 Testing, Inspection, and Examination

The tests performed to ensure satisfactory performance of the confinement vessel are:

1. All components are visually examined for conformance with the fabrication drawings.

2. All welds that are directly visible are visually examined in accordance with the requirements of ASME Code Section V, Article 9.

3. The acceptance standards for visual examination of the canister welded joints are as specified in ASME Code, Section III, NB-4424 and NB-4427. Unacceptable weld defects are repaired in accordance with ASME Code Section III, Subarticle NB-4450, and visually re-examined.

4. Canister welds designated to be examined by radiographic examination are examined in accordance with the requirements of Section V, Article 2 of the ASME Code. The minimum acceptance standards for radiographic examination are as specified in ASME Code Section III, NB-5320. Welds designated for ultrasonic examination are examined in accordance with the requirements of Section V, Article 5, of the ASME Code. The acceptance standards for ultrasonic examination are as specified in ASME Code Section III, NB-5330. Unacceptable defects in the welds are repaired in accordance with ASME Code Section III, NB-4450, and re-examined.

5. A written report of each weld examination is prepared. At a minimum, the written report includes: identification of part, material, name and level of examiner, NDE procedure used and the findings or dispositions, if any.

6. All personnel performing nondestructive testing are qualified in accordance with American Society of Nondestructive Testing Recommended Practice No. SNT-TC-1A.

7. Individuals qualified for NDT Level I, NDT Level II, or NDT Level III may perform nondestructive testing. Only Level II or Level III personnel may interpret the results of examination or make determination of the acceptability of examined parts.

8. The vendor completely assembles the canister prior to shipping. The purpose of assembling the canister is to ensure that all items specified have been supplied and to test the fit of the shield lid assembly including drain tube and the structural lid.

9. A helium leak test is used to verify that the shield lid welds are leaktight. The canister is pressurized with helium to 0 psig when the canister is closed. A leak test fixture is used to create a volume above the shield lid, which is evacuated. This volume is then tested, using a mass spectrometer type helium leak detector, to verify that the shield lid welds meet the leaktight criteria. For the Yankee-MPC, the test sensitivity shall be at least 4×10^{-8} cm^3/sec (helium) to demonstrate a leakage rate not greater than 8×10^{-8} cm^3/sec (helium). For the CY-MPC, the test sensitivity shall be at least 1×10^{-7} cm^3/sec (helium) to demonstrate a leakage rate not greater than 2×10^{-7} cm^3/sec (helium). The leak test conforms to the evacuated envelope method of ANSI N14.5. As noted in the procedure presented in Section 8.1.1, a "sniffer detector" test method may be used as an optional informational leak test prior to the installation of the vent and drain port covers. This "sniffer" type leak test is intended to ensure that there are

no leaks in the shield lid welds at a leak rate of 1×10^{-5} cm^3/sec (helium) based on the detector leak rate sensitivity of 5×10^{-6} cm^3/sec (helium).

10. Liquid penetrant examinations are in accordance with ASME Code Section V, Article 6, with acceptance criteria as specified in ASME Code Section III, NB-5350.

11. The results of the structural lid weld liquid penetrant examination final interpretation as described by ASME Section V, Article 6, T-676, including all relevant indications, are recorded by video, photographic or other means to provide a retrievable record of weld integrity.

7.1.4 Closure

The primary closure of the transportable storage canister consists of the welded shield lid and the two (2) welded port covers. There are no bolted closures or mechanical seals in the primary closure. A secondary, or redundant, closure is provided at the top end of the canister by the structural lid. The structural lid, when welded to the canister shell, fully encloses the shield lid and the port covers.

Figure 7.1-1 Transportable Storage Canister Primary and Secondary Confinement Boundaries

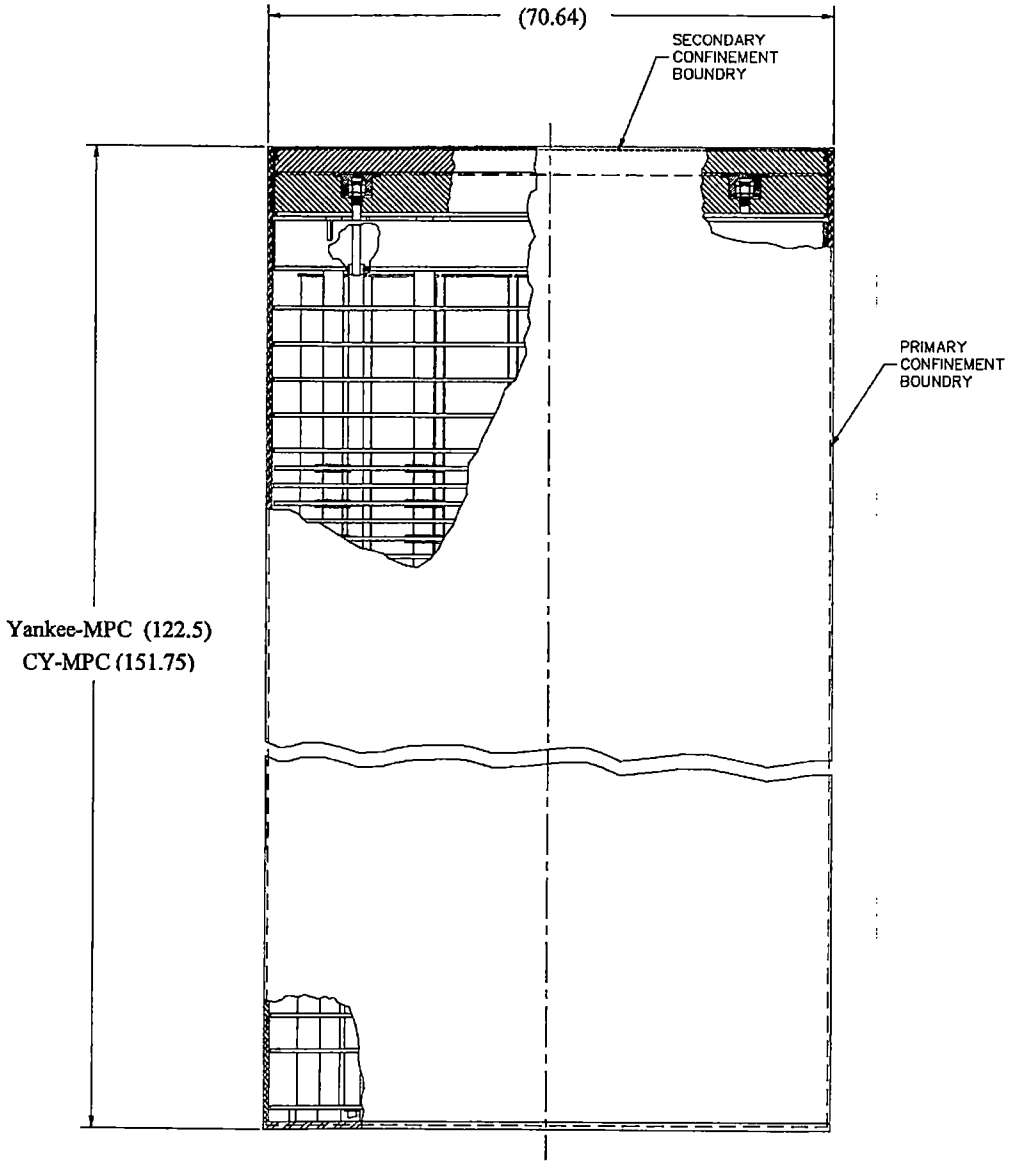

Figure 7.1-2 Confinement Boundary Detail at Shield Lid Penetration

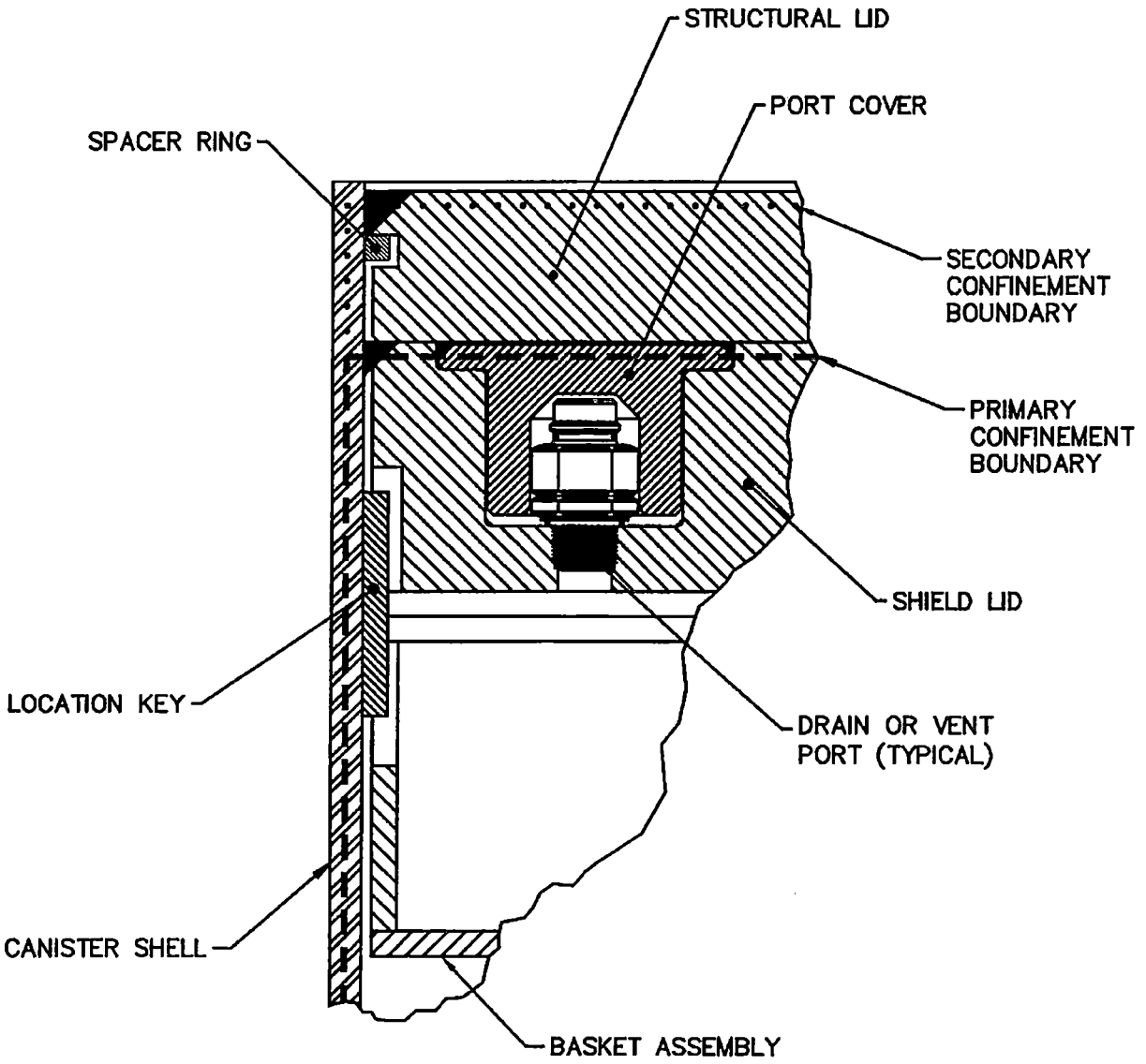

Table 7.1-1 Canister Confinement Boundary Welds

Confinement Boundary Weld Location	Weld Type	ASME Code Category (Section III, Subsection NB)
Shell longitudinal	Full penetration groove (shop weld)	A
Shell circumferential (if used)	Full penetration groove (shop weld)	B
Bottom plate to shell	Full penetration groove (shop weld)	C
Shield lid to shell	Bevel (field weld)	C
Structural lid to shell	Bevel (field weld)	C
Vent and drain port covers to shield lid	Bevel (field weld)	C

7.2 Requirements for Normal Conditions of Storage

The canister is transferred to the vertical concrete storage cask using the transfer cask. During this transfer, the canister is subject to handling loads. The evaluation of the canister for normal handling loads is provided in Section 3.4.4. The principal design criteria for the NAC-MPC system are provided in Chapter 2.0.

Once the canister is placed inside of the concrete storage cask, it is effectively protected from direct loading due to natural phenomena, such as wind, snow and ice loading. The principal direct loading for normal operating conditions arises from increased internal pressure caused by decay heat, solar insolation, and ambient temperature. The normal operating internal pressure is evaluated in Section 3.4.4, as described in Section 7.2.2.

7.2.1 Release of Radioactive Material

The structural analysis of the canister for normal conditions of storage that is presented in Section 3.4.4 shows that the canister is not breached in any of the normal operating events. Consequently, there is no release of radioactive material during normal conditions of storage.

7.2.2 Pressurization of the Confinement Vessel

The canister is vacuum dried and backfilled with helium at approximately one (1) atmosphere prior to installing and welding the penetration port covers. In service, the internal pressure increases due to an increase in temperature of the helium and due to the postulated failure of fuel rod cladding of 3% of the fuel rods, which releases 30% of the available fission gases in those rods.

The temperature of the helium increases due to the fuel decay heat, high ambient temperature, and the effect of full solar insolation on the concrete cask surface. Fuel cladding failure is assumed to release a fraction of the available fission gas and other radionuclides that are assumed to be releasable and all of the charge gas installed in the fuel rods at the time of manufacture of the rod. The evaluation conservatively adds the fission gas and volatile radionuclide releasable inventory of the reconfigured fuel rods classified as damaged to the inventory of the intact fuel that is assumed to fail in normal conditions. For fuel classified as damaged and loaded in a damaged fuel can, this inventory is considered to be previously released and it does not contribute to the pressurization of the canister.

The canister, shield lid, fittings, and the canister basket are fabricated from materials that do not react with ordinary or borated spent fuel pool water to generate gases. The aluminum heat transfer disks, fuel tubes, and BORAL® plates used for criticality control are protected by an oxide film that forms shortly after fabrication. This oxide layer effectively precludes further oxidation of the aluminum components or other reaction with water in the canister at temperatures less than 200°F, which is higher than the typical spent fuel pool water temperature. No steels requiring protective coatings or paints are used in the canister, shield lid, fittings, or basket. Therefore, there are no protective coatings or paints present that could interact with water to release gases.

The calculation of the Yankee-MPC canister pressure, based on normal storage conditions, is presented in Section 4.4.5 and is 7.9 psig. This pressure is well within the Yankee-MPC design internal pressure value of 11.5 psig for normal condition of storage. Similarly, for the CY-MPC, the normal conditions canister pressure is 9.0 psig, and the bounding pressure for normal and off-normal conditions is 15.0 psig. There are no adverse consequences for either configuration due to the respective internal pressures that result from normal storage conditions.

Since the canister is vacuum dried and backfilled with helium prior to sealing, no significant moisture or gases remain in the canister. Consequently, there is no potential that radiolytic decomposition could cause an increase in canister internal pressure or result in a buildup of explosive gases in the canister.

7.3 Confinement Requirements for Hypothetical Accident Conditions

The evaluation of the canister for off-normal and accident condition loading is provided in Sections 3.6, 11.1 and 11.2, respectively.

Once the canister is placed inside the vertical concrete storage cask, it is effectively protected from direct loading due to natural phenomena, such as seismic events, flooding and tornado (wind driven) missiles. Accident conditions assume the cladding failure of all the fuel rods stored in the canister. Consequently, there is an increase in canister internal pressure due to the release of a fraction of the fission product and charge gases. As described in Section 7.2.2, evaluation of the canister pressure considering all of the fuel rods to be initially intact is conservative. The accident conditions internal pressure for the Yankee-MPC configuration is 43.3 psig, and is 49 psig for the CY-MPC configuration, as calculated in Section 11.2.1. The design pressure for accident conditions for both NAC-MPC configurations is 55 psig.

For evaluation purposes, a class of accidents identified as off-normal is also considered in Section 11.1. This class of accidents is not considered here, since off-normal conditions are bounded by the hypothetical accident conditions.

The structural analysis of the canister for off-normal and accident conditions of storage, which is presented in Chapter 11, shows that the canister is not breached in any of the evaluated events. Consequently, based on a leaktight configuration, there is no release of radioactive material during off-normal or accident conditions of storage.

The resulting site boundary dose due to a hypothetical accident is, therefore, less than the 5 rem whole body or organ (including skin) dose at a 100 meter minimum boundary required by 10 CFR 72.106 (b) for accident exposures.

Appendix 7.A CONFINEMENT – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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7.A CONFINEMENT IN THE MPC-LACBWR STORAGE SYSTEM

The MPC-LACBWR Transportable Storage Canister (TSC) provides confinement for its radioactive contents in long-term storage. The confinement boundary provided by the TSC is closed by welding, creating a solid barrier to the release of contents in the design basis normal conditions and off-normal or accident events. The welds are visually inspected and nondestructively examined to verify integrity.

The sealed TSC contains helium, an inert gas, at atmospheric pressure. The confinement boundary retains the helium and also prevents entry of outside air into the TSC in long-term storage. The exclusion of air from the confinement boundary precludes fuel rod cladding oxidation failures during storage.

The TSC confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material. The design of the TSC allows the recovery of stored spent fuel should it become necessary per the requirements of 10 CFR 72.122. The TSC meets the requirements of 10 CFR 72.122 (h) for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The MPC-LACBWR TSC provides an austenitic stainless steel closure design sealed by welding, precluding the need for continuous monitoring. The analysis for normal conditions and off-normal or accident events demonstrates that the integrity of the confinement boundary is maintained in all the evaluated conditions. Consequently, there is no release of radionuclides from the TSC resulting in site boundary doses in excess of regulatory requirements. Therefore, the confinement design of the MPC-LACBWR system meets the regulatory requirements of 10 CFR 72 [A1] and the acceptance criteria defined in NUREG-1536 [A2].

7.A.1 MPC-LACBWR Confinement Boundary

The MPC-LACBWR TSC provides the confinement vessel for the radioactive contents.

7.A.1.1 Confinement Vessel

The TSC confinement vessel consists of three principal components: the TSC shell, the bottom plate and the closure lid. The TSC shell is a right-circular cylinder constructed of rolled Type 304/304L (dual certified) stainless steel plate with the edges of the plate joined by full-penetration welds. It is closed at the bottom end by a circular plate joined to the shell by a full-penetration weld. The TSC shell is helium leak tested following fabrication.

After loading, the TSC is closed at the top by a closure lid fabricated from Type 304 stainless steel. It is joined to the TSC shell using a field-installed groove weld. The closure lid-to-TSC shell weld is analyzed, installed and examined in accordance with Interim Staff Guidance (ISG)-15 [A5] and ISG-18 [A4] guidance. This closure lid-to-TSC shell weld is a partial penetration weld progressively examined at the root, midplane and final surface by dye penetrant (PT) examination. Following NDE of the closure lid-to-TSC shell weld, the TSC cavity is reflooded and the TSC vessel is hydrostatically pressure tested as described in the Operating Procedures of Appendix 8A and the Acceptance Test Program of Appendix 9A. The acceptance criteria for the test are no leakage and no loss of pressure during the minimum 10-minute test duration.

After successful completion of the hydrostatic pressure test, the Type 304 stainless steel closure ring is installed in the TSC-to-closure lid weld groove and welded to both the closure lid and the TSC shell. The closure ring welds are inspected by PT examination of the final weld surfaces. The closure ring provides the double-weld redundant sealing of the confinement boundary, as required by 10 CFR 72.236(e). The TSC confinement boundary welds are listed in Table 7.A.1-1.

The closure lid incorporates drain and vent penetrations, which provide access to the TSC cavity for canister draining, drying and helium backfilling operations during TSC closure and placement into storage. The design of the penetrations incorporates features to provide adequate shielding for the operators during these operations and closure welding.

Following final helium backfill, the vent and drain port penetrations are closed with Type 304 stainless steel inner port covers that are partial-penetration welded in place. Each inner port cover weld is helium leak tested. Each inner port cover weld final surface is then PT examined.

A second (outer) port cover is then installed and welded to the closure lid at each of the ports to provide the double-weld redundant sealing of the confinement boundary. The outer port cover weld final surfaces are inspected by PT examination.

Prior to sealing, the TSC cavity is backfilled with helium. The minimum helium purity level of 99.995% (minimum) specified in the Operating Procedures (Appendix 8.A) maintains the quantity of oxidizing contaminants to less than one mole per canister for all loading conditions. Based on the maximum empty canister free volume of 4,000 liters and the design basis helium density, an empty canister would contain approximately 100 moles of gases. Conservatively, assuming that all of the impurities in the helium are oxidants, a maximum of less than 0.1 mole of oxidants could exist in the canister during storage. By limiting the amount of oxidants to less than one mole, the recommended limits for preventing cladding degradation found in the PNL-6365 [A3] are satisfied. The maintenance of a positive helium pressure (e.g., atmospheric or greater) eliminates any potential for in-leakage of air into the TSC cavity during storage operations.

The closure lid weld completed in the field is not helium leakage tested. ISG-18 [A4] provides that an adequate confinement boundary is established for stainless steel spent fuel storage canisters that are closed using a closure weld that meets the guidance of ISG-15 [A5]. The TSC closure weld meets the ISG-15 guidance in that the analysis of the weld considers a stress reduction factor of 0.8. The weld is qualified and performed in accordance with the ASME Code, Section IX [A6] requirements; and the weld is PT examined after the root, midplane and final surface passes. The final surfaces of the welds joining the closure ring to the closure lid and shell, and joining the redundant port covers to the closure lid, are PT examined. The inner port cover welds are helium leakage tested as defined in Appendix 9.A.

During fabrication, the TSC shell and bottom plate welds are volumetrically inspected and the shell assembly is shop helium leakage tested to the leaktight criteria of 1×10^{-7} ref cm^3/sec, or 2×10^{-7} cm^3/sec (helium), in accordance with ANSI N14.5 [A7] using the evacuated envelope test method. A minimum test sensitivity of 1×10^{-7} cm^3/sec (helium) is required.

The loaded TSC is considered and analyzed as having no credible leakage based on: the shop helium leakage testing of the TSC shell, bottom plate and the joining welds; the design analyses and qualifications of the closure lid and port cover welds; the performance of a TSC field hydrostatic pressure test of the closure lid-to-TSC shell weld; the helium leakage test performed

on the inner vent and drain port covers; and the multiple NDE performed on all of the confinement boundary welds.

The confinement boundary details at the top of the TSC are shown in Figure 7.A.1-1. The closure is welded by qualified welders using weld procedures certified in accordance with ASME Code, Section IX. Over its 50-year design life, the TSC precludes the release of radioactive contents to the environment and the entry of air or water that could potentially damage the cladding of the stored spent fuel.

7.A.1.2 Confinement Penetrations

Two penetrations fitted with quick-disconnect fittings are provided in the TSC closure lid for operational functions during system loading and sealing operations. The drain port accesses a drain tube that extends into a sump located in the bottom plate. The vent port extends to the underside of the closure lid and accesses the top of the TSC cavity.

After the completion of the closure lid-to-TSC shell weld, TSC pressure test, closure ring welding and cavity draining, the vent and drain penetrations are utilized for drying the TSC internals and contents and for helium backfilling and pressurizing the TSC. After backfilling with helium, both penetrations are closed with redundant port covers welded to the closure lid. As presented for storage, the TSC has no exposed or accessible penetrations and uses no mechanical closures or seals to maintain confinement.

7.A.1.3 Seals and Welds

The confinement boundary welds consist of the field-installed welds that close and seal the TSC and the shop welds that join the bottom plate to the TSC and that join the rolled plates that form the TSC shell. The TSC shell may incorporate both longitudinal and circumferential weld seams in joining the rolled plates. No elastomer or metallic seals are used in the confinement boundary of the TSC.

All cutting, machining, welding, and forming of the TSC vessel are performed in accordance with Section III, Article NB-4000 of the ASME Code, unless otherwise specified in the approved fabrication drawings and specifications. Code alternatives are listed in Table B.3-1 of Appendix 12.B of the Technical Specifications.

Weld procedures, welders, and welding machine operators shall be qualified in accordance with ASME Code, Section IX. Refer to Appendix 9.A for the acceptance criteria for the TSC weld visual inspections and nondestructive examinations (NDE).

The loaded TSC is closed using field-installed welds. The closure lid to TSC shell weld is dye penetrant (PT) examined at the root, at the midplane level and the final surface. After the completion of TSC hydrostatic pressure testing, the closure ring is installed and welded to the TSC shell and closure lid. The final surface of each of the closure ring welds is PT examined. Following draining, drying, and helium backfilling operations, the vent and drain ports are closed with redundant port covers that are welded in place. The inner port cover welds are helium leakage tested. The final surface of each port cover to closure lid weld is PT examined.

Shop and field examinations of TSC confinement boundary welds are performed by personnel qualified in accordance with American Society of Nondestructive Testing Recommended Practice No. SNT-TC-1A [A8]. Weld examinations are documented in written reports.

7.A.1.4 Closure

The closure of the TSC consists of the welded closure lid, the welded closure ring, and the welded redundant vent and drain port covers. There are no bolted closures or mechanical seals in the confinement boundary.

Figure 7.A.1-1 TSC Confinement Boundary

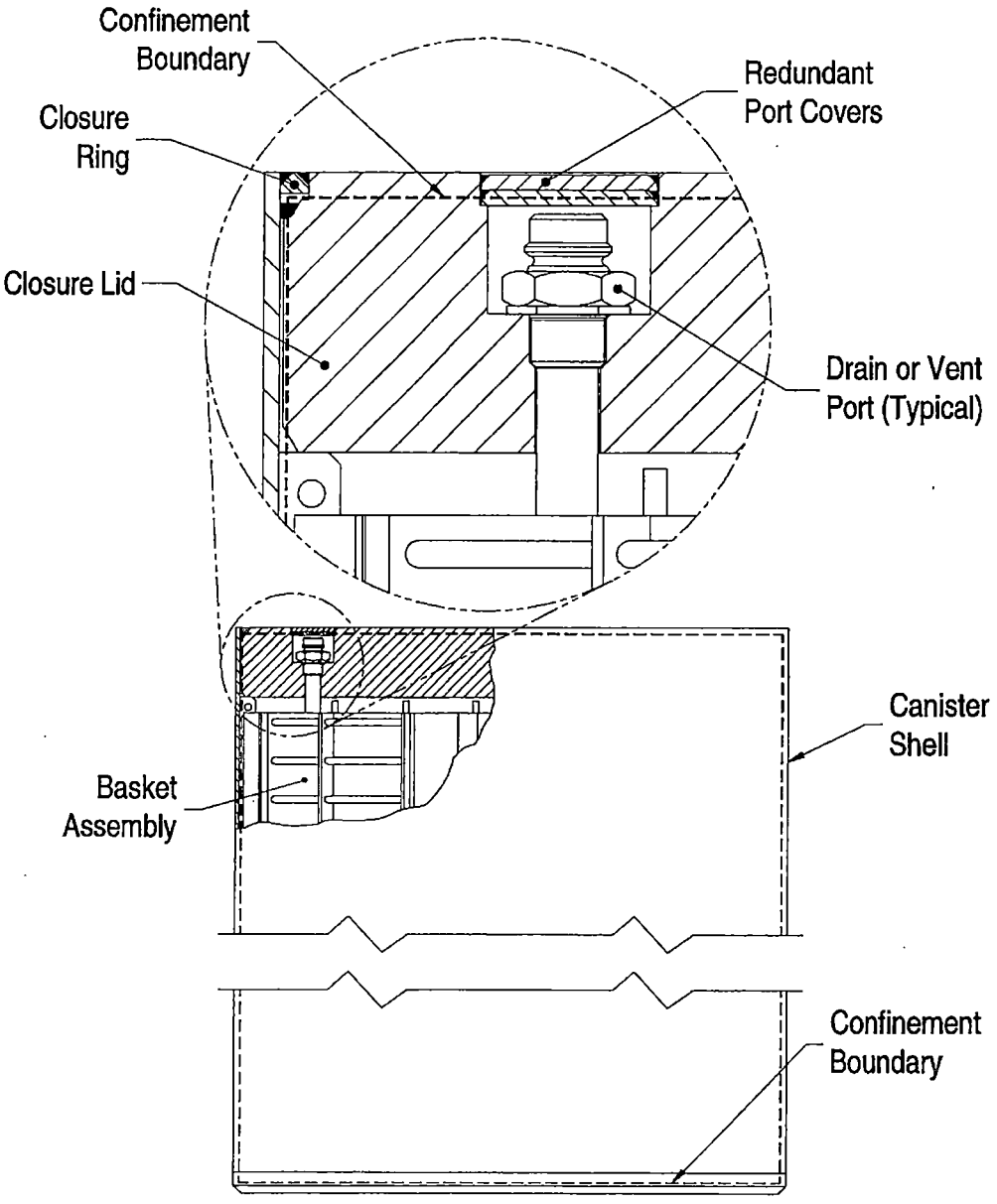

Table 7.A.1-1 TSC Confinement Boundary Welds

Weld Location	Weld Type	ASME Code Category (Section III, Subsection NB)
Shell longitudinal	Full penetration groove (shop weld)	A
Shell circumferential (if used)	Full penetration groove (shop weld)	B
Bottom plate to shell	Full penetration groove (shop weld)	C
TSC closure lid to shell	Groove (field weld)	C
Redundant vent and drain port covers to closure lid	Bevel (field weld)	C
Closure ring to TSC shell and to closure lid	Bevel (field weld)	C

7.A.2 Confinement Requirements for Normal Conditions of Storage

The TSC is transferred to a concrete cask using a transfer cask. Once the TSC is placed inside the concrete cask, it is effectively protected from direct structural loading due to natural phenomena, such as wind, snow and ice loading. The principal direct loading for normal operating conditions results from increased internal pressure caused by decay heat, solar insolation and ambient temperature. Loading due to transient handling may occur during the transfer of the loaded TSC to the concrete cask.

7.A.2.1 Release of Radioactive Material

The structural analysis of the TSC for normal conditions of storage presented in Appendix 3.A demonstrates that the confinement boundary is not breached in any of the normal operating events. Therefore, there is no release of radioactive material during normal storage conditions.

7.A.2.2 Pressurization of the Confinement Vessel

The TSC cavity is dried and backfilled with helium prior to installing and welding the vent and drain port covers. Under normal conditions, the internal pressure increases due to an increase in temperature of the helium and the postulated normal storage cladding failure of 1% of the stored fuel rods, which is assumed to release 30% of the available fission gases in the rods.

The TSC, closure lid, fittings and the basket assembly are fabricated from materials that do not react with spent fuel pool water to generate gases. The BORAL® neutron absorber and aluminum sheets in the fuel baskets, as described in Appendix 6.A, are held in place by stainless steel sheathing welded to the fuel tubes. The BORAL® neutron absorber plates are aluminum clad encasing a layer of B_4C, and the BORAL® is protected from excessive oxidation by an oxide film that forms shortly after fabrication of the plates. This oxide layer effectively precludes further oxidation that could result in the generation of gases in the TSC.

The TSC is dried and helium backfilled during closure and, therefore, no significant moisture or other gases, such as air, remain in the TSC. Consequently, there is no potential that radiolytic decomposition could cause an increase in TSC internal pressure or result in a buildup of explosive gases in the TSC. Foreign materials will be excluded from the cavity to ensure that explosive levels of gases due to radiological decomposition will not be generated.

The calculated TSC pressure for normal conditions of storage is presented in Appendix 4.A and is less than the pressure evaluated in Appendix 3.A for the maximum normal operating pressure. Consequently, there is no adverse consequence due to the internal pressure resulting from normal storage conditions.

As the confinement boundary is closed by welding and does not contain seals or O-rings, and the boundary is not ruptured or otherwise compromised under any normal handling event, the release of contents during normal conditions of storage is precluded.

7.A.3 Confinement Requirements for Hypothetical Accident Conditions

The results of the structural analyses of the TSC for off-normal and accident events of storage, presented in Appendix 11.A, show that the TSC is not breached in any of the evaluated events. Consequently, based on the welded closure TSC confinement boundary and the leakage tests described in Section 9.A.2 of Appendix 9.A, the TSC has no credible leakage and, therefore, there is no release of radioactive material during off-normal or accident events of storage.

A hypothetical accident condition assumes the cladding failure of all the fuel rods stored in the TSC. This postulated event results in an increase in TSC internal pressure due to the release of the fission product and fuel rod charge gases. The accident condition internal pressures for the LACBWR fuel configuration is calculated in Appendix 4.A of Chapter 4 and is shown to be less than the design pressure. Consequently, the integrity of the TSC confinement boundary is maintained and there is no release of radioactive material under off-normal or accident events of storage.

Since no release occurs as the result of accident events, the resulting site boundary dose due to a hypothetical accident is less than the 5 rem whole body or organ (including skin) dose at the 100-meter minimum boundary specified by 10 CFR 72.106 (b) for accident exposures.

7.A.4 References

[A1] 10 CFR 72, Code of Federal Regulations, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," US Nuclear Regulatory Commission, Washington, DC.

[A2] NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," Nuclear Regulatory Commission, Washington, DC, January 1997.

[A3] PNL-6365, "Evaluation of Cover Gas Impurities and Their Effects on the Dry Storage of LWR Spent Fuel," Pacific Northwest Laboratory, Richland, Washington, November, 1987.

[A4] ISG-18, "The Design/Qualification of Final Closure Welds on Austenitic Stainless Steel Canisters as Confinement Boundary for Spent Fuel Storage and Containment Boundary for Spent Fuel Transportation," US Nuclear Regulatory Commission, Washington, DC, May 2003.

[A5] ISG-15, "Materials Evaluation," US Nuclear Regulatory Commission, Washington, DC, Revision 0, January 10, 2001.

[A6] ASME Boiler and Pressure Vessel Code, Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," American Society of Mechanical Engineers, New York, NY, 1995 Edition with 1997Addenda.

[A7] ANSI N14.5-1997. "American National Standard for Radioactive Materials – Leakage Tests on Packages for Shipment," American National Standards Institute, Washington, DC, 1997.

[A8] Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," The American Society for Nondestructive Testing, Inc., Columbus, OH, edition as invoked by the applicable ASME Code.

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8.0 OPERATING PROCEDURES

This chapter provides general guidance for using the NAC-MPC spent fuel storage system configured for the Yankee-MPC and the CY-MPC for storage operations. MPC-LACBWR operations are addressed in Appendix 8.A. Three operating conditions are addressed. The first is loading the transportable storage canister (canister), installing it in the vertical concrete cask (concrete cask), and transferring it to the storage (ISFSI) pad. The second is the removal of the loaded canister from the concrete cask. The third is opening the canister to remove spent fuel in the unlikely event that this should be necessary. The procedures provided describe acceptable methods of performing the NAC-MPC system loading, unloading and recovery operations. Users may alter these procedures to allow alternate methods and operations to be performed in parallel or out of the given sequence as long as the general intent of the procedure is met. The procedures provided in Sections 8.1, 8.2 and 8.3 can also be appropriately revised to allow dry loading and unloading of the NAC-MPC system.

The operating procedure for transferring a loaded canister from a concrete cask to the NAC Storage Transport Cask (NAC-STC) is described in Section 7.2.2 of the NAC-STC Safety Analysis Report, Docket 71-9235.

In accordance with the Standard Review Plan (NUREG-1536), the operating sequences described in this chapter are intended to provide an effective basis for the development of the more detailed operating and test procedures required by the NAC-MPC system user. The user will use procedures provided by NAC as guidance when preparing and implementing detailed site procedures. The procedures in this chapter show the sequence in which limiting conditions established by the LCOs and Certificate of Compliance should be met, but mechanical operations may be performed in an appropriate sequence. Further, site procedures are expected to include the additional detailed activities that are required to perform the operation sequences.

Operation of the NAC-MPC system requires the use of ancillary equipment items. The ancillary equipment supplied with the system is shown in Table 8.1-1. The system does not rely on the use of bolted closures, but bolts are used to secure retaining rings and lids. The hoist rings used for lifting the shield lid and the canister, have threaded fittings. Table 8.1-2 provides the torque values for installed bolts and hoist rings. In addition, supplemental shielding may be employed to reduce radiation exposure for certain tasks specified by these procedures. The use of supplemental shielding is at the discretion of the User.

The design of the NAC-MPC is such that the potential for spread of contamination during handling and future transport of the canister is minimized. The concrete cask is constructed of new materials. The canister is loaded in the spent fuel pool, but is protected from gross contact with pool water by a jacket of clean water while it is in the transfer cask. Clean water is processed or filtered pool water, or any water external to the spent fuel pool that that has water chemistry that is compatible with use in the pool. Only the top of the open canister is exposed to contaminated pool water. The top of the canister is closed by the structural lid, which is not contaminated when it is installed. Consequently, the canister external surface is expected to be essentially clean.

When the NAC-MPC system is used in accordance with these procedures, the user dose is As Low As Reasonably Achievable (ALARA).

A training program is described in Section A5.0 of Appendix A of the Certificate of Compliance that is intended to assist the User in complying with the training and dry run requirements of 10 CFR 72. This program addresses the NAC-MPC storage system operational features and requirements.

8.1 Loading the NAC-MPC Storage System

The NAC-MPC storage system consists of three principal components: the transportable storage canister (canister), the transfer cask, and the vertical concrete cask (concrete cask). The transfer cask is used to hold the canister during loading and while the canister is being closed and sealed. The transfer cask is also used to transfer the canister to the concrete cask and to load the canister into the transport cask. The principal handling operations involve closing and sealing the canister by welding and loading it into the concrete cask. The vent and drain port locations are shown in Figure 8.1-1.

This procedure assumes that the canister with an empty basket is installed in the transfer cask, that the transfer cask is positioned in the decontamination area or other suitable work station, and that the concrete cask is positioned on a heavy-haul transporter in the cask receiving area or other suitable staging area.

The User must ensure that the fuel assemblies selected for loading into the canister conform to the Approved Contents provisions of Section B2.0 of Appendix B of the Certificate of Compliance. Fuel assembly loading may also be administratively controlled to ensure that fuel assemblies or other contents, including reconfigured fuel assemblies and fuel cans, with specific characteristics, are preferentially loaded in specified positions in the NAC-MPC basket. Preferential loading requirements for the CY-MPC are described in Section B2.1.2 of the Certificate of Compliance.

8.1.1 Loading and Closing the Transportable Storage Canister

This section provides the loading and closing procedures for the Transportable Storage Canister. The procedure for the Yankee-MPC presented in Section 8.1.1.1 and the procedure for the CY-MPC is presented in Section 8.1.1.2. The Limiting Conditions of Operation (LCOs), and Appendix B references in this section refer to Appendices A and B of the Certificate of Compliance for NAC-MPC system.

8.1.1.1 Loading and Closing the Yankee-MPC Transportable Storage Canister

1. Visually inspect the basket fuel tubes to ensure they 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/lock pins are installed and secure.
2. Flood the canister with clean 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. If it is not already attached, attach the transfer cask lifting yoke to the site approved crane, and engage the transfer cask lifting trunnions.

   Note: The minimum temperature of the transfer cask (i.e., external ambient temperature) must be verified to be higher than 0°F prior to lifting, in accordance with Section B3.4(8) of the Certificate of Compliance.
4. Raise the transfer cask and move it over the pool, following the prescribed travel path.
5. Install the annulus fill system to the transfer cask including the clean water lines.
6. Lower the transfer cask to the pool surface and turn on the clean water line to flood the annulus between the transfer cask and canister.
7. Slowly lower the transfer cask as the annulus fills with water until the top of the cask is approximately 1 to 4 inches above the pool surface and hold that position until water overflows through the upper fill lines or annulus 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 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.
10. Attach a three-legged sling to the shield lid using the swivel hoist rings.
11. Using the site approved crane, lower the shield lid until it rests in the top of the canister. Note the time that the shield lid is installed.

    Note: Ensure that the shield lid key slot aligns with the key welded to the canister shell.
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 water to wash off any gross contamination.

14. When the cask is clear of the pool surface, but still over the pool, turn off the water flow to the annulus and allow the annulus water to drain to the pool. Move the cask to the decontamination area or other suitable work station. Note the time the transfer cask is removed from the pool. Operations through 26a must be completed within the time shown for the applicable heat load (L):

Total Total Heat Load (L) (kW)	Allowable Time (Hours)
$10.5 < L \leq 12.5$	22
$8.5 < L \leq 10.5$	32
$6.5 < L \leq 8.5$	48
$4.5 < L \leq 6.5$	60
$L \leq 4.5$	90

Note: In the event a time limit is not met, cooling of the canister is required. Forced air cooling may be implemented by supplying 250 cfm air with a maximum temperature of 75°F to the inlets on the transfer cask. Forced air cooling must be continuously maintained for heat loads greater than 8.5 kW. Forced air cooling may be discontinued for 8 hours after 24 hours of continuous cooling for heat loads less than 8.5 kW. In-pool cooling may be used for heat loads less than 8.5 kW. In-pool cooling may be discontinued for 14 hours after 48 hours of continuous in-pool cooling. In-pool or forced air cooling may be repeated as necessary.

Note: Access to the top of the transfer cask is required. A suitable work platform may need to be erected.

15. Visually verify that the shield lid is level. 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.

16. Install mating female quick-disconnect to drain tube quick-disconnect. Insert the drain tube through the drain port of the shield lid into the basket drain tube sleeve. Remove the female quick-disconnect. Torque the drain tube to 135 ± 15 ft-lbs for Furon metal seals or 115 ± 5 ft-lbs for elastomer seals (EPDM or Viton). Remove the hoist rings. Connect a female quick-disconnect to the valve installed in the vent port.

17. Connect the suction pump to the drain port. Remove approximately 50 gallons of water from the canister. Disconnect and remove the pump.

    Note: Fuel rods shall not be exposed to air during the 50-gallon pump-down.

18. Install the semiautomated welding equipment with secondary shield plate.

19. 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%, connect and operate the vacuum system to remove gases from the under side of the shield lid and reverify hydrogen gas concentration.

20. Operate the welding equipment to complete the root weld joining the shield lid to the canister shell following approved procedures.

    Note: Stop welding if the hydrogen detector indicates a hydrogen concentration above 2.4% and clear hydrogen gas buildup.

21. Prepare the weld and perform a liquid penetrant weld examination of the root pass. Record the results of the weld examination.

    Note: The hydrogen detector may be removed from the vent port, if necessary. Leave the connector and vent tube installed to vent the canister.

22. Complete welding of the shield lid to the canister wall.
23. Prepare the weld and perform a liquid penetrant weld examination of the final pass. Record the results of the weld examination.

    Note: Re-rounding, if required, shall be performed prior to weld examination.

24. Remove any lines attached to the drain port. Attach a gas pressure line to the vent port. Pressurize the canister to 15 psig and hold the pressure. There shall be no loss of pressure for 10 minutes.
25. Release the pressure and visually inspect the shield lid to canister shell weld for indications of leaks and defects. Perform a liquid penetrant examination of the final weld surface. Record the results of the inspection.
26. Drain the Canister.

    26a. 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.

    26b. Remove the suction pump from the drain line and close the drain line. Attach a nitrogen supply to the vent port.

    26c. Using the vent port, pressurize the canister with nitrogen to 15 (+0, -3) psig.

    26d. Open the drain line to blow any remaining free water from the canister. Remove any free water in the drain port cavity. Install the drain port cover.

    26e. Repeat Steps 26b-26d until water no longer discharges from the drain line. Stop the flow of nitrogen, vent the remaining pressure and remove the nitrogen supply line. Remove the drain line from the drain port.

    Note: Fuel rods shall not be exposed to air during canister draining operations.

    Note: Steps 26b through 32 must be completed within the time limits of LCO 3.1.1.

27. Attach the vacuum equipment to the vent and/or drain line as needed.
28. Operate the vacuum equipment, until a vacuum ≤ 3 mm of mercury exists in the canister.

29. Verify that no water remains in the canister by holding the vacuum ≤ 3 mm for a minimum of 30 minutes. If water is present in the cavity, the pressure will rise as the water vaporizes. Pressure should not continuously rise during the period of the test.
30. Backfill the canister cavity with helium to 1.0 ATM (+1, -0 psig) with helium having a minimum purity of 99.9%.
31. Restart the vacuum equipment and evacuate the canister to 3 mm of mercury.
32. Backfill the canister cavity with helium to 1.0 ATM (+1, -0 psig).

    Note: Step 32 through Step 12 of the concrete cask loading procedure (Section 8.1.2) must be completed within 30 days.
33. Remove any attachments to the vent ports.
34. Remove any free water in the drain port cavity. Install the drain port cover.
35. Weld the drain port cover to the shield lid.
36. Prepare the weld to perform a liquid penetrant examination of the drain port cover weld. Record the result of the weld examination.

    Note: If the drain port cover weld is completed in a single pass, the weld final surface is examined in accordance with this step.
37. Install the vent port cover and weld the vent port cover to the shield lid.
38. Prepare the weld and perform a liquid penetrant examination of the vent port cover weld. Record the results of the weld examination.

    Note: If the vent port cover weld is completed in a single pass, the weld final surface is examined in accordance with this step.
39. Remove weld machine and supplemental shield plate.
40. Install leak test cover and attach helium Mass Spectrometer Leak Detector (MSLD) and vacuum pump. Evacuate leak test cover volume to ≤2mm and perform helium leak test of shield lid welds to verify helium leakage of $\leq 8 \times 10^{-8}$ cm^3/sec at the test sensitivity of $\leq 4 \times 10^{-8}$ cm^3/sec.
41. Vent and remove leak test cover and helium MSLD.
42. Attach a three-legged sling to the structural lid using the swivel hoist rings.

    Note: Verify that the structural lid is stamped, or otherwise marked, to provide traceability of the canister contents. Verify that the structural lid weld spacer ring is in place on the structural lid.
43. Using the site approved crane, install the structural lid in the top of the canister. Verify that the structural lid is approximately centered in the canister shell. Verify that the gap in the spacer ring is not aligned with the shield lid alignment key. Remove the lifting sling and the hoist rings.
44. Install the automated welding equipment on the structural lid.
45. Complete the root weld pass joining the structural lid to the canister shell.

46. Prepare the weld and perform a liquid penetrant examination of the weld root pass and record the results of the weld examination.
47. Complete the remainder of the weld, performing NDE (progressive liquid penetrant or ultrasonic testing) examination. Record the results of each weld examination.
48. Remove the welding equipment.
49. Prepare the weld and perform an ultrasonic inspection of the weld, if required, then perform a liquid penetrant examination of the final weld pass. Record the results of the weld examinations.
50. 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 by Technical Specification LCO 3.2.1.
51. Install the transfer cask retaining ring.
52. Decontaminate the external surface of the transfer cask.

8.1.1.2 Loading and Closing the CY-MPC Transportable Storage Canister

1. Visually inspect the basket fuel tubes to ensure they 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/lock pins are installed and secure.
2. Flood the canister with clean 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 a clean water line(s) to the transfer cask. Install threaded pipe plugs on unused fill/drain lines on 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 external ambient air temperature must be verified to be higher than 0°F prior to lifting, in accordance with Appendix B, Section B3.4(8).
5. Raise the transfer cask and move it over the pool, following the prescribed travel path. If not already installed, attach clean water line(s) to the transfer cask.
6. Lower the transfer cask to the pool surface and turn on the clean or filtered water line to flood the annulus between the transfer cask and canister.
7. Lower the transfer cask as the annulus fills with clean water until the top of the cask is approximately 1 to 4 inches above the surface and hold that position until clean water fills the remainder of the canister and overflows through the upper fill lines or annulus 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 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 selected and loaded in accordance with the Approved Contents provisions of Appendix B, Section B2.0, of the Certificate of Compliance.
10. Attach a three-legged sling to the shield lid using the swivel hoist rings.
11. Using the cask handling crane, or auxiliary hook, lower the shield lid until it rests in the top of the canister.

    Note: Ensure that the shield lid key slot aligns with the key welded to the canister shell.
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. Note the time that the transfer cask is removed from the pool. Operations through Step 28 must be completed within 30 hours; or for the CY-MPC configuration with less than the design basis heat load, the time limits shown in Table 8.1-3 are applied.

    Note: In the event that the drain time limit will not be met, forced air cooling or in-pool cooling of the canister is required to be initiated prior to exceeding the allowable time in water established for the canister heat load. Forced air cooling is implemented by supplying 375 CFM air with a maximum temperature of 75°F to the 8 transfer cask lower inlets. Forced air or in-pool cooling of the canister shall be maintained for a minimum of 24 hours. After 24 hours, the cooling may be discontinued based on heat load as follows:

Time Periods for Discontinued Cooling after 24 Hours[1]

Heat Load (kW)	For Forced Air Cooling (hrs)	For In-Pool Cooling (hrs)
$13 < Q \leq 17.5$	7	7
$9 < Q \leq 13$	16	14
$Q \leq 9$	48	47

[1] Interruption of forced air cooling, as described in the Note of Step 30, is not applicable to the forced air cooling required during canister time in water evolutions.

13. As the cask is raised, spray the transfer cask outer surface with clean or filtered 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 water flow to the annulus, remove the 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.

Note: Supplemental shielding may be used for activities around the shield lid.

16. Attach the suction pump to the suction pump fitting on the drain 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.
18. Insert the drain tube through the drain port of the shield lid into the basket drain tube sleeve. Install the drain tube assembly by hand until metal-to-metal contact is achieved; then torque to 135 ± 15 ft-lbs for Furon metal seals or 115 ± 5 ft-lbs for elastomer seals (EPDM or Viton). Install a mating quick-disconnect fitting in the vent line to open the vent. Remove the shield lid hoist rings and replace with threaded plugs.
19. Verify that the vent port is open. Connect the suction pump to the drain port. Remove approximately 65 gallons of water from the canister. Disconnect and remove the pump.

    Note: Fuel rods shall not be exposed to air during the 65-gallon pump-down.

    Caution: Radiation level may increase as water is removed from the canister.
20. Install the semiautomated 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 under side of the shield lid and re-verify hydrogen gas concentration. Disconnect and remove the vacuum system.
22. Operate the welding equipment to complete the root weld joining the shield lid to the canister shell following approved procedures.
23. Prepare the weld and perform a liquid penetrant weld examination of the root pass. Record the results of the weld examination.

    Note: The hydrogen detector may be removed from the vent port, if necessary.
24. Complete welding of the shield lid to the canister wall. Prepare the weld and perform a liquid penetrant weld examination of the final pass. Record the results of the weld examination.

    Note: At the discretion of the user, the weld examination may be deferred until completion of the pressure test.

    Note: Re-rounding, if required, shall be performed prior to final weld examinations and pressure testing.
25. Remove the weld equipment and the hydrogen gas detector.
26. Remove any lines attached to the drain port. Attach a gas pressure line to the vent port. Pressurize the canister to 20 psig and isolate the gas supply. There must be no loss of pressure for 10 minutes.

27. Release the pressure. Visually inspect the shield lid to canister shell weld for indications of defects. Record the results of the inspection.
28. Drain the remaining water from the canister cavity. Draining of the canister may be performed by suction, by a blow-down gas pressure of 15-18 psig, or by a combination of suction and a blow-down gas pressure of 15-18 psig. Draining is a continuous process, which should not exceed 2 hours (i.e., allowable drain down time) under normal operations. Completion of draining occurs when the pump loses suction, or when gas becomes evident, if gas is being used for assistance for draining the canister cavity. Note the time draining is completed. After removal of the water from the canister, disconnect the equipment from the canister. If not already installed, install a quick-disconnect to open the vent valve.

    Note: Fuel rods shall not be exposed to air during canister draining operations.

    Note: Should draining be interrupted, or exceed 2 hours, end the drain down time clock and start the vacuum drying time clock of LCO 3.1.1.

    Note: The time duration from completion of draining, or termination of the drain down time clock, through the completion of helium backfill (Step 34) shall be in accordance with LCO 3.1.1.

    Note: The transfer cask (with the canister inside) may be tilted up to 6° from vertical to assist in canister water removal and draining.

    Note: A temporary full-length siphon/drain tube may be used in place of the permanent drain tube to facilitate removal of remaining free water from the canister cavity. If the temporary full-length siphon/drain tube is used, following completion of the canister water removal process, it shall be removed and replaced by the permanent drain tube prior to initiating Step 29.

    Note: At the completion of draining operations, an external heater may be used to add heat to the transfer cask shield doors during vacuum drying and during forced air cooling operations implemented per LCO 3.1.1 until the dryness verification of LCO 3.1.2 is completed. The heater will be sized and operated to limit the peak temperature of the bottom of the shield doors to < 200°F. The addition of heat will assist vacuum drying operations.

    Caution: The user shall ensure the stability of the transfer cask and canister during all operations.

    Caution: Radiation levels at the top and sides of the transfer cask may rise as water is removed.
29. Attach the vacuum equipment to the vent and drain ports. Dry any free standing water in the vent and drain port recesses.

Note: At the option of the user, dry nitrogen (ambient temperature up to 300°F) may be purged or bled into the cavity during vacuum drying at a low flow rate (i.e., ≤10 CFM).

Note: At the option of the user, dry nitrogen or helium may be used during the vacuum drying cycle to backfill the cavity to ≤1 atmosphere to allow canister internals to thermally stabilize.

30. Operate the vacuum equipment, until a vacuum of ≤ 10 mm of mercury exists in the canister. Vacuum drying pressure must conform to the requirements of LCO 3.1.2.

Note: If the vacuum drying operations are not completed within the allowable vacuum drying cycle time periods established in LCO 3.1.1.1.b or LCO 3.1.1.2.b, the canister shall be backfilled with helium and either forced air cooling or water cooling operations shall be initiated and maintained for a minimum of 24 hours prior to the restart of loading operations. To ensure that sufficient helium is introduced into the canister cavity for adequate heat transfer, reduce the canister cavity pressure to less than 75 mm Hg and backfill with minimum 99.9% pure helium to the pressure specified in LCO 3.1.1, Action A.1. Alternatively, backfill the canister cavity through the vent port with 99.9% pure helium to a pressure of 15-18 psig and vent through the drain line. Repeat the process a minimum of 4 times (approximately 24 to 30 m^3 of helium at standard pressure) and adjust cavity pressure to the pressure specified in LCO 3.1.1, Action A.1.

In the event of an interruption of the forced air cooling process during the required minimum 24 hours of operation, remedial actions to extend the forced air cooling time to account for interruptions is required. The period of the required additional forced air cooling is based on the duration of the interruption(s) as follows:

Duration of Interruption(s) T (hr)	Additional Forced Air Cooling Time (hr)
T ≤0.5	0
0.5 < T ≤1	2
1 < T ≤2	4
2 < T ≤3	6
3 < T ≤4	8

The duration of the interruption(s) corresponds to the cumulative time of interruption events. The additional forced air cooling time is required to be added to the remaining time of the original minimum 24 hours of cooling prior to the first interruption. If the duration of the interruption(s) exceeds 4 hours, a minimum duration of 30 hours of forced air cooling is required from the end of the interruption(s).

31. Verify that no water remains in the canister by holding the vacuum for 10 minutes. If water is present in the cavity, the pressure will rise as the water vaporizes. Continue the vacuum/hold cycle until the conditions of LCO 3.1.2 are met.
32. Evacuate the canister to ≤ 3 mm of mercury and backfill the canister cavity with helium, having a minimum purity of 99.9%, to a pressure of one atmosphere.

    Note: As an option, an informational helium leak test may be conducted at this point 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^{-6} 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 evacuate the canister to ≤ 3 mm of mercury.
34. Backfill the canister cavity with helium having a minimum purity of 99.9% to a pressure of one atmosphere (+1, -0 psig).

    Note: Canister vacuum and helium backfill pressure must conform to the requirements of LCO 3.1.3.

    Note: Step 34 through Step 19 of the concrete cask loading procedure (Section 8.1.2) must be completed within 25 days in accordance with LCO 3.1.4.
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. Weld 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 of the weld examination.

    Note: If the drain port cover weld is completed in a single pass, the weld final surface is examined in accordance with this step.
39. Weld the vent port cover to the shield lid.
40. Prepare the weld and perform a liquid penetrant examination of the root pass. Record the results.

    Note: If the vent port cover weld is completed in a single pass, the weld final surface is examined in accordance with this step.
41. Remove any supplemental shielding used during shield lid closure activities.
42. Install the helium leak test fixture.
43. Attach the vacuum line and leak detector to the leak test fixture fitting.

44. Operate the vacuum system to establish a vacuum in the leak test fixture.
45. Operate the helium leak detector to verify that there is no indication of a helium leak exceeding 2×10^{-7} cm^3/second (helium) in accordance with the requirements of LCO 3.1.5.
46. Release the vacuum and disconnect the vacuum and leak detector line from the fixture.
47. Remove the leak test fixture.
48. 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. Torque the hoist rings in accordance with Table 8.1-2. Verify that the structural lid weld spacer 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.
49. Using the cask handling or the auxiliary crane, install the structural lid in the top of the canister. Verify that the structural lid is even with or slightly above the canister shell and is approximately centered in the canister shell. Verify that the gap in the spacer ring is not aligned with the shield lid alignment key. Remove the lifting sling and the hoist rings.
50. Install the automated welding equipment on the structural lid.
51. Operate the welding equipment to complete the root weld pass joining the structural lid to the canister shell, following approved procedures.
52. Prepare the weld and perform a liquid penetrant examination of the weld root pass and record the results of the weld examination.
53. Complete the remainder of the weld, examining the weld at 3/8-inch intervals and the final weld surface using the liquid penetrant method. Record the results of each intermediate examination.

    Note: If ultrasonic testing of the weld is used, testing is performed after the weld is completed.
54. Remove the welding equipment.
55. 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. Smear survey results shall meet the requirements of LCO 3.2.1.
56. Install the transfer cask retaining ring. Torque bolts as required by Table 8.1-2.
57. Decontaminate the external surface of the transfer cask to the limits established for the site.

8.1.2 Loading the Vertical Concrete Cask

This section of the loading procedure assumes that the vertical concrete cask (concrete cask) is located on the bed of a heavy-haul trailer, or on the floor of the work area, under the site

approved crane and that the concrete cask shield plug and lid are not in place and that the bottom pedestal plate cover is installed.

1. Using a site approved crane, place the transfer adapter on the top of the concrete cask.
2. Using the transfer adapter bolt hole pattern, align the adapter to the concrete cask. Bolt the adapter to the cask using four (4) socket head cap screws. (Note: Bolting of the transfer adapter to the cask is optional, if the transfer adapter centering segments/guides are installed.)
3. Verify that the bottom door connectors on the adapter plate are in the fully extended position.
4. If not already done, attach the transfer cask lifting yoke to the site approved crane. Verify that the transfer cask retaining ring is installed.
5. Install six (6) swivel hoist rings in the structural lid of the canister. Verify that the hoist ring threads are fully engaged, and attach two (2) three-legged slings. Stack the slings on the top of the canister so they are available for use in lowering the canister into the concrete cask.
6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.
7. Raise the transfer cask and move it over the concrete cask. Lower the transfer cask, ensuring that the bottom door rails and connector tees align with the adapter plate rails and door connectors. Prior to final set down, remove transfer cask door lock bolts/lock pins.

   Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting in accordance with Appendix B, Section B3.4(8).
8. Ensure that the bottom door connector tees are engaged with the adapter plate door connectors.
9. Disengage the transfer cask yoke from the transfer cask and from the site approved crane hook.
10. Return the cask site approved crane hook to the top of the transfer cask and engage the two (2) three-legged slings attached to the canister. Lift the canister slightly (about 1/2 inch) to take the canister weight off of the transfer cask bottom doors.

    Note: A load cell may be used to determine when the canister is supported by the crane. Avoid raising the canister to the point that the structural lid engages the transfer cask retaining ring, as this could result in lifting the transfer cask.

    Caution: The top connection of the three-legged slings must be at least 67 inches above the Yankee-MPC canister lid, and at least 53 inches above the CY-MPC lid.
11. Using the hydraulic system, open the bottom doors to access the concrete cask cavity.
12. Lower the canister into the concrete cask, using a slow crane speed as the canister nears the bottom of the concrete cask.

13. Disconnect the slings from the crane hook and lower them to the top of the canister. Close the transfer cask bottom doors.
14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.
15. Lift the transfer cask off the concrete cask and return it to the decontamination area or designated work station.

    Note: For the YR-MPC, ensure that a visible gap exists between the canister and the concrete cask liner (i.e., the canister is not in contact with the concrete cask liner). For the CY-MPC, visually verify that the canister is located within the cylinder of the projection of the support ring.
16. Using the site approved crane, remove the adapter plate from the top of the concrete cask.
17. Remove the swivel hoist rings from the structural lid and replace them with threaded plugs.
18. Using the site approved crane, retrieve the shield plug and install the shield plug in the top of the concrete cask.
19. Using the site approved crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask using six stainless steel bolts.
20. Ensure that there is no foreign material left at the top of the concrete cask. At the option of the user, a tamper-indicating seal wire and seal may be installed.
21. If used, install a supplemental shielding fixture in each of the four air inlets.

    Note: The supplemental shielding fixtures may also be shop installed.

8.1.3 Transport and Placement of the Vertical Concrete Cask

This section of the procedure assumes that the loaded concrete cask is positioned on a heavy-haul trailer.

After placement on the ISFSI pad, the concrete cask surface dose rates must be verified in accordance with the requirements of LCO 3.2.2. The dose rate measurements may be made prior to movement of the concrete cask, at a location along the transport path, or at the ISFSI. Following placement of the concrete cask at the ISFSI, the operability of the concrete cask heat removal system shall be verified in accordance with LCO 3.1.6.

1. Using a suitable towing vehicle, tow the heavy-haul trailer to the dry storage pad (ISFSI). Verify that the bed of the trailer is approximately at the same height as the pad surface.
2. Install four (4) hydraulic jacks at the four (4) designated jacking points at the bottom cooling air vents.
3. Raise the concrete cask approximately 4 inches.

   Caution: Do not exceed a maximum lift height of 6 inches, in accordance with the requirements of Section A 5.5(d) of the Certificate of Compliance.

4. Move the air-bearing rig set under the cask, if not already in place.
   Note: A hydraulic skid may also be used to move the concrete cask. The height the concrete cask is raised depends upon the height of the skid or air pad set used, but may not exceed 6 inches.
5. Remove the four (4) hydraulic jacks. Inflate the air-bearing rig set.
6. Using a suitable towing vehicle, move the concrete cask from the bed of the transporter to the designated location on the storage pad.
7. Turn off the air-bearing rig set, allowing it to deflate.
8. Reinstall the four (4) hydraulic jacks and raise the concrete cask approximately 4 inches.
   Caution: Do not exceed a maximum lift height of 6 inches.
9. Remove the air-bearing rig set pads. Ensure that the surface of the dry storage pad under the cask is free of foreign objects.
10. Lower the concrete cask to the surface.
    Note: Ensure that the centerline spacing between concrete casks is 15 feet minimum.
11. Remove the four (4) hydraulic jacks.
12. Install screens in the inlets and outlets.
13. Install/connect the temperature monitoring equipment and verify operation.
14. Scribe/stamp the concrete cask name plate to indicate loading date.

Figure 8.1-1 Vent and Drain Port Locations

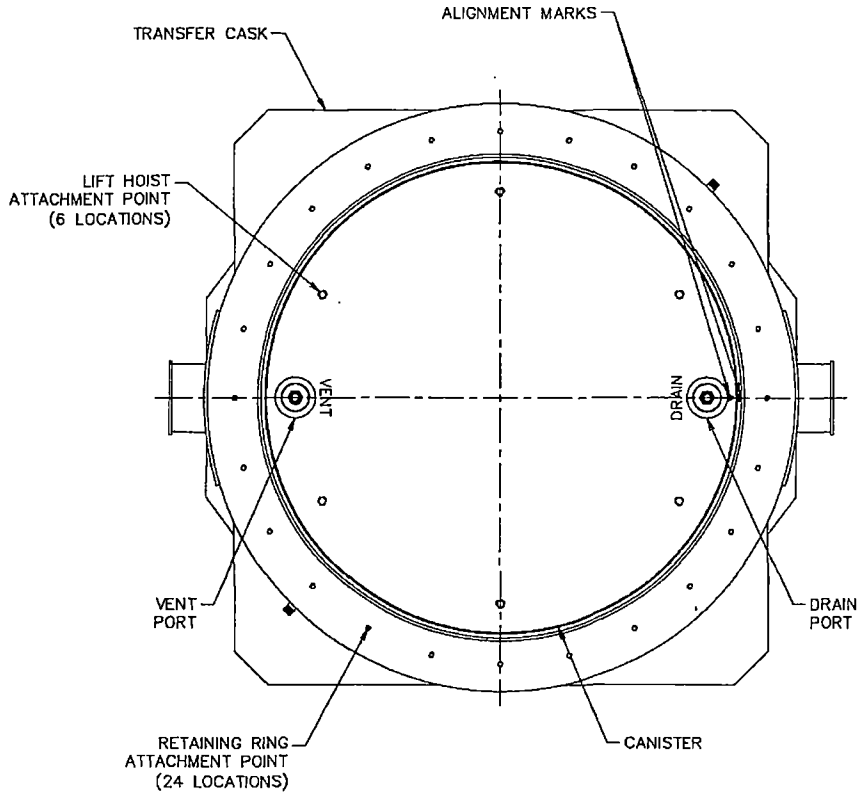

Table 8.1-1 List of Ancillary Equipment

Item	Description
Transfer Cask Lifting Yoke	Required for lifting and moving the transfer cask.
Transport Trailer (Optional)	Heavy-haul (double drop frame) trailer required for moving the loaded and empty concrete cask to and from the ISFSI pad.
Helium Supply System	Supplies helium to the canister for helium backfill and purging operations.
Vacuum Drying System	Used for evacuating the canister. Used to remove residual water, gas and initial helium backfill.
Automated Welding System	Used for welding the shield lid and structural lid to the canister shell.
Self-Priming Pump	Used to remove water from the canister.
Shield Lid Sling	Used to make a three-point lift of the shield lid and the concrete cask shield plug and lid.
Canister Sling	Used to make a six-point lift of the loaded canister. These slings are also used to make a three-point lift of the structural lid.
Transfer Adapter	Used to align the transfer cask to the concrete cask or transport cask. Provides the platform for the operation of the transfer cask bottom doors.
Hydraulic Unit	Operates the bottom doors of the transfer cask.
Lift Pump Unit	Jacking system for raising and lowering the concrete cask.
Air Pad Rig Set	Air cushion system used for moving the concrete cask.
Supplemental Shielding Fixture	An optional carbon steel fixture inserted in the Yankee-MPC vertical concrete cask air inlets to reduce radiation dose rates at the inlets.

Table 8.1-2 Torque Values

Fastener	Torque Value (ft-lbs)	Torque Pattern
Transfer Adapter Bolts (Optional)	40 ± 5	None
Transfer Cask Retaining Ring Bolts	100 ±10	None
Vertical Concrete Cask Lid Bolts	40 ± 5	None
Lifting Hoist Rings* (Loaded Canister Lift) * Threads must be fully engaged	800 + 80, - 0	None
Lifting Hoist Rings* (Components) Vertical Concrete Cask Lid Transfer Cask Retaining Ring GTCC Canister (Empty) Vertical Concrete Cask Shield Plug Fuel Canister (Empty) Canister Shield Lid Welding Plate Canister Shield Lid Canister Structural Lid * Threads must be fully engaged	 60 + 5, - 0 100 + 10, - 0 230 + 25, - 0 230 + 25, - 0 230 +25, - 0 230 +25, - 0 470 +50, - 0 Hand Tight	 None None None None None None None None
Canister and Lid Plug Bolts	Hand Tight	None
Transfer Cask Door Lock Bolts/ Lock Pins	Hand Tight	None
Canister Drain Tube Canister Vent Valve	135 ± 15 (Furon metal seals) 115 ± 5 (elastomer seals, EPDM or Viton) 135 ± 15 (Furon metal seals) 115 ± 5 (elastomer seals, EPDM or Viton)	None None

Table 8.1-3 Time Limits for Removing Water from the CY-MPC Canister

Total Heat Load (L) kW	Time Limit (Hours)
$13 < L \leq 17.5$	30
$9 < L \leq 13$	43
$L \leq 9$	82

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8.2 Removal of the Transportable Storage Canister from the Vertical Concrete Cask

Removal of the loaded canister from the concrete cask is expected to occur at the time of shipment of the canistered fuel off site. Alternately, removal could be required in the unlikely event of an accident condition that rendered the concrete cask or canister unsuitable for continued long-term storage or for transport. This procedure identifies the general steps to return the loaded canister to the transfer cask and return the transfer cask to the decontamination station, or other designated work area. Since these steps are the reverse of those undertaken to place the canister in the concrete cask, as described in Section 8.1.2, they are summarized here. The procedure assumes that the inlet and outlet screens and the temperature-sensing instrumentation, if installed, have been removed.

Mechanical operation steps of the procedure may be performed in an appropriate sequence to allow for operational efficiency. Changing the order of these steps, within the intent of the procedures, has no effect on the safety of the canister removal process and does not violate any requirements stated in the Technical Specifications.

At the option of the user, the canister may be removed from the concrete cask and transferred to another concrete cask or to the NAC-STC transport cask at the ISFSI site. This transfer is done using the transfer cask, which provides shielding for the canister contents during the transfer.

1. Using the hydraulic jacking system and the air pad set, move the concrete cask from the ISFSI pad to the heavy-haul trailer. The bed of the trailer must be approximately level with the surface of the pad.

   Caution: Do not exceed a maximum lift height of 6 inches when raising the concrete cask in accordance with the requirements of Section A 5.5(d) of the Certificate of Compliance.
2. Tow the transporter to the cask receiving area or other designated work station.
3. Remove the concrete cask shield plug and lid. Install the hoist rings in the canister structural lid. Verify that the hoist ring threads are fully engaged and torque the hoist rings as required in Table 8.1-2. Attach the lift slings. Install the transfer adapter.
4. Retrieve the transfer cask and position it on the transfer adapter on the top of the concrete cask.

   Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting in accordance with Appendix B, Section B3.4(8) of the Certificate of Compliance.

5. Open the shield doors. Attach the canister lift slings to the site approved crane hook.
   Caution: The top connection of the three-legged sling must be at least 67 inches above the Yankee-MPC canister lid and at least 53 inches above the CY-MPC canister lid.
6. Raise the canister into the transfer cask. Use caution to avoid contacting the transfer cask retaining ring with the canister.
7. Close the shield doors. Lower the canister to rest on the bottom doors. Disconnect the canister slings from the crane hook.
8. Retrieve the transfer cask lifting yoke. Engage the transfer cask trunnions and move the transfer cask to the decontamination area or designated work station.
   Note: Prior to moving transfer cask, install and secure door lock bolts/ lock pins.

After the transfer cask containing the canister is in the decontamination area or other suitable work station, additional operations may be performed on the canister. It may be opened, transferred to another concrete cask, or placed in the NAC-STC transport cask. The length of time that the loaded canister is in the transfer cask and spent fuel cooldown operations must be monitored in accordance with LCO 3.1.4 and LCO 3.1.7 of the Certificate of Compliance.

8.3 Unloading the Transportable Storage Canister

Circumstances could arise that dictate the opening of a previously loaded canister and the removal of the stored spent fuel. This section describes the basic operations needed to open the sealed canister. It is assumed that the canister is positioned in the transfer cask and that the transfer cask is in the decontamination station or other suitable work station. The principal mechanical operations are the cutting of the closure welds, filling with water, and the removal of the spent fuel. Supplemental shielding is used as required and mechanical/hydraulic fixturing or tooling may be used to assist lid removal. The length of time that the loaded canister is in the transfer cask and spent fuel cooldown operations must be monitored in accordance with LCO 3.1.4 and LCO 3.1.7 of the Certificate of Compliance.

Mechanical operation steps of the procedure may be performed in an appropriate sequence to allow for operational efficiency. Changing the order of these steps, within the intent of the procedures, has no effect on the safety of the canister removal process and does not violate any requirements stated in the Technical Specifications.

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. Tent the top of the transfer cask as required.
5. Operate the cutting equipment to cut the structural lid weld.
   Note: Monitor for any out-gassing. Wear respiratory protection as required.
6. Remove the cutting equipment and attach a three-legged sling to the structural lid.
7. Using the site approved crane, lift the structural lid off of the canister and 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.
9. Tent the top of the transfer cask, if required. Using an abrasive grinder or other appropriate style mechanical cutting equipment, and wearing suitable respiratory protection, cut the welds joining the vent and drain port covers to the shield lid.

10. Remove the port covers. Monitor for any out-gassing and survey the radiation level at the quick-disconnect fittings. 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.
    Caution: The canister could be pressurized.
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 or other site-approved filtration system. Monitor the vent line, so that the radiation level of the discharge gas and the temperature of the discharge gas are indicated.
    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.
    Caution: Discharge gas temperature could initially be above 400°F
12. Continue to flow 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.
    Caution: The discharge line and fittings may be very hot.
    Note: See Figure 8.3-1 for a typical line diagram of the canister cool down support system.
13. For the Yankee-MPC, remove the vent port quick-disconnect and replace with a 1-inch female NPT to 1-5/16-inch SAE/MS adapter, modified to a 15/16-inch bore, fitted with a Viton O-ring. Install fitting hand tight until metal-to-metal contact is achieved, then torque to 115 ± 5 ft-lbs. For the CY-MPC, ensure the vent port quick-disconnect has new Viton seals. This may be accomplished by replacing the seals in the existing quick-disconnect or installing a new quick-disconnect. Ensure the quick-disconnect assembly is torqued to the value specified in Table 8.1-2.
14. Ensure the drain port quick-disconnect has new Viton seals. This may be accomplished by replacing the seals in the existing quick-disconnect, installing a new quick-disconnect or installing a new drain tube assembly. Ensure the quick-disconnect assembly is torqued to the value specified in Table 8.1-2.
15. Perform canister refill and cooldown operations in accordance with the requirements of LCO 3.1.7. Attach a source of water with a minimum temperature of 70°F and a supply pressure of 25 (+10, -0) psig to the drain port quick-disconnect. Attach a steam-rated discharge line to the vent port connector and route it to the spent fuel pool, an in-pool

cooler, or an in-pool steam condensing unit. Slowly start the flow of water to establish a flow rate of 5 (+ 3, - 0) gpm. Monitor the discharge line pressure gage during canister flooding. Secure filling the canister if at any time the canister vent line discharge pressure exceeds 30 psig. Re-establish flow when canister pressure is reduced below 20 psig. The discharge line will initially discharge hot gas, but after the canister fills, it will discharge hot water. The canister filling is expected to take less than 8 hours.

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.

16. Monitor water flow through the canister until the exit water 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 the temperature exceeds 200°F.

17. Connect a suction pump to the drain port and for the Yankee-MPC, remove approximately 50 gallons of water. For the CY-MPC remove approximately 65 gallons of water. Disconnect and remove the pump.
18. Attach a hydrogen gas detector to the vent port. Verify that the concentration of hydrogen gas is less than 2.4%.
19. 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.
20. 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.

21. Remove the cutting equipment. Remove all loose shims. Install the shield lid lifting hoist rings and attach a three-legged sling. Attach a line to the sling master link to aid in attaching the sling to the crane hook.
22. Install the annulus fill system to the transfer cask including the clean water lines.
23. Retrieve the transfer cask lifting yoke and engage the transfer cask lifting trunnions.

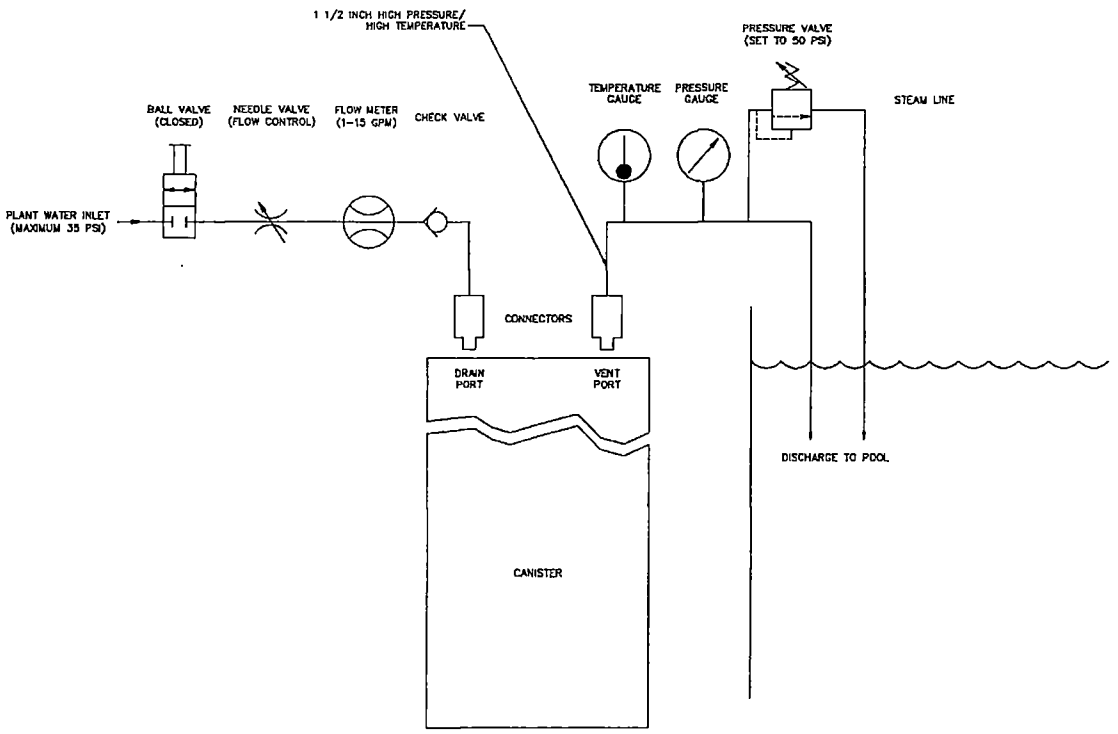
    Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting in accordance with Appendix B, Section B3.4(8).

24. Move the transfer cask over the pool and lower the bottom of the transfer cask to the surface. Start the flow of clean water to the transfer cask annulus. Continue to lower the transfer cask, as the annulus fills with clean water, until the top of the transfer cask is about 4 inches above the pool surface. Hold this position until clean water fills the top of the transfer cask.
25. Lower the transfer cask to the bottom of the cask loading area and remove the lifting yoke.
26. Attach the shield lid lifting sling to the crane hook.
27. Slowly lift the shield lid. Move the shield lid to one side after it is raised clear of the transfer cask.

    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 tube clears the canister basket. Use caution if the shield lid is removed from the pool. The under side of the shield lid and the attached drain line could be highly contaminated.
28. 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. 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.

Figure 8.3-1 Canister Reflood Piping and Controls Schematic



Note: The fuel cooldown procedure must conform to the requirements of Technical Specification LCO 3.1.7.

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Appendix 8.A OPERATING PROCEDURES – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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8.A OPERATING PROCEDURES FOR THE MPC-LACBWR STORAGE SYSTEM

This chapter provides general procedural guidance for the loading, unloading and recovery of the MPC-LACBWR system. This information shall be used to prepare the detailed, site-specific procedures for loading, handling, storing and unloading the MPC-LACBWR system. Users may add, delete or change the sequence of specific steps of the procedures to accommodate site-specific requirements provided that the intent of the tasks associated with Transportable Storage Canister (TSC) closure and storage is preserved and that the specific numerical acceptance criteria, such as: fastener torque values, temperature limits for operations and other defined values in these procedure are also met.

All facility-specific procedures prepared by users must fully comply with the applicable requirements of the NAC-MPC Certificate of Compliance (CoC) and Technical Specifications, including the approved contents and design features.

Equipment and operating requirements will be established by the user prior to implementation. Refer to Table 8.A.1-1 for a listing of the major ancillary equipment generally required by the user to load and close or to open and unload the system. The MPC-LACBWR system provides effective shielding for operations personnel; however, the licensee/user may utilize supplemental shielding to further reduce operator radiation exposure. The planned location, type and possible interactions of the temporary supplemental shielding with MPC-LACBWR components shall be appropriately evaluated by the licensee/user. The MPC-LACBWR system, when operated by properly trained personnel in accordance with the generic procedures provided herein, will meet As Low As Reasonably Achievable (ALARA) guidance for personnel exposure control.

The design features of the MPC-LACBWR system minimize the potential for contamination of the TSC during fuel loading, canister preparation and transfer. The TSC is loaded in the fuel pool, but the external surfaces of the canister are protected from contact with the contaminated pool water by clean water maintained in the annulus between the transfer cask and the TSC. For purposes of the operating procedures, clean water is defined as demineralized, processed or filtered pool water, or any water external to the fuel pool that has water chemistry compatible for use in spent fuel pools. During loading operations, only the TSC closure lid is exposed to the spent fuel pool water. The smooth top surface of the closure lid can be readily decontaminated. Therefore, the TSC external surfaces are expected to be essentially free of removable contamination during long-term storage operations.

Tables in Chapter 3, Appendix 3.A provide the handling weights for the major components of the MPC-LACBWR system and the loads to be lifted during various phases of the loading and unloading operations. Licensees/users must perform appropriate reviews and evaluations to ensure that the lifted loads do not exceed rated load limits of user-supplied lifting equipment and comply with the facility's heavy-load control program.

8.A.1 Loading of the MPC-LACBWR Storage System

The MPC-LACBWR system is used to load, transfer and store used intact, damaged fuel and fuel debris from the La Crosse BWR at the onsite Independent Spent Fuel Storage Installation (ISFSI). Damaged fuel and fuel debris are required to be stored in damaged fuel cans (DFCs). The three principal components of the system are the transportable storage canister (TSC), the transfer cask and the concrete cask. The transfer cask contains and supports the TSC during fuel loading, lid welding and closure operations. The transfer cask, with the transfer adapter, is also used to move the TSC into position for placement in the concrete cask.

These loading procedures are based on three initial conditions:

- the transfer cask is located in a facility's designated workstation for cask preparation
- an empty TSC (properly receipt inspected and accepted) is located in the transfer cask cavity
- an accepted concrete cask is available to receive the TSC when loading and preparation activities are complete

The TSC is filled with clean or filtered pool water, and the transfer cask containing the TSC is lowered into the fuel pool for fuel assembly loading and verification. The user must identify and select the fuel assemblies to be loaded and ensure that all loaded fuel assemblies comply with the Approved Content provisions of the CoC.

Following fuel loading, the closure lid is installed and the transfer cask containing the loaded TSC is lifted from the bottom of the fuel pool and placed in the cask preparation area. The TSC water level is lowered to allow for thermal expansion of the cavity water and the closure lid is welded to the TSC shell. The closure lid-to-shell weld is visual and progressive liquid penetrant (PT) examined. The cavity is refilled, and the TSC is subjected to a hydrostatic pressure test. Following hydrostatic pressure test acceptance, the closure ring, which provides the redundant confinement closure barrier, is installed, welded and inspected.

The TSC cavity water is drained, the residual moisture in the TSC is removed by vacuum drying techniques and the TSC dryness is verified. The TSC is evacuated to $\leq$3 torr (e.g., torr = mm of Hg) and backfilled with high-purity helium to provide an inert atmosphere for the safe long-term storage of the spent fuel contents. System connections to the vent and drain openings are removed

and the inner port covers are installed, welded, PT examined and helium leak tested. The outer port covers, which provide the redundant sealing of the confinement boundary, are installed, welded and PT examined. Installation, welding examination and testing of the closure lid, closure ring and port covers complete the assembly of the confinement boundary.

The concrete cask is positioned for the transfer of the TSC and the transfer adapter is installed. The transfer cask containing the loaded TSC is positioned on the transfer adapter on the top of the concrete cask. The TSC is lowered into the concrete cask, and the transfer cask and transfer adapter are removed. The concrete lid assembly is installed and secured to complete the loading process.

The loaded concrete cask is moved onto the ISFSI storage pad using the heavy-haul trailer and air pads, and placed in its long-term storage location.

8.A.1.1 Loading and Closing the TSC

This section describes the sequence of operations to load and close the TSC in preparation for transferring the TSC to the concrete cask. The empty TSC is assumed to be positioned inside the transfer cask located at the designated workstation.

1. Perform gross visual inspection of the TSC and basket internals for foreign materials or debris.
2. Visually inspect the top of the TSC shell and closure lid weld preps.
3. Verify that at least one lock pin or door stop is installed on each transfer cask shield door.
4. Fill the TSC with clean or pool water to approximately 6" from the top.
5. Attach the lift yoke to a crane suitable for handling the loaded TSC, transfer cask and yoke. Position the lift yoke over the transfer cask and engage the lift yoke to the two transfer cask trunnions.

   Note: The temperature of the transfer cask (surrounding ambient air temperature) must be verified to be at or above the minimum operating temperature of 0°F, per Appendix 12.B, Section B 3.4.8 of the Technical Specifications.

6. Lift the transfer cask containing the empty TSC and move it into position above the fuel pool following the prescribed load path.

Note: A protective cover, attached to the bottom of the transfer cask, may be used to prevent imbedding contaminated particles in the shield doors and door rails.

7. Connect the clean water lines to the lower annulus fill ports of the transfer cask. Ensure that the unused ports are closed or capped to prevent pool water in-leakage.

8. Lower the transfer cask to the pool surface and turn on the clean water supply lines to the lower annulus fill ports to fill the transfer cask/TSC annulus.

9. If desired, spray the transfer cask and lift yoke with clean water to wet the exposed surfaces.

   Note: Wetting the components that enter the fuel pool and spraying the components leaving the pool will reduce the effort required to decontaminate the components.

10. Lower the transfer cask as the annulus fills with clean water until the upper annulus fill ports are accessible. Hold this position and connect the clean water annulus fill lines to the upper fill ports. Ensure the unused ports are closed or capped to prevent pool water in-leakage.

11. Lower the transfer cask to the bottom of the pool in the cask loading area.

12. Disengage the lift yoke, visually verify that the lift yoke is fully disengaged and remove it from the pool.

13. Load the previously selected fuel assemblies or DFCs containing damaged fuel assemblies, damaged fuel rods or fuel debris into the TSC basket.

    Note: The fuel assemblies shall be selected in compliance with the requirements of the approved contents specified in Appendix 12.B of the Technical Specifications including limitations on fuel assembly and DFC positions within the basket. Assembly selection and placement within the basket shall be independently verified.

14. Visually verify the fuel assembly identification prior to loading into the TSC to confirm the serial numbers match the approved fuel-loading pattern.

    Note: For DFC contents, the verification shall be performed prior to installing the DFC lid.

15. Install three swivel hoist rings hand tight in three of the six TSC closure lid lift holes. Connect a three-legged sling set to the hoist rings and the crane hook.

16. Raise the closure lid and adjust closure lid rigging to level the closure lid.

17. Move the closure lid over the fuel pool and align the lift yoke (if used) to the transfer cask trunnions and align the closure lid to the match marks of the TSC.

18. Lower the closure lid until it enters the TSC and seats in the top of the TSC. Visually verify closure lid alignment using the match marks.
19. Allow lid sling cables to go slack and disengage lift slings from the crane hook.
20. Install lift yoke to the crane hook, lower the lift yoke into the fuel pool and move the lift yoke into position to engage the transfer cask trunnions. Actuate the lift yoke arms and engage the lift yoke to the trunnions. Apply a slight tension to the yoke and visually verify engagement of the arm to the trunnions.
21. Raise the transfer cask and visually verify that the closure lid is properly seated. Rinse and flush the lift yoke, transfer cask and top of TSC with clean water as the equipment is removed from the pool. Survey the top of the TSC closure lid and the top of the transfer cask to check for radioactive particles.
22. As the transfer cask is removed from the fuel pool, terminate the annulus fill water supply, remove the annulus fill system hoses and allow annulus water to drain into the fuel pool.
23. Following the prescribed load path, move the transfer cask to the designated workstation for TSC closure operations.
24. Disengage the three-legged sling set from the closure lid and the lift yoke from the transfer cask trunnions. Place lift yoke and sling set in storage/lay-down area.
25. Detorque and remove the lifting hoist rings from the closure lid.
26. Using a portable suction pump, remove any standing water from the closure lid weld groove, and the vent and drain ports.
27. Decontaminate the top of the transfer cask and TSC closure lid to allow installation of the welding equipment. Decontaminate external surfaces of the transfer cask.
28. Insert the drain line with a female quick-connector attached to the drain line male quick disconnect nipple through the drain port opening and into the basket drain port sleeve. After insertion, disconnect the female quick-disconnect from the drain port quick disconnect, and remove any contaminated water displaced from the cavity.
29. Torque the drain tube connector to the drain opening to the value specified in Table 8.A.1-2. Confirm the vent port male quick disconnect nipple is properly installed and torqued in the vent port opening.
30. Install a venting device (e.g., hose line) to the vent port quick-disconnect to prevent combustible gas or pressure buildup below the closure lid.

31. Verify that the top of the closure lid is level (flush) with, or slightly above (< 0.25 inch), the top of the TSC shell.

32. At the discretion of the user, establish foreign material exclusion controls to prevent objects from being dropped into the annulus or TSC.

33. Install the welding system, including supplemental shielding if used, to the top of the closure lid.

    Note: At the discretion of the user, supplemental shielding may be installed around the transfer cask to reduce operator dose. Use of supplemental shielding shall be evaluated to ensure its use does not adversely affect the safety performance of the MPC-LACBWR system.

34. Connect a suction pump to the drain port quick-disconnect and verify venting through the vent port quick-disconnect.

35. Operate the suction pump to remove approximately 50 gallons of water from the TSC. Disconnect the suction pump.

    Note: The radiation level may increase as water is removed from the TSC cavity.

    Note: Fuel rods shall not be exposed to air during the 50-gallon pump-down.

36. Attach a hydrogen detector to the vent line. Ensure that the vent line does not interfere with the operation of the weld machine.

37. Sample the gas volume below the closure lid and observe hydrogen detector for H_2 concentration prior to commencing closure lid welding operations. Monitor H_2 concentration in the TSC until the closure lid-to-shell weld root pass is completed.

    Note: If H_2 concentration exceeds 2.4% prior to or during root pass welding operations, immediately stop welding operations. Evacuate the TSC gas volume or purge the gas volume with helium or argon. Verify H_2 levels are <2.4% prior to restarting welding operations.

38. Install shims into the closure lid-to-TSC shell gap, as necessary, to establish a uniform gap for welding. Tack weld the closure lid and shims, as required.

39. Operate the welding equipment to complete the closure lid-to-TSC shell root pass weld in accordance with the approved weld procedure.

40. At the completion of the root pass, discontinue use of the hydrogen detector. Leave the connector and vent tube installed to vent the canister.

Caution: It is necessary to continue to vent the cavity volume below the closure lid to ensure that there is no buildup of hydrogen gas until the completion of closure lid welding.

41. Perform visual and liquid penetrant (PT) examinations of the root pass and record the results.

42. Operate the welding equipment to perform the closure lid-to-shell weld to the midplane between the root and final weld surfaces. Perform visual and PT examinations for the midplane weld pass and record the results.

43. Complete welding through the completion of the final pass of the closure lid weld, perform final visual and PT examinations, and record the results.

44. Perform the hydrostatic test of the TSC as follows:

    a. Connect a drain line to the vent port and a pressure test system to the drain port.

    b. Refill the TSC with clean water until water is observed flowing from the vent port drain line. Close the vent line isolation valve.

    c. Pressurize the TSC to 15 (+2, -0) psig and isolate the TSC.

    d. Maintain the TSC test pressure for a minimum 10-minute hold period. At the end of the 10-minute hold period, visually examine the closure lid-to-TSC shell weld for water leakage, while maintaining the test pressure. The test pressure shall be maintained until the completion of the visual inspection of the closure lid-to-TSC shell weld is completed.

    e. The hydrostatic test is acceptable if there is no visible water leakage from the closure lid-to-TSC shell weld based on visual examination of the weld after a minimum 10-minute hold period, while maintaining the test pressure.

    f. Vent the TSC cavity and remove the pressure test system from the drain port and the drain line from the vent line. Reinstall a vent line to the vent port to prevent pressurization of the TSC.

45. Install and tack the closure ring in position in the closure lid-to-TSC shell weld groove.

46. Weld the closure ring to the TSC shell and to the closure lid. Perform visual and PT examinations of the final surfaces of the welds and record the results.

47. Remove the water from the TSC using one of the following methods: a) drain down using a suction pump supplemented with pressurized helium cover gas; or b) blow down using pressurized helium gas.

    Note: Fuel rods shall not be exposed to air during canister draining operations.

48. Connect a drain line with or without suction pump to the drain port connector.

49. Connect a regulated helium gas supply to the vent port connector.

50. Open gas supply valve and start suction pump, if used, and drain water from the TSC until water ceases to flow out of the drain line. Close gas supply valve and stop suction pump.

51. At the option of the user, disconnect suction pump, close discharge line isolation valve, and open helium gas supply line. Pressurize TSC to approximately 10 psig and open discharge line isolation valve to blow down the TSC. Repeat blow down operations until no significant water flows out of the drain line.

52. Disconnect the drain line and gas supply line from the drain and vent port quick-disconnects.

53. Dry the TSC cavity using vacuum drying methods as follows.

    Note: The low maximum decay heat load of the MPC-LACBWR system precludes the need to monitor total vacuum drying times (LCO 3.1.1 provides for unlimited vacuum drying time) in order to maintain the fuel clad temperatures below 806°F.

    Note: At the option of the user, the drain and/or vent port quick-disconnects can be removed and replaced temporarily with suitable straight-through fittings to increase flow area cross-section and to reduce resistance to gas flow. The quick-disconnect fittings must be reinstalled and torqued prior to final helium backfill.

    a. Connect the vacuum drying system to the vent and drain port openings.

    b. Operate the vacuum pump until a vapor pressure of < 10 torr is achieved in the TSC. The time duration for vacuum drying per LCO 3.1.1 is unlimited.

    c. Isolate the vacuum pump from the TSC and turn off the vacuum pump. Observe the vacuum gauge connected to the TSC for an increase in pressure for a minimum period of 10 minutes. If the TSC pressure is ≤ 10 torr at the end of 10 minutes, the TSC is considered dry in accordance with LCO 3.1.2.

54. Upon satisfactory completion of the dryness verification, continue to evacuate the TSC cavity to a pressure of ≤ 3 torr. Isolate the vacuum pump and backfill the TSC cavity with 99.995% (minimum) pure helium to 15 (+2,-0) psia per LCO 3.1.3.

    Note: This Step 55 through Step 18 (of the concrete cask loading procedure, Section 8.A.1.2) must be completed within 25 days in accordance with LCO 3.1.4.

55. Disconnect the vacuum drying helium backfill system from the vent and drain openings. Note the time the helium backfill is completed.

56. Install and weld the inner port cover on the drain port opening.

57. Install and weld the inner port cover on the vent port opening.
    Note: At the option of the user, the port cavity may be backfilled with helium during placement of the weld (see steps 56 and 57) to establish a trace gas for the step 59 leak test of the inner port cover welds.
58. Perform visual and PT examinations of the final surface of the port cover welds and record the results.
59. Perform helium leak test on each of the inner port cover welds to verify the absence of helium leakage past the inner port cover welds.
60. Install and weld the outer port cover on the drain port opening. Perform visual and PT examinations of the final weld surface and record the results.
61. Install and weld the outer port cover on the vent port opening. Perform visual and PT examinations of the final weld surface and record the results.
62. Remove the weld machine and supplemental shielding if used.
63. Install the transfer cask retaining ring.
64. Install the six swivel hoist rings into the six threaded holes in the closure lid and torque the hoist rings to the value specified in Table 8.A.1-2.
65. Complete final decontamination of the transfer cask exterior surfaces. Perform final TSC canister exterior surface contamination surveys in accordance with LCO 3.2.1.
66. Proceed to Section 8.A.1.2.

8.A.1.2 Transferring the TSC to the Concrete Cask

This loading procedure section assumes that the concrete cask is located on the bed of a heavy-haul trailer sitting on a deflated air pad set under the site-approved crane, the concrete cask lid is not in place and the bottom pedestal plate cover is installed. The hydraulic jacks of the trailer are extended, as appropriate.

1. Using a site-approved crane, place the transfer adapter on the top of the concrete cask.
2. Align the transfer adapter to the concrete cask, and at the option of the user, bolt the adapter to the concrete cask using four (4) socket head cap screws.
3. Connect the hydraulic actuation system to the transfer adapter and verify that the shield door connectors on the adapter plate are in the fully extended position.
4. If not already completed, attach the transfer cask lifting yoke to the site-approved crane. Verify that the transfer cask retaining ring is installed.

5. Install six (6) swivel hoist rings in the TSC closure lid. Verify that the hoist ring threads are fully engaged, and attach two (2) three-legged slings. Stack the slings on the top of the TSC so they are available for use in lowering the TSC into the concrete cask.

6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.

   Note: The minimum temperature of the surrounding air must be verified to be higher than 0°F prior to lifting in accordance with Appendix 12.B, Section B 3.4.8 of the Technical Specifications.

7. Raise the transfer cask and move it to a position above the concrete cask and transfer adapter. Lower the transfer cask, ensuring that the shield door rails and connector tees align with the transfer adapter plate rails and door connectors. Prior to final set-down, remove transfer cask shield door lock bolts/lock pins.

8. Ensure that the shield door connector tees are engaged with the adapter plate door connectors.

9. Disengage the transfer cask lift yoke from the transfer cask.

10. Return the cask site-approved crane hook to the top of the transfer cask and engage the two (2) three-legged slings attached to the TSC. Lift the TSC slightly (approximately 1/2 inch) to take the canister weight off of the transfer cask shield doors.

11. Using the hydraulic system, open the shield doors to access the concrete cask cavity.

12. Lower the TSC into the concrete cask, using a slow crane speed as the TSC nears the bottom of the concrete cask.

13. Disconnect the slings from the crane hook and lower them to the top of the TSC. Close the transfer cask bottom doors.

14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.

15. Lift the transfer cask off the concrete cask and return it to the decontamination area or designated workstation.

16. Using the site-approved crane, remove the adapter plate from the top of the concrete cask.

17. Remove the swivel hoist rings, slings, and other lifting equipment from the TSC closure lid and install lid hole plugs hand-tight.

18. Using the site-approved crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask and secure using the concrete cask lid bolts. Record the time the concrete cask lid is secured. The total time from 8.A.1.1, Step 56 through 8.A.1.2, Step 18 shall be less than 25 days in accordance with LCO 3.1.4.
19. Ensure that there is no foreign material left at the top of the concrete cask.
20. Retract the trailer hydraulic jacks and tow the heavy-haul trailer containing the loaded concrete cask to the ISFSI.

8.A.1.3 Transporting and Placing the Loaded Concrete Cask

This section of the procedure assumes that the loaded concrete cask is positioned on a heavy-haul trailer.

1. Using a suitable towing vehicle, tow the heavy-haul trailer to the ISFSI storage pad. Position the trailer bed adjacent to the storage pad and verify that the bed of the trailer is approximately at the same height as the pad surface.
2. Lower trailer hydraulic jacks to provide trailer stability.
3. Install bridging plates to cover the gap between the trailer bed and pad surface.
4. Connect air compressor lines to the air pad set control box and start air compressor.
5. Connect appropriate towing/pushing vehicle to the concrete cask to move and restrain the concrete cask.
6. Inflate the air pad set.
7. Move the concrete cask from the bed of the transporter to the designated location on the storage pad.
8. Deflate air pads by turning off the air supply.
9. Install a hydraulic jack in each inlet vent and raise the concrete cask approximately 4 inches.

   Caution: Do not exceed a maximum lift height of 6 inches.
10. Remove the air pads. Ensure that the surface of the storage pad under the cask is free of foreign objects.
11. Lower the concrete cask to the surface.

    Note: Ensure that the centerline spacing between concrete casks is 15 feet minimum.

12. Remove the four (4) hydraulic jacks.
13. Install screens on the inlets and outlets.
14. Install/connect the temperature monitoring equipment, if required, and verify operation.
15. Scribe/stamp the concrete cask name plate to indicate loading date.
16. Perform radiological survey of the concrete cask within the ISFSI array to confirm the concrete dose rates comply with LCO 3.2.2 dose rate limits.
17. Verify operability of the concrete cask heat removal system in accordance with LCO 3.1.6.

Table 8.A.1-1 Major MPC-LACBWR Ancillary Equipment

Item	Description
Air Pad Rig Set	A device consisting of four air pads, a controller, and an air supply source that lifts the concrete cask using air supplied at a high volume.
Annulus Fill System	System that supplies clean/filtered fuel pool water through the transfer cask/TSC annulus using the lower and upper transfer cask fill lines. The system maintains a positive clean water flow to minimize the exposure of the TSC external surfaces to contaminated fuel pool water.
Bottom Protective Cover	Optional plate temporarily attached to the base of the transfer cask to prevent particulate contamination of the transfer cask shield doors and rails.
Canister Upender	Lifting device used to upright a TSC from the horizontal position to a vertical orientation to allow vertical handling for placing the TSC in the transfer cask.
Cask Transporter	A heavy-haul trailer used onsite to move the concrete cask. The loaded concrete cask is transported vertically resting on its base.
Closure Lid Lifting Sling System	Sling system used to install the closure lid into the TSC in the fuel pool. At the user's option, the sling system can be suspended from the lift yoke and used to install the lid and engage the yoke with one crane sequence.
Cooldown System (CDS)	Gas and water system used to cool down the TSC internals and stored fuel to allow the return of the TSC to the fuel pool for the unloading of the fuel assemblies. This system would only be required in the highly unlikely event that a loaded TSC had to be unloaded.
Drain and Blow Down System (DBS)	System used to pump out and/or blow down the water from the TSC cavity prior to the start of drying operations, and to refill the cavity and hydrostatic test the closure lid weld. The system includes the appropriate suction pump, piping/hoses, helium cover gas supply, pressure gauges, and valves to connect to the TSC vent and drain port connections to complete the draining and hydrostatic testing of the cavity.

Table 8.A.1-1 Major MPC-LACBWR Ancillary Equipment (continued)

Item	Description
Hydrogen Detection System	System that detects increased concentration of H_2 in the cavity resulting from material reactions during closure lid welding operations and for closure lid weld removal operations.
Helium Mass Spectrometer Leak Detector (MSLD)	A system utilized to perform the helium leakage testing of the inner vent and drain port cover welds.
Lift Yoke	Device for lifting and moving the transfer cask by engaging the lifting trunnions.
Loaded TSC Sling System	Redundant sling system (two 3-legged slings) used to transfer a TSC into a concrete cask or a transfer cask and meeting the requirements of ANSI N14.6.
Remote/Robotic Welding System	System that completes the closure lid and port cover welds with minimal operator assistance. The system may include video cameras and a recording device to remotely observe the welding activities and to videotape the results of the closure lid PT examinations.
Supplemental Weld Shield	Optional steel plate installed on the closure lid to provide additional shielding to the cask operators during TSC welding, preparation, and test activities. The supplemental weld shield may be installed separately or as the base plate for the welding system.
Vacuum Drying and Helium Backfill System	The system used to vaporize and remove residual water, water vapor, and oxidizing gases from the TSC cavity prior to backfilling with helium. The system includes the appropriate vacuum pump(s), vacuum and pressure gauges, helium supply connections and valves, and hoses to connect the system to the vent and drain connections.
Weld Removal System	Semiautomatic mechanical weld and/or TSC shell cutting system used to remove the closure lid and port cover welds in the unlikely event that a TSC needs to be unloaded.

Table 8.A.1-2 Threaded Component Torque Values

Threaded Component	Torque Value (ft-lb)
Concrete Cask Lid Bolts	Snug + 1 wrench flat
Closure Lid Lifting Hoist Rings	
• Lid Handling Only	Hand Tight
• Loaded TSC Handling	Per hoist ring manufacturer's recommendation
Drain Tube Connector	
• Viton, EDPM, or Elastomer Seal	Per seal manufacturer's specs
• Metallic Seal	Per seal manufacturer's specs
Vent Port Connector	
• Viton, EDPM, or Elastomer Seal	Per seal manufacturer's specs
• Metallic Seal	Per seal manufacturer's specs
Concrete Cask Lid Lifting Hoist Rings	Hand Tight

8.A.2 Removal of the Loaded MPC-LACBWR Transportable Storage Canister from the Vertical Concrete Cask

This procedure assumes the loaded concrete cask is returned to the reactor loading facility for unloading. However, transfer of the TSC to another concrete cask can be performed at the ISFSI without the need to return to the loading facility, provided a canister handling cask transfer facility that meets the requirements specified in the Technical Specifications is available.

As the steps to move a loaded concrete cask are essentially the reverse of the procedures in Section 8.A.1.3 and Section 8.A.1.2, the procedural steps are only summarized here.

1. Remove inlet and outlet screens and temperature measuring equipment (if installed).
2. Move the loaded concrete cask to the handling facility.
3. Remove the concrete cask lid.
4. Install the six hoist rings into the canister closure lid threaded holes.
5. Install transfer adapter on top of the concrete cask.
6. Note: The minimum ambient air temperature (either in the facility or external air temperature, as applicable for the handling sequence) must be ≥0°F for the use of the transfer cask, per Appendix 12.B, Section B 3.4.8 of the Technical Specifications.
7. Place transfer cask onto the transfer adapter and engage the shield door connectors.
8. Open the shield doors, retrieve the lifting slings, and install the slings on the lifting system.
9. Slowly withdraw the TSC from the concrete cask. The chamfer on the underside of the transfer adapter assists in the alignment into the transfer cask.
10. Bring the TSC up to just below the retaining ring. Close the transfer cask shield doors and install the shield door lock pins.
11. Lift transfer cask off the concrete cask and move to the designated workstation.

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8.A.3 Wet Unloading the MPC-LACBWR Transportable Storage Canister

This section provides the basic operational sequence to prepare, open and unload a TSC in a spent fuel pool. Due to the rugged design and fabrication of the TSC, users are not expected to perform this operational sequence. However, in accordance with the LCO 3.1.7 of the Technical Specifications, each user shall have the procedures and required equipment available, and perform a dry run of the unloading process.

The procedure that follows assumes that the TSC is in a transfer cask in the appropriate workstation.

1. Remove the retaining ring from the transfer cask.
2. Survey the TSC and transfer cask to establish radiation areas.
3. Install the weld removal system on the closure lid and bolt the system to the closure lid threaded holes.
4. Establish appropriate airborne radiation controls.
5. Using the weld removal system, remove the outer and inner port covers from the vent and drain ports.
6. Remove the weld removal system.
7. Using a vacuum sample bottle, take a gas sample of cavity gas.
8. Determine total gaseous inventory and connect a venting system to the vent connector and route to HEPA filters or to the off-gas system.
9. Determine TSC internal pressure and vent the cavity gas.
10. Once pressure has been reduced to atmospheric, and using appropriate radiological controls, remove the vent and drain quick-disconnects and seals.
11. Replace the quick-connects and seals with approved spares, and torque them to the value specified in Table 8.A.1-2.
12. Attach the cooldown system to the vent and drain connections.
13. Initiate nitrogen gas flow through the TSC to flush out residual radioactive gases. Continue nitrogen flow for a minimum of 10 minutes.
14. Initiate the controlled filling (5 +3/-0 gpm) of the TSC with clean or pool water through the drain connector under controlled temperature (minimum 70°F) and pressure conditions (25 +10/-0 psig). Limit maximum outlet to < 50 psig.
15. Monitor gassteam/water temperature of the discharge from the vent connection.
16. Continue cooldown operations until the discharge water temperature is below 200°F.

17. Terminate cooling water flow and disconnect the cooldown system from the drain and vent ports. Install a vent line to the vent port.
18. Connect a suction pump to the drain connector. Operate the pump and remove approximately 50 gallons of water from the cavity. Disconnect and remove the pump.
19. Remove the drain line from the closure lid.
20. Install the hydrogen detector to the vent line and verify hydrogen gas concentration in the gas volume in the cavity. If the concentration reaches 2.4%, stop all cutting activities and remove cavity gas using a vacuum pump.
21. Install the weld removal system on the closure lid. Operate the weld removal system to remove the closure ring-to-TSC shell and closure ring-to-closure lid welds. Remove the closure ring from the lid area.
22. Operate the weld removal system to remove the closure lid-to-shell weld.
23. Remove shims, if installed, to provide a suitable gap to be able to extract the closure lid under water.
24. Remove the weld removal system.
25. Install three swivel hoist rings into the closure lid threaded holes. Attach three-legged sling set to the hoist rings and the lifting system (or, alternately, the transfer cask lifting yoke).
26. Engage the lift yoke to the transfer cask trunnions and bring the transfer cask over the spent fuel pool.
27. Install lower annulus fill lines and fill the annulus with clean water while lowering the transfer cask.
28. When the trunnions are near the pool surface, install upper annulus fill lines and start clean water flow.
29. Lower the transfer cask to the bottom of the pool. Disengage the lift yoke.
30. Slowly remove the closure lid and move the lid to an appropriate storage area.
    Note: The closure lid may be contaminated and slightly activated.
31. Unload the fuel assemblies and DFCs from the MPC-LACBWR basket.
32. Following fuel unloading, reengage the lift yoke to the transfer cask trunnions and remove the transfer cask from the pool.
33. While the transfer cask is over the pool, stop the flow of water to the annulus, disconnect the upper and lower fill lines, and allow the water in the annulus to drain back into the pool.
34. Place transfer cask and empty TSC in the cask decontamination area or other workstation.
35. Using a suction pump, remove the water from the TSC and pump to radioactive waste drains or return the water to the spent fuel pool designated plant location.

36. Remove and store the contaminated TSC until a determination is made regarding reuse or disposition of the closure lid and TSC.
37. As appropriate, the user may proceed with the loading of the removed fuel assemblies in a new TSC in accordance with the procedures in Section 8.A.1.

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9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

The NAC-MPC storage system is provided in three configurations. The Yankee-MPC designed for the safe storage of Yankee Class spent fuel, the CY-MPC designed for the safe storage of Connecticut Yankee spent fuel, and the MPC-LACBWR designed for the safe storage of Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel. These three configurations of the NAC-MPC differ in principal dimensions and basket design to accommodate the respective fuel designs and characteristics.

The acceptance tests and maintenance program for the Yankee-MPC and the CY-MPC are addressed in the main body of Chapter 9. The acceptance tests and maintenance program for MPC-LACBWR are presented in Appendix 9.A.

The acceptance criteria and the maintenance program for the NAC-MPC Storage System primary components – the vertical concrete cask (storage cask), transfer cask and the transportable storage canister (canister) – described in this chapter are applicable to both configurations. The design of the NAC-MPC system requires shop fabrication of the canister shell with the bottom plate, the shield and structural lids for the canister, and the basket that holds the spent fuel. The storage cask consists of reinforced concrete placed around steel components that are integral to the performance of the storage cask. These steel components include: a liner that forms the central cavity of the storage cask, a set of air outlet passage-ways that allow cooling to the stored canister, a shield plug, a steel closure lid, and a steel base. The base includes the air inlets and associated pathways, it provides a pedestal upon which the canister rests, and it provides a structural support for raising the storage cask. The steel components are shop fabricated. The reinforcing steel will be fabricated in accordance with ACI 318-95. The storage cask construction will include the erection of the cask liner onto the steel base. The concrete is placed around the liner after the reinforcing steel has been properly erected.

As described in Chapter 8, the storage cask is designed to be lifted using hydraulic jacks and moved using air pads under the base. It does not have lifting trunnions.

9.1 Acceptance Tests

The acceptance tests ensure that the storage cask and canister are fabricated, assembled, inspected and tested in accordance with the requirements of this Safety Analysis Report and the license drawings.

9.1.1 Visual and Nondestructive Examination Inspections

The acceptance test program establishes a set of visual inspections and nondestructive examination or test requirements for the fabrication and assembly of the storage cask and canister. Satisfactory results for these inspections, examinations and tests demonstrate that the components comply with the requirements of the Safety Analysis Report and the license drawings, and the initial operation of the storage system complies with regulatory requirements.

A fit-up test of the canister and its components is performed during the acceptance inspection. The fit-up test demonstrates that the canister, basket, shield lid and structural lid can be properly assembled during fuel loading and canister closure operations.

A visual inspection is performed on all materials and welds used for storage cask, canister and basket fabrication. The visual inspection applies to finished surfaces of the components. All welds (shop and field installed) are visually inspected for defects prior to the nondestructive examinations that are specified. The welding of the canister is performed in accordance with ASME Code, Section III, Subsection NB-4000, except as described in Section 7.1.3 and Table B3-1 of the Certificate of Compliance.

The visual inspections of the canister welds are performed in accordance with the ASME Code Section V, Article 9. Acceptance criteria for the visual examinations of the canister welds are in accordance with ASME Code Section III, NB-4424, NB-4426 and NB-4427. Required weld repairs on the canister are performed in accordance with ASME Code Section III, NB-4450, and are reexamined in accordance with the original acceptance criteria.

The visual inspection of the storage cask steel component welds, including field welds, will be performed in accordance with ASME Code Section VIII, Division 1, UW-35 and UW-36 or ANSI/AWS D1.1, Table 6.1. Weld procedures and welder qualifications shall be in accordance with ANSI/AWS D1.1, Section 5, or ASME Code Section IX.

Fabrication of the spent fuel basket assemblies, the Yankee-MPC damaged fuel can, the CY-MPC reconfigured fuel assembly and the CY-MPC damaged fuel can is performed in accordance with ASME Code Section III, NG-4000. Visual examination of the welds is performed per the requirements of ASME Code Section V, Article 9. Acceptance criteria for the visual examination of the basket assembly welds are that of ASME Code Section III, Subsection NG-5360. Any required weld repairs are performed in accordance with ASME Code Section III, NG-4450 and are re-examined in accordance with the original acceptance criteria.

Qualified personnel perform all visual inspections according to written and approved procedures. The results of all visual weld inspections are recorded.

9.1.1.1 Nondestructive Weld Examination

All of the welds of the canister assembly are nondestructively examined in addition to the visual examination previously described. In accordance with the ASME Code Section III, Subsection NB, requirements for confinement vessels, the canister shell welds are volumetrically examined by radiography (RT) in accordance with the ASME Code Section V, Article 2, with acceptance criteria in accordance with ASME Code Section III, NB-5320. The weld that joins the bottom plate to the canister shell is ultrasonically (UT) examined per ASME Code Section V, Article 5, with acceptance criteria in accordance with ASME Code Section III, NB-5330. The finished surface of the canister shell and bottom plate welds are liquid penetrant examined in accordance with ASME Code Section V, Article 6, with acceptance in accordance with ASME Code Section III, NB-5350. The shield lid to canister shell weld and the structural lid to shell weld, as well as the vent and drain port covers to shield lid welds, are field welds that are performed after the canister is loaded. The root and final passes of the shield lid to canister shell weld are liquid penetrant (PT) examined per ASME Code, Section V, Article 6. The acceptance criteria are in accordance with ASME Code, Section III, NB-5350. The canister vent port cover and drain port cover to shield lid welds are liquid penetrant examined (i.e., root and final surfaces for multipass welds or final surface only for welds completed in a single pass), in accordance with ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, NB-5350. The canister structural lid to canister shell weld is either: 1) ultrasonically (UT) examined in accordance with ASME Code Section V, Article 5, with the final weld surface liquid penetrant examined in accordance with ASME Code Section V, Article 6; or 2) progressively liquid penetrant examined in accordance with the ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, NB-5330 (ultrasonic) and NB-5350 (liquid penetrant).

The welds of the spent fuel basket assemblies, the Yankee-MPC damaged fuel can, the CY-MPC reconfigured fuel assembly, and the CY-MPC damaged fuel can are liquid penetrant examined in accordance with ASME Code Section V, Article 6. The acceptance criteria are in accordance with ASME Code Section III, NG-5350.

All welding of canister and basket components is performed using procedures and welders qualified in accordance with the ASME Code Section IX. Welding of the fabricated steel components of the concrete cask is performed using procedures and welders qualified in accordance with AWS D1.1-96 or ASME Code Section IX..

9.1.1.2 Fabrication Inspections

Materials used in the fabrication of the NAC-MPC storage cask and canister are procured with certifications and supporting documentation, as necessary, to assure compliance with procurement specifications. All materials are receipt inspected for appropriate acceptance requirements and for traceability to required material certification.

The canister assembly is fabricated to the requirements of ASME Code Section III, Subsection NB. Specific alternatives to the ASME Code are listed in Table B3-1 of the Certificate of Compliance. The basket assemblies, Yankee-MPC damaged fuel can, CY-MPC reconfigured fuel assembly, and CY-MPC damaged fuel can are fabricated to ASME Code Section III, Subsection NG.

A complete dimensional inspection of all critical components and a components fit-up test is performed on the canister assembly to ensure proper assembly in the field. Acceptance criteria for dimensions shall conform to the license drawings.

Concrete strength and density shall be field verified to American Concrete Institute (ACI) and American Society for Testing and Materials (ASTM) standards to ensure adequacy. Reinforcing steel is installed per specification requirements based on ACI 318.

On completion of fabrication, the canister, basket, and other shop fabricated components shall be inspected for cleanliness. All components shall be free of any foreign material, oil, grease and solvents. Carbon steel components assembled for the storage cask shall be coated with a corrosion-resistant paint as specified on the license drawings.

9.1.2 Structural and Pressure Tests

The canister is pressure tested at the time of use. After loading of the canister basket with spent fuel, the shield lid is welded in place. Approximately 50 gallons of water are removed from the Yankee-MPC canister or 65 gallons are removed from the CY-MPC canister. Prior to removing the remaining spent fuel pool water from the canister, the Yankee-MPC canister is pressure tested at 15 psig and the CY-MPC canister is tested at 20 psig. This pressure is held for 10 minutes. Any loss of pressure during the test period is unacceptable, and the leak must be located and repaired. The pressure test is described in Section 8.1.

The transfer cask lifting trunnions and bottom shield doors shall be load tested in accordance with the requirements of ANSI N14.6, "Special Lifting Devices for Shipping Containers Weighing 10,000 pounds (4500 kg) or More" for nuclear materials.

The load tests shall consist of applying 300 percent of the maximum vertical loads for a minimum of 10 minutes to the lifting trunnions and bottom shield door components. The load tests will be performed in accordance with approved written procedures. The test conditions are:

NAC-MPC System	Transfer Cask Shield Doors		Transfer Cask Trunnions	
	Canister Weight (lbs)	Test Load (lbs)	Loaded Cask Weight (lbs)	Test Load (lbs)
Yankee-MPC	62,270	186,810 (+5%, -0%)	143,013	429,040 (+5%, -0%)
CY-MPC	76,324	228,970 (+5%, -0%)	183,218	549,660 (+5%, -0%)

Following completion of the lifting trunnion load tests, all trunnion welds and all load bearing on accessible trunnion and shield door rail load bearing welds in accordance with ASME Code Section V, Articles 1, 6 and/or 7, with acceptance in accordance with ASME Code Section III, NF-5340 or NF-5350, as applicable.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant or magnetic particle examination results shall be cause for rejection of the affected component.

The first Yankee-MPC damaged fuel can is load tested at a minimum of 1,650 pounds to qualify the can design. The test load is calculated as 150% of the weight of the heaviest Yankee class fuel assembly (950 pounds) plus the weight of the damaged fuel can (150 pounds). The test weight is held for 10 minutes. Following completion of the load test, all welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Load bearing welds shall be inspected using liquid penetrant examination in accordance with the ASME Code Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code Section III, NG-5350.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant results shall be cause for rejection of the can and of the design. The first damaged fuel can of a revised design must also be load tested in accordance with this section.

The first CY-MPC reconfigured fuel assembly is load tested at the fabricator to 1,500 pounds to qualify the assembly design. The test weight is calculated as 150% of the weight of 100 fuel rods(600 pounds) plus the weight of the assembly (300 pounds), conservatively rounded to 1,000 pounds. The test load is held for a minimum of 10 minutes. Following completion of the load test, all welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Load bearing welds shall be inspected using liquid penetrant examination in accordance with the ASME Code Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code Section III, NG-5350.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant results shall be cause for rejection of the assembly and of the design. The first reconfigured fuel assembly of a revised design must also be load tested in accordance with this section.

The first CY-MPC damaged fuel can is load tested at the fabricator to 2,250 pounds to qualify the can design. The test load is calculated as 150% of the weight of the heaviest Connecticut Yankee fuel assembly (1,350 pounds) plus the weight of the damaged fuel can (150 pounds). The test weight is held for 10 minutes. Following completion of the load test, all welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Load bearing welds shall be inspected using liquid penetrant examination in accordance with the ASME Code Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code Section III, NG-5350.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant results shall be cause for rejection of the can and of the design. The first damaged fuel can of a revised design must also be load tested in accordance with this section.

9.1.3 Leak Tests

The canister is leak tested at the time of use. After the pressure test described in Section 9.1.2, the canister is drained of residual water, vacuum dried and backfilled with helium. The shield lid to canister shell weld is helium leak tested using a leak test fixture installed above the shield lid. The leaktight criterion of 2.0×10^{-7} cm^3/sec (helium) of ANSI N14.5-1997 is applied. The leak test is performed at a sensitivity of 1.0×10^{-7} cm^3/sec (helium). Any indication of a leak of 2.0 x 10^{-7} cm^3/sec (helium), or greater, is unacceptable and repair is required as appropriate. The leak test shall be repeated after any weld repair.

9.1.4 Component Tests

The components of the NAC-MPC do not require any special tests in addition to the material receipt, dimensional, and form and fit tests described above, or as described below.

9.1.4.1 Valves, Rupture Disks and Fluid Transport Devices

The NAC-MPC canister, storage cask, and transfer cask do not contain rupture disks or fluid transport devices. There are no valves that are part of the confinement boundary for transport or storage. Quick-disconnect valves are installed in the canister vent and drain ports of the shield lid. These valves are intended to be convenience items for the operator, as they provide a means of quickly connecting (or disconnecting) ancillary drain and vent lines to the canister. The quick-disconnect fittings consist of male and female halves. The male fitting is installed in the canister and the female fitting is used as the connecting piece. The male fitting automatically closes when the mating fitting is removed; however, no credit is taken for this sealing feature. During storage and transport, these fittings are not accessible, as port covers that are welded in place cover them when the canister is closed. As presented for storage, the canister has no accessible valves or fittings.

9.1.4.2 Gaskets

The NAC-MPC canister and concrete cask have no mechanical seals or gaskets that form an integral part of the package, and there are no mechanical seals or gaskets in the confinement boundary.

9.1.5 Shielding Tests

Based on the conservative design of the NAC-MPC storage cask for shielding criteria and the detailed construction requirements, no shielding tests of the concrete storage cask are required. However, shielding dose rates of loaded concrete casks are measured in accordance with LCO 3.2.2 of the Certificate of Compliance, to ensure that the average concrete cask surface dose rates do not exceed the design limits.

9.1.6 Neutron-Absorber Tests

Neutron absorber material (commercially available as BORAL®), in the form of sheets consisting of boron-carbide evenly dispersed within a matrix of aluminum and clad with aluminum, is used in the NAC-MPC transportable storage canister fuel baskets. BORAL® used in the Yankee-MPC and CY-MPC systems was manufactured by AAR Advanced Structures (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 to control the weight and to blend the powders were patented and proprietary processes of AAR and, subsequently, of Ceradyne Corporation of Chicoutimi (Quebec), Canada.

After manufacturing, test samples from each batch of BORAL® neutron absorber (poison) sheets shall be tested using wet chemistry or neutron absorption 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.

9.1.6.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 (95% probability and 95% confidence level) statistical confidence level in the neutron absorber sheet material

compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least 6 measurements (along the edges near each corner and the longitudinal centerline) on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each sheet of the first set of 100 sheets of absorber material. Thereafter, coupon samples are taken from 20 randomly selected sheets from each set of 100 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion), or a process change, at which time the sampling process is reinitiated as previously described. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

9.1.6.2 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.

9.1.6.3 Neutron Absorption Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests, if the neutron absorption test method is used. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a reduction of neutron flux between the thermalized neutron source and the neutron detector—depending on the material thickness and boron content.

Typical test equipment will consist of thermal neutron source equipment, a neutron detector and a counting instrument. The test equipment is calibrated using BORAL standards, whose ^{10}B content has been checked and verified by an independent method such as chemical analysis. The highest permissible counting rate is determined from the neutron counting rates of the reference sheet(s), which should be ground to the minimum allowable plate thickness. This calibration process shall be repeated daily (every 24 hours) while tests are being performed.

9.1.6.4 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings. The neutron absorption test shall be considered acceptable if the neutron count determined for each test specimen is less than or equal to the highest permissible neutron count rate determined from the BORAL standard, which is based on the ^{10}B areal density specified on the fuel tube drawings. Any specimen not meeting the acceptance criteria for either test method shall be rejected and all of the sheets from that batch shall be similarly rejected.

9.1.7 Thermal Tests

No thermal acceptance testing of the NAC-MPC system is required during construction. The continued operability of the concrete cask's heat removal system is verified by the performance of Surveillance 3.1.6.1 of Technical Specification LCO 3.1.6

9.1.8 Cask Identification

A stamped stainless steel nameplate, as shown on Drawing No. 455-856 for the Yankee-MPC and on Drawing No. 414-856 for the CY-MPC, and on Drawing No. 630045-864 for MPC-LACBWR, is permanently attached on the outer surface of the storage cask.

The nameplate includes the following information:

	Yankee-MPC	CY-MPC	MPC-LACBWR
Owner	(Utility Name)	(Utility Name)	(Utility Name)
Designer	NAC International	NAC International	NAC International
Fabricator	(Vendor Name)	(Vendor Name)	(Vendor Name)
Date of Manufacture	(mm/dd/yy)	(mm/dd/yy)	(mm/dd/yy)
Model Number	YR-MPC	CY-MPC	MPC-LACBWR
Cask Number	(XXX)	(XXXX)	(LACBWR-VCC-ZZ)
Date of Loading	(mm/dd/yy)	(mm/dd/yy)	(mm/dd/yy)
Empty Weight	(Pounds [kilograms])	(Pounds [kilograms])	N/A
Empty System Weight	N/A	N/A	(Pounds)

9.2 Maintenance Program

The NAC-MPC storage system is a passive system. There are no active components or systems incorporated in the design. Consequently, there is a minimal amount of maintenance that is required over its lifetime.

The system has no valves, gaskets, rupture discs or seals, and there are no accessible penetrations. Consequently, there is no maintenance associated with these types of features.

The routine thermal performance surveillance requirements for a loaded NAC-MPC system are described in the Technical Specifications of Appendix A, LCO 3.1.6 of the Certificate of Complianc.

The continuing operability of the concrete cask is verified on a 24-hour frequency by completion of SR 3.1.6.1, which allows verification by visual inspection of the inlet and outlet vents for blockage, or verification by measurement of the air temperature difference between ambient and outlet average. If the operable status of the concrete cask is reduced, the concrete cask will be returned to an operable status as specified in LCO 3.1.6.

Following an off-normal, accident or natural phenomena event, the user shall perform a Response Surveillance of the NAC-MPC systems in use at the ISFSI and take corrective actions, as required, in accordance with the requirements of Section A 5.3 of the Technical Specifications.

An annual inspection of the vertical concrete cask exterior is required, and includes:

- Visual inspection of concrete surfaces for chipping, spalling or other surface defects. Any defects larger than one inch in diameter (or width) and deeper than one inch shall be regrouted, according to the grout manufacturer's recommendations.

- Reapplication of corrosion-inhibiting (external) coatings on accessible surfaces.

9.3 References

ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NB, "Class 1 Components," 1995 Edition with 1995 Addenda.

ASME Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination," 1995 Edition with 1995 Addenda.

ASME Boiler and Pressure Vessel Code, Section VIII, Subsection B, Part UW, "Requirements for Pressure Vessels Fabricated by Welding," 1995 Edition with 1995 Addenda.

American Welding Society, Inc., "Structural Welding Code - Steel," AWS D1.1-96, 1996.

ASME Boiler and Pressure Vessel Code, Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," 1995 Edition with 1995 Addenda.

ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NG, "Core Support Structures," 1995 Edition with 1995 Addenda.

American Concrete Institute, "Building Code Requirements for Structural Concrete," ACI-318-95, October 1995.

American National Standards Institute, "Radioactive Materials - Special Lifting Devices for Shipping Containers Weighting 10,000 Pounds (4,500 kg) or More," ANSI N14.6-1993.

American National Standards Institute, "Leakage Tests on Packages for Shipment," ANSI N14.5-1997.

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Appendix 9.A ACCEPTANCE TESTS AND MAINTENANCE PROGRAM – MPC –LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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9.A ACCEPTANCE CRITERIA FOR THE MPC-LACBWR STORAGE SYSTEM

This Appendix provides the workmanship and acceptance tests to be performed on the MPC-LACBWR System components prior to and during loading operations and the continuing maintenance program requirements. These tests and inspections described herein provide assurance that the MPC-LACBWR components and systems have been procured, fabricated, assembled, inspected, tested and accepted for use under the conditions and controls specified in this document and the Certificate of Compliance.

The acceptance criteria and the maintenance program for the NAC-MPC storage system primary components – the vertical concrete cask (storage cask), transfer cask and the transportable storage canister (canister) – described in this Appendix to Chapter 9 are applicable to the MPC-LACBWR system. The design of the MPC-LACBWR system requires shop fabrication of the canister shell with the bottom plate, the closure lid and ring for the canister, and the basket that holds the spent fuel. The storage cask consists of reinforced concrete placed around steel components that are integral to the performance of the storage cask. These steel components include: a liner that forms the central cavity of the storage cask, a set of air outlet passage-ways that allows cooling to the stored canister, a steel and concrete lid, and a steel base weldment. The base weldment includes the air inlets and associated pathways and provides a pedestal upon which the canister rests. The weldment also provides structural support for the lifting of the storage cask using jacks or air pads. The steel components are shop fabricated. The reinforcing steel will be fabricated in accordance with ACI 318-95 [A7]. The storage cask construction will include the erection of the cask liner onto the steel base weldment. The concrete is placed around the liner after the reinforcing steel has been properly erected.

As described in Chapter 8, the storage cask is designed to be lifted using hydraulic jacks and moved using air pads under the base. It does not have lifting lugs.

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9.A.1 Visual Inspection and Nondestructive Examination

NAC-MPC fabrication, inspection and testing are performed in accordance with the applicable design criteria, codes and standards specified in Chapter 2, on the license drawings and in the Certificate of Compliance (CoC).

The following fabrication controls and inspections shall be performed on the MPC-LACBWR system components to ensure compliance with this document and the license drawings:

a) Materials of construction for the MPC-LACBWR system are identified on the license drawings and shall be procured with certification and supporting documentation as required by the ASME Code, Section II, when applicable, and the requirements of ASME Code, Section III, Subsection NB [A1] and Subsection NG [A6], when applicable.

b) Materials and components shall be receipt inspected for visual and dimensional acceptability, material conformance to the applicable Code specification and traceability markings, as applicable. Materials for the TSC confinement boundary (e.g., TSC shell plates, base plate, closure lid and port covers) shall also be inspected per the requirements of ASME Code, Section III, Subsection NB-2500.

c) The confinement boundary shall be fabricated and inspected in accordance with ASME Code, Section III, Subsection NB, with the code alternatives as listed in Table B3-1 of the Technical Specifications. The TSC fuel basket and basket supports shall be fabricated and inspected in accordance with the ASME Code, Section III, Subsection NG, with the alternatives listed in Table B.3-1 of the Technical Specifications in Appendix 12.B.

d) The steel components of the concrete cask shall be in accordance with ASTM specifications and fabricated in accordance with ASME Code, Section VIII (or fabrication may be in accordance with ANSI/AWS D1.1 [A4]). Inspections of the welded steel components of the concrete cask shall be in accordance with ASME Code, Section VIII or ANSI/AWS D1.1.

e) ASME Code welding shall be performed using welders and weld procedures qualified in accordance with ASME Code, Section IX [A5], and the ASME Code, Section III subsection applicable to the component (e.g., NB, NG or NF). ANSI/AWS code welding may be performed using welders and procedures qualified in accordance with the applicable AWS requirements or in accordance with ASME Code, Section IX.

f) Construction and inspections of the concrete component of the concrete cask shall be performed in accordance with the applicable sections and requirements of ACI-318 [A7].

g) Visual examinations of the welds of the confinement boundary shall be performed in accordance with ASME Code, Section V [A2], Articles 1 and 9, with acceptance per Section III, Subsection NF, Article NF-5360. The final surface of TSC shell welds shall be dye penetrant (PT) examined in accordance with ASME Code, Section V, Articles 1 and 6, with acceptance per Section III, Subsection NB, Article NB-5350. The TSC shell longitudinal and circumferential welds shall be radiographic (RT) examined in accordance with ASME Code, Section V, Articles 1 and 2, with acceptance per Section III, Subsection NB, Article NB-5320. The weld of the TSC baseplate to the TSC shell shall be ultrasonic (UT) examined in accordance with ASME Code, Section V, Articles 1 and 5, with acceptance per Section III, Subsection NB, Article NB-5330. In accordance with ISG-15 [A10], the TSC closure lid to shell weld, performed following fuel loading, shall be PT examined at the root, midplane and final surface in accordance with ASME Code, Section V, Articles 1 and 6, with acceptance per Section III, Subsection NB, Article NB-5350. The closure ring to TSC shell weld and the closure ring to closure lid weld shall be PT examined in accordance with the same code and acceptance criteria as the closure lid to TSC shell weld, except that only the weld final surface will be examined. The inner and outer (redundant) port covers to closure lid welds shall be PT examined at the final surface in accordance with the same code and acceptance criteria as for the closure lid to shell weld. Repairs to TSC vessel welds shall be performed in accordance with ASME Code, Section III, Subsection NB, Article NB-4450, and the welds reinspected per the original acceptance criteria applicable to the examination method.

h) Visual examinations of the welds of the fuel basket and basket supports shall be performed in accordance with ASME Code, Section V, Articles 1 and 9, with acceptance per Section III, Subsection NG, Article NG-5360. Repairs to fuel basket welds shall be performed in accordance with ASME Code, Section III, Subsection NG, Article NG-4450, and the welds reinspected per the original acceptance criteria applicable to the examination method.

i) Visual examinations of the concrete cask structural steel weldments shall be performed in accordance with the ASME Code, Section V, Articles 1 and 9, or ANS/AWS D1.1, Section 6.9, with acceptance per Section VIII, Division 1, Part UW [A3], Articles UW-35 and UW-36, or Table 6.1 of ANSI/AWS D1.1. Repairs to concrete cask structural

weldment welds shall be performed in accordance with ANSI/AWS D1.1, and the welds reinspected per the original acceptance criteria.

j) Dimensional inspections of components shall be performed in accordance with written and approved procedures to verify compliance to the license drawings and fit-up of individual components. All dimensional inspections and functional fit-up tests shall be documented.

k) All components shall be inspected for cleanliness and proper packaging for shipping in accordance with written and approved procedures. All components will be free of any foreign material, oil, grease and solvents.

l) Inspection and nondestructive examination personnel shall be qualified in accordance with the requirements of SNT-TC-1A [A11].

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9.A.2 Structural and Pressure Tests

9.A.2.1 Pressure Testing of the TSC

Following completion of the closure lid-to-TSC shell weld during the TSC preparation operations after fuel loading, the TSC shall be hydrostatically pressure tested in accordance with ASME Code, Section III, Subsection NB, NB-6000 requirements as described in operating procedures in Appendix 8A. The minimum test pressure of 15 psig shall be applied to the drain port connection for a minimum 10-minute hold period. The minimum test pressure is 125% of the normal design pressure of 12 psig. There shall be no visible water leakage from the closure lid-to-TSC shell weld based on visual examination of the weld after a minimum 10-minute hold period, while maintaining the test pressure. Test pressure shall be maintained until the completion of the visual weld examination.

9.A.2.2 Transfer Cask Structural Load Testing

The Yankee-MPC Transfer Cask will be utilized for the loading operations of the MPC-LACBWR system. Prior to delivery to the La Crosse BWR site, the Yankee Transfer Cask lifting trunnions and bottom shield doors will be load tested in accordance with the requirements of ANSI N14.6 "Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4500 kg) or More" [A8] for nuclear materials.

The load tests shall consist of applying 300 percent of the maximum vertical loads for a minimum of 10 minutes to the lifting trunnions and bottom shield door components. The load tests will be performed in accordance with approved written procedures. The bounding design load test conditions are:

	Transfer Cask Shield Doors		**Transfer Cask Trunnions**	
NAC-MPC System	**Design Load (lbs)**	**Test Load (lbs)**	**Design Load (lbs)**	**Test Load (lbs)**
MPC-LACBWR	65,000	195,000	150,000	450,000

Following completion of the lifting trunnion load tests, all trunnion welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Similarly, following completion of the bottom shield door load test, all door rail welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling and cracking. Magnetic particle or liquid penetrant examinations, using the method appropriate to the material, shall be performed on accessible trunnion and shield door rail load bearing welds in accordance with

ASME Code Section V, Articles 1, 6 and/or 7, with acceptance in accordance with ASME Code Section III, NF-5340 or NF-5350, as applicable.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant or magnetic particle examination results shall be cause for rejection of the affected component.

9.A.2.3 Damaged Fuel Can (DFC) Load Testing

The first MPC-LACBWR damaged fuel can (DFC) shall be load tested at the fabricator to 685 +50, -0 pounds to qualify the DFC design. The test load is calculated as 150% of the weight of the heaviest LACBWR fuel assembly (400 pounds) plus the weight of the damaged fuel can (55 pounds). The test load is applied and held for a minimum of 10 minutes. Following completion of the load test, all load bearing welds and surfaces shall be visually inspected for permanent deformation, galling or cracking. Load bearing welds shall be inspected using liquid penetrant examination in accordance with the ASME Code Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code Section III, NG-5350.

9.A.2.4 Leakage Tests

The MPC-LACBWR confinement boundary is defined as the TSC shell weldment, closure lid, and inner vent and drain port covers. As described in Appendix 7.A.1, the confinement boundary is designed, fabricated, examined and tested in accordance with the requirements of the ASME Code, Section III, Subsection NB, except for the code alternatives listed in Table B.3-1 of the Technical Specifications.

At the completion of the TSC shell weldment confinement boundary welds (e.g., TSC shell seam and shell to baseplate), the TSC shell weldment shall be leakage tested. The leakage test shall be performed in accordance with the requirements and approved methods of ASME Code, Section V, Article 10, and ANSI N14.5-1997 [A9] to confirm the total leakage rate is less than, or equal to, 1×10^{-7} ref. cm^3/s (i.e., leaktight). The sensitivity of the test shall be one-half of the acceptance test criteria as specified in ANSI N14.5-1997.

The TSC shell weldment will be closed using a test lid installed over the top of the shell and the cavity evacuated. A test envelope will be installed around the TSC enclosing all of the TSC shell confinement welds and filled with 99.995% (minimum) pure helium to an acceptable test

concentration. The percentage of helium gas in the test envelope shall be accounted for in the determination of the test sensitivity. A mass spectrometer leak detector (MSLD) will be used to sample the evacuated volume for helium.

If helium leakage is detected, the area of leakage shall be identified and repaired in accordance with the ASME Code, Section III, Subsection NB, NB-4450. Following repair, the complete helium leakage test shall be reperformed to the original test acceptance criteria.

Leakage testing of the TSC shell weldment shall be performed in accordance with written and approved procedures, and the test results documented.

Based on the confinement system materials, welding requirements and inspection methods, leakage testing of the closure lid is not required. To ensure the integrity of the vent and drain inner port cover welds, a helium leakage test of each weld is performed using the evacuated envelope method, as described in ASME Code, Section V, Article 10, and ANSI N14.5. The leakage test is intended to identify the presence of any weld voids indicated by the leakage of helium past the valved coupling installed in the vent and drain ports. A minimum leakage rate sensitivity of $\leq 1\times10^{-7}$ ref. cm^3/s is used for each port cover, which corresponds to a helium test leakage rate of $\leq 2\times10^{-7}$ ref. cm^3/s. Following inner port cover welding, a test bell is installed over the top of the port cover and the test bell volume is evacuated to a low pressure by a helium MSLD system.

If leakage is detected, the area of leakage shall be identified and repaired in accordance with ASME Code, Section III, Subsection NB, NB-4450. Following repair, the helium leak test shall be reperformed to the original test acceptance criteria.

9.A.2.5 Component Tests

The components of the MPC-LACBWR system do not require any special tests in addition to the material receipt, dimensional, and form and fit tests described above, or as described below.

9.A.2.5.1 Valves, Rupture Disks and Fluid Transport Devices

The MPC-LACBWR canister, concrete cask, and transfer cask do not contain rupture disks or fluid transport devices. There are no valves that are part of the confinement boundary for transport or storage. Quick-disconnect valves are installed in the canister vent and drain ports of the closure lid. These valves are intended to be convenience items for the operator, as they provide a means of quickly connecting (or disconnecting) ancillary drain and vent lines to the canister. The quick-disconnect fittings consist of male and female halves. The male fitting is installed in the canister and the female fitting is used as the connecting piece. The male fitting automatically closes when the mating fitting is removed; however, no credit is taken for this sealing feature. During storage and transport, these fittings are not accessible, as port cover plates are welded in place. As presented for storage, the canister has no accessible valves or fittings.

9.A.2.5.2 Gaskets

The MPC-LACBWR canister and concrete cask have no mechanical seals or gaskets that form an integral part of the package, and there are no mechanical seals or gaskets in the confinement boundary.

9.A.2.6 Shielding Tests

Based on the conservative design of the MPC-LACBWR storage cask for shielding criteria and the detailed construction requirements, no shielding tests of the concrete storage cask are required. However, shielding dose rates of loaded concrete casks are measured in accordance with LCO 3.2.2 of the Technical Specifications to ensure that the average concrete cask surface dose rates do not exceed the design limits.

9.A.2.7 Neutron Absorber Tests

Neutron absorber material (commercially available as BORAL®), in the form of sheets consisting of boron-carbide evenly dispersed within a matrix of aluminum and clad with aluminum, is used in the MPC-LACBWR TSC fuel baskets.

After manufacturing, test samples from each batch of BORAL® neutron absorber (poison) sheets shall be tested using wet chemistry or neutron absorption 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.

9.A.2.7.1 Neutron Absorber Material Sampling Plan

The neutron absorber sampling plan is selected to demonstrate a 95/95 (95% probability and 95% confidence level) statistical confidence level in the neutron absorber sheet material compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least 6 measurements (along the edges near each corner and the longitudinal centerline) on each sheet. No rejected neutron absorber sheet is used. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each sheet of the first set of 50 sheets of absorber material. Thereafter, coupon samples are taken from 10 randomly selected sheets from each set of 50 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion), or a process change, at which time the sampling process is reinitiated as previously described. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

9.A.2.7.2 Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will verify the presence of boron and provide input to the calculation of the ^{10}B areal density. Chemical test methods will be calibrated against neutron absorption methods for the BORAL® neutron absorber.

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.

9.A.2.7.3 Neutron Absorption Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests, if the neutron absorption test method is used. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given

reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a reduction of neutron flux between the thermalized neutron source and the neutron detector—depending on the material thickness and boron content.

Determination of neutron absorber material acceptance shall be performed by neutron attenuation testing. Neutron attenuation testing of the final product or the coupons shall compare the results with those for calibrated standards composed of a homogeneous ^{10}B compound. Other calibrated standards may be used, but those standards must be shown to be equivalent to a homogeneous standard. These tests shall include a statistical sample of finished product or test couponstaken from each lot of material to verify the presence, uniform distribution and the minimum areal density of ^{10}B.

9.A.2.7.4 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings. The neutron absorption test shall be considered acceptable if the neutron count determined for each test specimen is less than or equal to the highest permissible neutron count rate determined from the BORAL standard, which is based on the ^{10}B areal density specified on the fuel tube drawings. Any specimen not meeting the acceptance criteria for either test method shall be rejected. Nonconforming material shall be evaluated within the NAC International QA Program and shall be assigned one of the following dispositions: "use-as-is," "rework" or "reject." Only material that is determined to meet all applicable conditions of the license will be accepted.

9.A.2.8 Thermal Tests

No thermal acceptance testing of the MPC-LACBWR system is required during fabrication and construction. The thermal analysis of the MPC-LACBWR system in Appendix 4.A, which is limited to a maximum fuel content decay heat load of 4.5 kW, confirms that thermal monitoring of the MPC-LACBWR system in storage operations is not required to ensure system safety.

9.A.2.9 Cask Identification

Each MPC-LACBWR concrete cask will be appropriately identified by a stamped stainless steel nameplate as shown on Drawing No. 630045-864 that will be affixed to the outer surface of the cask.

9.A.3 Maintenance Program

This section presents the maintenance requirements for the MPC-LACBWR system and the transfer cask.

9.A.3.1 MPC-LACBWR System Maintenance

The MPC-LACBWR system is a passive system. No active components or systems are incorporated in the design. Consequently, only a minimal amount of maintenance is required over its lifetime.

The MPC-LACBWR system has no valves, gaskets, rupture discs, seals, or accessible penetrations. Consequently, there is no maintenance associated with these types of features.

Following an off-normal, accident or natural phenomena event, the user shall perform a Response Surveillance of the MPC-LACBWR systems in use at the ISFSI and take corrective actions, as required, in accordance with the requirements of Section A 5.3 of the Technical Specifications.

Annually, or on a frequency established by the user based on the environmental conditions at the ISFSI (i.e., higher inspection frequency may be appropriate at ISFSIs exposed to marine environments, lower frequency for sites located in dry environments, etc.), a program of visual inspections and maintenance of the loaded MPC-LACBWR systems in service shall be implemented. The concrete cask(s) shall be inspected as described herein.

- Visually inspect exterior concrete surfaces for chipping, spalling or other defects. Minor surface defects (i.e., approximately one cubic inch) shall be repaired by cleaning and regrouting.
- Visually inspect accessible exterior coated carbon steel surfaces for loss of coating, corrosion or other damage. The repair of corroded surfaces or surfaces missing coating materials shall be done by cleaning the areas and reapplying corrosion-inhibiting coatings in accordance with the coating manufacturer's recommendations. Exterior surface coatings authorized for use on the exposed carbon steel surfaces of concrete cask are not limited to those defined in Chapter 3 of the MPC FSAR or specified on the original design drawings. The user shall select coating appropriate to the ability to clean and recoat the affected surface areas.

- Visually inspect the installed lid bolts for presence of external corrosion. Excessively corroded, or missing, bolting shall be replaced with approved spare parts.
- Visually inspect the attachment hardware and the integrity of the inlet and outlet screens. Damaged or missing components shall be repaired or replaced with approved spare parts.
- Significant damage or defects identified during the visual inspections that exceed routine maintenance shall be processed as nonconforming items.

The schedule, results and corrective actions taken during the performance of the MPC-LACBWR system inspection and maintenance program shall be documented and retained as part of the system maintenance program.

9.A.3.2 Transfer Cask Maintenance

The transfer cask trunnions and shield door assemblies shall be visually inspected for gross damage and proper function prior to each use.

Annually (or a period not exceeding 14 months), an inspection and testing program shall be performed on the transfer cask in accordance with the requirements of ANSI N14.6. The following actions or alternatives shall be performed:

- Visually inspect the lifting trunnions, shield doors and shield door rails for permanent deformation and cracking. Carbon steel-coated surfaces will be inspected for chipped, cracked or missing areas of coating, and repaired by reapplication of the approved coating(s) in accordance with the coating manufacturer's recommendations.
- In addition, one of the following testing/inspection methods shall be completed.
- Perform a load test equal to or greater than 300% of the maximum service load and a post-test visual inspection of major load-bearing welds and critical components for defects, weld cracking, material displacement or permanent deformation; or
- If surface cleanliness and conditions permit, perform a dimensional and visual inspection of load-bearing components, and a nondestructive examination of major load-bearing welds.

The annual examination and testing program may be deferred during periods of nonuse of the transfer cask, provided that the transfer cask examination or testing program is performed prior to the next use of the transfer cask. The inspection results and corrective actions taken as part of the maintenance program shall be documented and retained as part of the system maintenance program.

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9.A.4 References

[A1] ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NB, "Class 1 Components," 1995 Edition with 1995 Addenda.

[A2] ASME Boiler and Pressure Vessel Code, Section V, "Nondestructive Examination," 1995 Edition with 1995 Addenda.

[A3] ASME Boiler and Pressure Vessel Code, Section VIII, Subsection B, Part UW, "Requirements for Pressure Vessels Fabricated by Welding," 1995 Edition with 1995 Addenda.

[A4] American Welding Society, Inc., "Structural Welding Code - Steel," AWS D1.1-96, 1996.

[A5] ASME Boiler and Pressure Vessel Code, Section IX, "Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and Welding and Brazing Operators," 1995 Edition with 1995 Addenda.

[A6] ASME Boiler and Pressure Vessel Code, Section III, Division I, Subsection NG, "Core Support Structures," 1995 Edition with 1995 Addenda.

[A7] American Concrete Institute, "Building Code Requirements for Structural Concrete," ACI-318-95, October 1995.

[A8] American National Standards Institute, "Radioactive Materials - Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds (4,500 kg) or More," ANSI N14.6-1993.

[A9] American National Standards Institute, "Leakage Tests on Packages for Shipment," ANSI N14.5-1997.

[A10] ISG-15, "Materials Evaluation," US Nuclear Regulatory Commission, Washington, DC, Revision 0, January 10, 2001.

[A11] Recommended Practice No. SNT-TC-1A, "Personnel Qualification and Certification in Nondestructive Testing," The American Society for Nondestructive Testing, Inc., Columbus, OH, edition as invoked by the applicable ASME Code.

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10.0 RADIATION PROTECTION

The NAC-MPC is provided in three configurations. The Yankee Class MPC (Yankee-MPC) is designed to store up to 36 Yankee Class spent fuel assemblies. The Connecticut Yankee MPC (CY-MPC) is designed to store up to 26 Connecticut Yankee spent fuel assemblies. The Dairyland Power Cooperative La Crosse Boiling Water Reactor MPC (MPC-LACBWR) is designed to store up to 68 LACBWR spent fuel assemblies, including up to 32 LACBWR damaged fuel cans. The radiation protection features and analysis presented in this chapter apply to both Yankee-MPC configurations, except as noted in the appropriate sections.

Appendix 10.A contains the description of radiation protection features and analysis for the MPC-LACBWR system.

10.1 Ensuring that Occupational Radiation Exposures Are As Low As Reasonably Achievable (ALARA)

The NAC-MPC provides radiation protection for all areas and systems that may expose personnel to radiation or radioactive materials. The components of the NAC-MPC system that require operation, maintenance and inspection are designed, fabricated, located, and shielded to minimize radiation exposure to personnel.

10.1.1 Policy Considerations

It is the policy of NAC to ensure that the NAC-MPC system is designed so that operation, inspection, repair and maintenance can be carried out while maintaining occupational exposure as low as reasonably achievable (ALARA).

10.1.2 Design Considerations

The design of the NAC-MPC system complies with the requirement of 10 CFR 72.3 concerning ALARA and meets the requirements of 10 CFR 72.126(a) and 10 CFR 20.1101 with regard to maintaining occupational radiation exposures ALARA. Specific design features that demonstrate the ALARA philosophy are:

- Material selection and surface preparation that facilitate decontamination.
- A basket configuration that allows spent fuel loading using accepted standard practice and current experience.

- Positive clean water flow in the transfer cask/canister annulus to minimize the potential for contamination of the canister surface during in-pool loading.
- Passive confinement, thermal, criticality, and shielding systems that require no maintenance.
- Thick steel and concrete walls to reduce the average side surface dose rate to 40 mrem/hr (average) for the Yankee-MPC and 108 mrem/hr for the CY-MPC.
- Nonplanar cooling air pathways to minimize radiation streaming at the inlets and outlets of the concrete cask.
- Optional use of remote, automated outlet air temperature measurement to reduce surveillance time.

10.1.3 Operational Considerations

The ALARA philosophy has been incorporated into the procedural steps necessary to operate the NAC-MPC in accordance with its design. The following features or actions, which comprise a baseline radiological controls approach, have been incorporated in the design or procedures to minimize occupational radiation exposure:

- Use of prefabricated, shaped temporary shielding during automated welding equipment set up and removal, manual welding, and weld inspection of the shielding and structural lids and for use during all of the canister closing and sealing operations.
- Use of automatic equipment for welding the shield lid and structural lid to the canister shell.
- Decontamination of the exterior surface of the transfer cask, welding of the shield lid, and pressure testing of the canister while the canister remains filled with water.
- Use of quick-disconnect fittings at penetrations to facilitate required service connections.
- Use of remote handling equipment, where practical, to reduce radiation exposure.

The operational procedures at a particular facility will be determined by the user's operational conditions and facilities.

10.2 Radiation Protection Design Features

The description of the radiation shielding design is provided in Chapter 5.0. The design basis radiation exposure rates are summarized in this section and in Chapter 2.0. The principal radiation protection design features are the shielding necessary to meet the design objectives, the placement of penetrations near the edge of the canister shield lid to reduce operator exposure and handling time, and the use of shaped supplemental shielding for work on and around the shield and structural lids. This supplemental shielding reduces operator dose rates during the welding, inspection, draining, drying and backfilling operations that seal the canister. An optional supplemental shielding fixture, shown in Drawing 455-913, may be installed in the air inlets to reduce the radiation dose rate at the base of the vertical concrete cask.

Radiation exposure rates at various work locations were determined for the principal NAC-MPC operational steps. For the Yankee-MPC configuration, these exposure rates were determined using a combination of the SAS1 and SKYSHINE-III computer codes. For the CY-MPC configuration, the exposure rates were determined using a combination of the MCBEND and SKYSHINE-III computer codes. The use of SAS1 and MCBEND are described in Chapter 5.0. The SKYSHINE-III code is discussed in Section 10.4. The dose rates decrease with time as the fuel cools.

10.2.1 Design Basis for Normal Storage Conditions

The radiation protection design basis for the NAC-MPC storage cask is derived from 10 CFR 72 and the applicable ALARA guidelines. The design basis surface dose rates and the calculated one meter dose rates are shown below.

Yankee-MPC Concrete Storage Cask	Design Basis Average Surface Dose Rate (mrem/hr)	Surface Average Dose Rate (mrem/hr)	1 Meter Maximum Dose Rate (mrem/hr)
Side wall	50	35.7	21.2
Air inlet/air outlet	200	168	27.5
Top lid	55	34.9	13.2

Air inlet dose rates are based on the use of the supplemental shielding in the air inlets. Design basis source terms require the use of the inlet shields to remain below the technical specification limits. Listed values are the average of air inlet and outlet results.

CY-MPC Concrete Storage Cask	Design Basis Maximum Surface Dose Rate (mrem/hr)	1 Meter Maximum Dose Rate (mrem/hr)
Side wall	170	85
Air inlet/air outlet	105	25
Top lid	40	15

The calculated dose rates at these, and at other dose points, are also reported in Sections 5.1 and 5.4.

Activities associated with closing the canister, including welding of the shield and structural lids, draining, drying, backfilling and testing, will employ temporary shielding to minimize personnel dose in the performance of those tasks.

10.2.2 Design Basis for Accident Conditions

Damage to the NAC-MPC cask after a design basis accident will not result in a radiation exposure at the controlled area boundary in excess of 5 rem to the whole body or any organ, including skin. The high energy missile impact is estimated to reduce the concrete shielding thickness, locally at the point of impact, by 6 inches. This reduction in shielding results in a calculated dose rate of 314 mrem/hr at one meter for the Yankee-MPC. For the CY-MPC, the local surface dose rate for the accident condition is approximately 1000 mrem/hr as shown in Section 11.2.13.3. There are no other design basis accident conditions that result in a greater estimated loss of shielding.

Two hypothetical accident events that evaluate storage cask tip over and the rupture of 100% of the fuel rods are considered in Chapter 11. There are no design basis events that result in the tip over of the NAC-MPC storage cask or the release of any radioactive material from the canister.

10.3 Estimated On-Site Collective Dose Assessment

Occupational radiation exposures (person-mrem) resulting from the use of the NAC-MPC storage system are calculated using estimated exposure rates presented in Chapter 5.0 and Section 10.2.1. Exposure was evaluated by identifying the tasks and estimating the duration and number of personnel performing those tasks based on industry experience. The tasks identified were based on the design basis operating procedures, as presented in Chapter 8.0.

An estimated collective dose assessment is made for loading a single NAC-MPC, for dose related to routine storage operations and for unloading a single NAC-MPC. The collective dose assessments for the Yankee-MPC configuration is provided in Section 10.3.1. The collective dose assessment for the CY-MPC configuration is provided in Section 10.3.2.

Estimated Dose Due to Loading

The estimated dose due to loading considers the collective dose due to the loading, sealing, transfer and placement of a single NAC-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background will vary with site specificity. The number of persons allocated to task completion is generally the minimum number required for the task.

Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

The calculated exposures differ significantly between the Yankee-MPC and CY-MPC. The CY-MPC evaluation considers the increased use of automated equipment to off-set the elevated cask surface dose rates. The use of automated equipment is expected to reduce exposure time during transfer and welding operations. The CY-MPC evaluation also employs dose rates determined by three-dimensional profiling, rather than the average or one-dimensional dose rates used for the Yankee-MPC evaluations. Combining these effects results in lower occupational exposures for the CY-MPC loading and unloading operations compared to the Yankee-MPC system, even though the cask surface dose rates are higher for the CY-MPC system.

Estimated Dose Due to Routine Operations

Once in place, the ISFSI will require limited ongoing maintenance and surveillance throughout its design life. The annual dose evaluation considers the combination of the requirements specified in the NAC-MPC Technical Specifications and tasks that are anticipated to be representative of an operational facility. Typically, no maintenance of the storage system is expected to be required annually. Collective dose due to certain events, such as clearing the blockage of air vents, is accounted for in Chapter 11.0.

Routine operations are expected to include:

- The daily electronic measurement of ambient air and outlet air temperatures for each NAC-MPC in service, or the daily visual inspection of the concrete cask inlet and outlet screens to verify they are intact and unobstructed. Outlet temperature indicators are located away from the cask array and the operator is not expected to incur dose as a result of the temperature measurement. The time required to perform the visual inspection, and the expected dose, will be site specific due to ISFSI pad dimensions and configurations, concrete cask array, distance of the inspector to the casks, etc.
- A daily visual security inspection of the security fence and equipment surrounding the storage area. This surveillance is assumed to require 1 minute per cask for the Yankee-MPC array and a total of 10 minutes for the CY-MPC array and 1 security officer.
- Grounds maintenance performed no less than twice a month by 1 maintenance technician. Grounds maintenance is assumed to require 0.5 hour for the Yankee-MPC array and 1 hour for the CY-MPC array.
- Quarterly radiological surveillance. The surveillance consists of a radiological survey comprised of a surface radiation measurement on each cask, the determination and/or verification of general area exposure rates and radiological postings. This surveillance is assumed to require 1 person and 1 hour for the Yankee-MPC array and 2 hours for the CY-MPC array.
- Annual inspection of the general condition of the storage casks. This inspection is estimated to require 3-15 minutes per cask and 2 technicians.

For the Yankee-MPC evaluation, the storage array is conservatively assumed to have a fuel population having cooling times ranging from 8 to 20 years. To account for the different ages of the fuel, weighting factors are applied to the single cask dose rates. The application of these factors permits a more accurate representation of the exposure commitment necessary for the routine operation of the ISFSI. The weighting factors applied are based on the decayed spectra of the fuel neutron and fuel gamma components of the source term. Table 10.3-2 presents the

weighting factors applied to the individual casks in the array. The arrangement of the array is shown in Figure 10.3-1.

For the CY-MPC evaluation, the storage array is assumed to have a mixture of 5-year and 10-year cooled stainless steel clad fuel. The array is modeled as having 32 casks with 10-year cooled fuel and eight casks with 5-year cooled fuel. The cask surface source terms are directly extracted from MCBEND outputs.

Estimated Dose Due to Unloading

The estimated collective dose due to unloading includes the transfer, opening and unloading of a single NAC-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background radiation varies with each site. The number of persons allocated to task completion is generally the minimum number required for the task. Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

The estimated total exposure, by task, attributable to the transfer, opening and unloading of a design basis Yankee-MPC or CY-MPC is presented in the appropriate section.

10.3.1 Collective Dose Estimates for the Yankee-MPC

This section provides the estimated collective dose assessment for loading a single Yankee-MPC, for dose related to routine Yankee-MPC storage array operations and for unloading a single Yankee-MPC.

Estimated Dose Due to Loading a Single Yankee-MPC

This section estimates the collective dose due to the loading, sealing, transfer and placement of a single Yankee-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background will vary with site specificity. The number of persons allocated to task completion is generally the minimum number required for the task.

Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Table 10.3-1 summarizes the estimated total exposure, by task, attributable to the loading, transfer, sealing and placement of a design basis Yankee-MPC.

Due to the additional cooling of casks in a typical array, the actual loading, transfer and storage dose associated with the 16 storage cask array is significantly lower than that of a cask array consisting of design basis casks. Based on the source term weighting factors presented in Table 10.3.2, the occupational dose is approximately 20% lower for a typical cask array.

Estimated Dose Due to Routine Operations of the 16 Yankee-MPC Cask Array

The estimated annual exposure due to routine operations of the array is calculated by applying weighting factors to the neutron and gamma radiation spectra based on the assumed cooling time of the fuel stored in the Yankee-MPC casks. The storage array is conservatively assumed to have a fuel population having cooling times ranging from 8 to 20 years. To account for the different ages of the fuel, weighting factors are applied to the single cask dose rates. The application of these factors permits a more accurate representation of the exposure commitment necessary for the routine operation of the ISFSI. The weighting factors are based on the decayed spectra of the fuel neutron and fuel gamma components of the source term. Table 10.3-2 presents the weighting factors applied to the individual casks in the array. The arrangement of the array is shown in Figure 10.3-1.

For this evaluation, it is assumed that the storage cask array consists of four casks containing the design basis Combustion Engineering Type A 36,000 MWD/MTU burnup, 8 year cooled fuel, and twelve casks loaded with CE Type A 36,000 MWD/MTU burned fuel with cool times representative of the staggered core discharge. The assumed cool times of the fuel in the Yankee-MPC cask array are shown in Table 10.3-3. The design basis casks represent not only the design basis CE fuel assembly, but also any of the other Yankee fuel categories at the minimum cool time and maximum burnup limit. As stated in Sections 5.4.1 and 5.4.2, maximum design basis cask surface dose rates were employed to establish the minimum cool time for each of the fuel categories.

Based on these assumptions, the annual operation and surveillance requirements result in an estimated annual collective exposure of 901 person-mrem for the 16 cask ISFSI. The estimated annual exposure, by task, for the 16 Yankee-MPC casks is shown in Table 10.3-4.

Estimated Collective Dose for Unloading a Single Yankee-MPC

This section estimates the collective dose due to the transfer, opening and unloading of a single Yankee-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background radiation varies with each site. The number of persons allocated to task completion is generally the minimum number required for the task. Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Table 10.3-5 summarizes the estimated total exposure, by task, attributable to the transfer, opening and unloading of a design basis Yankee-MPC.

10.3.2 Collective Dose Estimates for the CY-MPC

This section provides the estimated collective dose assessment for loading/unloading a single CY-MPC and summarizes the dose related CY-MPC storage array operations.

Dose Due to Loading a Single CY-MPC

The estimated total exposure, by task, attributable to the loading, transfer, sealing and placement of a single CY-MPC cask containing design basis fuel is presented in Table 10.3-6.

Dose rates shown in Table 10.3-6 are based on the design basis fuel assembly for shielding, the stainless steel clad fuel as described in Section 5.2.2, with a burnup of 38,000 MWD/MTU, and a minimum cooling time of 5 years. Most of the Connecticut Yankee fuel assemblies to be loaded have a lower source term, or longer cool time, than the design basis fuel. Consequently, the total dose associated with loading any given CY-MPC is expected to be less than the total dose shown in Table 10.3-6.

Estimated Dose Due to Routine Operations of the 40 CY-MPC Cask Array

The estimated annual exposure due to routine operations of the array is calculated by applying SKYSHINE dose rates (Section 10.4) based on 5- and 10-year cooled fuel stored in the CY-MPC casks. The use of these dose rates provides a more accurate representation of the exposure commitment necessary for routine operation of the ISFSI, since most of the casks in the array will not contain the design basis fuel (stainless-steel clad, burned to 38,000 MWD/MTU and

cooled 5 years). The arrangement of the array is shown in Figure 10.3-2. The casks with 5-year cooled fuel are restricted to locations in the interior of the array as shown in Table 10.3-9.

The annual operation and surveillance requirements result in an estimated annual collective exposure of 1,542 person-mrem for the 40 cask ISFSI. The estimated annual exposure, by task, for the 40 CY-MPC casks is shown in Table 10.3-7. The CY-MPC result is higher than the Yankee-MPC result (246 person-mrem) because of the increased number of casks (40 as opposed to 16) and the increased concrete cask dose rates.

Estimated Collective Dose for Unloading a Single CY-MPC

The estimated collective dose due to the transfer, opening and unloading a single CY-MPC containing design basis fuel is shown in Table 10.3-8. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background radiation varies with each site. The number of persons allocated to task completion is generally the minimum number required for the task. Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Figure 10.3-1 Typical ISFSI 16 Yankee-MPC Cask Array Layout

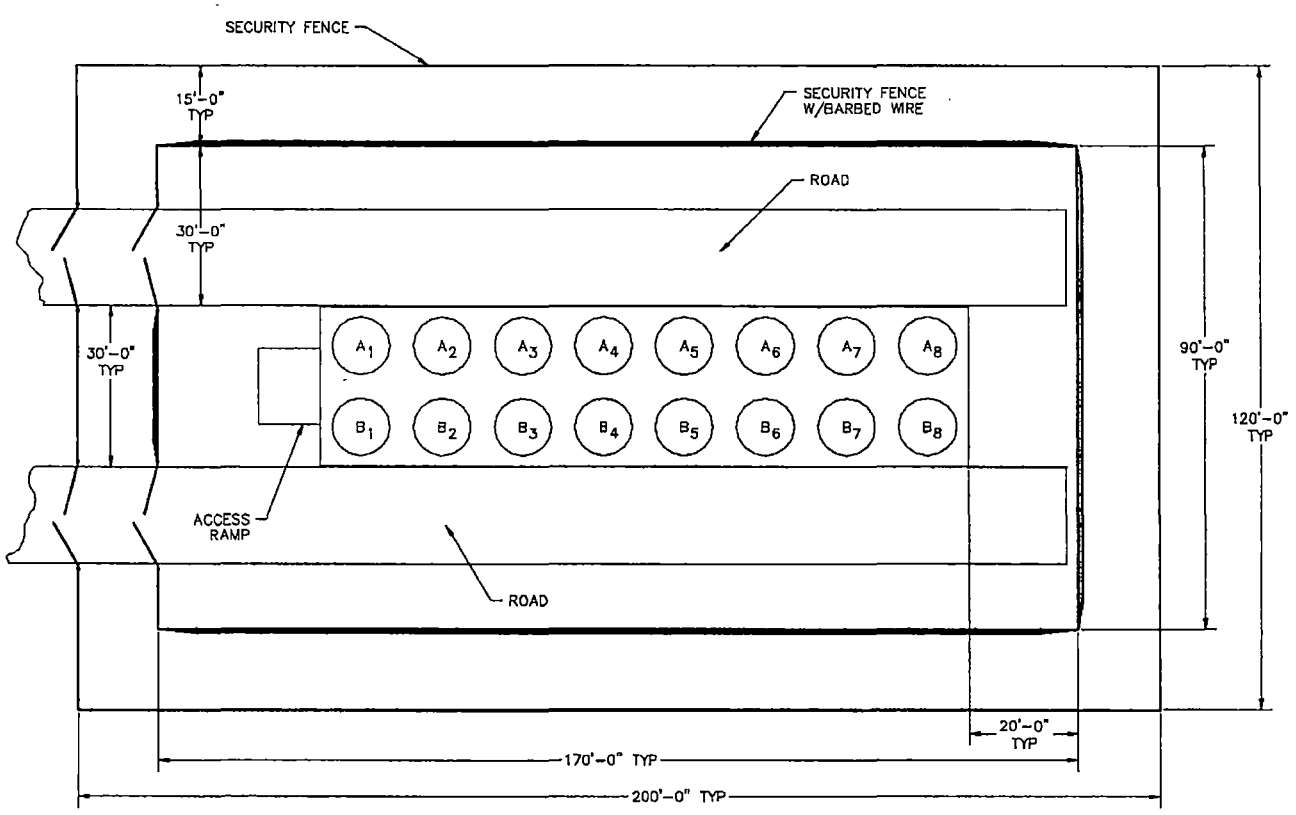


Figure 10.3-2 Typical ISFSI 40 CY-MPC Cask Array Layout

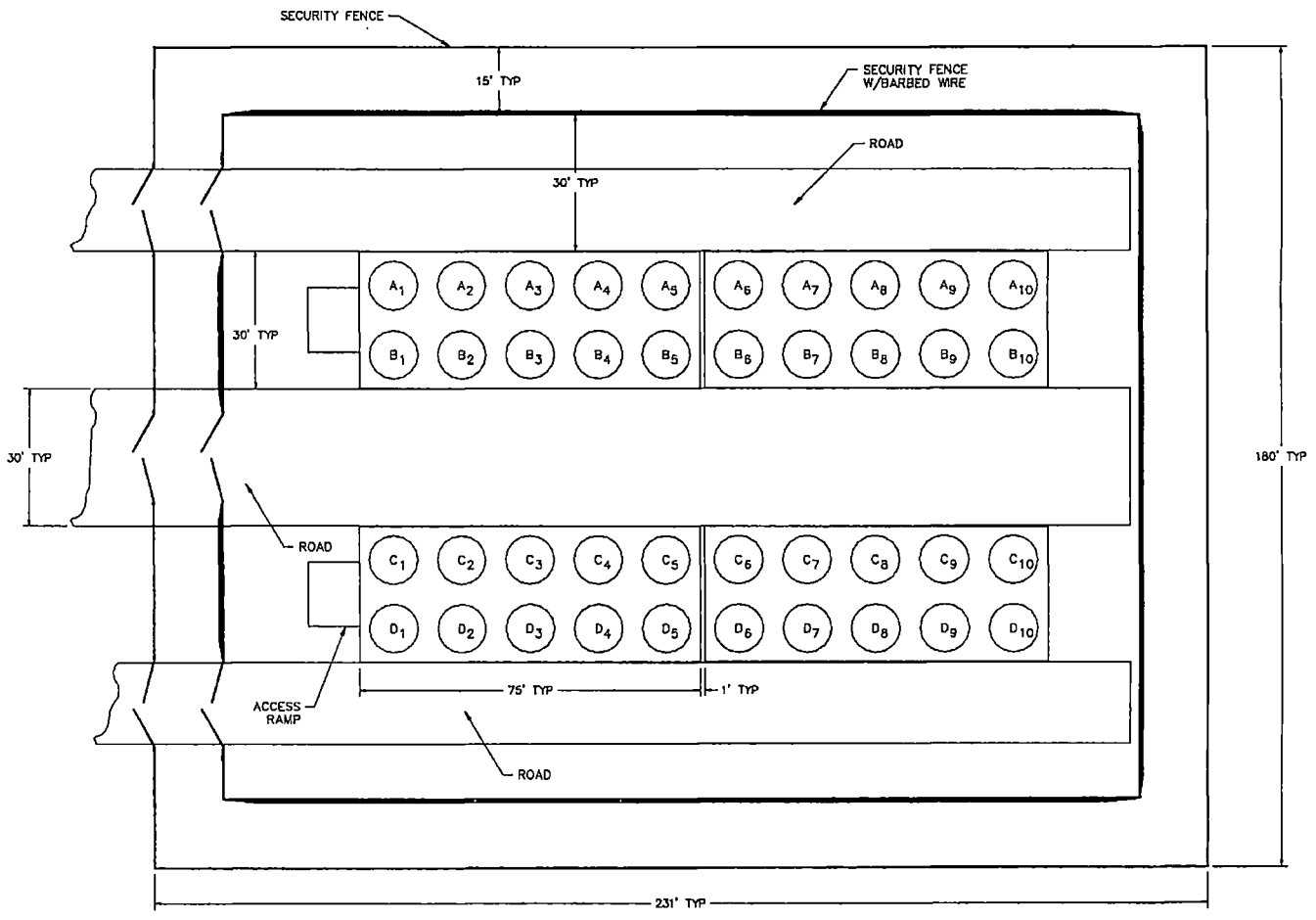


Table 10.3-1 Estimated Person-Mrem Exposure for Operation of the Yankee-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Load Canister	2	7.5	5.0	75.7
Move to Decon Area	2	1.1	11.5	25.3
Setup, Weld Shield Lid, and Inspect Weld	2	7.9	21.5	339.8
Drain/Dry/Backfill and Leak Test Vacuum Drying	2	0.6	45.1	54.1
Weld and Inspect Port Covers	2	2.5	118.8	594.2
Setup, Weld Structural Lid and Inspect Weld	2	7.7	59.4	915.5
Transfer to Storage Cask	4	2.2	18.3	161.0
Position on ISFSI Pad	2	0.8	17.8	28.4
Total				2,194

Note: See discussion of "Estimated Dose Due to Loading" in Section 10.3 for discussion of the Yankee-MPC and CY-MPC differences.

Table 10.3-2 Yankee-MPC Storage Cask Radiation Spectra Weighting Factors

Cask	Neutron Weighting Factor	Gamma Weighting Factor	Cask	Neutron Weighting Factor	Gamma Weighting Factor
A-1	1	1	B-1	.83	.74
A-2	1	1	B-2	.80	.71
A-3	1	1	B-3	.78	.69
A-4	1	1	B-4	.75	.67
A-5	.96	.93	B-5	.72	.65
A-6	.93	.86	B-6	.70	.63
A-7	.90	.82	B-7	.67	.61
A-8	.86	.77	B-8	.65	.59

Table 10.3-3 Assumed Fuel Cooling Time for the Yankee-MPC Storage Casks in the ISFSI Array

Cask	Cooling Time	Cask	Cooling Time
A-1	8 yr.	B-1	13 yr.
A-2	8 yr.	B-2	14 yr.
A-3	8 yr.	B-3	15 yr.
A-4	8 yr.	B-4	16 yr.
A-5	9 yr.	B-5	17 yr.
A-6	10 yr.	B-6	18 yr.
A-7	11 yr.	B-7	19 yr.
A-8	12 yr.	B-8	20 yr.

Table 10.3-4 Estimate of Annual Exposures for a 16 Yankee-MPC Storage Cask Array

Activity	Dose Rate Distance (meters)	Frequency	Time (hr)	Dose Rate (mrem/hr)	Personnel Required	Total Exposure (person-mrem)
Temperature Readings	Remote	365	0.8	0	1	0
Security surveillance/ visual inspection	10	365	0.3	4.7	1	511
Radiological surveillance	5	4	1.0	9.6	1	38
Annual inspection	0.3	1	4.0	28.4	2	227
Grounds maintenance	5	26	0.5	9.6	1	125
Total (person-mrem)						901

Table 10.3-5 Estimated Collective Dose for Unloading a Single Yankee-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Move Storage Cask to Receiving Area	2	0.8	17.8	28.5
Transfer Canister to Transfer Cask	4	2.2	18.3	161.0
Setup, Cut Structural Lid	2	3.9	59.4	463.3
Cut Port Covers	2	1.3	118.8	308.9
Cool Down and Fill Canister with Water	2	8.0	45.1	721.6
Setup and Cut Shield Lid	2	4.0	21.5	172.0
Move to Pool	2	1.1	11.5	25.3
Unload Canister	2	7.5	5.0	75.0
Total		28.8		1,955.6

Table 10.3-6 Estimated Person-Mrem Exposure for Operation of the CY-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Load Canister	2	5.80	2	26
Move to Decon Area	2	1.30	11	28
Setup, Weld Shield Lid, and Inspect Weld	2	7.90	16	254
Drain/Dry/Backfill and Leak Test Vacuum Drying	2	0.60	28	34
Weld and Inspect Port Covers	2	2.50	76	378
Setup, Weld Structural Lid and Inspect Weld	2	7.70	52	798
Transfer to Storage Cask	4	2.20	14	125
Position on ISFSI Pad	2	0.80	66	105
Total				1,748

Note: See discussion of "Estimated Dose Due to Loading" in Section 10.3 for discussion of the Yankee-MPC and CY-MPC differences.

Table 10.3-7 Estimate of Annual Exposures for a 40 CY-MPC Storage Cask Array

Activity	Dose Rate Distance (meters)	Frequency	Total Time (min)	Dose Rate (mrem/hr)	Personnel Required	Total Exposure (person-mrem)
Temperature readings	Remote	365	0.8	0	1	0
Security Surveillance	10	365	10	9.8	1	596
Radiological Surveillance	5	4	120	34.0	1	272
Annual Inspection	0.30	1	120	98.3	2	439[1]
Grounds Maintenance	10	24	60	9.8	1	235
Total (person-mrem)						1,542

1. Includes exposure associated with health physics support.

Table 10.3-8 Estimated Collective Dose for Unloading a Single CY-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Move Storage Cask to Receiving Area	2	0.80	66	105
Transfer Canister to Transfer Cask	4	2.20	14	125
Setup, Cut Structural Lid	2	3.90	52	404
Cut Port Covers	2	1.30	76	197
Cool Down and Fill Canister with Water	2	8.00	28	456
Setup and Cut Shield Lid	2	4.00	16	129
Move to Pool	2	1.30	11	29
Unload Canister	2	5.80	2	26
Total				1,471

Table 10.3-9 Assumed Fuel Cool Time for the CY-MPC Storage Casks in the ISFSI Array

Cask	Cool Time (years)	Cask	Cool Time (years)	Cask	Cool Time (years)	Cask	Cool Time (years)
A-1	10	B-1	10	C-1	10	D-1	10
A-2	10	B-2	10	C-2	10	D-2	10
A-3	10	B-3	10	C-3	10	D-3	10
A-4	10	B-4	5	C-4	5	D-4	10
A-5	10	B-5	5	C-5	5	D-5	10
A-6	10	B-6	5	C-6	5	D-6	10
A-7	10	B-7	5	C-7	5	D-7	10
A-8	10	B-8	10	C-8	10	D-8	10
A-9	10	B-9	10	C-9	10	D-9	10
A-10	10	B-10	10	C-10	10	D-10	10

10.4 Exposures to the Public

The Yankee-MPC cask array shown in Figure 10.3-1 and the CY-MPC cask array shown in Figure 10.3-2 were evaluated to determine the minimum distance necessary to achieve a controlled area boundary dose of 25 mrem/year as required by 10 CFR 72.104(a). NAC's Version 6.0.1 of the SKYSHINE-III code is used to evaluate the placement of the controlled area boundary for the Yankee-MPC cask array and Version 5.1.0 was used to analyze the CY-MPC cask array. The principal difference in the two versions is the input format for the cask source term. Version 6.0.1 accepts input with an angular distribution whereas Version 5.1.0 assumes the source to be isotropic. Given the source geometry, spectra and desired detector locations, SKYSHINE III calculates dose rates using a combination of pre-calculated transmission and reflection data and the Monte Carlo technique to integrate over the source direction and energy variables.

Versions 6.0.1 and 5.1.0 of SKYSHINE-III both explicitly calculate cask self-shielding based on the cask geometry and arrangement of the cask array. A ray tracing technique is utilized. Given the source position on the cask surface and the direction cosines for the source emission, geometric tests are made to see if any adjacent casks are in the path of the emission. If so, the emission history does not contribute to the air scatter dose. Also, given the source position on the cask surface and the direction cosines for the source to detector location, geometric tests are made to see if any adjacent casks are in the source path. If so, the emission position does not contribute to the uncollided dose at the detector location.

The performance of the SKYSHINE-III Code is benchmarked by modeling a set of Kansas State University ^{60}Co skyshine experiments and by modeling two Kansas State University neutron computational benchmarks. The code compared well with these benchmarks for both neutron and gamma doses versus distance.

While these analyses are performed for typical arrays of casks containing design-basis spent fuel assemblies, full compliance with the requirements of 10 CFR 72.104(a) can only be demonstrated on a site-specific basis. Consequently, each ISFSI licensee performs a site-specific dose analysis for the facility to show that the requirements of 10 CFR 72 are met. Site-specific boundary distances may vary significantly based on fuel type, fuel cooling time, exposure duration and number of casks in service.

10.4.1 Yankee-MPC Public Exposure Evaluation

The 2×8 Yankee-MPC cask array is explicitly modeled in the code, with the source term from each cask represented as top and side surface sources. The cask surface source strength is provided from the three-dimensional MCBEND shielding evaluation. The top and side source energy distributions for both neutron and gamma radiation are taken from the design basis cask results in Table 5.4.1-4. Table 5.4.1-5 lists the total neutron and gamma source strengths based on the cylindrical area on the side of the storage cask and the circular area on the top of the storage cask. As stated in Section 10.2, the associated reference cask source strengths for Yankee-MPC are multiplied by weighting factors to correct for the differences in cooling times.

Annual exposures, based on an 8,760-hour residence year, were determined at distances ranging from 264 to 360 meters from the center of the 2×8 cask array (Figure 10.3-1). The storage array is assumed to have a fuel population reflective of that of an operating reactor facility and that fuel cool time will range from 8 to 20 years.

Table 10.4-1 presents a summary of the results of the SKYSHINE-III evaluation on the north and south sides of the array. Figure 10.4-1 includes a plot of the limiting boundary distances. The results for each direction are interpolated to determine the minimum distance necessary to achieve an annual dose of 25 mrem. These interpolated results are presented for each direction in Table 10.4-2 and indicate that the required minimum distance varies around the ISFSI from approximately 290 meters on the 2-cask side to 335 meters on the 8-cask side. An enveloping boundary around the ISFSI, using the dimensions in Table 10.4-2, will ensure compliance with the requirements of 10 CFR 72.104(a), i.e., a dose rate not exceeding 25 mrem/year.

10.4.2 CY-MPC Public Exposure Evaluation

The 4×10 CY-MPC cask array is explicitly modeled in the SKYSHINE-III code, with the source term from each cask represented as top and side surface sources. Surface source emission fluxes are provided from three-dimensional MCBEND shielding evaluations of the vertical concrete casks. The top and side source energy distributions for both neutron and gamma radiation are taken from the MCBEND shielding calculations for the 38 GWD/MTU stainless steel fuel with cooling times of 5 and 10 years. The two sets of source spectra used are shown in Tables 10.4-3 and 10.4-4. The associated total neutron and gamma-ray source strengths on a per cask basis are given in Table 10.4-5.

Source spectra for 38 GWD/MTU burnup stainless steel fuel for 5- and 10-year cooling times were used. Eight of the casks were assumed to be 5-year cooled fuel and the remaining 32 casks were assumed to contain 10-year cooled fuel. This fuel loading is illustrated in Table 10.3-9. Two separate sets of runs were performed for the CY-MPC array:

- One set with the spectra for the 5-year cooled fuel with weighting factors of zero assigned to the 10-year cooled fuel casks and of one assigned to the 5-year cooled fuel casks.
- A second set with the spectra for the 10-year cooled fuel with weighting factors of zero assigned to the 5-year cooled fuel and of one assigned to the 10-year cooled fuel casks.
- The summation of the doses from these two sets of calculations is the estimated dose distribution around the CY-MPC ISFSI.

Annual exposures, based on an 8,760-hour/year exposure, were determined at distances ranging from 64 to 750 meters from the center of the 4x10 cask array (Figure 10.3-2), as shown in Figure 10.4-2.

Table 10.4-6 presents a summary of the results of the SKYSHINE-III evaluation for the CY-MPC array along the x=0 and y=0 directions. The maximum dose rates at a given distance from the center of the array should occur in these directions since the cask loading is symmetric about the origin (see Table 10.3-9). Since it is anticipated that the controlled area boundary would be rectangular in shape, the interpolated boundaries in Table 10.4-6 define the enclosure required to maintain boundary doses to 25 mrem/y or less. In Figure 10.4-2, this rectangular boundary is superimposed on a plot of the detector locations at which a dose rate of 22-28 mrem per 8,760-hour exposure was calculated. The dose rates and associated locations shown in Figure 10.4-2 are presented in Tables 10.4-6 and 10.4-7. These results indicate that a 426-meter boundary on the top and bottom sides and a 455-meter boundary on the left and right sides of the array will ensure compliance with the requirements of 10 CFR 72.104(a), i.e., a dose rate not exceeding 25 mrem/year. These distances are measured from the center of the array.

Figure 10.4-1 Controlled Area Boundary Determination for a 16 Yankee-MPC Cask Array

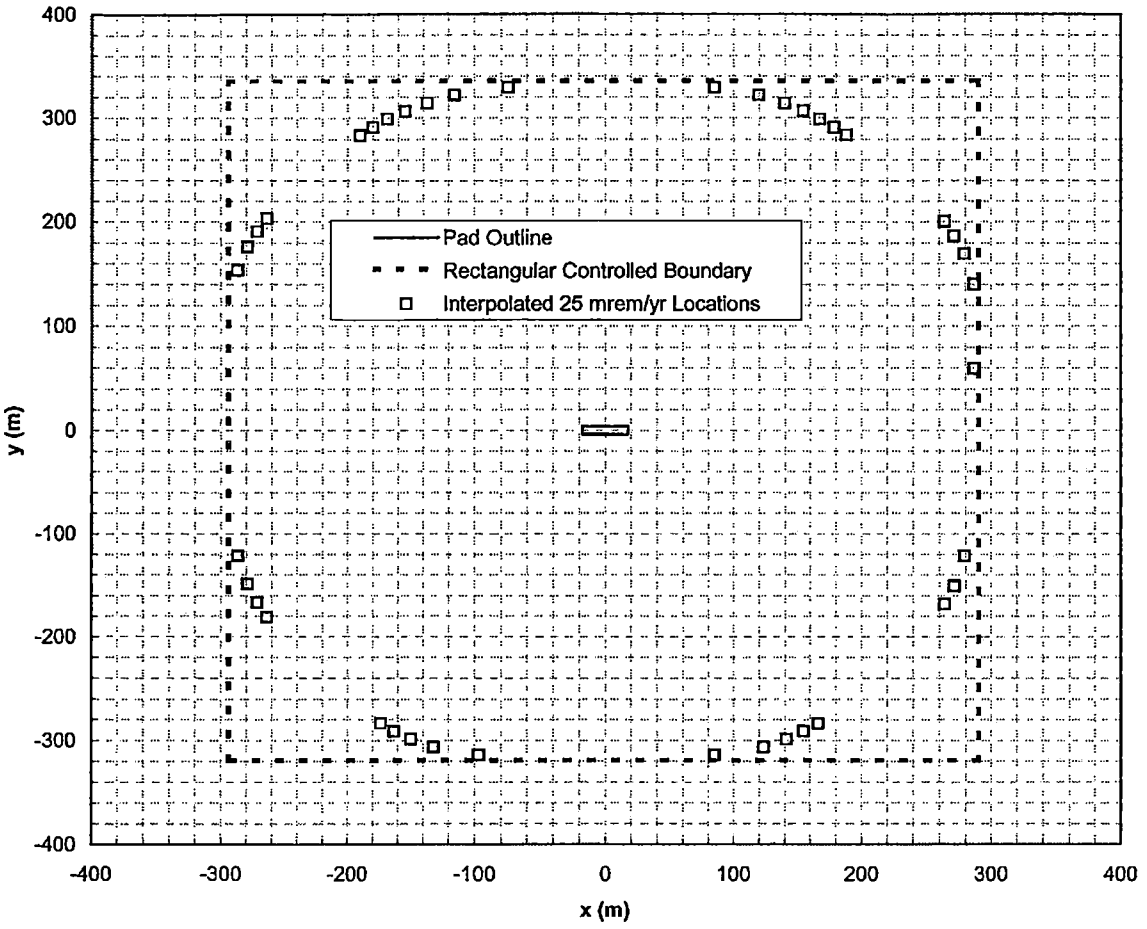
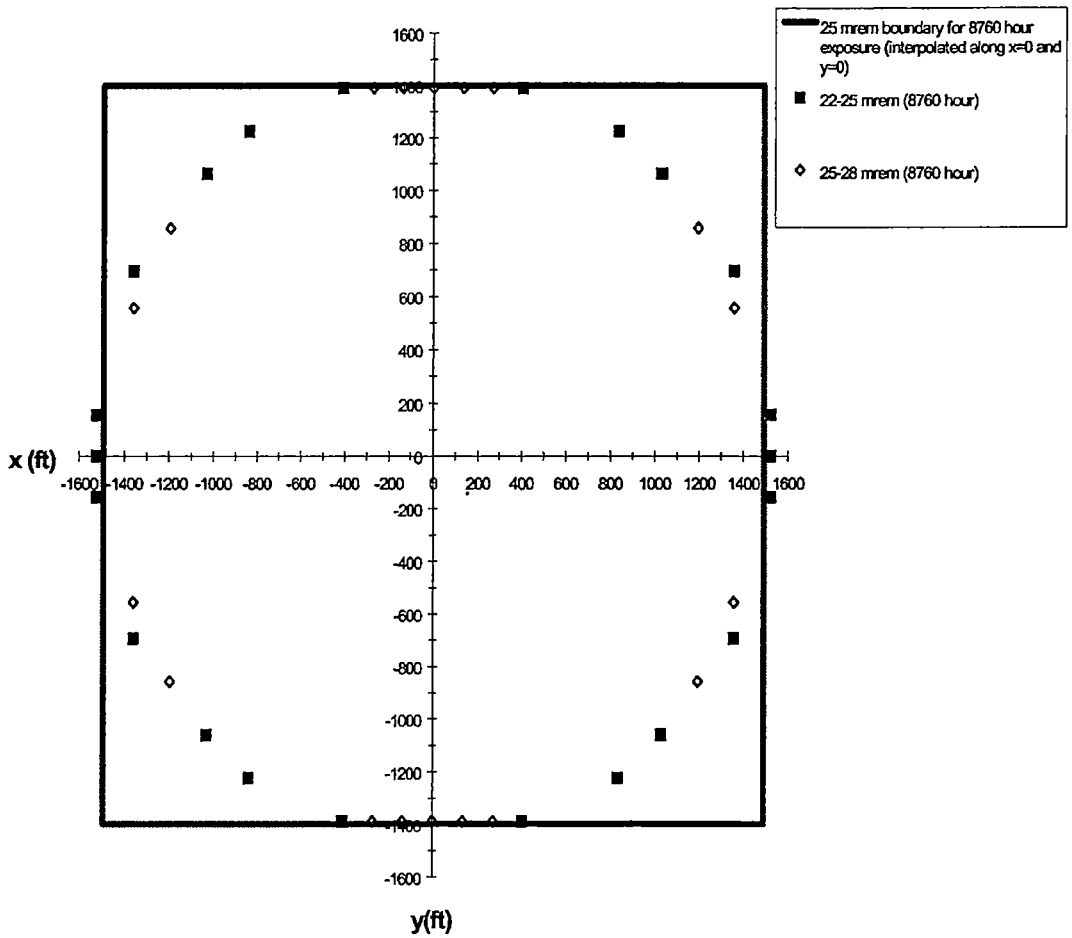


Figure 10.4-2 Controlled Area Boundary Determination for a 40 CY-MPC Cask Array



(The solid line is the rectangular boundary (25 mrem/y) for the array as interpolated from the 8,760-hour exposures along x = 0 and y = 0. The points shown are locations with doses from 22-25 and 25-28 mrem/y for 8,760-hour exposures.)

Table 10.4-1 Summary of Annual Exposure Doses at Distances Away from the Yankee-MPC Cask Array

Direction[1]	Dose at Distance from Cask Array (mrem)[2,3]				
	306 m	314 m	322 m	329 m	337 m
North	35.2	32.1	29.3	26.8	24.6
South	29.1	26.6	24.3	22.2	20.4

Notes:

1. Denotes direction based on Figure 10.3-1.
2. Boundary distance is from center of ISFSI.
3. Based on 8,760 hours of occupancy.

Table 10.4-2 Controlled Area Boundary for a 2×8 Yankee-MPC Cask Array

Direction[1]	Boundary Distance (m)[2,3]
North	335.3
South	319.3
West	294.1
East	290.2

Notes:

1. Denotes direction based on Figure 10.3-1.
2. Boundary distance is from center of ISFSI.
3. Based on 8,760 hours of occupancy.

Table 10.4-3 CY-MPC Surface Neutron Fluxes for Design Basis Stainless Steel Clad Fuel

Group	Group Upper Energy (MeV)	10-year cooled Radial (n/cm^2 s)	10-year cooled Axial (n/cm^2 s)	5-year cooled Radial (n/cm^2 s)	5-year cooled Axial (n/cm^2 s)
1	1.46E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	1.36E+01	9.52E-05	1.34E-04	1.96E-04	3.40E-05
3	1.25E+01	4.30E-04	2.53E-04	7.50E-04	3.66E-04
4	1.13E+01	1.60E-03	5.66E-04	1.62E-03	4.10E-04
5	1.00E+01	4.85E-03	1.35E-03	5.47E-03	1.62E-03
6	8.25E+00	1.18E-02	2.83E-03	1.53E-02	3.38E-03
7	7.00E+00	3.44E-02	5.70E-03	4.10E-02	5.67E-03
8	6.07E+00	9.33E-02	1.47E-02	1.14E-01	2.19E-02
9	4.72E+00	1.08E-01	2.82E-02	1.30E-01	3.49E-02
10	3.68E+00	1.32E-01	6.45E-02	1.55E-01	8.73E-02
11	2.87E+00	1.01E+00	4.87E-01	1.21E+00	5.87E-01
12	1.74E+00	1.02E+00	7.49E+00	1.23E+00	8.95E+00
13	6.40E-01	5.88E-01	1.16E+01	6.90E-01	1.38E+01
14	3.90E-01	1.84E+00	6.51E+01	2.06E+00	7.75E+01
15	1.10E-01	6.22E-01	1.95E+01	7.51E-01	2.32E+01
16	6.74E-02	8.34E-01	2.43E+01	1.44E+00	2.87E+01
17	2.48E-02	1.38E+00	3.71E+01	1.63E+00	4.47E+01
18	9.12E-03	1.12E+00	1.76E+01	1.17E+00	2.10E+01
18	2.95E-03	8.53E-01	1.86E+01	1.24E+00	2.25E+01
20	9.61E-04	7.65E-01	1.38E+01	9.91E-01	1.69E+01
21	3.54E-04	5.79E-01	9.78E+00	8.57E-01	1.23E+01
22	1.66E-04	1.06E+00	1.61E+01	1.32E+00	1.82E+01
23	4.81E-05	1.05E+00	1.32E+01	1.32E+00	1.58E+01
24	1.60E-05	1.81E+00	1.48E+01	1.54E+00	1.81E+01
25	4.00E-06	8.37E-01	8.94E+00	1.13E+00	1.08E+01
26	1.50E-06	9.01E-01	7.71E+00	1.23E+00	9.87E+00
27	5.50E-07	2.12E+01	1.28E+01	2.03E+01	1.64E+01
28	7.09E-08	4.74E+01	9.97E+00	4.44E+01	8.49E+00
	1.1 E-20				
Total		8.53E+01	3.09E+02	8.50E+01	3.68E+02

Table 10.4-4 CY-MPC Surface Gamma Fluxes for Design Basis Stainless Steel Clad Fuel

Group	Group Upper Energy (MeV)	10-year cooled Radial (g/cm^2 s)	10-year cooled Axial (g/cm^2 s)	5-year cooled Radial (g/cm^2 s)	5-year cooled Axial (g/cm^2 s)
1	1.40E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	1.20E+01	4.67E-02	3.23E-02	4.10E-02	4.31E-02
3	1.00E+01	5.91E-01	1.59E+00	6.92E-01	1.91E+00
4	8.00E+00	7.45E+00	2.28E+01	8.83E+00	2.74E+01
5	6.50E+00	1.71E+01	1.33E+01	1.98E+01	1.59E+01
6	5.00E+00	2.46E+01	1.05E+01	2.84E+01	1.25E+01
7	4.00E+00	2.39E+01	1.65E+01	3.78E+01	2.00E+01
8	3.00E+00	2.60E+01	1.31E+01	6.37E+01	1.66E+01
9	2.50E+00	6.09E+01	2.30E+01	5.41E+02	3.72E+01
10	2.00E+00	4.09E+01	2.01E+01	4.39E+02	3.38E+01
11	1.66E+00	1.00E+02	1.66E+01	4.89E+02	2.75E+01
12	1.44E+00	1.68E+03	2.19E+02	3.54E+03	4.09E+02
13	1.22E+00	2.66E+03	3.62E+02	5.57E+03	6.85E+02
14	1.00E+00	3.46E+03	4.68E+02	7.38E+03	8.95E+02
15	8.00E-01	5.31E+03	6.92E+02	1.10E+04	1.33E+03
16	6.00E-01	8.30E+03	1.05E+03	1.69E+04	2.05E+03
17	4.00E-01	5.74E+03	7.66E+02	1.17E+04	1.47E+03
18	3.00E-01	7.46E+03	9.24E+02	1.51E+04	1.76E+03
18	2.00E-01	1.21E+04	1.13E+03	2.44E+04	2.19E+03
20	1.00E-01	7.17E+03	4.90E+02	1.45E+04	9.59E+02
21	5.00E-02	2.11E+02	1.58E+01	2.86E+02	3.53E+01
22	2.00E-02	9.77E+00	4.82E-01	1.48E+01	1.83E-01
	1.00E-02				
Total		5.44E+04	6.26E+03	1.12E+05	1.20E+04

Table 10.4-5 CY-MPC Total Neutron and Gamma-Ray Source Strengths Per Cask for SKYSHINE-III Calculations

	10-year cooled Radial (n/s or g/s)	**10-year cooled Axial (n/s or g/s)**	**5-year cooled Radial (n/s or g/s)**	**5-year cooled Axial (n/s or g/s)**
Neutron	4.215E+07	2.565E+07	4.201E+07	3.054E+07
Gamma-Ray	2.689E+10	5.196E+08	5.543E+10	9.938E+08

Table 10.4-6 CY-MPC ISFSI Site Boundary Dose Rate Versus Distance

X (feet)	Y (feet)	Distance from the Center of the Array (meters)	8,760-Hour Dose Rate (mrem)	Interpolated Boundary (meters)
0	-1716.9	523	9.1	
0	-1552.9	473	15.1	**426.2**
0	-1388.8	423	25.6	
0	-1224.8	373	44.6	
0	-1060.8	323	80.0	
0	-896.71	273	149.0	
0	-732.67	223	291.2	
0	-568.63	173	615.8	
0	-404.58	123	1516.5	
0	-240.54	73	5587.3	
0	240.54	73	5610.0	
0	404.58	123	1531.6	
0	568.63	173	624.4	
0	732.67	223	295.2	
0	896.71	273	150.8	
0	1060.8	323	81.1	
0	1224.8	373	45.2	
0	1388.8	423	26.0	
0	1552.9	473	15.3	**426.2**
0	1716.9	523	9.2	
-1686.4	0	514	13.4	
-1522.4	0	464	22.2	**454.8**
-1358.3	0	414	37.5	
-1194.3	0	364	65.1	
-1030.3	0	314	117.0	
-866.21	0	264	218.2	
-702.17	0	214	432.2	
-538.13	0	164	935.2	
-374.08	0	114	2396.3	
-210.04	0	64	9409.7	
210.04	0	64	9383.2	
374.08	0	114	2389.8	
538.13	0	164	932.9	
702.17	0	214	431.4	
866.21	0	264	217.7	
1030.3	0	314	116.8	
1194.3	0	364	65.2	
1358.3	0	414	37.5	
1522.4	0	464	22.2	**454.9**
1686.4	0	514	13.4	
			Average for x=0	**427**
			Average for y=0	**455**

Table 10.4-7 CY-MPC ISFSI Site Boundary Annual Dose - Minimum Boundary Distances

X (feet)	Y (feet)	Distance from the Center of the Array (feet)	8,760 Hour Dose Rate (mrem)
-1522.4	0	1522	22.2
1522.4	0	1522	22.2
-1522.4	-155.29	1530	22.3
-1522.4	155.29	1530	22.4
1522.4	155.29	1530	22.4
1522.4	-155.29	1530	22.4
1358.3	694.42	1526	22.4
-1358.3	694.42	1526	22.6
1358.3	-694.42	1526	22.8
-1358.3	-694.42	1526	22.8
-836.01	-1224.8	1483	23.6
836.01	1224.8	1483	23.8
-836.01	1224.8	1483	23.8
836.01	-1224.8	1483	24.0
-407.5	-1388.8	1447	24.0
407.5	-1388.8	1447	24.2
-407.5	1388.8	1447	24.2
407.5	1388.8	1447	24.8
1030.3	1060.8	1479	24.8
-1030.3	1060.8	1479	25.0
-1030.3	-1060.8	1479	25.0
1030.3	-1060.8	1479	25.0
-271.67	-1388.8	1415	25.5
271.67	-1388.8	1415	25.6
0	-1388.8	1389	25.6
-271.67	1388.8	1415	25.8
-135.83	-1388.8	1395	25.9
0	1388.8	1389	26.0
135.83	-1388.8	1395	26.1
271.67	1388.8	1415	26.1
1194.3	857.36	1470	26.4
-135.83	1388.8	1395	26.5
135.83	1388.8	1395	26.5
-1194.3	857.36	1470	26.5
1194.3	-857.36	1470	26.7
-1194.3	-857.36	1470	26.7
1358.3	555.53	1468	27.3
1358.3	-555.53	1468	27.4
-1358.3	-555.53	1468	27.4
-1358.3	555.53	1468	27.5

Appendix 10.A RADIATION PROTECTION – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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10.A RADIATION PROTECTION FOR THE MPC-LACBWR STORAGE SYSTEM

This Appendix describes the radiation protection provisions of the MPC-LACBWR storage system. The MPC-LACBWR is designed to store up to 68 Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans.

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10.A.1 Ensuring that Occupational Radiation Exposures Are As Low As Reasonably Achievable (ALARA)

The MPC-LACBWR storage system provides appropriate radiation protection features in accordance with the requirements of 10 CFR 20 [A2] for system operations that may expose personnel to radiation or radioactive materials. The components of the system that require operation, maintenance, and inspection are designed to minimize radiation exposure to personnel.

10.A.1.1 Policy Considerations

The MPC-LACBWR system is designed so that operation, inspection, repair, and maintenance can be carried out while maintaining occupational exposure As Low As Reasonably Achievable (ALARA).

10.A.1.2 Design Considerations

When used in accordance with its design, the MPC-LACBWR system maintains occupational radiation exposures ALARA while meeting overall system performance objectives. The following specific design features demonstrate the ALARA philosophy:

- Material selection and surface preparation that facilitate decontamination.
- A basket configuration that allows spent fuel loading using accepted standard practices and current experience.
- Positive clean water flow in the transfer cask/TSC annulus to minimize the potential for contamination of the TSC surfaces during in-pool loading.
- Passive confinement, thermal, criticality, and shielding systems that require no maintenance.
- Thick steel and concrete shells in the storage system, and a steel/lead/neutron shield/steel configuration in the transfer system.
- Nonplanar cooling air pathways with respect to the spent fuel assembly source regions to minimize radiation streaming at the concrete cask inlets and outlets.

- Optional use of remote, automated outlet air temperature measurement to reduce surveillance time.

10.A.1.3 Operational Considerations

The ALARA philosophy has been incorporated into the procedural steps necessary to operate the MPC-LACBWR system in accordance with its design. The following features or actions, which comprise a baseline radiological controls approach, have been incorporated in the design or procedures to minimize occupational radiation exposure:

- Use of a prefabricated weld shield as a base for the welding system during welding equipment setup, removal, welding, and weld inspection of the closure lid, closure ring, and port covers. The weld shield is used during the TSC closing and sealing operations.

- Use of remote manual or automatic equipment for welding the closure lid and closure ring.

- Decontamination of the exterior surface of the transfer cask and welding of the closure lid while the TSC remains filled with water. (Personnel exposures reported in this chapter are based on a conservative dry TSC shielding evaluation.)

- Use of quick-disconnect fittings at vent and drain port penetrations to facilitate auxiliary system connections.

- Use of remote handling equipment, where practicable, to reduce radiation exposure. The operational procedures at a particular facility will be determined by the user's operational conditions and facilities.

10.A.2 Radiation Protection Design Features

The detailed description of the MPC-LACBWR radiation shielding design is provided in Appendix 5.A. Radiation protection features and site exposures are based on cask surface dose rates and fluxes determined in Appendix 5.A for a bounding source description. The bounding source description includes the conservative application of maximum cobalt content assembly hardware, maximum burnup, minimum cool time, and minimum enrichment fuel source to every fuel assembly location within the basket. In combination with the other analysis inputs described in Appendix 5.A, such as applying the minimum average concrete density allowed by the drawing to the bulk shield, this analysis configuration produces significantly higher dose rates and site exposures than those expected during implementation of the MPC-LACBWR system at the utility ISFSI.

The principal radiation protection design features are the shielding necessary to meet the design objectives, the placement of penetrations near the edge of the TSC lid to reduce operator exposure and improve access, and a weld shield used for work on and around the closure lid. Use of the weld shield reduces operator exposure during the welding, inspection, draining, drying and helium backfilling operations.

Radiation exposure rates at various work locations were determined with the MCNP5 code within the vicinity of a single transfer and concrete cask and the NAC-CASC code (a modified SKYSHINE-III version) for the concrete cask array. These codes generated bounding dose rate profiles at various distances from the transfer and concrete cask, which are used to estimate the operator exposures for loading and routine operations.

10.A.2.1 Design Basis for Normal Storage Conditions

The radiation protection design basis for the MPC-LACBWR storage cask is derived from 10 CFR 72 [A1] and the applicable ALARA guidelines. The design basis surface dose rates and the calculated one meter dose rates are shown in Appendix 5.A, Section 5.A.1, Table 5.A.1-1.

10.A.2.2 Design Basis for Accident Conditions

Damage to the MPC-LACBWR storage system after a design basis accident will not result in a radiation exposure at the controlled area boundary in excess of 5 rem to the whole body or any organ, including skin. The high-energy missile impact is estimated to reduce the concrete

shielding thickness, locally at the point of impact, by 6 inches. Dose rates and the analysis method for this accident are listed in Appendix 5.A., Section 5.A.4.3. There are no other design basis accident conditions that result in a greater estimated loss of shielding.

Two hypothetical accident events that evaluate storage cask tip-over and the rupture of 100% of the fuel rods are considered in Appendix 11.A. There are no design basis events that result in the tip-over of the MPC-LACBWR storage cask or the release of any radioactive material from the canister.

10.A.3 Estimated On-Site Collective Dose Assessment

Operations personnel exposure estimates are based on identifying the operational cask sequence, estimating the duration and number of personnel required to perform the tasks, determining the location of the personnel in relation to the cask, and multiplying the dose rates at the particular task location by the number of personnel and the task duration. The operational tasks identified are based on the MPC-LACBWR operating procedures provided in this document and operational experiences in loading other canister-based systems.

A collective dose estimate is provided for placing a single MPC-LACBWR on the ISFSI, and for exposures related to routine storage operations of a 5-cask ISFSI. Each cask in the array is assumed to be loaded with the contents that produce the maximum dose rate.

The personnel exposure estimates associated with loading and routine operations are presented in Table 10.A.3-1 and Table 10.A.3-2. The estimated durations, task sequences, and personnel requirements are based on the MPC-LACBWR design features, operational experiences in loading systems of similar design, and operational and equipment improvements based on previous experience. These estimates are provided to allow the user to perform ALARA evaluations on MPC-LACBWR implementation and use, and to establish personnel exposure guidelines for operating personnel. The site-specific design features, location and configuration of workstations, equipment staging, standard practices, operating crew size, temporary shielding use, etc., will result in personnel exposures that may be higher or lower than those presented.

10.A.3.1 Estimated Dose Due to Loading

The estimated dose due to loading operations considers the collective dose due to the loading, closure, transfer, and placement of a single TSC containing bounding fuel assembly contents. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background will vary with site conditions. A 2 mrem/hr dose rate is assigned to tasks not performed within four meters of the equipment or component surface. An example for these tasks is the monitoring of the operation of the welding system using cameras. This task may be performed at more than four meters from the cask body, and behind significant auxiliary shielding. The number of persons allocated to task completion is generally the minimum number of actual operators required for the task and excludes supervisory, health physics, security, and other nonoperating personnel.

Area dose rates are assigned based on the orientation of the worker(s) with respect to the source for a given operational task or sequence. Exposure estimates are shown in Table 10.A.3-1. The number of individual tasks required for loading and transfer of the TSCs is collapsed to eight groups for this presentation. Dose rates shown are time-averaged values across the individual subtasks. Activities 7 and 8 of Table 10.A.3-1 include a crane operator who is considered to be outside of the radiation zone around the cask. Exposures due to loading operations are based on design basis casks.

10.A.3.2 Estimated Dose Due to Routine Operations

Once the MPC-LACBWR is in storage at the ISFSI, limited ongoing maintenance and surveillance will be required. The annual dose evaluations presented herein consider the tasks that are anticipated to be representative of an operational facility. Exposure due to certain events, such as clearing the material blocking the air vents, is taken into account.
Routine operations may include the following:

- An optional daily electronic measurement of ambient air and outlet air temperatures for each TSC in service. Outlet temperature measurements are recorded at a location away from the cask array, and operators are not expected to incur dose as a result of the temperature measurement.

- An optional inspection of the concrete cask inlet and outlet screens to verify that they are unobstructed. The time required to perform the inspection, and the expected dose, will be site-specific due to ISFSI pad dimensions and configurations, the concrete cask array, distance of the inspector, etc.

- A daily inspection of the security fence and equipment surrounding the ISFSI storage area. This surveillance is assumed to require 15 minutes and is performed by one security officer.

- Radiological surveillance. The surveillance consists of a radiological survey comprised of a surface radiation measurement on each cask, the determination and/or verification of general area exposure rates and radiological postings. This surveillance is assumed to require 30 minutes, and be performed quarterly by one health physics technician.

- Annual visual inspection of the general condition of the concrete casks. This inspection is estimated to require 10 minutes per cask and require one technician. For each cask, three minutes of health physics support is also included.

- Corrective maintenance. As the MPC-LACBWR is a passively cooled and shielded system, no significant maintenance is expected over the lifetime of the IFSFI. To account for activities such as minor concrete repairs, air inlet and outlet cleaning, or temperature-monitoring equipment replacement, 20% of the array (one cask) is assumed to require maintenance each year. Maintenance exposure is evaluated based on two operators for 30 minutes each and one health physics technician for 10 minutes.

- Grounds maintenance performed twice a month by one maintenance technician. Grounds maintenance is assumed to require 60 minutes.

Storage operation exposures for a 5-cask array of MPC-LACBWR concrete casks loaded with TSCs containing bounding fuel assembly sources are presented in Table 10.A.3-2. ISFSI exposures are based on design basis casks.

Table 10.A.3-1 Estimated Person-mrem Exposure for Loading Operations of a Single MPC-LACBWR Storage Cask

Step	Description	# Sub-Tasks	# Personnel	Exposure Duration (min)	Average Dose Rate (mrem/hr)	Exposure (mrem)
1	Fuel Assembly Loading and Transfer Cask Removal from Pool	4	2	1605	2.0	108
2	HP Survey and Decon Top of TSC/Transfer Cask	3	1	30	8.0	4
3	Install Weld Shield/Weld Machine, and Perform Partial Drain of TSC	4	1	45	5.3	4
4	Perform Closure Lid and Ring Welding and PT Exams, Hydrostatically Test TSC	16	1	480	8.1	65
5	Drain TSC and Decontaminate Transfer Cask	5	1	230	4.2	16
6	Dry TSC Cavity, Backfill/Pressure TSC, Install Port Covers, Weld and Inspect Covers, Remove Weld Shield/Weld Machine, and Survey Cask/TSC Surfaces	13	1	505	6.5	55
7	Install Hoist Rings, Place Transfer Cask on Concrete Cask, Transfer TSC, Install Concrete Cask Lid, and Perform HP Survey	17	2	220	18.7	137
8	Move Concrete Cask to ISFSI, Position Concrete Cask on ISFSI Pad, and Install/Connect Screens and Temperature Measuring System	11	2	180	2.2	13
	Total					402

Table 10.A.3-2 Estimate of Annual Occupational Exposures Due to Routine Operations for a 5 MPC-LACBWR Storage Cask Array

Activity	Location	# of Casks	Frequency (/year)	Time (min)	Dose Rate (mrem/hr)	# of Personnel	Exposure (mrem)
Security Surveillance	Outside Fence	Array	365	15	2	1	183
Radiological Surveillance	4 m	Array	4	30	3.7	1	7
Annual Inspection	1 m	5	1	10	10.4	1	9
Radiological Support	1 m	5	1	3	10.4	1	3
Corrective Maintenance	1 ft	1	1	30	13.3	2	13
Radiological Support	1 m	1	1	10	10.4	1	2
Grounds Maintenance	Outside Fence	Array	26	60	2	1	52
Total Person-mrem for the Array							269
Total Person-mrem - Average Dose Per Cask							54

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10.A.4 Exposures to the Public

The MPC-LACBWR 5-cask array shown in Figure 10.A.4-1 is evaluated to determine the minimum distance necessary to achieve a controlled area boundary dose of 25 mrem/year as required by 10 CFR 72.104(a). NAC's Version 6.0.1 of the SKYSHINE-III code (NAC-CASC) is used to evaluate the placement of the controlled area boundary for the cask array. Given the source geometry, spectra and desired detector locations, SKYSHINE-III calculates dose rates using a combination of pre-calculated transmission and reflection data and the Monte Carlo technique to integrate over the source direction and energy variables.

Version 6.0.1 of SKYSHINE-III explicitly calculates cask self-shielding based on the cask geometry and arrangement of the cask array. A ray tracing technique is utilized. Given the source position on the cask surface and the direction cosines for the source emission, geometric tests are made to see if any adjacent casks are in the path of the emission. If so, the emission history does not contribute to the air scatter dose. Also, given the source position on the cask surface and the direction cosines for the source to detector location, geometric tests are made to see if any adjacent casks are in the source path. If so, the emission position does not contribute to the uncollided dose at the detector location.

The performance of the SKYSHINE-III Code is benchmarked by modeling a set of Kansas State University ^{60}Co skyshine experiments and by modeling two Kansas State University neutron computational benchmarks. The code compared well with these benchmarks for both neutron and gamma doses versus distance.

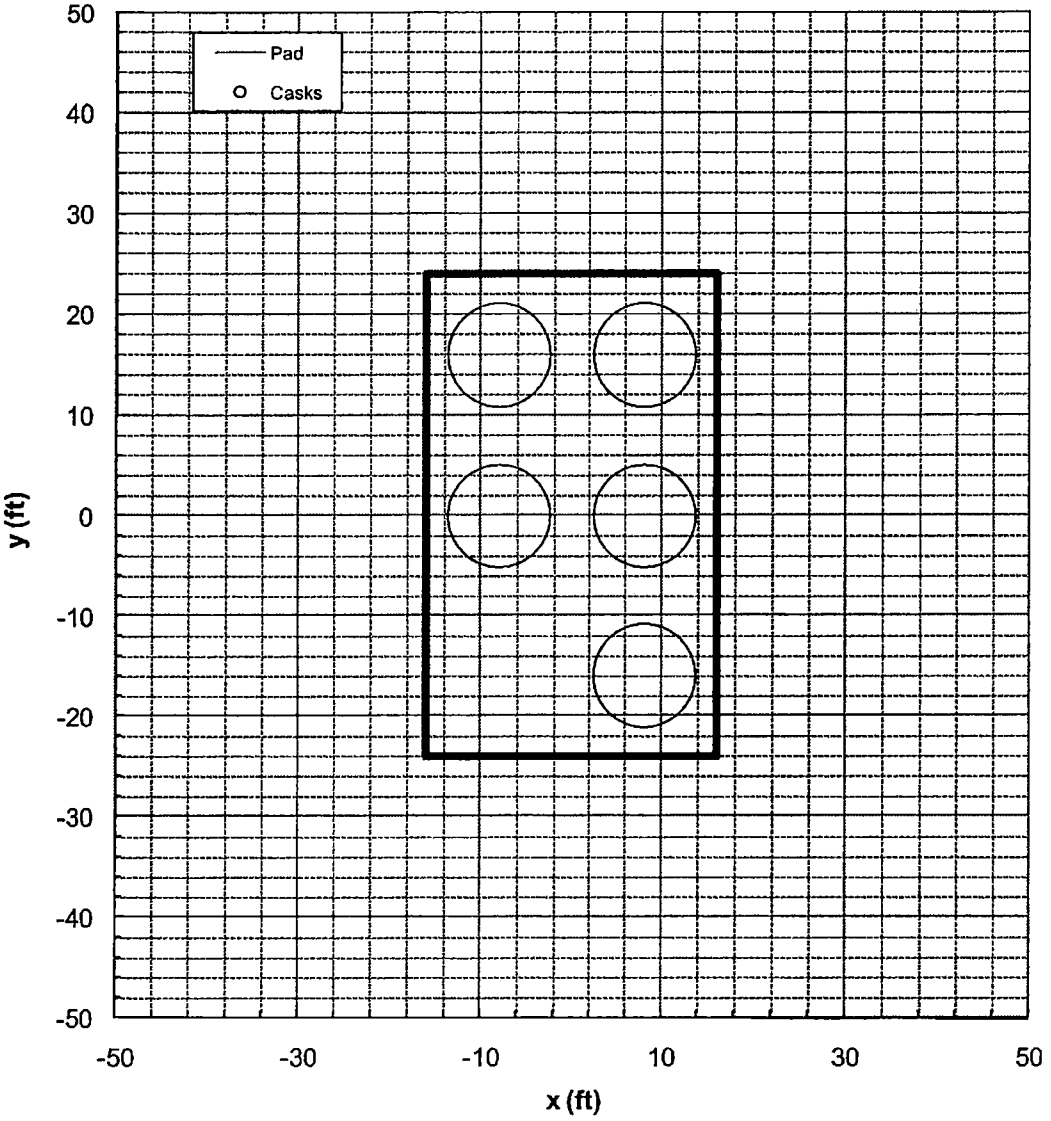
While these analyses are performed for typical arrays of casks containing design-basis spent fuel assemblies, full compliance with the requirements of 10 CFR 72.104(a) can only be demonstrated on a site-specific basis. Consequently, each ISFSI licensee performs a site-specific dose analysis for the facility to show that the requirements of 10 CFR 72 are met. Site-specific boundary distances may vary significantly based on fuel type, fuel cooling time, exposure duration and number of casks in service.

The MPC-LACBWR 5-cask array is explicitly modeled in the code, with the source term from each cask represented as top and side surface sources. The cask surface source strength is provided from the three-dimensional MCNP shielding evaluation. The top and side source energy distributions for both neutron and gamma radiation are taken from the design basis cask

results in Appendix 5.A. Table 10.A.4-1 and Table 10.A.4-2 list the total neutron and gamma source strengths based on the cylindrical area on the side of the storage cask and the circular area on the top of the storage cask.

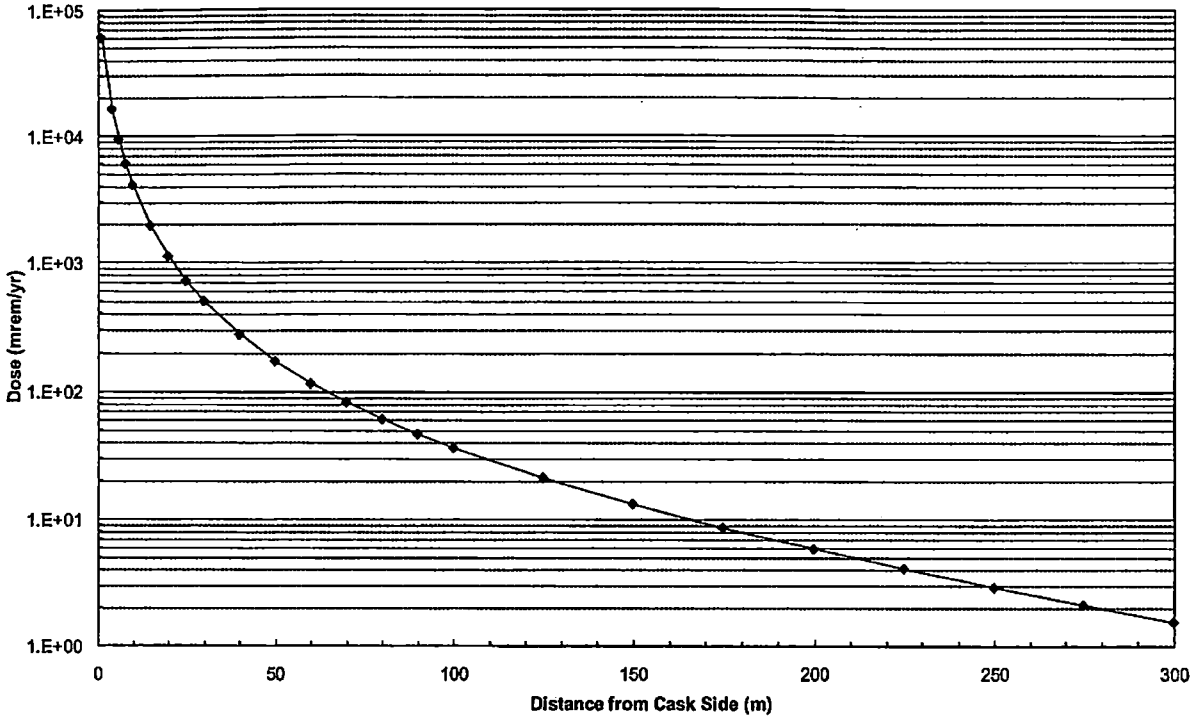
Annual exposures, based on an 8760-hour residence year, were determined from the center of a single cask and a 5-cask array and are shown in Figure 10.A.4-2 and Figure 10.A.4-3, respectively. Figure 10.A.4-4 includes a plot of the 25 mrem/year footprint and the resultant rectangular site boundary. An enveloping boundary around the ISFSI, using these dimensions, will ensure compliance with the requirements of 10 CFR 72.104(a), i.e., a dose rate not exceeding 25 mrem/year.

Figure 10.A.4-1 Layout of 5-Cask Array



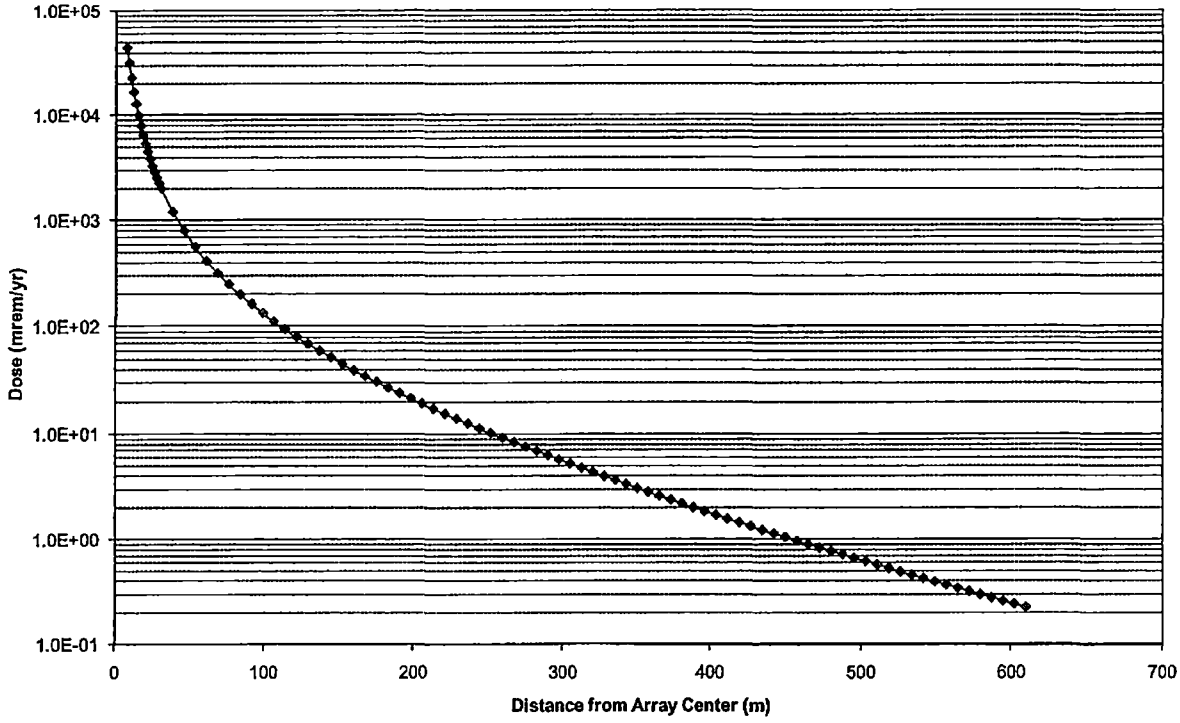
Note: Cask pitch of 16 feet is assumed for analysis.

Figure 10.A.4-2 Exposures from a Single Cask



Distance (m)	Dose Rate (mrem/year)					
	Radial Gamma	Radial Neutron	Axial Gamma	Axial Neutron	Total n-γ	Total
10	4.07E+03	1.35E+01	6.23E+00	3.64E-01	1.08E+01	4.10E+03
25	7.13E+02	2.59E+00	3.25E+00	1.97E-01	7.19E-03	7.19E+02
50	1.69E+02	7.11E-01	1.60E+00	9.89E-02	1.90E-04	1.71E+02
100	3.54E+01	1.82E-01	5.77E-01	3.59E-02	7.79E-05	3.62E+01
125	2.05E+01	1.12E-01	3.75E-01	2.33E-02	6.78E-05	2.10E+01
150	1.27E+01	7.37E-02	2.50E-01	1.56E-02	6.19E-05	1.31E+01
175	8.32E+00	5.05E-02	1.70E-01	1.07E-02	5.88E-05	8.56E+00
200	5.64E+00	3.58E-02	1.17E-01	7.47E-03	5.52E-05	5.80E+00
225	3.93E+00	2.59E-02	8.16E-02	5.30E-03	5.26E-05	4.04E+00
250	2.79E+00	1.92E-02	5.74E-02	3.81E-03	4.97E-05	2.87E+00
275	2.02E+00	1.44E-02	4.08E-02	2.78E-03	4.66E-05	2.08E+00
300	1.48E+00	1.10E-02	2.91E-02	2.05E-03	4.34E-05	1.52E+00

Figure 10.A.4-3 Exposures from a 5-Cask Array



Distance (m)	Dose Rate (mrem/year)			
	Gamma	Neutron	n-γ	Total
50	6.58E+02	3.25E+00	2.48E-03	6.61E+02
100	1.30E+02	8.49E-01	7.04E-04	1.31E+02
150	4.66E+01	3.48E-01	3.90E-04	4.70E+01
200	2.07E+01	1.68E-01	2.88E-04	2.09E+01
250	1.03E+01	8.92E-02	2.37E-04	1.04E+01
300	5.46E+00	5.02E-02	1.99E-04	5.51E+00
350	3.04E+00	2.96E-02	1.65E-04	3.07E+00
400	1.75E+00	1.82E-02	1.37E-04	1.77E+00
450	1.03E+00	1.15E-02	1.10E-04	1.05E+00
500	6.26E-01	7.41E-03	8.76E-05	6.33E-01
550	3.85E-01	4.89E-03	6.87E-05	3.90E-01
600	2.42E-01	3.28E-03	5.31E-05	2.45E-01

Figure 10.A.4-4 Controlled Area Boundary Determination for a 5-Cask Array

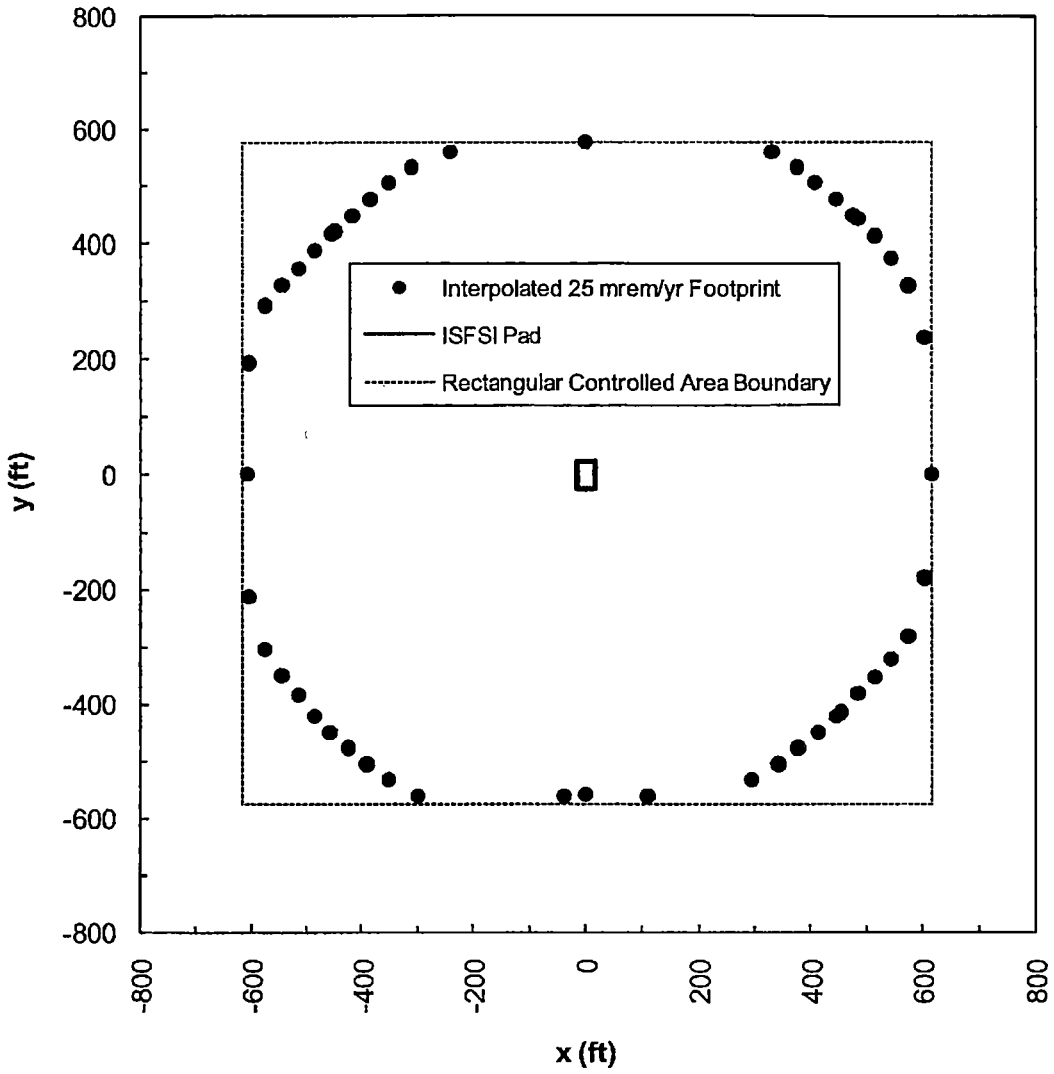


Table 10.A.4-1 MPC-LACBWR Neutron Surface Currents

Group	E Lower [MeV]	E Upper [MeV]	Surface Current [/sec]	
			Radial	Top Axial
1	1.360E+01	1.460E+01	0.000E+00	0.000E+00
2	1.250E+01	1.360E+01	0.000E+00	0.000E+00
3	1.125E+01	1.250E+01	0.000E+00	0.000E+00
4	1.000E+01	1.125E+01	2.038E+01	0.000E+00
5	8.250E+00	1.000E+01	5.653E+01	1.273E+01
6	7.000E+00	8.250E+00	2.251E+02	1.021E+01
7	6.070E+00	7.000E+00	4.991E+02	2.418E+01
8	4.720E+00	6.070E+00	1.680E+03	3.594E+01
9	3.680E+00	4.720E+00	1.843E+03	1.004E+02
10	2.870E+00	3.680E+00	2.173E+03	3.058E+02
11	1.740E+00	2.870E+00	2.119E+04	1.790E+03
12	6.400E-01	1.740E+00	2.356E+04	1.006E+04
13	3.900E-01	6.400E-01	1.753E+04	1.147E+04
14	1.100E-01	3.900E-01	5.338E+04	4.139E+04
15	6.740E-02	1.100E-01	1.595E+04	1.077E+04
16	2.480E-02	6.740E-02	2.615E+04	1.502E+04
17	9.120E-03	2.480E-02	3.456E+04	2.994E+04
18	2.950E-03	9.120E-03	2.179E+04	9.580E+03
19	9.610E-04	2.950E-03	1.964E+04	9.516E+03
20	3.540E-04	9.610E-04	1.808E+04	7.857E+03
21	1.660E-04	3.540E-04	1.312E+04	6.171E+03
22	4.810E-05	1.660E-04	2.167E+04	1.078E+04
23	1.600E-05	4.810E-05	2.105E+04	1.030E+04
24	4.000E-06	1.600E-05	2.500E+04	1.346E+04
25	1.500E-06	4.000E-06	1.512E+04	9.271E+03
26	5.500E-07	1.500E-06	1.811E+04	8.014E+03
27	7.090E-08	5.500E-07	2.968E+05	2.988E+04
28	1.000E-11	7.090E-08	7.439E+05	3.625E+04
Total	--	--	1.413E+06	2.720E+05

Table 10.A.4-2 MPC-LACBWR Gamma Surface Currents

Group	E Lower [MeV]	E Upper [MeV]	Surface Current [/sec]	
			Radial	Top Axial
1	1.20E+01	1.40E+01	0.000E+00	0.000E+00
2	1.00E+01	1.20E+01	8.420E+02	3.096E+01
3	8.00E+00	1.00E+01	4.721E+04	7.182E+03
4	6.50E+00	8.00E+00	5.221E+05	5.750E+04
5	5.00E+00	6.50E+00	4.472E+05	3.126E+04
6	4.00E+00	5.00E+00	4.955E+05	2.704E+04
7	3.00E+00	4.00E+00	5.939E+05	3.566E+04
8	2.50E+00	3.00E+00	2.750E+05	1.866E+04
9	2.00E+00	2.50E+00	8.755E+05	3.352E+04
10	1.66E+00	2.00E+00	1.539E+06	2.123E+04
11	1.44E+00	1.66E+00	5.377E+06	3.736E+04
12	1.22E+00	1.44E+00	1.602E+08	5.362E+06
13	1.00E+00	1.22E+00	2.555E+08	9.967E+06
14	8.00E-01	1.00E+00	3.137E+08	1.472E+07
15	6.00E-01	8.00E-01	4.968E+08	2.580E+07
16	4.00E-01	6.00E-01	7.374E+08	8.537E+07
17	3.00E-01	4.00E-01	4.858E+08	8.234E+07
18	2.00E-01	3.00E-01	6.096E+08	8.675E+07
19	1.00E-01	2.00E-01	1.034E+09	6.107E+07
20	5.00E-02	1.00E-01	5.650E+08	4.088E+06
21	2.00E-02	5.00E-02	1.522E+07	7.878E+04
22	1.00E-02	2.00E-02	2.349E+05	1.508E+04
Total	--	--	4.684E+09	3.758E+08

10.A.5 References

[A1] 10 CFR 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," US Nuclear Regulatory Commission, Washington, DC.

[A2] 10 CFR 20, "Standards for Protection Against Radiation," US Nuclear Regulatory Commission, Washington, DC.

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11.0 ACCIDENT ANALYSIS

The analyses of the off-normal and accident design events, including those identified by ANSI/ANS 57.9-1992, are presented in this section. Section 11.1 describes the off-normal events that could occur during the use of the NAC-MPC storage system, possibly as often as once per calendar year. Section 11.2 addresses very low probability events that might occur once during the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the surrounding environment. Section 11.3 describes the design basis load conditions for the Yankee-MPC transportable storage canister. As described in Section 11.3, the canister is analyzed for loads imposed during transportation. These transport condition loads envelope the loads for the storage condition analyzed herein.

This chapter demonstrates that the NAC-MPC satisfies the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident conditions. These analyses are based on conservative assumptions to ensure that the consequences of off-normal conditions and accident events are bounded by the reported results. The actual response of the NAC-MPC system to the postulated events will be much better than that reported, i.e., stresses, temperatures, and radiation doses will be lower than predicted. If required for a site-specific application, a more detailed evaluation could be used to extend the limits defined by the events evaluated in this section.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee fuel assemblies, reconfigured fuel assemblies or damaged fuel cans and is referred to as the CY-MPC. The third configuration is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans, and is referred to as MPC-LACBWR.

The off-normal and accident conditions evaluation for each configuration is presented separately when appropriate due to differences in capacity, weight and principal dimensions. The off-normal and accident conditions evaluation for the MPC-LACBWR configuration is presented in Appendix 11.A.

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11.1 Off-Normal Events

This section evaluates postulated events that might occur once during any calendar year of operations. The actual occurrence of any of these events is unlikely.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee fuel assemblies, CY-MPC reconfigured fuel assemblies, and CY-MPC damaged fuel cans and is referred to as the CY-MPC. The third configuration is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans, and is referred to as MPC-LACBWR.

The off-normal condition evaluation for each configuration is presented separately when appropriate due to differences in capacity, weight and principal dimensions. The postulated off-normal events evaluation for the MPC-LACBWR storage system is presented in Section 11.A.1 of Appendix 11.A.

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11.1.1 Blockage of Half of the Air Inlets

This section evaluates the NAC-MPC storage cask for the steady state effects of a blockage of one-half of the air inlets at the normal ambient temperature (75°F).

11.1.1.1 Cause of Event

The likely cause of air inlet blockage is debris deposited in the inlets by wind or by intrusion of a burrowing animal. It is expected that screens over the inlets would preclude such animals and would exclude debris from the inlet channels.

This event would be detected by the daily concrete cask operability inspection, which is performed either by outlet air temperature measurements or by visual inspection of the inlet and outlet screens for blockage and integrity. It could also be detected by security forces, or other operations personnel engaged in other routine activities, such as fence inspection or grounds maintenance.

11.1.1.2 Analysis of the Blockage Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.4.1 for the Yankee-MPC and in Section 4.5.1 for the CY-MPC. Air mass flow and air carried heat are calculated using the airflow models described in Sections 4.4.1 and 4.5.1 for the Yankee-MPC and CY-MPC configurations, respectively. The maximum component temperatures due to one-half of the air inlets being blocked are compared to the allowable component temperatures for the off-normal event as shown:

Component	Yankee-MPC 1/2 Inlets Blocked Max Temp. (°F)	Yankee-MPC Allowable Temp. (°F)	CY-MPC 1/2 Inlets Blocked Max Temp. (°F)	CY-MPC Allowable Temp. (°F)
Fuel Cladding	565	806	632	806
Support Disks	531	800	541	800
Heat Transfer Disks	529	700	538	700
Canister Shell	318	800	315	800
Concrete	168	350	178	350

These evaluations show that the component temperatures are within the allowable temperature range for the one-half of the inlets blocked condition for both configurations.

11.1.1.3 Radiological Consequences

There are no significant radiological consequences for this event. It is assumed that a worker kneeling with his hands on the inlets would require 15 minutes to clear the inlets.

For the Yankee-MPC, personnel will be subject to an estimated maximum contact dose rate of 219 mrem/hr. The estimated maximum extremity dose is 55 mrem. The whole body dose would be significantly less.

For the CY-MPC, personnel will be subject to an estimated maximum contact dose rate of 105 mrem/hr. The estimated maximum extremity dose is 25 mrem. The whole body dose would be significantly less.

11.1.1.4 NAC-MPC Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are less than the allowable temperatures. The NAC-MPC storage cask continues to perform its function with one-half of the air inlets blocked.

11.1.1.5 Recovery and/or Corrective Actions

The debris blocking the inlets must be manually removed. The nature of the debris may indicate that other actions are required to prevent recurrence of the blockage.

11.1.2 Canister Off-Normal Handling Load

This section evaluates the consequence of loads on the transportable storage canister during the installation of the canister in the storage cask, or removal of the canister from the storage or transfer casks.

11.1.2.1 Cause of Event

Unintended loads could be applied to the canister, due to misalignment or faulty crane operation or inattention of the operators.

Detection of the event is expected to occur by observation of the event or banging or scraping noise associated with movement of the canister. The event is expected to be obvious to the operators at the time of occurrence.

11.1.2.2 Analysis of the Canister Off-Normal Handling Load Event

The off-normal handling load condition is assumed to consist of loads of 0.5 g applied in all directions (i.e., in the global x, y, and z directions).

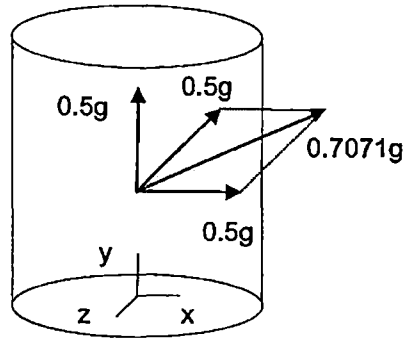
11.1.2.2.1 Analysis of the Yankee-MPC Canister Off-Normal Handling Load Event

The Yankee-MPC canister structural analysis, including lifting loads, was evaluated using an ANSYS finite element model. The model is described in Section 3.4.4-1.

The stresses resulting from off-normal handling are estimated by combining the normal handling stresses at the design off-normal internal pressure of 18 psig with the stress results from a 20 g side and a 20 g bottom end impact of the canister ratioed to the off-normal 0.5 g-loading.

A design off-normal internal pressure is calculated based on the condition of 10 percent fuel rod failure with 30 percent fission gas release at a conservative gas temperature of 620°F. The calculated off-normal internal pressure is 14.4 psig. A design internal off-normal pressure of 18 psig is conservatively used in the canister finite element model as shown in Figure 3.4.4.1-1.

The 0.5 g acceleration in the vertical direction is additive to the 1.1 g acceleration for normal lifting. The two 0.5-g accelerations in the horizontal directions result in a single horizontal acceleration of 0.7071 g as shown below:



$$\sqrt{(0.5g)^2+(0.5g)^2}=0.7071g$$

The stresses obtained from the 20 g side and 20 g bottom end impacts of the canister were then scaled to obtain the additive off-normal handling stresses for 0.7071g side load ($\sigma_{0.7071g}$) and 0.5g vertical load ($\sigma_{0.5g}$) as follows:

$$\sigma_{0.7071g}=\sigma_{1-ft,side}\left(\frac{0.7071g}{20g}\right)$$

and,

$$\sigma_{0.5g}=\sigma_{1-ft,bottomend}\left(\frac{0.5g}{20g}\right)$$

Where 20 g is the deceleration applied in the canister model analysis.

The off-normal handling stresses for the side and the vertical g-loading were then added to the normal-handling stresses to obtain the total off-normal handling stresses.

The pertinent stress results from the 20 g side impact and 20 g bottom end impact of the canister are summarized below. These stress results are presented in Section 11.3.1.

Side: S_{pm} = 13,884 psi
S_{pm+pb} = 24,044 psi

Bottom End: S_{pm} = 1,961 psi
S_{pm+pb} = 4,273 psi

The side and bottom end impact stresses scaled to off-normal handling g-loads were calculated as:

Side:

$$(S_{pm})_{0.7071g} = (S_{pm})_{20g}\left(\frac{0.7071g}{20g}\right) = 13{,}884\text{psi}\left(\frac{0.7071g}{20g}\right) = 491\text{ psi (0.491 ksi)}$$

$$(S_{pm+pb})_{0.7071g} = (P_{pm+pb})_{20g}\left(\frac{0.7071g}{20g}\right) = 24{,}044\text{psi}\left(\frac{0.7071g}{20g}\right) = 850\text{ psi (0.85 ksi)}$$

Vertical (bottom):

$$(S_{pm})_{0.5g} = (S_{pm})_{20g}\left(\frac{0.5g}{20g}\right) = 1{,}961\text{psi}\left(\frac{0.5g}{20g}\right) = 49\text{ psi (0.049 ksi)}$$

$$(S_{pm+pb})_{0.5g} = (S_{pm+pb})_{20g}\left(\frac{0.5g}{20g}\right) = 4{,}273\text{psi}\left(\frac{0.5g}{20g}\right) = 107\text{ psi (0.107 ksi)}$$

The total stresses for a load condition that includes off-normal handling is obtained by adding the off-normal handling stresses to the normal handling stresses at a design off normal internal pressure of 18 psig.

$$\begin{aligned}(S_{pm})_{Casew/Off-normal} &= (S_{pm})_{Normal} + (S_{pm})_{0.7071g} + (S_{pm})_{0.5g} \\ &= (S_{pm})_{Normal} + 0.491\text{ ksi} + 0.049\text{ ksi} \\ &= (S_{pm})_{Normal} + 0.54\text{ ksi}\end{aligned}$$

$$\begin{aligned}(S_{pm+pb})_{Casew/Off-normal} &= (S_{pm+pb})_{Normal} + (S_{pm+pb})_{0.7071g} + (S_{pm+pb})_{0.5g} \\ &= (S_{pm+pb})_{Normal} + 0.85\text{ ksi} + 0.107\text{ ksi} \\ &= (S_{pm+pb})_{Normal} + 0.96\text{ ksi}\end{aligned}$$

The maximum primary membrane stress (S_{pm}) for normal handling occurs at location 13. The maximum primary membrane plus bending stress (S_{pm+pb}) for normal handling occurs at location 2. These stress locations are shown in Figure 3.4.4.1-4. Allowable stresses are determined at 250°F in accordance with ASME Code Section NB, Service Level C (See Table2.2-3).

For location 13:

Normal Handling P_m Stress (ksi)	12.07
Additional P_m Stress Due to Off-Normal Handling (ksi)	0.54
Off-Normal Handling P_m Stress (ksi)	12.61
Allowable P_m Stress (ksi)	20.30
Margin of Safety	+0.61

For location 2:

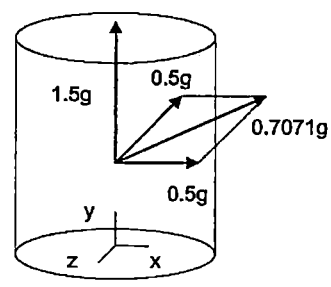
Normal Handling $P_m + P_b$ Stress (ksi)	26.15
Additional $P_m + P_b$ Stress Due to Off-Normal Handling (ksi)	0.96
Off-Normal Handling $P_m + P_b$ Stress (ksi)	27.11
Allowable $P_m + P_b$ Stress (ksi)	30.06
Margin of Safety	+0.11

These results show that the Yankee-MPC canister maintains a positive margin of safety for the off-normal handling condition.

11.1.2.2.2 Analysis of the CY-MPC Canister Off-Normal Handling Load Event

The CY-MPC canister is evaluated for the off-normal handling load condition using the ANSYS finite element model described in Section 3.4.4.3. The minimum structural lid weld size is 0.75 inch and the minimum shield lid weld size is 0.375 inch.

The off-normal canister handling loads are defined as 0.5g applied in all directions (i.e., in the global x, y, and z directions) in addition to a 1g dead load applied in the vertical direction. The resulting off-normal handling accelerations are 0.7071g in the horizontal direction and 1.5g (0.5g+1g) in the vertical direction.



The stresses resulting from off-normal handling are evaluated by applying off-normal handling loads combined with the bounding pressure for normal and off-normal conditions of 15 psig. The off-normal internal pressure is calculated to be 13 psig based on the condition of 10 percent fuel rod failure with 30 percent fission gas release at a conservative gas temperature of 500°F.

Tables 11.1.2-1 and 11.1.2-2 provide the maximum primary membrane stress (P_m) and primary membrane plus bending stress (P_m+P_b) stress intensities for locations 1 through 16 (see Figure 3.4.4.3-1). The maximum P_m and P_m+P_b stress intensities occur at location 3. The minimum margins of safety are +2.21 and +0.32 for P_m and P_m+P_b, respectively.

These results show that the CY-MPC canister maintains a positive margin of safety for the off-normal handling condition.

11.1.2.3 Radiological Consequences

There are no radiological consequences for this off-normal event.

11.1.2.4 NAC-MPC Performance

This evaluation shows that the stress induced in the canister as a consequence of the assumed off-normal handling loading is within the allowable stress for Service Level C loading. There is no deterioration of canister performance.

11.1.2.5 Recovery and/or Corrective Actions

Operations should be halted until the cause of the misalignment, interference or faulty operation is identified and corrected. Since the radiation level of the canister sides and bottom is high, extreme caution should be exercised if inspection of these surfaces is required.

Table 11.1.2-1 CY-MPC Canister Off-Normal Handling + Internal Pressure, Primary Membrane (P_m) Stresses (ksi)

Location No.[2]	Angle (degrees)	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Stress Allowable	Margin of Safety
1	0	-0.4	1.1	3.7	0	0	-0.4	4.2	21.79	4.19
2	0	2.3	-3.6	-2.4	0.5	0	-0.6	6.1	21.76	2.57
3	0	-0.1	-5.4	0.8	0.5	0.1	0.8	6.75	21.67	2.21
4	0	-0.1	0.8	1	-0.1	0	0	1.11	19.83	16.87
5	0	-0.1	0.8	1	-0.1	0	0	1.12	18.45	15.47
6	0	-0.1	0.8	1	-0.1	0	0	1.13	18.29	15.18
7	0	-0.1	0.8	1.1	-0.1	0	0	1.15	19.3	15.78
8	0	-0.1	0.3	1.3	0	-0.1	0	1.39	20.35	13.64
9	0	-0.6	0.4	1.6	-0.1	-0.1	0.1	2.24	20.56	8.18
10	0	-0.7	0.4	1.5	-0.1	-0.2	-0.3	2.36	20.57	7.71
11	90	0.7	0.4	-0.3	0	0	0.2	1.02	20.66	19.26
12	0	-0.8	0.1	0	0	-0.1	-0.3	1.09	20.56	17.86
13	0	-0.9	0.9	0.4	-0.1	0	-0.4	1.95	16.54[3]	7.48
14	180	0.4	0.4	0	0	-0.1	-0.1	0.57	21.88	37.39
15	0	-0.1	0	0	0	0	0	0.05	20.59	+large
16	180	0	0.1	0	0	0	0	0.07	20.68	+large

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

Table 11.1.2-2 CY-MPC Canister Off-Normal Handling + Internal Pressure, Primary Membrane Plus Bending ($P_m + P_b$) Stresses (ksi)

Location No.[2]	Angle (degrees)	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Stress Allowable	Margin of Safety
1	0	3.5	-0.2	9.4	0.2	0	0	9.54	32.68	2.43
2	10	1.3	-7.9	-17.8	0	0.1	-1.3	19.27	32.65	0.69
3	0	-0.9	0.5	23.6	-0.1	0	1.1	24.57	32.5	0.32
4	0	-0.1	0.9	1.1	-0.1	0	0	1.14	28.32	23.84
5	0	-0.1	0.9	1	-0.1	0	0	1.13	25.55	21.61
6	0	-0.1	0.9	1	-0.1	0	0	1.14	25.33	21.22
7	0	-0.1	0.8	1.1	-0.1	0	0	1.16	27.05	22.32
8	0	-0.1	0.6	1.7	0	-0.1	0	1.79	29.55	15.51
9	0	-0.5	0.8	3.3	-0.1	-0.1	0.1	3.77	30.05	6.97
10	0	-0.5	0.6	2.3	-0.1	-0.2	-0.2	2.9	30.08	9.37
11	30	0.5	-0.2	-2.2	0	0	0.3	2.78	30.32	9.9
12	0	-1	0.2	0.5	-0.1	0	-0.5	1.75	30.06	16.18
13	0	-1.6	0.9	-0.3	-0.2	0.1	-0.1	2.56	24.26[3]	8.48
14	100	12.1	12.2	-0.1	0	-0.1	-0.1	12.34	32.83	1.66
15	0	-0.7	-0.7	0	0	0	0	0.65	30.13	45.35
16	0	1.1	1.1	0	0	0	0	1.14	30.36	25.64

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

11.1.3 Failure of Instrumentation

The NAC-MPC system may use a temperature-sensing system to measure the outlet air temperature at each of the four air outlets on each storage cask. The air temperatures at the outlets may be measured and reviewed daily in lieu of performing daily visual verification that all four inlet and outlet screens are unobstructed.

11.1.3.1 Cause of Accident

Failure of the temperature measuring instrumentation could occur as a result of component failure, or as a result of another accident condition that interrupted power or damaged the sensing or reader terminals.

The failure may be identified by the lack of a reading, or an inappropriate reading, at the temperature reader terminal. The event could also be identified by disparities between outlet temperatures in a cask or between similar storage casks.

11.1.3.2 Analysis of Instrumentation Failure

For concrete casks incorporating daily temperature-monitoring programs, the maximum time period during which an increase in outlet air temperatures may go undetected is 24 hours. The principal condition that could cause an increase in temperature is the blockage of the air inlets and/or outlets. Section 11.2.8 shows that even if all of the inlets and outlets of a single cask are blocked immediately after a temperature measurement, it would take longer than 24 hours before any component approaches its allowable temperature limit. Therefore, there would be sufficient time to identify and correct temperature instrumentation failure events prior to critical system components reaching their temperature limits. During the period of loss of instrumentation, no significant change in canister temperature will occur under normal conditions. Therefore, instrument failure would be of no consequence when the affected storage cask continues to operate in a normal storage condition.

Because the canister and the concrete cask are a large heat sink, and because there are few conditions that could result in a cooling air temperature increase, the temporary loss of remote sensing and monitoring of the outlet air temperature is not a major concern. No applicable regulatory criteria are violated by the failure of the temperature instrumentation system.

11.1.3.3 Radiological Consequences

There are no radiological consequences for this event.

11.1.3.4 NAC-MPC Performance

The NAC-MPC canister and storage casks are a large thermal sink. During the period of loss of instrumentation, no significant change in canister temperature will occur under normal conditions.

11.1.3.5 Recovery and Corrective Actions

Following the loss of instrumentation, the temperature instrumentation shall be replaced or repaired and returned to service to allow the surveillance requirements and frequency of LCO 3.1.6 to be met. Alternatively, the surveillance requirement may be met by the daily visual inspection of the inlet and outlet screens of each concrete cask to verify they are not blocked and are intact.

11.1.4 Severe Environmental Conditions (100°F and -40°F)

This section evaluates the NAC-MPC for the steady state effects of high and low ambient temperature conditions.

11.1.4.1 Cause of Event

Large geographical areas of the United States are subjected to sustained summer temperatures in the 90°F to 100°F range and winter temperatures that are significantly below zero. To bound the expected steady state temperatures of the canister and storage cask during these severe ambient conditions, analyses were performed to calculate the steady state storage cask, canister, and fuel cladding temperatures for a 100°F ambient temperature and 24-hour average solar loads. Similarly, winter weather analyses were performed for a -40°F ambient temperature with no solar load. The maximum thermal load of 12.5 kW was applied for the evaluation of the Yankee-MPC. The maximum thermal load of 17.5 kW was applied for the evaluation of the CY-MPC. Neither ambient temperature condition is expected to last more than several days.

Detection of off-normal ambient temperatures would occur during measurement of site ambient temperatures.

11.1.4.2 Analysis of the Off-Normal Ambient Temperature Event

The Yankee-MPC and CY-MPC configurations are evaluated separately.

11.1.4.2.1 Yankee-MPC Off-Normal Ambient Temperature Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.4.1. The temperature profile for the concrete cask and for the air flow for the steady state conditions associated with a 100°F ambient condition are shown in Figures 11.1.4-1 and 11.1.4-2, respectively. Similar profiles for the -40°F ambient temperature condition are shown in Figures 11.1.4-3 and 11.1.4-4. The principal component temperatures for each of these ambient temperature conditions are summarized below.

This evaluation shows that the component temperatures are within the allowable values for the off-normal ambient conditions.

Yankee-MPC Component	100°F Ambient Max Temp. (°F)	-40°F Ambient Max Temp. (°F)	Allowable Temp. (°F)
Fuel Cladding	587	453	806
Support Disks	554	412	800
Heat Transfer Disks	552	411	700
Canister Shell	347	187	800
Concrete	196	5	350

The thermal stress evaluation for the Yankee-MPC concrete cask for these off-normal conditions are bounded by that for the accident condition with 125°F ambient temperature (Section 11.2.10), since the accident condition has the maximum temperature gradient through the storage cask concrete wall.

The thermal stresses for the Yankee-MPC canister the support disks and weldments due to these off-normal conditions are bounded in the thermal stress analysis presented in Section 3.4.4.1.

11.1.4.2.2 Analysis of the CY-MPC for the Off-Normal Ambient Temperature Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.5.1. The temperature profile for the concrete cask and for the air flow for the steady state conditions associated with these off-normal conditions for the CY-MPC system are similar to those for the Yankee-MPC system as shown in Figures 11.1.4-1 through 11.1.4-4. The principal component temperatures for each of these ambient temperature conditions are summarized as:

CY-MPC Component	100°F Ambient Max Temp. (°F)	-40°F Ambient Max Temp. (°F)	Allowable Temp. (°F)
Fuel Cladding	649	530	806
Support Disks	560	428	800
Heat Transfer Disks	557	424	700
Canister Shell	337	188	800
Concrete	203	10	350

The thermal stress evaluation for the concrete cask for these off-normal conditions are bounded by that for the accident condition with 125°F ambient temperature (Section 11.2.10), since the accident condition has the maximum temperature gradient through the storage cask concrete wall.

The thermal stresses for the canister, the support disks and weldments due to these off-normal conditions are bounded in the thermal stress analysis presented in Section 3.4.4.3.

11.1.4.3 Radiological Consequences

There are no radiological consequences for this off-normal event.

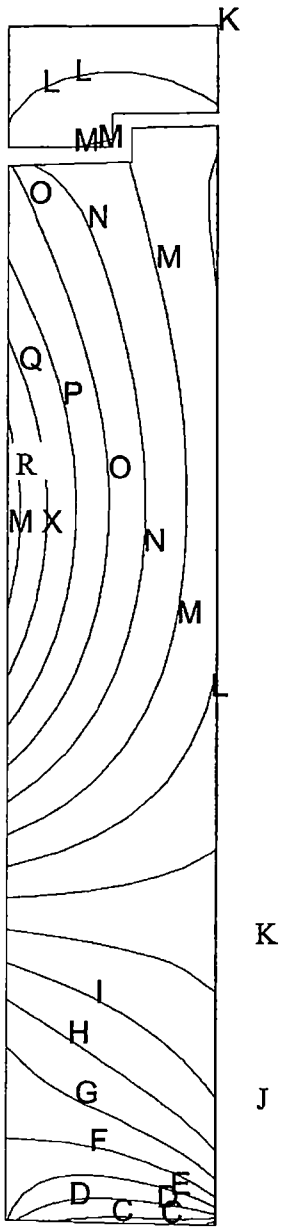
11.1.4.4 NAC-MPC Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are within the allowable temperature values. The materials used are not subject to low temperature brittle fracture.

11.1.4.5 Corrective Actions

No corrective actions are required for this off-normal condition.

Figure 11.1.4-1 Temperature Profile of the Yankee-MPC Concrete Cask in 100°F Ambient Steady State Conditions



	°F
MX=	196
*A=	103
*B=	108
C=	113
D=	119
E=	124
F=	129
G=	134
H=	140
I=	145
J=	150
K=	156
L=	161
M=	166
N=	172
O=	177
P=	182
Q=	188
R=	193

MX = Maximum Temperature

*These temperatures occur over short distances around the inlet vent, but are not shown due to the scale of the figure.

Figure 11.1.4-2 Temperature Profile of the Yankee-MPC Air Flow Stream in 100°F Ambient Steady State Conditions

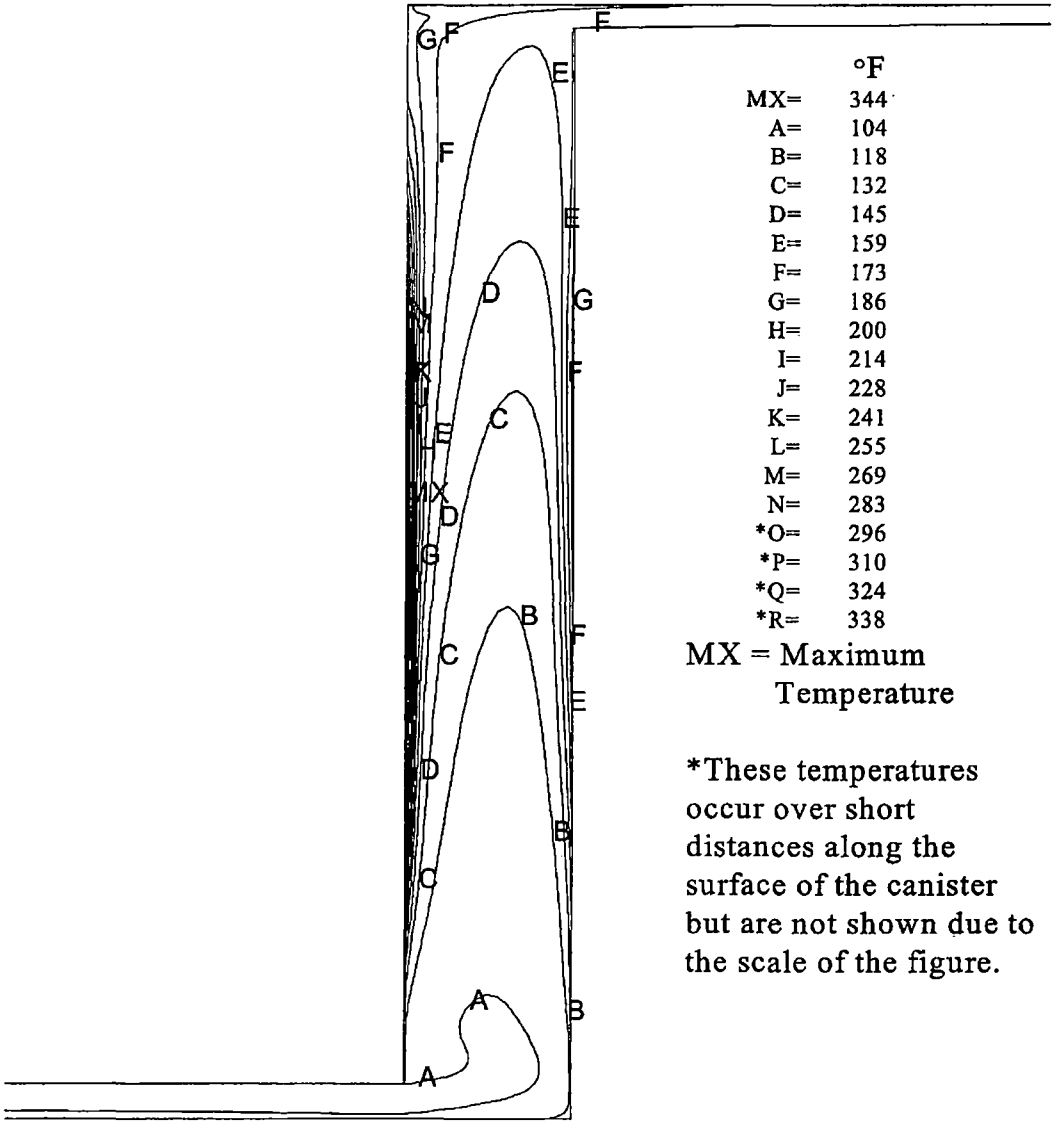
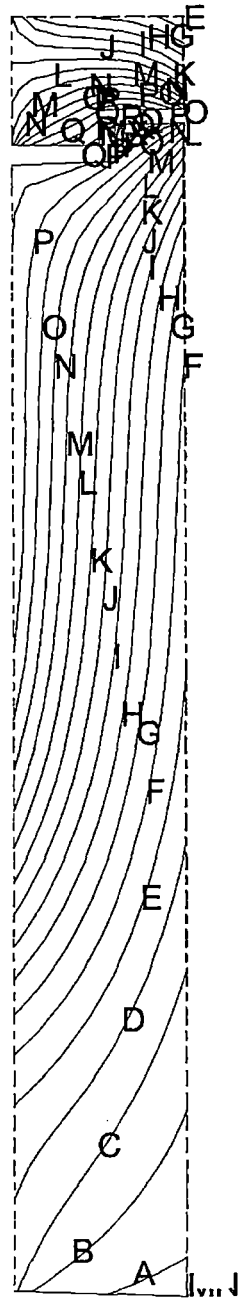
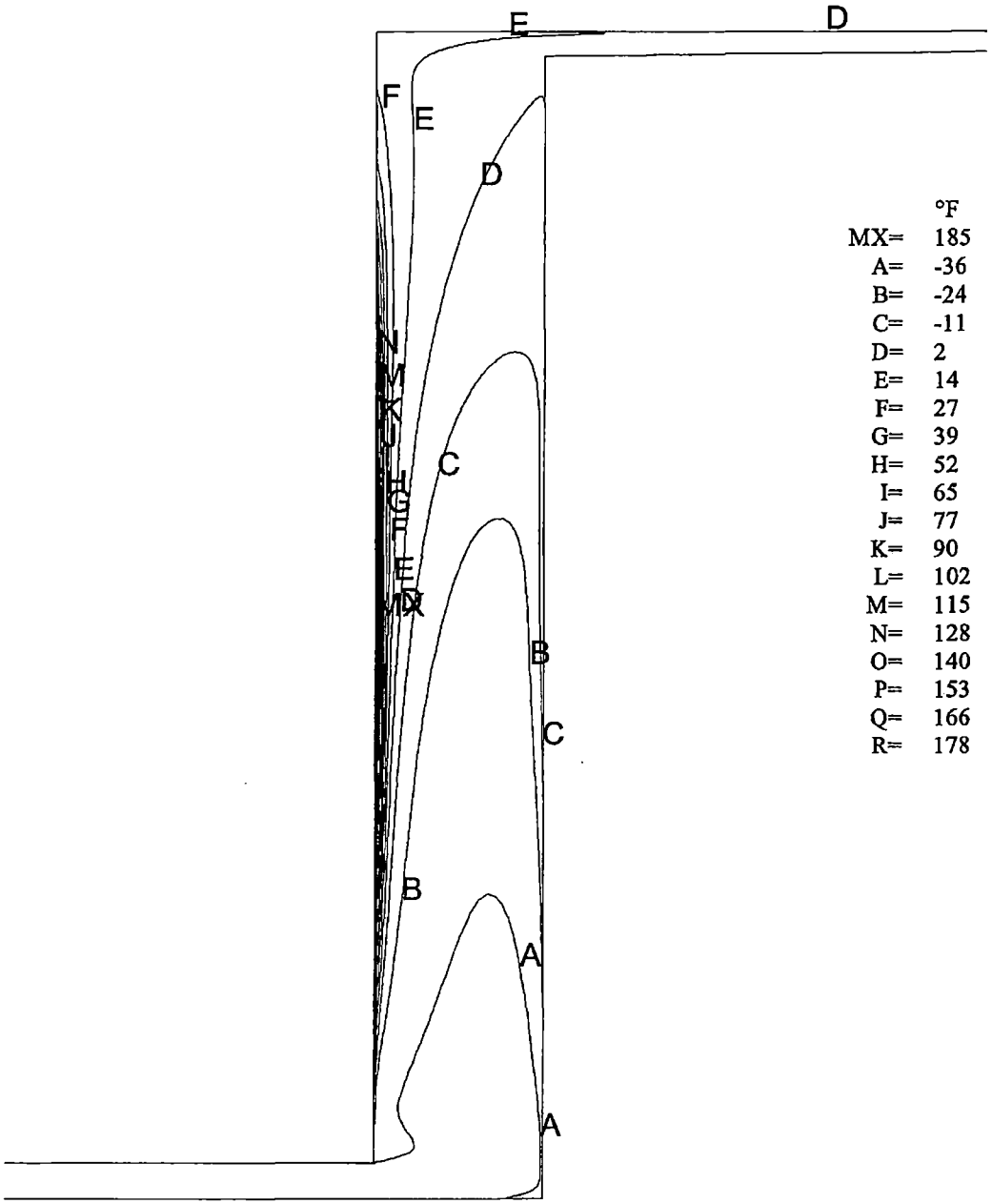


Figure 11.1.4-3 Temperature Profile of the Yankee-MPC Concrete in -40°F Ambient Steady State Conditions



	°F
MX=	5
A=	-39
B=	-36
C=	-34
D=	-31
E=	-29
F=	-26
G=	-24
H=	-21
I=	-19
J=	-16
K=	-14
L=	-11
M=	-9
N=	-6
O=	-4
P=	-1
Q=	1
R=	4

Figure 11.1.4-4 Temperature Profile of the Yankee-MPC Air Flow Stream in -40°F Ambient Steady State Conditions



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11.1.5 Small Release of Radioactive Particulate From the Canister Exterior

The procedures for loading the canister provide for steps to ensure that the canister exterior surface does not come into contact with contaminated spent fuel pool water, and the exterior surface of the canister is surveyed by smear at the top end to verify canister surface conditions. No particulate release from the canister exterior surface is expected to occur in normal use.

11.1.5.1 Cause of Event

In spite of precautions taken to preclude contamination to the external surface of the canister, it is possible that a portion of the canister surface may become slightly contaminated and that the contamination will go undetected. Surface contamination could become airborne and be released as a result of the air flow over the canister surface.

Detection of the release of small amounts of radioactive particles over time would be difficult to ascertain. The release would likely not be at a level that would result in detection by any of the long-term radiation dose monitoring methods (such as TLDs) normally employed. It is possible that a suspected release could be verified by a smear survey of the air outlets.

11.1.5.2 Analysis

The small release analysis is performed using the plume dispersion method of Regulatory Guides 1.109 and 1.145. The analysis for the Yankee-MPC is presented in Section 11.1.5.2.1. The CY-MPC analysis is presented in Section 11.1.5.2.2.

11.1.5.2.1 Release Analysis for the Yankee-MPC Configuration

A calculation was made to determine the level of surface contamination that results in a dose of one (1) mrem annually at a point 100 meters from the ISFSI site. The calculation shows that at the minimum distance of 100 meters permitted by 10 CFR 72, a residual contamination limit of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α activity, on the surface of each of 16 casks yields a dose of one (1) mrem annually.

The method for determining the residual contamination limit is based on the plume dispersion, calculations presented in U.S. NRC Regulatory Guides 1.109 and 1.145.

The factor χ/Q is determined according to the formula from Reg. Guide 1.145:

$$\frac{\chi}{Q} = \frac{1}{U_{10} \cdot \pi \cdot \Sigma_y \cdot \sigma_z}$$

where:

U_{10} = the wind speed at ten meters above plant grade [m/sec]

Σ_y = the lateral plume spread with meander and building wake effects [m]

σ_z = the vertical plume spread [m]

For distances less than 800 meters, Σ_y is the product of the horizontal plume spread, σ_y, and the plume meander and building wake correction factor, M.

From Reg. Guide 1.145, the values for these parameters are as follows, with σ values taken at 100 meters:

U_{10} = 1 m/sec
M = 4
σ_y = 4.0
σ_z = 2.4
Σ_y = 16.0
χ/Q = 8.29×10^{-3} sec/m^3

Reg. Guide 1.109 defines the annual dose due to submersion and inhalation. These equations are solved for the amount of activity released in a year, Q [Ci].

Submersion: $$Q = \frac{D}{\chi/Q \cdot DCF}$$

Inhalation: $$Q = \frac{D}{\chi/Q \cdot DCF \cdot BR}$$

where:

D = dose [rem]

DCF = dose conversion factor [rem-m^3/Ci-yr]
BR = amount of air breathed annually [8,000 m^3]

The selected dose conversion factors are based on the results of the source term analysis, with ^{60}Co assumed to comprise all the β-γ activity and ^{241}Pu all the α activity. Dose conversion factors are taken from EPA Federal Guidance Report No. 11, Table 2.1 and Federal Guidance Report No. 12, Table III.1. The dose conversion factors employed after conversion for unit consistency are:

Activity	Submersion Skin (Rem-m^3/Ci-yr)	Inhalation -Lung (Rem/Ci)	Inhalation-Whole Body (Rem/Ci)	Inhalation -bone (Rem/Ci)
β-γ (^{60}Co)	1.70×10^7	1.28×10^6	2.19×10^5	--
α (^{241}Pu)	--	--	--	1.55×10^8

Employing the submersion and inhalation equations from Reg. Guide 1.109, allowable activities are calculated based on skin submersion, lung dose, and whole body dose for β-γ, and for bone surface dose for α activity. The lesser activity for the β-γ activity becomes the activity limit and the α activity limit is self-limiting and no others are calculated. The resulting activities for a 1 mrem annual dose at 100 meters are:

Dose Type	Activity [μCi]
Bone surface (α)	3.06
Lung	3.71×10^2
Whole body	2.17×10^3
Skin	2.24×10^5

The contamination limit is determined using:

$$C_1 = \frac{Q \cdot 2.22 \cdot 10^{12} \cdot 100}{A \cdot N}$$

where:

C_1 = the contamination limit [dpm/100 cm^2]
A = the surface area of the canister [225,000 cm^2]
N = the number of canisters placed in service (16)

Therefore, contamination limits of 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α, based on a beta-gamma activity of 371 μCi and an alpha activity of 3.06 μCi, result in a dose of one (1) mrem annually at a point 100 meters from the ISFSI site. This dose assumes the simultaneous release of all of the postulated surface contamination from all 16 canisters.

11.1.5.2.2 Release Analysis for the CY-MPC Configuration

A calculation was made to determine dose rate as a function of distance based on residual contamination limits of 20,000 dpm/100 cm^2 β-γ activity and 200 dpm/100 cm^2 α activity, simultaneously released from the surface of 43 CY-MPC canisters, using the plume dispersion method of Regulatory Guides 1.109 and 1.145.

The χ/Q factor is determined according to the formula from Reg. Guide 1.145:

$$\frac{\chi}{Q} = \frac{1}{U_{10} \cdot \pi \cdot \Sigma_y \cdot \sigma_z}$$

where:

U_{10} = the wind speed at ten meters above plant grade [m/sec]
Σ_y = the lateral plume spread with meander and building wake effects [m]
σ_z = the vertical plume spread [m]

For distances less than 800 meters, $\Sigma_y = \sigma_y \times M$

where:

σ_y = the horizontal plume spread
M = the plume meander and building wake correction factor

From Reg. Guide 1.145, the values for these parameters are:

U_{10}	=	1 m/sec
M	=	4
σ_y	=	4.0 at 100 meters
σ_z	=	2.4 at 100 meters
Σ_y	=	16.0

$$\frac{X}{Q} = 8.29\text{ E-03 [sec/m}^3\text{]}$$

The releasable activity is determined using:

$$Q[Ci] = \frac{(C)(A)(N)}{(2.22E+12)(100)}$$

where 2.22E+12 is the conversion from curies (Ci) to disintegrates per minute [dpm], and

C = the contamination limits [20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α]
Q = the activity released [Ci]
A = the surface area of the canister [268,000 cm^2]
N = the number of canisters placed in service [43]

Therefore, the releasable activities are:

Q(β-γ) = 1.04E-03 Ci
Q(α) = 1.04E-05 Ci

Reg. Guide 1.109 defines the annual dose due to submersion and inhalation. These equations are solved for the amount of activity released in a year, Q [Ci].

Submersion: $D_{submersion} = Q \cdot \frac{\chi}{Q} \cdot DCF_S$

Inhalation: $D_{inhalation} = Q \cdot \frac{\chi}{Q} \cdot BR \cdot DCF_I$

where:

D = dose [rem]
DCF_S = submersion dose conversion factor [rem-m^3/Ci-yr]
DCF_I = inhalation dose conversion factor [rem/Ci]
BR = amount of air breathed annually [8000 m^3]

The selected dose conversion factors are based on using the highest conversion factor for each group of nuclides, with ^{60}Co assumed to comprise all of the β-γ activity and ^{241}Am assumed to comprise all of the α activity. Dose conversion factors are taken from EPA Federal Guidance Report No. 11, Table 2.1 and Federal Guidance Report No. 12, Table III.1. Both Class Y (oxide) and W compound dose conversion factors were extracted. Class Y (oxide) conversion factors are

bounding for the β-γ cobalt release. Only class W conversion factors are available for the ^{241}Am release. The dose conversion factors employed after conversion for unit consistency are:

Dose Type	Unit	β–γ (^{60}Co)	α(^{241}Am)
Submersion – Skin	[rem-m^3/Ci-yr]	1.69E+07	--
Inhalation – Lung	[rem/Ci]	1.28E+06	6.81E+07
Inhalation - Whole Body	[rem/Ci]	2.19E+05	4.44E+08
Inhalation – Bone	[rem/Ci]	--	8.03E+09

The inventory available for release is calculated assuming that 100% of the surface area of each canister is covered with the contamination levels listed above, and applies a conservative release fraction of 1% using the methodology presented in Section 1.2.1 of NUREG-1400, which references the values presented in 10 CFR 30.72. The resulting inventory available for release is conservative, as the release fractions presented in 10 CFR 30.72 are a factor of 10 lower for ^{241}Am (0.001) and ^{60}Co (0.001). This inventory is conservatively assumed to be simultaneously released from every canister for the purposes of calculating the worst-case dose contributions at the site boundary.

Employing the submersion and inhalation equations from Reg. Guide 1.109, doses were calculated over a range of distances from 100 to 1000 meters. A dose summary for a distance of 100 meters is shown below for 16, 32, and 48 cask arrays. Included in the listing is the skin dose, followed by the β–γ and α dose contributors to the significant organs and whole body. Also shown is the total exposure from α and β–γ for lungs, bone and whole body.

	Unit	16 Casks	32 Casks	48 Casks
Skin Dose (β–γ)	[mrem]	1.72E-05	3.43E-05	5.15E-05
Lung Dose (β–γ)	[mrem]	1.04E-02	2.07E-02	3.11E-02
Whole Body Dose (β–γ)	[mrem]	1.77E-03	3.55E-03	5.32E-03
Bone Surface Dose (α)	[mrem]	6.51E-01	1.30E+00	1.95E+00
Lung Dose (α)	[mrem]	5.52E-03	1.10E-02	1.66E-02
Whole Body Dose (α)	[mrem]	3.60E-02	7.20E-02	1.08E-01
Whole Body Dose (α + β–γ)	[mrem]	3.78E-02	7.56E-02	1.13E-01
Lung Dose (α + β–γ)	[mrem]	1.59E-02	3.18E-02	4.76E-02
Bone Surface Dose (α)	[mrem]	6.51E-01	1.30E+00	1.95E+00

11.1.5.3 Radiological Consequences

The projected dose at a boundary located 100 meters from the Yankee-MPC 16 cask ISFSI is estimated to be less than one (1) mrem due to the postulated release of surface contamination. This dose is based on a postulated surface contamination of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α, for each of 16 storage casks being simultaneously released to the environment.

The projected dose at a boundary located 100 meters from the CY-MPC cask ISFSI, modeled as 48 casks, is calculated to be less than 2 mrem based on the postulated surface contamination of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α being simultaneously released from each of the 48 canisters. These analyses are highly conservative and demonstrate that the potential off-site radiological consequences from the release of canister surface contamination are negligible.

11.1.5.4 NAC-MPC Performance

Procedural steps are employed to ensure that the canister surface is generally free of surface contamination prior to its installation in the storage cask. The surface of the canister is free of traps that could hold contamination. The presence of external surface contamination on the canister is unlikely.

11.1.5.5 Corrective Actions

No corrective action is required, since the radiological consequence is negligible.

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11.2 Accidents

This section provides the results of analyses of the design basis and hypothetical accident conditions evaluated for the NAC-MPC system. The analyses presented show that the NAC-MPC system has substantial design margin of safety and provides protection to the public and to occupational personnel. In addition to these design basis accidents, this section addresses very low probability events that might occur over the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the immediate environment.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second is designed to store up to 26 Connecticut Yankee fuel assemblies, CY-MPC reconfigured fuel assemblies or CY-MPC damaged fuel cans and is referred to as the CY-MPC. The third configuration is designed to store up to 68 Dairyland Power Cooperative La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies, including up to 32 LACBWR damaged fuel cans, and is referred to as MPC-LACBWR.

The accident conditions evaluation for each configuration is presented separately when appropriate due to differences in capacity, weight and principal dimensions. The accident conditions evaluation for the MPC-LACBWR configuration is presented in Section 11.A.2 of Appendix 11.A.

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11.2.1 Accident Pressurization

Accident pressurization is a hypothetical event that assumes the failure of all of the fuel rods contained within the canister at the maximum internal temperature. There are no storage conditions that are expected to lead to the rupture of all of the fuel rods and none that result in the assumed maximum bulk gas temperature assumed for either NAC-MPC storage system.

11.2.1.1 Cause of Pressurization

The hypothetical breach of all of the fuel rods in a canister would release the fission and fill gases to the interior of the canister.

11.2.1.2 Analysis of Accident Pressurization

11.2.1.2.1 Yankee-MPC Maximum Canister Internal Pressure and Maximum Canister Stress

The analysis requires the calculation of the free volume of the canister, calculation of the quantity of fill and fission gas in the 36 fuel assemblies, and the subsequent calculation of the pressure in the canister if these gases are added to the helium pressure (initially at 1 atm) already present in the canister (Section 4.4.5). The quantity of fission gases was conservatively estimated assuming that 30% of the total gases present are released from the intact fuel. The bulk temperature of the helium is conservatively taken to be 650°F. This temperature bounds the calculated bulk temperature of helium for any of the evaluated normal, off-normal, or accident conditions. This analysis bounds the storage of damaged fuel rods in the Reconfigured Fuel Assemblies or damaged fuel cans as fission, and backfill gases from damaged fuel rods are considered to have been previously released and do not contribute to canister pressurization in accident conditions.

The internal pressure is a function of rod-fill, fission and canister backfill gases. All of the gases, except the fission gases, are assumed to be helium. The total pressure for each volume are found by calculating the molar quantity of each gas and summing those directly. The design basis fuel assembly for the internal pressure calculation is the Combustion Engineering Type A assembly. This assembly has the highest fuel rod back-fill pressure (315 psig) and received the highest burnup (36,000 MWD/MTU [Section 2.1.1]).

The number of moles of the backfill gases are calculated using the Ideal Gas Law, PV = NRT. Backfill gases for the canister and cavity are assumed to be initially at 1 atmosphere. The quantity of fission gas is derived from the SAS2H source term evaluation of the CE Type A fuel assembly.

The number of moles of gas in the canister is:

$$N = N_{TSC\ Back\text{-}Fill} + N_{Rod\ Back\text{-}Fill} + 0.3\left(N_{Fission\ Gas}\right)$$

The number of moles of helium contained in the canister as backfill and the number of moles of gas in the fuel rods (as helium backfill and fission products) were calculated in Section 4.4.5.

The number of moles of gas due to the hypothetical failure of 100% ~~of~~ the fuel rods is:

$$N = \underset{\text{(canister backfill)}}{175.26\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(rod backfill)}}{77.95\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(fission gas)}}{0.3\left(423.44\frac{\text{Moles}}{\text{Cask}}\right)}$$

$$N = 380.24\ \frac{\text{Moles}}{\text{Cask}}$$

Based on an assumed bounding temperature of 650°F, the maximum pressure in the canister is:

$$P = \frac{\left(380.24\ \frac{\text{Moles}}{\text{Cask}}\right)\times\left(0.0821\frac{\text{atm}\ \ell}{\text{mole K}}\right)\times 616.48\ \text{K}}{\left(4{,}877.93\frac{\ell}{\text{Cask}}\right)} = 3.95\ \text{atm} \approx 58.0\ \text{psia} \approx 43.3\ \text{psig.}$$

Maximum Yankee-MPC Canister Stress Due to Internal Pressure

The stresses that result in the canister due to the internal pressure were evaluated using the ANSYS finite element model described in Section 3.4.4. The pressure used for the evaluation is 55 psig, which is conservatively assumed to bound all loading conditions, including canister re-flooding. The results of the analysis are shown in Tables 11.2.1-1 (primary membrane stress) and 11.2.1-2 (primary membrane plus bending stress). The locations of the canister analysis sections are shown in Figure 11.2.1-1.

A uniform pressure of 55 psig is applied to the underside of the canister shield lid and the inner surface of the canister shell. A uniform pressure of 65.61 psig (55 psig + the pressure representing the weight of the contents) is applied to the bottom plate. CONTAC52 elements are

used to model the contact between the bottom plate and the supporting surface. An acceleration of 1g is applied in the axial direction of the canister model.

These results show that the minimum margin of safety for primary membrane stress is +1.83 at location 1. The minimum margin of safety for primary membrane plus bending stress is 0.58 at location 2.

11.2.1.2.2 CY-MPC Maximum Canister Internal Pressure and Maximum Canister Stress

The analysis requires the calculation of the free volume of the canister, calculation of the quantity of fill and fission gas in the 26 fuel assemblies, and the subsequent calculation of the pressure in the canister if these gases are added to the helium pressure (initially at 1 atm) already present in the canister (Section 4.5.5). The quantity of fission gases was conservatively estimated assuming that 30% of the total gases present are released from the fuel. The bulk temperature of the helium is conservatively taken to be 550°F. This temperature bounds the calculated bulk temperature of helium for any of the evaluated normal, off-normal, or accident conditions. The internal pressure is a function of rod-fill, fission and canister backfill gases. All of the gases, except the fission gases, are assumed to be helium. The total pressure for each volume are found by calculating the molar quantity of each gas and summing those directly. The design basis fuel assembly for the internal pressure calculation is the Westinghouse Zircaloy clad 15×15 fuel assembly. This assembly has the highest fuel rod back-fill pressure (475 psig) and received the highest burnup (43,000 MWD/MTU [Section 2.1.2]).

The number of moles of the backfill gases is calculated using the Ideal Gas Law, PV = NRT. Backfill gases for the canister and cavity are assumed to be initially at 1 atmosphere. The quantity of fission gas is derived from the SAS2H source term evaluation of the Westinghouse fuel assembly.

The number of moles of gas in the canister is:

$$N = N_{\text{TSC Back-Fill}} + N_{\text{Rod Back-Fill}} + 0.3\left(N_{\text{Fission Gas}}\right)$$

The number of moles of helium contained in the canister as backfill and the number of moles of gas in the fuel rods (as helium backfill and fission products) are calculated in Section 4.5.5.

The number of moles of gas due to the hypothetical failure of 100% of the fuel rods is:

$$N = \underset{\text{(canister fill)}}{210\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(rod backfill)}}{140\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(fission gas)}}{0.3\left(610\frac{\text{Moles}}{\text{Cask}}\right)}$$

$$N = 533\frac{\text{Moles}}{\text{Cask}}$$

Based on an assumed bounding temperature of 550°F, the maximum pressure in the canister is:

$$P = \frac{\left(533\frac{\text{Moles}}{\text{Cask}}\right)\times\left(0.0821\frac{\text{atm}\,\ell}{\text{mole K}}\right)\times 561\,\text{K}}{\left(5{,}700\frac{\ell}{\text{Cask}}\right)} = 4.31\,\text{atm} = 64.0\,\text{psia} \approx 49.0\,\text{psig}$$

Maximum CY-MPC Canister Stress Due to Internal Pressure

The stresses that result in the canister due to the internal pressure were evaluated using the ANSYS finite element model described in Section 3.4.4.3. The pressure used for the evaluation is 55 psig, which is conservatively assumed to bound all loading conditions, including canister re-flooding. The results of the analysis are shown in Tables 11.2.1-3 (primary membrane stress) and 11.2.1-4 (primary membrane plus bending stress). The locations of the canister analysis sections are shown in Figure 3.4.4.3-1.

A uniform pressure of 55 psig is applied to the underside of the canister shield lid and the inner surface of the canister shell. A uniform pressure of 69.3 psig (55 psig + the pressure representing the weight of the contents) is applied to the bottom plate. CONTAC52 elements are used to model the contact between the bottom plate and the supporting surface. An acceleration of 1g is applied in the axial direction of the canister model.

These results show that the minimum margin of safety for primary membrane stress is +2.19 at location 3. The minimum margin of safety for primary membrane plus bending stress is +0.25 at location 3.

11.2.1.3 Radiological Consequences

There are no radiological consequences for this accident.

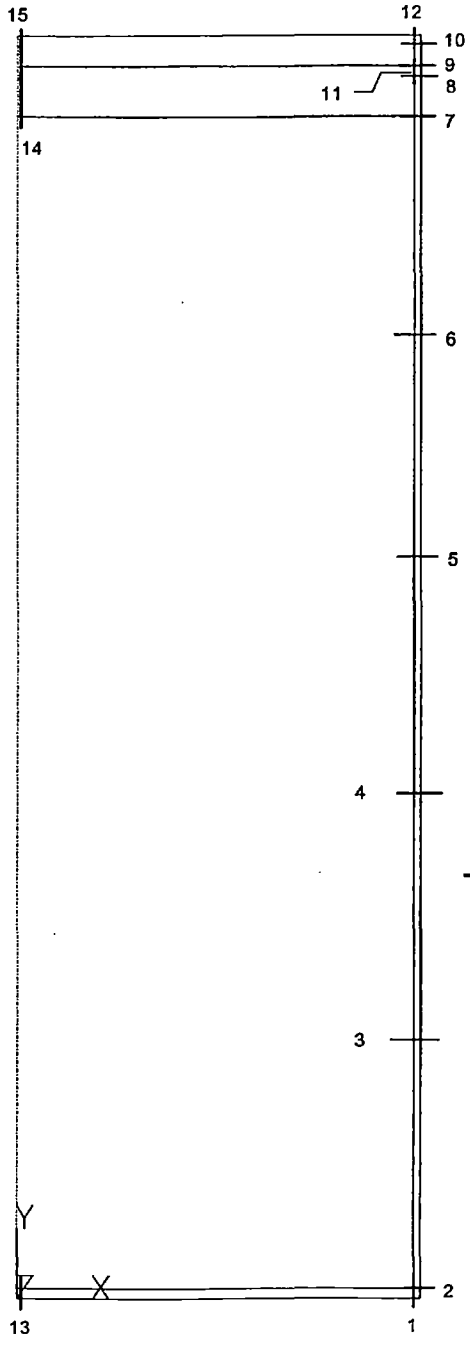
11.2.1.4 NAC-MPC Performance

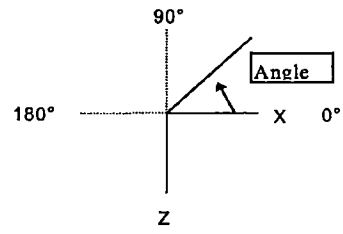
This analysis demonstrates that the canister performance is not significantly affected by the increase in internal pressure that results from the hypothetical rupture of all of the fuel rods contained in the canister. There is a positive margin of safety throughout the canister.

11.2.1.5 Recovery and/or Corrective Actions

There are no recovery or corrective actions required for this hypothetical accident event. The rupture of fuel rods within the canister is unlikely to be detected by any measurements or inspections that could be undertaken from the exterior of the canister or storage cask.

Figure 11.2.1-1 Section Location for Yankee-MPC Canister Stress Evaluation





Top View of Axis

Location of sections at Z=0 (Note: these sections are repeated at each angular division in the 180° model).

	Node 1		Node 2	
Loc.	X1	Y1	X2	Y2
1	34.695	0.0	34.695	1.0
2	34.695	1.0	35.32	1.0
3	34.695	23.7	35.32	23.7
4	34.695	46.4	35.32	46.4
5	34.695	69.1	35.32	69.1
6	34.695	91.8	35.32	91.8
7	34.695	114.5	35.32	114.5
8	34.695	118.5	35.32	118.5
9	34.695	119.5	35.32	119.5
10	34.695	121.62	35.32	121.62
11	34.695	118.5	34.695	119.5
12	34.695	121.62	34.695	122.5
13	0.01	0.0	0.01	1.0
14	0.01	114.5	0.01	119.5
15	0.01	119.5	0.01	122.5

Table 11.2.1-1 Yankee-MPC Canister Primary Membrane Stress (ksi) Due to Internal Pressure (55 psig) for the Accident Pressurization Condition

Location	Angle	SX	SY	SZ	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-1.8	9.6	3.3	-2.1	0.9	0.3	12.3	34.8	1.83
2	0	4.7	-3.7	-3.1	-1.8	0.3	-0.5	9.29	34.8	2.74
3	0	0	1.4	2.9	0	0	0.2	3.0	34.8	10.61
4	0	0	1.4	3	0	0	0.2	3.08	34.8	10.31
5	0	0	1.4	3	0	0	0.2	3.08	34.8	10.3
6	0	0	1.4	3	0	0	0.2	3.06	34.8	10.38
7	0	0	1.4	1.4	-0.1	0	0.1	1.47	34.8	22.66
8	0	0.6	1	1	0.4	0	0	0.88	34.8	38.36
9	0	-1.2	0.9	0.7	0	0	0.1	2.04	34.8	16.02
10	0	1.1	-0.3	0.4	0.1	0	0	1.45	34.8	22.98
11	0	-0.2	-1	0.3	0	0	0	1.35	34.8	24.87
12	0	-0.2	1.1	0.3	0.2	0	0	1.3	34.8	25.69
13	63	1.3	-0.1	1.3	0	0	0	1.42	34.8	23.46
14	72	-0.1	0	-0.1	0	0	0	0.13	34.8	270.66
15	0	0.2	0	0.2	0	0	0	0.16	34.8	211.2

A stress of "0" indicates that the stress at the location is less than 0.1 ksi. Components x, y, and z correspond to the radial, circumferential, and axial directions, respectively.

Table 11.2.1-2 Yankee-MPC Canister Primary Membrane Plus Bending Stress (ksi) Due to Internal Pressure (55 psig) for the Accident Pressurization Condition

Location	Angle	SX	SY	SZ	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-11.7	0.8	1.8	-3.1	1.1	0.6	14.99	52.2	2.48
2	0	2.9	-29.7	-11.6	-2.3	0	-1	32.94	52.2	0.58
3	0	0	1.8	3.1	0	0	0.3	3.17	52.2	15.48
4	0	0	1.4	3.1	0	0	0.2	3.13	52.2	15.7
5	0	0	1.4	3.1	0	0	0.2	3.13	52.2	15.68
6	0	0	1.5	3.1	0	0	0.2	3.11	52.2	15.78
7	0	0.1	1.7	1.5	-0.1	0	0.1	1.61	52.2	31.52
8	0	0.4	0.5	0.8	0.5	0	0	1.05	52.2	48.53
9	0	-0.7	5.6	2.3	0.3	0	0.2	6.27	52.2	7.33
10	0	0.9	-2.3	-0.3	0	0	-0.1	3.21	52.2	15.27
11	0	-1.5	-3.3	-0.6	-0.3	0	0.1	2.7	52.2	18.33
12	0	-1.5	0.6	-0.3	0.2	0	0.1	2.2	52.2	22.73
13	72	1.3	-0.1	1.3	0	0	0	1.46	52.2	34.83
14	0	-3.2	-0.1	-3.2	0	0	0	3.1	52.2	15.84
15	0	0.4	0	0.4	0	0	0	0.37	52.2	138.46

A stress of "0" indicates that the stress at the location is less than 0.1 ksi. Components x, y, and z correspond to the radial, circumferential, and axial directions, respectively.

Table 11.2.1-3 CY-MPC Canister Primary Membrane Stress (ksi) Due to Internal Pressure (55 psig) for the Accident Pressurization Condition + Normal Handling

Location[2]	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	0.4	2.7	7.4	0.2	0.1	-1.2	7.39	40.08	4.42
2	4.7	-6.7	-5.1	0.9	-0.1	-1.2	11.68	40.08	2.43
3	-0.2	-10.2	1.2	0.9	0.1	1.7	12.57	40.08	2.19
4	0	3	1.9	-0.3	0	0	3.04	39.67	12.05
5	0	3	1.9	-0.3	0	0	3.08	36.9	10.98
6	0	3	1.9	-0.3	0	0	3.08	36.58	10.88
7	0	3	2	-0.3	0	0	3.07	38.6	11.57
8	0	1.7	2.1	-0.1	0	0	2.17	40.08	17.47
9	0.8	1.5	1.8	0.1	0	0.6	1.58	40.08	24.37
10	-1.6	0.9	1.5	0.2	0	0	3.08	40.08	12.01
11	1.4	0.5	-0.5	0	0	0.3	2.02	40.08	18.84
12	-0.8	0.2	-1.6	0	0	-0.3	1.92	40.08	19.88
13	-0.2	0.6	1.2	0	0	0.2	1.47	32.06[3]	20.81
14	0.8	0.8	-0.1	0	-0.2	-0.4	1.28	40.08	30.31
15	-0.1	-0.1	0	0	0	0	0.1	40.08	+large
16	0.2	0.2	0	0	0	0	0.16	40.08	+large

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

Table 11.2.1-4 CY-MPC Canister Primary Membrane Plus Bending Stress (ksi) Due to Internal Pressure (55 psig) for the Accident PressurizationCondition + Normal Handling

Location[2]	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	5.3	-0.4	18	0.3	-0.1	-0.2	18.43	60.12	2.26
2	2.5	-15.5	-35.4	-1.5	0.2	-2.5	38.38	60.12	0.57
3	-1.8	1.5	46	0.2	-0.2	2.2	47.93	60.12	0.25
4	0	3	1.9	0.3	0	0	3.07	59.5	18.38
5	0	3.1	1.9	-0.3	0	0	3.13	55.35	16.68
6	0	3.1	2	0.3	0	0	3.12	54.86	16.58
7	0	3.1	2	0	0	0	3.13	57.89	17.5
8	0	1.8	2.5	-0.2	0	0	2.47	60.12	23.34
9	0.7	1.9	3.3	0.1	0	0.9	3.23	60.12	17.61
10	-0.7	2	5.1	-0.2	-0.1	0.5	5.95	60.12	9.1
11	1.1	-0.4	-3.6	0	0	0.5	4.85	60.12	11.4
12	-2.5	-0.5	-2.8	0	0	-0.8	2.87	60.12	19.95
13	-2	-0.1	0.5	0	0	0.3	2.6	48.10[3]	17.5
14	23.8	24	-0.3	0	-0.2	-0.4	24.3	60.12	1.47
15	-2.8	-2.8	0	0	0	0	2.79	60.12	20.55
16	0.9	0.9	0	0	0	0	0.92	60.12	64.35

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

11.2.2 Earthquake Event

11.2.2.1 Cause of Earthquake

At any storage site, the cask might be subjected to an earthquake. The design basis seismic event is described in Section 2.2.3. This analysis shows that the concrete storage cask containing the loaded canister does not tip over or slide in the design basis earthquake.

11.2.2.2 Earthquake Analysis

The NAC-MPC design basis earthquake is one imparting a horizontal acceleration 0.25g at the top surface of the storage pad. The vertical acceleration is defined as two-thirds of the horizontal acceleration in accordance with ASCE 4-86.

11.2.2.2.1 Earthquake Analysis for the Yankee-MPC

The concrete storage cask is a very stiff structure. Although free-standing, it has been analyzed as a cantilever fixed at the base (Roark). For the purpose of calculating seismic loads, the cask is treated as a rigid body attached to the ground and equivalent static analysis methods were used to calculated loads, stresses, and overturning moments.

The natural frequencies of the empty concrete storage cask and the storage cask and canister are calculated to be 89 cycles per second and 36.1 cycles per second, respectively. The natural frequency of the empty storage cask was calculated using the frequency equation:

$$fn = \left(\frac{Kn}{2\pi}\right)\sqrt{\frac{EIg}{WL^4}} \qquad \text{(Roark, Table 36, Case 3)}$$

The natural frequency of the loaded canister is calculated using:

$$\frac{1}{\omega^2} = \frac{1}{\omega^2{}_F} + \frac{1}{\omega^2{}_S} \qquad \text{(Blevins, Equation 8 • 30)}$$

where:

$$\omega_F = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{M}} \qquad \text{and}$$

$$\omega_S = \frac{\lambda}{2\pi L}\sqrt{\frac{KG}{M}}$$

Since the natural frequency is above 33 cycles per second, there is no dynamic amplification and the storage cask and canister are considered to be rigid bodies (NUREG-0800). Static analysis is applied to the evaluation of the earthquake event response.

The following paragraphs present the calculations for acceleration, overturning/restoring forces, and moments for the fully loaded concrete cask.

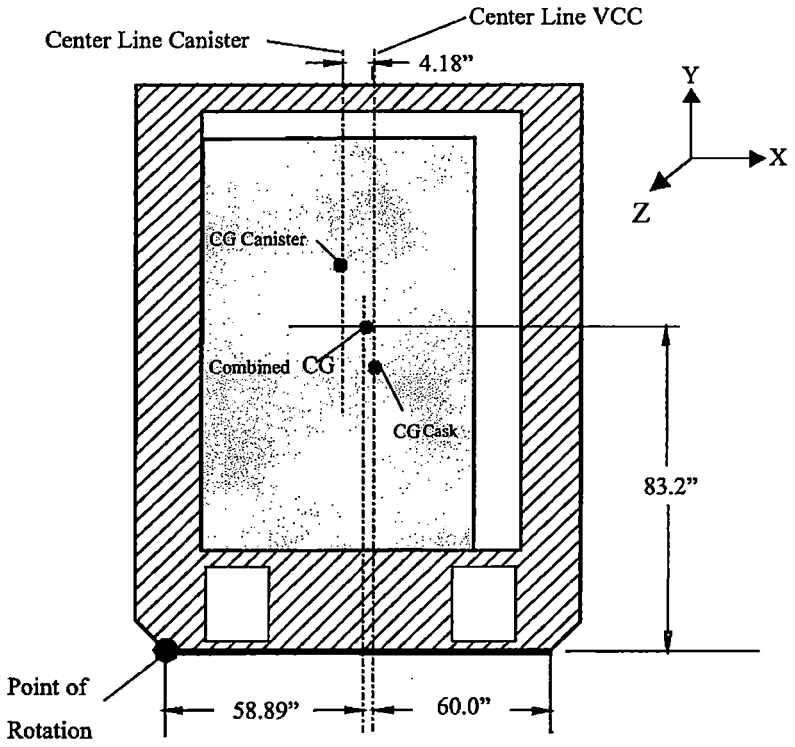
Because the canister is not attached to the concrete cask, the combined center of gravity (CG) for the concrete cask, with the canister in its maximum off-center position, must be calculated. For convenience, a point of rotation (P.O.R.) is established at the outside lower edge of the concrete cask.

The inside diameter of the concrete cask is 79.0" and the outside diameter of the canister is 70.64"; therefore, the maximum eccentricity between the two is $\left(\frac{79.0''-70.64''}{2}\right) = 4.18''$

The horizontal displacement, x, of the combined CG due to eccentric placement of the canister is:

$x = \left(\frac{54730 \times 4.18}{206100}\right) = 1.11''$, therefore, the distance from the postulated point of rotation to the horizontal center of gravity is: (60.0 - 1.11) = 58.89 in.

The vertical location of the CG remains at 83.2". The various moment arms resulting from this calculation are shown in the sketch below.



To maintain the concrete cask in equilibrium, the restoring moment, M_R, must be greater than, or equal to, the overturning moment (i.e., $M_R \geq M_O$). Based on this premise, the following derivation shows that the 0.25g acceleration of the design basis earthquake is well below the acceleration required to tip the concrete cask over.

The combination of horizontal and vertical acceleration components is based on the 100-40-40 approach of ASCE 4-86, which considers that when the maximum response from one component occurs, the responses from the other two components are 40% of the maximum. The vertical component of acceleration is obtained by scaling the corresponding ordinates of the horizontal components by two-thirds.

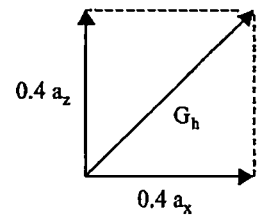
Let $a_x = a_z = a$ = horizontal acceleration components
$a_y = (2/3)a$ = vertical acceleration component
G_h= resultant of two horizontal acceleration components
G_v= vertical acceleration component

There are two combinations that have to be analyzed:

1)

$$G_h = \sqrt{(0.4 \times a_x)^2 + (0.4 \times a_z)^2} = 0.566 \times a$$

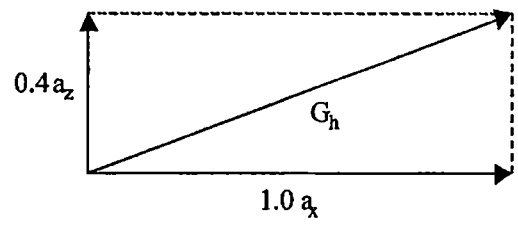
$$G_v = 1.0 \times a_y = 0.667 \times a$$



2)

$$G_h = \sqrt{(1.0 \times a_x)^2 + (0.4 \times a_z)^2} = 1.077 \times a$$

$$G_v = 0.4 \times a_y = 0.267 \times a$$



For the cask to resist overturning, the restoring moment, M_R, about the point of rotation, must be greater than or equal to the overturning moment, M_o.

$$M_R \geq M_o \text{, or}$$
$$F_r \times b \geq F_o \times d \Rightarrow (W \times 1 - W \times G_v) \times b \geq (W \times G_h) \times d$$

where:

- d = center of gravity measured from the base of the concrete cask (83.2 inch)
- b = horizontal distance from the point of rotation to the CG (58.89 inch)
- W = the weight of the concrete cask (206,100 lbs)
- F_o = overturning force
- F_r = restoring force

Substituting for G_h and G_v gives:

1) $(1 - 0.667a)\frac{b}{d} \geq 0.566 \times a$

$$a \leq \frac{b/d}{0.566 + 0.667(b/d)}$$

1) $$a \leq \frac{58.89/83.2}{0.566 + 0.667 \times 58.89/83.2}$$

$$a \leq 0.682g$$

2) $(1 - 0.267a)\ \frac{b}{d} \geq 1.077\ a$

$$a \leq \frac{b/d}{1.077 + 0.267\ (b/d)}$$

2) $$a \leq \frac{58.89/83.2}{1.077 + 0.267 \times 58.89/83.2}$$

$$a \leq 0.559g$$

Therefore, the minimum acceleration that may cause a tip over of a fully loaded concrete cask is 0.559g. Since the 0.25g design basis earthquake acceleration is less than 0.559g, the concrete cask will not tip over.

The factor of safety is 0.559 / 0.25 = 2.24, which is greater than the factor of safety of 1.1 required by ANSI /ANS-57.9.

To keep the cask from sliding, the force holding the cask (F_s) has to be greater than or equal to the force trying to move the cask. Based on the equation for static friction:

$$F_s = \mu N \geq G_h W$$

$$\mu (1-G_v)W \geq G_h W$$

where:
- μ = coefficient of friction
- N = normal force
- W = weight of the concrete cask
- G_v = vertical acceleration component
- G_h = resultant of horizontal acceleration component

Substituting for G_h and G_v for the two combination conditions:

1) $\mu(1-0.667a) \geq 0.566\,a$

$$\mu \geq \frac{0.566a}{1-0.667a}$$

2) $\mu(1-0.267a) \geq 1.077\,a$

$$\mu \geq \frac{1.077a}{1-0.267a}$$

For a = 0.25g

1) $\mu \geq 0.17$

2) $\mu \geq 0.29$

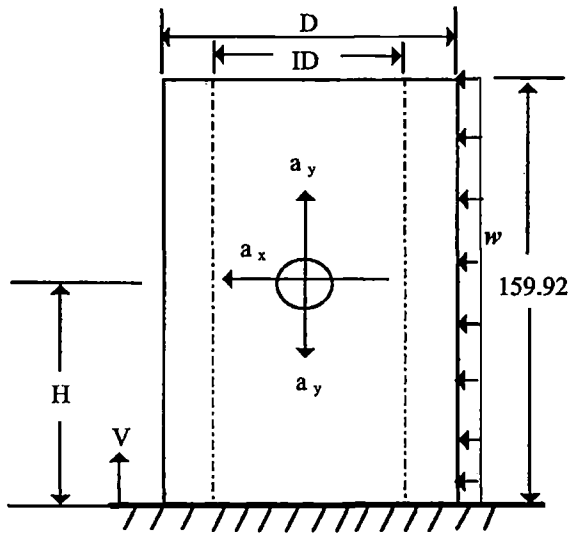
The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.29. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad, 0.35 (Funk), is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis earthquake conditions. The factor of safety is 0.35 / 0.29 =1.21 which is greater than the factor of safety of 1.1 required by ANSI/ANS-57.9.

The stresses in the concrete due to the design basis G-loads are conservatively calculated below. The fully loaded concrete cask is considered to be fixed at its base and subjected to seismic loads equal to 0.25 g in the two orthogonal horizontal directions and the vertical direction.

The accelerations are:

$a_x = (0.25^2 + 0.25^2)^{0.5} = 0.354$ g (horizontal direction)

$a_y = \pm 0.25$ g (vertical direction)



The following parameters are used in the calculation:

H	= 83.2 in. (Location of Center of Gravity)	
W_{vcc}	= 206,100 lb. (VCC weight)	
D	= 128 in. (concrete exterior diameter)	
ID	= 86 in. (concrete interior diameter)	
A	$= \pi (D^2 - ID^{2)} / 4$	$= 7{,}059.2$ in.^{2}
I	$= \pi (D^4 - ID^{4)} / 64$	$= 10.492 \times 10^6$ in.^{4}
S_{outer}	$= 2I / D$	$= 163{,}937.5$ in.^{3}
S_{inner}	$= 2I / (ID)$	$= 244{,}000.0$ in.^{3}
w	$= a_x W_{vcc} / 159.92$	$= 456.22$ lb / in.

The maximum bending moment (M) at support is:

$$M = w (159.92)^2 / 2 = 5.834 \times 10^6 \text{ in.-lb}$$

With a_y = - 0.25g, the maximum compressive stress at the outer and inner surfaces of the concrete shell are:

$$\sigma_{v\,outer} = (M / S_{outer}) + (a_y (W_{vcc}) / A) = -35.59 - 7.30 = -42.9 \text{ psi}$$
$$\sigma_{v\,inner} = (M / S_{inner}) + (a_y (W_{vcc}) / A) = -23.91 - 7.30 = -31.2 \text{ psi}$$

The compressive stresses are included in the load combination No. 5 in Table 3.4.4.2-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and

3.4.4.2-2, the maximum combined stresses for the load combination of dead, live, thermal and earthquake are below the allowable stress.

11.2.2.2.2 Earthquake Analysis for the CY-MPC

The earthquake evaluation of the CY-MPC is based on the 26-assembly configuration, which has the higher center of gravity. In the event of an earthquake, there exists a base shear force or overturning force due to the horizontal ground acceleration and a restoring force due to the net force of vertical ground acceleration and gravity. This ground motion tends to rotate the concrete cask about the bottom corner at the point of rotation (at the chamfer). The horizontal moment arm extends from the center of gravity (C.G.) toward the outer radius of the concrete cask. The vertical moment arm reaches from the C.G. to the bottom of the concrete cask. When the overturning moment is greater than the restoring moment, the cask will tip over. Based upon the requirements presented in NUREG-0800, the static analysis method is considered applicable if the natural frequency of the structure is greater than 33 cycles per second.

The combined effect of shear and flexure is computed as:

$$\frac{1}{f^2} = \frac{1}{f_f^2} + \frac{1}{f_s^2} = \frac{1}{479.9^2} + \frac{1}{178.0^2} \qquad \text{(Blevins, Equation 8-30)}$$

or

$$f = 166.9\,\text{Hz} > 33\,\text{Hz},$$

where:

f_f = frequency for the first free-free mode based on flexure deformation only (Hz)
f_s = frequency for the first free-free mode based on shear deformation only (Hz)

The flexural, f_f, is computed as:

$$f_f = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{M}} = \frac{4.730^2}{2\times\pi\times190.6^2}\sqrt{\frac{(3.38\times10^6)(1.0492\times10^7)}{1.4796}} = 479.9\,\text{Hz}, \quad \text{(Blevins)}$$

where:

λ = 4.730,

L = 190.6 inch, length of VCC,

E = 3.38×10^6 psi, modulus of elasticity for concrete at 200°F,

$$I = \text{moment of inertia} = \frac{\pi\left(D_o^4 - D_i^4\right)}{64} = \frac{\pi\left(128^4 - 86^4\right)}{64} = 1.0492\times10^7 \text{ in}^4,$$

$$\rho = \frac{140}{1728\times386.4} = 2.096\times10^{-4} \text{ lbm/in}^3, \text{ mass density,}$$

$$M = \pi\left(64^2 - 43^2\right)\times\left(2.096\times10^{-4}\right) = 1.4796 \text{ lbm/in.}$$

The frequency accounting for the shear deformation is:

$$f_s = \frac{\lambda_s}{2\pi L}\sqrt{\frac{KG}{\mu}} = \frac{\pi}{2\pi\times190.6}\sqrt{\frac{0.689\times\left(1.4\times10^6\right)}{2.096\times10^{-4}}} = 178.0 \text{ Hz} \qquad \text{(Blevins)}$$

where :

$\lambda_s = \pi$,

L = 190.6 inch, length of the concrete cask,

$$K = \frac{6(1+\nu)\left(1+m^2\right)^2}{(7+6\nu)\left(1+m^2\right)+(20+12\nu)m^2} = 0.689$$

$$= \frac{140}{1728\times386.4} = 2.096\times10^{-4} \text{ lbm/in}^3, \text{ mass density}$$

$$G = \frac{0.5E}{1+\nu} = \frac{0.5(3.38\times10^6)}{1+0.2} = 1.4\times10^6 \text{ psi (modulus of rigidity)}$$

and,

$$m = \frac{R_i}{R_o} = \frac{43}{64} = 0.6719$$

$\nu = 0.2$, Poisson's ratio for concrete

Since the fundamental mode is greater than 33 cycles per second, static analysis is appropriate.

To maintain the concrete cask in equilibrium, the restoring moment, M_R, must be greater than, or equal to, the overturning moment, M_O (i.e., $M_R \geq M_O$). The design basis earthquake acceleration, 'a', occurs at the surface of the concrete pad. The peak ground acceleration in the horizontal directions are a_x and a_z, ($a_x = a_z = a$). The peak vertical acceleration, a_y, is 2/3a.

The horizontal and vertical acceleration components are obtained by using the 100-40-40 approach of ASCE 4-86. This approach directly combines the three orthogonal components where the peak response from one component is combined with the other components that are 40% of their peak values.

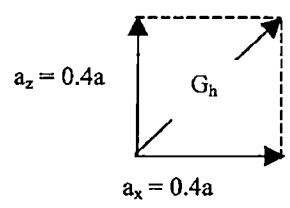
For the CY-MPC concrete cask, there are two combinations that have to be analyzed:

1) The vertical acceleration, a_y, is at its peak: ($a_y = 2/3a$, $a_x = 0.4a$, $a_z = 0.4a$)

$$G_h = \sqrt{a_x^2 + a_z^2}$$

$$= \sqrt{(0.4\times a_x)^2 + (0.4\times a_z)^2} = 0.566\times a$$

$$G_v = 1.0\times a_y = 0.667\times a$$

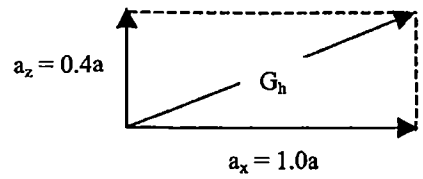


2) One horizontal acceleration, a_x, is at its peak: ($a_y = 0.4\times2/3a$, $a_x = a$, $a_z = 0.4a$)

$$G_h = \sqrt{a_x^2 + a_z^2}$$

$$= \sqrt{(1.0 \times a_x)^2 + (1.0 \times a_z)^2} = 1.077 \times a$$

$$G_v = 0.4 \times a_y = 0.267 \times a$$



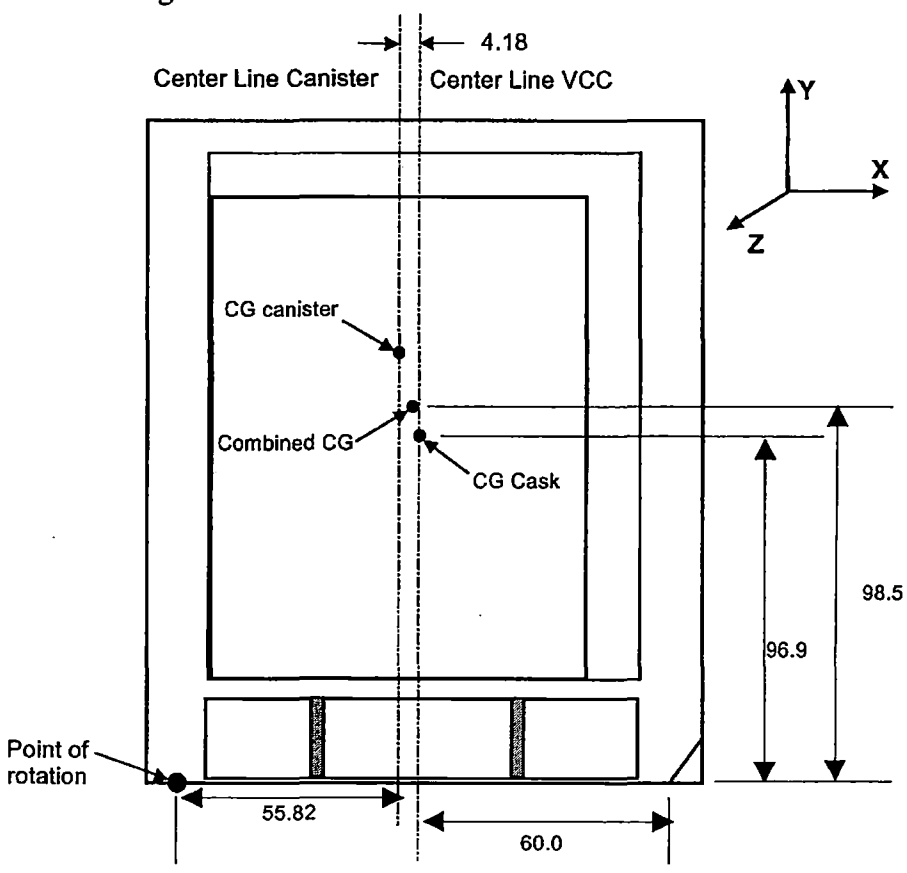
For the cask to resist overturning, the restoring moment, M_R, about the point of rotation, must be greater than or equal to the overturning moment, M_o.

$$M_R \geq M_o \text{, or}$$

$$F_r \times b \geq F_o \times d \Rightarrow (W \times 1 - W \times G_v) \times b \geq (W \times G_h) \times d,$$

where:

d	=	center of gravity measured from the base of the concrete cask (96.9 inch)
b	=	horizontal distance from the point of rotation to the CG (60.0 inch)
W	=	the weight of the concrete cask (251,771 lb)
F_o	=	overturning force
F_r	=	restoring force



Acceleration of Concrete Cask without Canister and Fuel

The acceleration required to tip over an empty concrete cask is calculated by substituting for G_h and G_v:.

1) $$(1-0.667a)\frac{b}{d} \geq 0.566 \times a$$
$$a \leq \frac{b/d}{0.566 + 0.667 \times (b/d)}$$

2) $$(1-0.267a)\frac{b}{d} \geq 1.077 \times a$$
$$a \leq \frac{b/d}{1.077 + 0.267 \times (b/d)}$$

For b = 60 inch and d = 96.9 inch:

1) $a \leq 0.63g$

2) $a \leq 0.50\,g$

Therefore, the minimum acceleration that may cause a tip over of an empty concrete cask is 0.50g. Since the 0.25g design basis earthquake acceleration is less than 0.50g, the concrete cask will not tip over.

Acceleration of Concrete Cask with Canister and Fuel

Because the canister is not attached to the concrete cask, the combined center of gravity for the concrete cask, with the canister in its maximum off-center position, must be calculated. The point of rotation is established at the outside lower edge of the concrete cask.

The inside diameter of the concrete cask is 79.0 inches and the outside diameter of the canister is 70.64 inches; therefore, the maximum eccentricity between the two is:

$$e = \frac{79.0\text{ in} - 70.64\text{ in}}{2} = 4.18\text{ in.}$$

The horizontal displacement, x, of the combined C.G. due to eccentric placement of the canister is:

$$x = \frac{65{,}821(4.18)}{251{,}771} = 1.09 \text{ in.}$$

Therefore,

$$b = 60.0 - 1.09 = 58.91 \text{ in.}$$

The center of gravity of the loaded CY-MPC is:

$$d = 98.5 \text{ in.}$$

Using condition 2, the acceleration is:

$$a \le \frac{58.91/98.5}{1.077 + 0.267 \times (58.91/98.5)}$$

$$a \le 0.48g.$$

Therefore, the minimum ground acceleration that may cause a tip over of a loaded concrete cask is 0.48g. Since the 0.25g design basis earthquake ground acceleration for the CY-MPC system is less than 0.48g, the storage cask will not tip over.

The factor of safety is 0.48 / 0.25 = 1.92, which is greater than the factor of safety of 1.1 required by ANSI /ANS-57.9.

Sliding Evaluation of the Vertical Concrete Cask

To keep the cask from sliding, the force holding the cask (F_s) has to be greater than or equal to the force trying to move the cask. Based on the equation for static friction:

$$F_s = \mu N \ge G_h W$$

$$\mu (1-G_v) W \ge G_h W$$

where:

μ = coefficient of friction
N = normal force
W = weight of the concrete cask

G_v = vertical acceleration component
G_h = resultant of horizontal acceleration component

Substituting for G_h and G_v for the two conditions:

1) $\mu(1-0.667a) \geq 0.566\,a$

$$\mu \geq \frac{0.566a}{1-0.667a}$$

2) $\mu(1-0.267a) \geq 1.077\,a$

$$\mu \geq \frac{1.077a}{1-0.267a}$$

For a = 0.25g

1) $\mu \geq 0.17$

2) $\mu \geq 0.29$

The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.29. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad, 0.35 (Funk), is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis earthquake conditions. The factor of safety is 0.35 / 0.29 =1.21, which is greater than the factor of safety of 1.1 required by ANSI/ANS-57.9.

Stress Generated in the Vertical Concrete Cask During an Earthquake Event

To demonstrate the ability of the concrete cask to withstand earthquake-loading conditions, the fully loaded cask is conservatively evaluated for seismic loads of 0.5g in the horizontal direction and 0.5g in the vertical direction. These accelerations reflect a more rigorous seismic loading; and, therefore, bound the design basis earthquake event. No credit is taken for the inner liner of the concrete cask. The maximum compressive stress at the outer and inner surfaces of the concrete shell are conservatively calculated by assuming the vertical concrete cask to be a cantilever beam with its bottom end fixed.

The maximum longitudinal compressive stress at the outer and inner surfaces of the concrete shell are:

$$S_{v\,outer} = \frac{M}{S_{outer}} + \frac{(1+a_y)W_{VCC}}{A} = -73 + -54 = -127\ \text{psi}$$

$$S_{vinner} = \frac{M}{S_{innerr}} + \frac{(1+a_y)W_{VCC}}{A} = -49 + -54 = -103\ \text{psi}$$

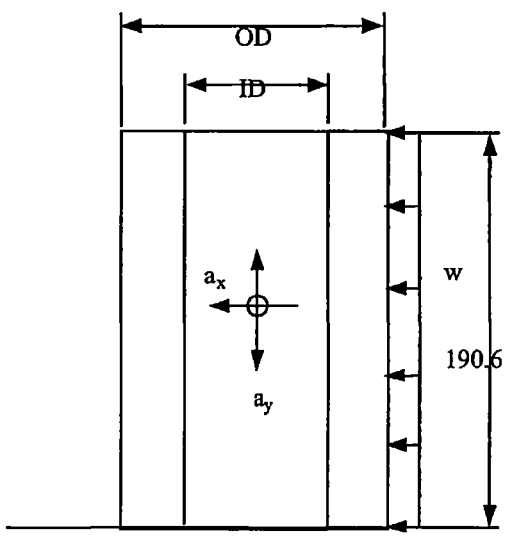
The maximum longitudinal tensile stress at the outer and inner surfaces of the concrete shell are:

$$S_{v\,outer} = \frac{M}{S_{outer}} + \frac{(a_y)W_{VCC}}{A} = 73 + -18 = 55\ \text{psi}$$

$$S_{vinner} = \frac{M}{S_{innerr}} + \frac{(a_y)W_{VCC}}{A} = 49 + -18 = 31\ \text{psi}$$

where:

a_x = 0.50g horizontal direction
a_y = 0.50g vertical direction
W_{VCC} = 251,771 lbs (fully loaded VCC)
OD = 128.0 inch
ID = 86.0 inch
A = $\pi(OD^2-ID^2)/4 = 7{,}059.2\ in^2$
I = $\pi(OD^4-ID^4)/64 = 10.49e6\ in^4$
S_{outer} = $2I/OD = 163932.4\ in^3$
S_{inner} = $2I/ID = 243992.4\ in^3$
w = $a_x W_{VCC}/190.6 = 661$ lb/in
M = $\frac{w(190.6)^2}{2} = 1.201\times10^7$ in-lbs



The compressive stresses are included in the load combination No. 5 in Table 3.4.4.4-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.4-1 and 3.4.4.4-2, the maximum combined stresses for the load combination of dead, live, thermal, and earthquake are below the allowable stress.

11.2.2.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.2.4 NAC-MPC Performance

This analysis shows that the design basis earthquake does not affect the NAC-MPC vertical concrete cask performance. The vertical concrete cask does not tip over for the design-basis earthquake having ground accelerations of 0.25g.

11.2.2.5 Recovery and/or Corrective Actions

Response Surveillance of the storage casks at the ISFSI is required following an earthquake accident in accordance with Section A 5.3 of the Technical Specifications to verify the heat removal systems of the casks are operable. While the cask does not tip over, there is a potential for movement of a cask relative to other casks and for superficial damage at the bottom edge due to that movement.

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11.2.3 Explosion

The flood analysis presented in Section 11.2.6 shows that the NAC-MPC system would not experience adverse effects due to a pressure of 22 psig applied to the canister. The vertical concrete cask will also be unaffected. This pressure is considered to bound any explosions occurring in the vicinity of the ISFSI.

11.2.3.1 Cause of Accident

An explosion is an unlikely event because administrative controls will exclude explosive substances in the vicinity of the ISFSI. No flammable or explosive substances are stored or used at the storage facility; therefore, an explosion affecting the site is extremely unlikely. This evaluation is provided in order to provide a bounding pressure that could be used in the event that the potential of an explosion must be considered at a given site.

11.2.3.2 Evaluation of the Explosion Event

The NAC-MPC canister shell was evaluated in Section 11.2.6 for the effects of a flood having a depth of 50 feet. The water exerts an external hydrostatic pressure of 22 psig on the canister, which results in stress in the canister shell.

The concrete cask is a monolithic structure that is not affected by the explosion overpressure.

11.2.3.2.1 Yankee-MPC Canister Stress Due to the Explosion Event

The maximum primary membrane stress calculated in the canister is 8.82 ksi. The allowable stress for accident conditions is 40.08 ksi. The margin of safety for primary membrane stress is + 3.54.

The maximum primary membrane plus bending stress calculated in the canister is 19.18 ksi. The allowable primary membrane plus bending stress for accident conditions is 60.12 ksi. The margin of safety for primary membrane plus bending stress is + 2.13.

Consequently, there is no adverse consequence to the canister as a result of the 22 psig external pressure. This pressure conservatively bounds an explosion event.

11.2.3.2.2 CY-MPC Canister Stress Due to the Explosion Event

The maximum primary membrane stress calculated in the canister is 3.91 ksi. The allowable stress for accident conditions is 40.08 ksi. The margin of safety for primary membrane stress is +9.26.

The maximum primary membrane plus bending stress calculated in the canister is 15.18 ksi. The allowable primary membrane plus bending stress for accident conditions is 60.12 ksi. The margin of safety for primary membrane plus bending stress is +2.96.

Consequently, there is no adverse consequence to the canister as a result of the 22 psig external pressure. This pressure conservatively bounds an explosion event.

11.2.3.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.3.4 NAC-MPC Performance

This analysis shows that the NAC-MPC system performance is not affected by explosion over pressure.

11.2.3.5 Recovery and/or Corrective Actions

Response Surveillance of the storage casks at the ISFSI in accordance with Section A 5.3 of the Technical Specifications is required following an explosion event to verify the heat removal systems of the casks are operable.

11.2.4 Failure of All Fuel Rods with a Subsequent Ground Level Breach of the Canister

This section addresses the potential mechanistic failure of the canister and subsequent release of radioactive gas, volatile and particulate material from the canister.

As described in Chapters 3, 4, and 11, the NAC-MPC is evaluated for normal conditions and for a series of off-normal and accident events that include cask tip over, cask drop, flooding, fire and explosion, lightning, earthquake, loss of shielding, adiabatic heat up, and tornado generated missiles. The evaluations show that for these design basis events, there is no mechanistic failure of the confinement boundary of the canister, i.e., the canister maintains its structural integrity. As described in Chapter 7 and in Section 8.1.1, the canister is tested to demonstrate that it is leaktight as defined by ANSI N14.5-1997.

Therefore, no further evaluation of this potential accident condition is required.

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11.2.5 Fire Accident

This section evaluates the effects of a hypothetical fire accident as a bounding condition. A fire accident is a very unlikely occurrence in the storage cask lifetime.

11.2.5.1 Cause of Accident

There is no probable cause for this accident event. There are no flammable materials in the area of the ISFSI. While it is possible that a transport vehicle could start a fire while transferring a loaded storage cask at the ISFSI, this fire would be confined to the vehicle and would be rapidly extinguished by the persons performing the transfer operations.

Detection of the event would be by observation of fire or smoke.

11.2.5.2 Accident Analysis

The bounding hypothetical fire accident condition is assumed to be an 8-minute fire in which the following conditions are applied:

1) The air inlets are not blocked; air flows into the inlets, upward past the canister shell surface, and out the outlets.

2) A temperature of 1475°F is applied to the boundary of the air along the inlet surfaces, up to an elevation of 10 inches above the base, to force the air to be heated as the air flows through the inlets. Both the top and bottom surfaces of the inlets have the temperature specification of 1475°F applied to them.

3) The fire condition is applied for 8 minutes.

4) After the fire condition, the air inlet temperature is returned to 75°F.

5) Solar insolation is applied during the fire, since the fire condition is applied only to the base of the concrete cask.

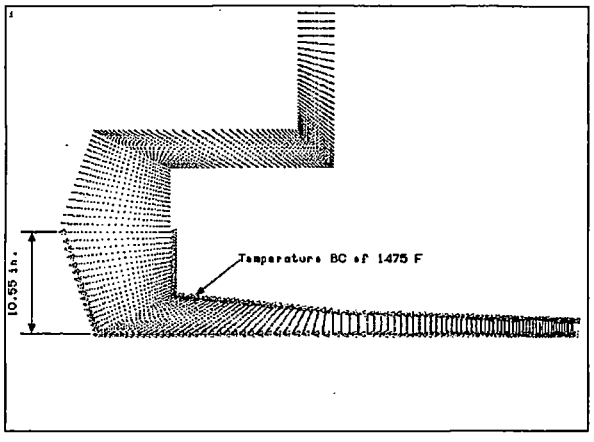
6) The initial condition for the fire is the steady state normal operating condition with an ambient temperature of 75°F, a heat input corresponding to a 12.5 kW fuel heat

source for the Yankee-MPC configuration and 17.5 kW for the CY-MPC and the solar insolation applied to the top and sides of the Vertical Concrete Cask. During the steady state condition, the air entering the inlet is at a temperature of 75°F.

The assumptions used in the hypothetical fire accident are very conservative due to the limited amount of combustible material (less than 50 gallons of diesel fuel) present at the ISFSI. The fuel is assumed to spread over a large combustible area and the fire is assumed to totally engulf the entire base of the cask. Thus, the duration of an associated fire is relatively short (assumed to be 8 minutes). The analysis is further simplified by assuming an instantaneous change of the ambient air temperature from 75°F to 1475°F.

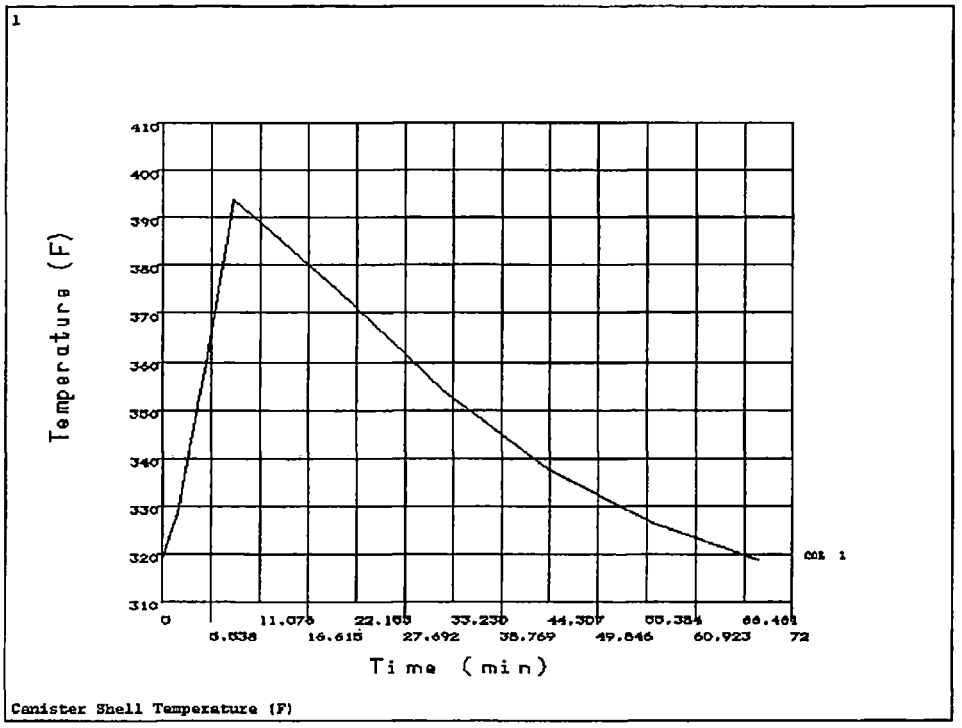
11.2.5.2.1 Fire Accident Evaluation for the Yankee-MPC

The event is evaluated using the two-dimensional air flow model described in Section 4.4.1.1. The initial phase of the transient solution is to bring the air flow model to steady state conditions using the conditions described in Section 4.4.1.1. The next phase is started with a step change of the temperature to 1475°F, which is applied to the inner surface of the inlets as shown below:



This condition is applied for 8 minutes. After the 8-minute period, the 1475°F boundary condition is removed and the external conditions at the time of normal operating steady state conditions are applied. This initiates the cool down phase, which is analyzed for an additional 60 minutes.

The time history for the canister shell temperature is shown below.



The sharp change in the canister shell temperature near the end of the fire condition results because the canister contents are not modeled. This is considered to be conservative, since the reduced thermal capacitance of the system maximizes the temperature change of the canister surface due to flow of the heated air. The temperature rise of the canister shell due to the fire condition is determined to be 75°F. This change in temperature is added to the component maximum steady state normal condition temperature to compute the maximum component temperatures due to the fire. The bulk concrete temperature experienced a temperature change of 11°F, due to the local heating of the concrete. The maximum temperatures for the 8-minute fire/vents not blocked condition are:

Component	Steady State Temperature (°F)	Maximum Temperature as a Result of the Fire (°F)	Allowable Short Term Temperatures (°F)
Canister shell	319	394	800
Heat transfer disk	527	602	700
Support disk	529	604	800
Fuel cladding	563	638	806
Bulk concrete	133	144	350

The component temperatures are shown to be less than the allowable temperatures, which confirms that the thermal response of the Yankee-MPC system is acceptable for the fire condition.

11.2.5.2.2 Fire Accident Evaluation for the CY-MPC

The CY-MPC concrete cask differs from the Yankee-MPC concrete cask in overall height, but is identical to the Yankee-MPC with respect to the size of the air inlet and outlet, the diameters of the canister and concrete cask, and the annulus gap, which are the parameters that control heat input in the fire transient condition. Based on the similarity of the two NAC-MPC configurations, the fire accident results for the CY-MPC configuration can be determined using the Yankee-MPC fire accident results presented in Section 11.2.5.2.1. The increase in the temperature of the Yankee-MPC canister shell is (394°F-319°F=) 75°F and is (144°F-133°F =) 11°F for the concrete shell. The maximum temperatures for the 8-minute fire for the CY-MPC are obtained by adding the temperature increase due to the fire to the normal operational temperatures of the components.

Component	Steady State Temperature (°F)	Maximum Temperature as a Result of the Fire (°F)	Allowable Short-Term Temperatures (°F)
Canister shell	312	387	800
Heat transfer disk	534	609	700
Support disk	538	613	800
Fuel cladding	629	704	806
Bulk concrete	130	141	350

The component temperatures are shown to be less than the allowable temperatures, which confirms that the thermal response of the CY-MPC system is acceptable for the fire condition.

11.2.5.3 Radiological Consequences

The radiological consequences for this accident are associated with the potential loss of concrete at the base of the cask. Concrete that reaches a temperature above 300°F could become dehydrated and separate from the bulk concrete that forms the storage cask. It is conservatively assumed that up to a three-inch square section around the base of the cask could potentially spall

from the concrete cask. This postulated loss of concrete could result in a post accident dose rate of approximately 140 mrem/hr for the Yankee-MPC and 564 mrem/hr for the CY-MPC containing stainless steel fuel. No loss of concrete is expected to occur since the postulated fire occurs at the base of the storage cask.

11.2.5.4 NAC-MPC Performance

11.2.5.4.1 Yankee-MPC Performance

The peak temperature of the canister shell is 394°F, which is reached 8 minutes after the fire starts. The canister shell temperature cools rapidly following the end of the fire event and is at normal temperature in about 60 minutes. The concrete temperature increases only slightly during the hypothetical event. The peak temperature of the heat transfer disk is 602°F, which is less than the short-term allowable temperature of 700°F. The peak fuel temperature is 638°F, which is much less than the short-term allowable fuel temperature of 806°F. The fuel, canister, and support disk are not significantly affected by the accident.

11.2.5.4.2 CY-MPC Performance

The peak temperature of the canister shell is 387°F, which is reached 8 minutes after the fire starts. The canister shell temperature cools rapidly following the end of the fire event and is at normal temperature in about 60 minutes. The concrete temperature increases only slightly during the hypothetical event. The peak temperature of the heat transfer disk is 609°F, which is less than the short-term allowable temperature of 700°F. The peak fuel temperature is 704°F, which is much less than the short-term allowable fuel temperature of 806°F. The fuel, canister, and support disk are not significantly affected by the accident.

11.2.5.5 Recovery and/or Corrective Actions

In the unlikely event of such a severe fire at an ISFSI site, the operator will take appropriate immediate response to suppress and extinguish the fire. Following the fire, the concrete cask should be inspected for general deterioration of the concrete, loss of shielding (spalling of concrete), exposed reinforcing bar, and surface discoloration that could affect heat rejection. This inspection would determine the repair activities necessary to return the concrete storage cask to its design basis configuration.

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11.2.6 Flood

This evaluation shows that the NAC-MPC system is not adversely affected by a design basis flood having a depth of water of 50 feet and a flow velocity of 15 feet per second. This flood is fully immersing for the NAC-MPC system.

11.2.6.1 Causes of Flood

The probability of a flood event is highly dependent on land contour and environmental factors that are specific to each ISFSI site. Most reactor sites are not susceptible to flooding as a result of site selection characteristics.

11.2.6.2 Flood Analysis

The concrete cask is considered to be resting on a flat level concrete pad when subjected to a flood velocity pressure distributed uniformly over the projected area of the concrete cask. Because of the concrete cask geometry, rigidity, and large mass, it is analyzed as a rigid body. Assuming full immersion of the concrete cask and steady-state flow conditions, the drag force, F_D, is calculated using classical fluid mechanics for turbulent flow conditions. A safety factor of 1.1 for stability against overturning and sliding is applied. The coefficient of friction between carbon steel and concrete used in this analysis is 0.35 (Funk).

The buoyancy force, F_b, is calculated from the weight of water (62.4 lb/ft^3) displaced by the fully immersed concrete cask.

11.2.6.2.1 Evaluation of the Yankee-MPC for the Design Basis Flood Condition

The displacement volume of the concrete cask containing the loaded canister is 1030 ft^3. The displacement volume is the occupied volume less the free space in the central annular cavity of the concrete cask.

$$F_b = \text{Vol} \times 62.4 \text{ lb/ft}^3$$
$$= 64.27 \text{ kip}$$

Assuming the steady-state flow conditions for a rigid cylinder, the total drag force of the water on the concrete cask is given by the formula:

$$F_D = (C_D)(\rho)(V^2)\left(\frac{A}{2}\right) \qquad \text{(Roberson)}$$

$$= 21.72 \text{ kip}$$

where:

C_D = Drag coefficient, which is dependent upon the Reynolds Number (Re). For flow velocities greater than 6 ft/sec, the value of C_D approaches 0.7. (Roberson)

ρ = mass density of water = 1.94 slugs/ft^3

D = concrete cask outside diameter (128 in. / 12 = 10.67 ft)

V = velocity of water flow (15 ft/sec)

A = projected area of the concrete cask normal to water flow (10.67 ft × 13.33 ft = 142.2 ft^2)

The drag force required to overturn the concrete cask is determined by summing the moments of the drag force and the submerged weight (weight of the cask less the buoyant force) about a point on the bottom edge of the cask. This method assumes a pinned connection, i.e., the cask will rotate about the point on the edge rather than slide. When these moments are in equilibrium, the cask is at the point of overturning.

$$F_D \times \left(\frac{h}{2}\right) = (W_{VCC} - F_b) \times r$$

and

$$F_D = 113.42 \text{ kip}$$

where:

h = concrete cask overall height (159.92 in., use 160 in. / 12 in./ft = 13.33 ft)

W_{VCC} = concrete weight = 206.1 kips

F_b = buoyant force = 64.27 kips

r = concrete cask radius (64 in. / 12 in./ft = 5.33 ft)

Solving the drag force equation for the velocity, V, that is required to overturn the concrete cask:

$$V = \sqrt{\frac{2F_D}{C_D \rho A}}$$

$$= 32.68 \text{ ft/sec. (including safety factor of 1.1)}$$

To prevent sliding, the minimum coefficient of friction (with a safety factor of 1.1) between the carbon steel bottom plate of the concrete cask and the concrete surface upon which it rests is:

$$\mu_{min} = \frac{(1.1)F_{D15}}{F_y}$$

where:

F_y = the immersed weight of the concrete cask

$$\mu_{min} = \frac{(1.1)21.72\text{kip}}{(206.10 - 64.27)\text{kip}} = 0.17$$

The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.17. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad (0.35) is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis flood conditions.

The water velocity required to overturn the concrete cask is greater than the design-basis velocity of 15 ft/sec. Therefore, the concrete cask will not be overturned under design basis flood conditions.

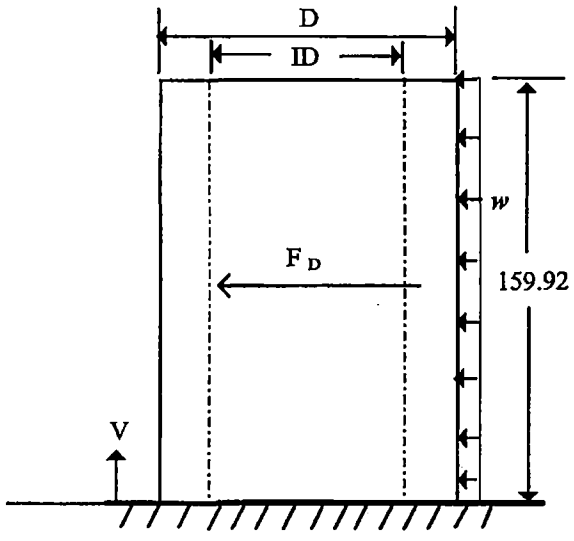
The flood depth of 50 feet exerts a hydrostatic pressure on the canister and the concrete cask. The water exerts a pressure of 22 psig (50 x 62.4/144) on the canister, which results in stresses in the canister shell.

The maximum primary membrane stress in the canister is 8.82 ksi. The allowable stress for accident conditions is 40.08 ksi. The margin of safety for primary membrane stress is +3.54.

The maximum primary membrane plus bending stress is 19.18 ksi. The allowable primary membrane plus bending stress for accident conditions is 60.12 ksi. The margin of safety is +2.13.

Consequently, there is no adverse consequence to the canister as a result of the hydrostatic pressure due to the flood condition.

The concrete cask is a thick monolithic structure and is not affected by the design basis flood hydrostatic pressure. However, the stresses in the concrete due to the drag force (F_D) are conservatively calculated as shown below. The concrete cask is considered to be fixed at its base.



F_D	= 21,720 lb		
D	= 128 in. (concrete exterior diameter)		
ID	= 86 in. (concrete interior diameter)		
A	$= \pi (D^2 - ID^{2)} / 4$	$= 7{,}059.2\ in^2$	
I	$= \pi (D^4 - ID^{4)} / 64$	$= 10.492 \times 10^6\ in^4$	(Moment of Inertia)
S_{outer}	$= 2I / D$	$= 163{,}937.5\ in^3$	(Section Modulus for inner surface)
S_{inner}	$= 2I / (ID)$	$= 244{,}000.0\ in^3$	(Section Modulus for outer surface)
w	$= F_D / 159.92$	= 135.82 lbf / in.	
M	$= w (159.92)^2 / 2$	$= 1.737 \times 10^6$ in.-lb	(Bending Moment at the base)

Maximum stresses at the base surface:

$\sigma_{v\ outer} = M / S_{outer} = 10.6$ psi (tension or compression)
$\sigma_{v\ inner} = M / S_{inner} = 7.1$ psi (tension or compression)

The compressive stresses are included in load combination No. 7 in Table 3.4.4.2-1, since they are the governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined stresses for the load combination due to dead, live, thermal and flood loading, are below the allowable stress.

11.2.6.2.2 Evaluation of the CY-MPC for the Design Basis Flood Condition

The displacement volume of the concrete cask containing the loaded canister is 1,419 ft^3. The displacement volume, V, is the occupied volume less the free space in the central annular cavity of the concrete cask. The buoyancy force, F_b, is equal to the weight of water (62.4 lb/ft^3) displaced by the fully submerged concrete cask.

$$F_b = V \times 62.4\ lb/ft^3$$

$$= 88{,}546\ lb$$

Assuming the steady-state flow conditions for a rigid cylinder, the total drag force of the water on the concrete cask is given by the formula:

$$F_{D15} = (C_D)(\rho)(V^2)(A/2) \quad \text{(Roberson)}$$

$$= 25{,}883\ lb,$$

where:

C_D = Drag coefficient, which is dependent upon the Reynolds Number (Re). For flow velocities greater than 6 ft/sec, the value of C_D approaches 0.7 (Roberson),

ρ = mass density of water = 1.94 $slugs/ft^3$,

D = concrete cask outside diameter = 128 inch = 10.67 ft,

h = overall height of the cask = 190.6 inch = 15.88 ft,
V = velocity of water flow = 15 ft/sec,

A = projected area of the cask normal to water flow = $D \times h$ = 169.42 ft^2.

The drag force required to overturn the concrete cask is determined by summing the moments of the drag force and the submerged weight (weight of the cask less the buoyant force) about a point on the bottom edge of the cask. This method assumes a pinned connection, i.e., the cask will rotate about the point on the edge rather than slide. When these moments are in equilibrium, the cask is at the point of overturning.

$$F_D \times \left(\frac{h}{2}\right) = (W_{VCC} - F_b) \times r$$

$$F_D = 109{,}616 \text{ lb},$$

where:

h = concrete cask overall height = 190.6 in,
W_{VCC} = loaded concrete cask weight = 251,771 lb,
r = concrete cask radius = 128/2 = 64.0 in.

Solving the drag force equation for the velocity, V, that is required to overturn the concrete cask:

$$V = \sqrt{\frac{2F_D}{C_D \rho A}}$$

$$= 30.9 \text{ ft/sec.}$$

To prevent sliding, the minimum coefficient of friction (with a safety factor of 1.1) between the carbon steel bottom plate of the concrete cask and the concrete surface upon which it rests is:

$$\mu_{min} = \frac{(1.1)F_{D15}}{F_y} = \frac{1.1 \text{ x } 25{,}883}{163{,}225} = 0.17,$$

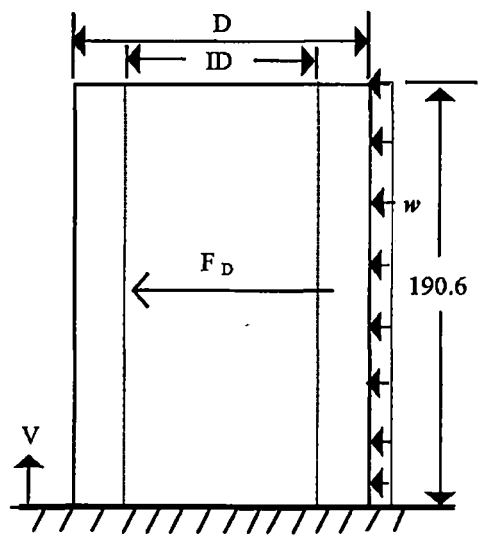
where:

F_y = the immersed weight of the concrete cask = 251,771 – 88,546 = 163,225 lb.

The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.17. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad (0.35) is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis flood conditions.

The water velocity required to overturn the concrete cask is greater than the design-basis velocity of 15 ft/sec. Therefore, the concrete cask will not be overturned under design basis flood conditions.

The concrete cask is a thick monolithic structure that is not affected by the design basis flood. However, stresses are generated in the concrete resulting from the drag force (F_D) created by the water flow and in the canister and concrete cask from the hydrostatic pressure that results from the flood depth. To maximize the drag force on the cask, the base is fixed and internal reinforcing of the concrete and steel liner are ignored. The maximum stresses (tension or compression) resulting from the drag force are:



$\sigma_{v\ outer}$ = M / S_{outer} = 15.0 psi

$\sigma_{v\ inner}$ = M / S_{inner} = 10.1 psi

where:

F_{D15} = 25,883 lb,

w = F_{D15} / 190.6 = 135.8 lb/in.,

ID = concrete interior diameter = 86 in.,

OD = concrete exterior diameter = 128 in.,

A = area = $\pi \times (OD^2 - ID^2) / 4$

$= 7{,}059 \text{ in.}^2$,

I = moment of inertia $= \pi \times (OD^4 - ID^4) / 64 = 10.492 \times 10^6 \text{ in.}^4$,

S_{outer} = section modulus for inner surface $= 2 \times I / (OD) = 163{,}937.5 \text{ in.}^3$,

S_{inner} = section modulus for outer surface $= 2 \times I / (ID) = 244{,}000.0 \text{ in.}^3$,

M = bending moment at the base $= w \times (190.6)^2 / 2 = 2.467 \times 10^6$ in.-lb.

The flood depth of 50 feet exerts a hydrostatic pressure on the canister and the concrete cask. The water exerts a pressure of 22 psig (50 × 62.4/144) on the canister, which results in stresses in the canister shell.

The maximum primary membrane stress in the canister is 3.90 ksi. The allowable stress for accident conditions is 40.08 ksi. The margin of safety for primary membrane stress is +9.28. The maximum primary membrane plus bending stress is 15.17 ksi. The allowable primary membrane plus bending stress for accident conditions is 60.12 ksi. The margin of safety is +2.96.

Consequently, there is no adverse consequence to the canister as a result of the hydrostatic pressure due to the flood condition.

The compressive stresses are included in load combination No. 7 in Table 3.4.4.4-1, since they are the governing stresses for the load combination. As shown in Tables 3.4.4.4-1 and 3.4.4.4-2, the maximum combined stresses for the load combination due to dead, live, thermal and flood loading, are below the allowable stress.

11.2.6.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.6.4 NAC-MPC Performance

This analysis shows that the NAC-MPC vertical concrete cask system performance is not affected by the design basis flood. The analysis demonstrates that the concrete cask will not slide and will not overturn in the design-basis flood. The hydrostatic pressure exerted by the 50 foot depth of water does not produce significant stress in the canister.

11.2.6.5 Recovery and/or Corrective Actions

Response Surveillance of the NAC-MPC systems at the ISFSI shall be performed following the flood accident in accordance with Section A 5.3 of the Technical Specifications to verify the heat removal systems of the casks are operable. Corrective actions will be taken, as required, to clear blockage of the inlet and outlet screens of each concrete cask.

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11.2.7 Fresh Fuel Loading in the Canister

This section presents the results of the evaluation of the effects of the inadvertent loading of fresh, unburned fuel assemblies in the canister. This event is not considered to be credible. The analysis of fresh fuel loading in the Yankee-MPC and CY-MPC is presented in Section 6.4.

11.2.7.1 Cause of Accident

The cause of this event would be operator and/or procedural error. The design basis criticality condition demonstrates that the canister is designed to accommodate fresh fuel without a resulting criticality event.

This accident is expected to be identified immediately by observation of the condition of the fuel installed in the canister or by a review of the fuel handling records.

11.2.7.2 Analysis of Fresh Fuel Loading in the Canister

The criticality analysis presented in Chapter 6 assumes the loading of up to 36 Yankee Class fuel assemblies in the Yankee-MPC and the loading of up to 26 Connecticut Yankee fuel assemblies in the CY-MPC having no burn up. The design of the NAC-MPC is adequate to preclude any effects due to this accident condition.

11.2.7.2.1 Analysis of Fresh Fuel Loading the Yankee-MPC Canister

The analysis presented in Section 6.4 shows that the maximum k_{eff} for the Yankee-MPC canister in the dry normal condition is 0.4503. The maximum k_{eff} in the accident condition is 0.9021. The accident condition assumes the most reactive configuration of the fuel and full moderator intrusion.

11.2.7.2.2 Analysis of Fresh Fuel Loading the CY-MPC Canister

The analysis presented in Section 6.4 shows that the maximum k_{eff} for the 26-assembly CY-MPC canister in the dry condition is 0.3555. The maximum k_{eff} in the accident (wet) condition is 0.9219. The accident condition assumes the most reactive configuration of the fuel and full moderator intrusion. The corresponding k_{eff} values for the 24-assembly canister are 0.3715 and 0.9318.

11.2.7.3 Radiological Consequences

There are no radiological consequences for this event.

11.2.7.4 NAC-MPC Performance

The criticality control features of the NAC-MPC canister and basket ensure that the k_{eff} of the fuel is less than 0.95 for all loading conditions of fresh fuel. There is no adverse impact on the NAC-MPC due to this event.

11.2.7.5 Recovery and Corrective Actions

This event requires that the canister be unloaded when the incorrect loading is identified. The controls placed on the movement of fuel assemblies are such that this accident event will not occur.

11.2.8 Full Blockage of Air Inlets and Outlets

This section evaluates the NAC-MPC for the steady state effects of full blockage of the air inlets and outlets at the normal ambient temperature (75°F). It estimates the duration of the event that would result in the concrete reaching its design basis limiting temperature of 350°F.

11.2.8.1 Cause of Event

The likely cause of complete air inlet and outlet blockage is the covering of the cask with earth in a catastrophic event such as greater than design basis earthquake or a land slide. This event is a bounding condition accident that is not credible.

This event would be detected by inspection of general conditions at the site following such an event. It would be detected visually by the persons inspecting the ISFSI site.

11.2.8.2 Analysis of the Blockage Event

11.2.8.2.1 Analysis of the Yankee-MPC Blockage Event

The accident temperature conditions are evaluated using the thermal models described in Section 4.4.1. The analysis assumes initial normal storage conditions, with the sudden loss of convective cooling of the canister. Heat is then rejected from the canister to the storage cask liner by radiation and conduction. The loss of convective cooling results in the fairly rapid and sustained heat-up of the canister and the concrete cask. To account for the loss of convective cooling in the ANSYS air flow model (Section 4.4.1.1), the elements in the model were replaced with thermal elements, employing the axis-symmetric option. This option assures that there is no axial temperature difference across the element. This model is used to evaluate the thermal transient resulting from the postulated boundary conditions.

The thermal transient analysis evaluated the concrete temperature conditions for 100 hours. At the end of 24 hours, the concrete temperature is 287°F, an increase of 122°F, compared with the initial (normal conditions) concrete temperature, 165°F. The maximum temperature in the concrete will exceed the thermal design criteria temperature of 350°F at 45.7 hours after the start of the event.

Other conservative assumptions include no internal convection and no heat transfer to the surrounding environment (i.e., the dirt covering the cask in the case of a landslide).

The maximum canister shell temperature is 536°F at 45.7 hours after the start of the event. Considering the maximum temperature difference of 250°F between the canister shell and fuel region (as shown in Table 4.1-4, the ΔT between canister shell and fuel clad is 563 - 319 = 244°F for normal condition of storage), the maximum fuel temperature will reach 786°F (536 + 250) in the same 45.7-hour period, which is less than the short-term allowable temperature of 806°F.

11.2.8.2.2 Analysis of the CY-MPC Blockage Event

The accident temperature conditions are evaluated using the thermal models described in Section 4.5.1. The analysis assumes initial normal storage conditions, with the sudden loss of convective cooling of the canister. Heat is then rejected from the canister to the storage cask liner by radiation and conduction. The loss of convective cooling results in the fairly rapid and sustained heat-up of the canister and the concrete cask. To account for the loss of convective cooling in the ANSYS air flow model (Section 4.5.1.1), the elements in the model were replaced with thermal elements, employing the axisymmetric option. This model is used to evaluate the thermal transient resulting from the postulated boundary conditions based on a conservative heat load of 21 kW (the design basis heat load is 17.5 kW). Internal convection and heat transfer to the surrounding environment (i.e., the dirt covering the cask in the case of a landslide) are conservatively neglected.

The blockage event thermal transient analysis evaluates a period of 100 hours. At the end of 24 hours, the concrete temperature is 297°F, an increase of 126°F, compared with the initial (normal conditions) concrete temperature, 171°F. At the end of 24 hours, the maximum temperature of the support disk is 624°F. The maximum temperature of the heat transfer disk is 620°F. The corresponding allowable temperatures are 800°F and 700°F, respectively.

The maximum temperature in the concrete will exceed the design criteria limit of 350°F, and the maximum canister shell temperature will reach 531°F, 43 hours after the start of the event. Based on the conservative 21 kW heat load, the fuel cladding temperature increases by 142°F during the same 43-hour period. This temperature rise is added to the steady-state fuel cladding temperature of 629°F, which occurs due to the 17.5 kW heat load. Therefore, the maximum fuel

cladding temperature at 43 hours after the start of the event is (629 + 142 =) 771°F, which is less than the short-term allowable temperature of 806°F.

11.2.8.3 Radiological Consequences

There are no significant radiological consequences for this event, as the NAC-MPC retains its shielding performance. Dose is incurred as a consequence of uncovering the storage cask and vent system. Since the dose rates at the air inlets and outlets are higher than the maximum dose rate (44.1 mrem/hr) at the cask wall, personnel will be subject to an estimated maximum dose rate of 168 mrem/hr when clearing the inlets and outlets. For the Yankee-MPC, if it is assumed that a worker kneeling with his hands on the inlets or outlets would require 15 minutes to clear each inlet or outlet, the estimated extremity dose is 336 mrem for the 8 openings. The whole body dose would be slightly less. In addition, some dose is incurred clearing debris away from the cask body. Based on an average dose rate at 1 foot from the cask of 25.3 mrem/hr, this dose is estimated at 51 mrem, assuming 2 hours is spent near the cask exterior surface. The corresponding estimated dose for the CY-MPC is the same since the dose rates are similar.

11.2.8.4 NAC-MPC Performance

There are no adverse consequences for this accident condition, assuming that debris is cleared within a reasonable time (<24hours). The maximum component temperatures are less than the allowable temperatures. The NAC-MPC continues to satisfactorily perform the cooling function with all the inlets and outlets blocked.

11.2.8.5 Recovery and/or Corrective Actions

The debris blocking the vents must be manually removed. In addition, a considerable effort may be involved in clearing the area around the storage casks. No actions are required with regard to the casks proper, provided that the vents are cleared within 24 hours.

11.2.9 Lightning

This analysis demonstrates that the NAC-MPC storage cask does not experience adverse effects due to a lightning strike.

11.2.9.1 Cause of Accident

A lightning strike is a random weather related event. Since the NAC-MPC storage cask is located on an unsheltered pad, the storage cask may be subject to a lightning strike. The probability of a lightning strike is primarily dependent on the geographical location of the ISFSI site, as some geographical regions experience a higher frequency of storms containing lightning than others.

The analysis of the consequence of a lightning strike assumes that the lightning strikes the upper most metal surface and proceeds through the storage cask liner to the ground. The electrical current flow path results in current induced Joulean heating along that path.

A lightning strike on a storage cask may be visually detected at the time of the strike, or by visible surface discoloration at the point of entry or exit of the current flow. Most reactor sites in locations experiencing a frequency of lightning bearing storms have lightning strike detection systems as an aid to ensuring stability of site electric power.

11.2.9.2 Analysis of the Lightning Strike Event

The lightning strike analysis is performed assuming the Yankee-MPC configuration. The Yankee-MPC analysis bounds the evaluation of the CY-MPC. The CY-MPC concrete cask is longer than the Yankee-MPC concrete cask, which provides a larger surface for the dissipation of lightning strike energy. This would result in a slightly lower temperature rise for the CY-MPC system.

The current path analyzed is from a strike point on the outer radius of the top flange of the storage cask, down through the carbon steel liner and the bottom plate to the ground.

The integrated maximum current for a lightning strike is a peak current of 250 kiloamps over a period of 260 microseconds and a continuing current of up to 2 kiloamps for 2 seconds in the case of severe lightning discharges (Cianos).

From Joule's Law, the amount of thermal energy developed by the combined currents is given by (Summer):

$$Q = 0.0009478R\left[I_1^2(dt_1) + I_2^2(dt_2)\right]$$
$$= (22.98 \times 10^3)\ R\ \text{Btu}$$

where:

Q = thermal energy (BTU)
I_1 = peak current (amps)
I_2 = continuing current (amps)
dt_1 = duration of peak current (seconds)
dt_2 = duration of continuing current (seconds)
R = resistance (ohms)

The maximum lightning discharge is assumed to attach to the smallest current-carrying component, that is, the top flange connected to the outer lid.

The propagation of the lightning through the carbon steel cask liner, which is both permeable and conductive, is considered to be a transient. For static conditions, the current would be distributed throughout the shell. In a transient condition the current will be near the surface of the conductor. It is assumed that the current is contained in a 90-degree sector of the circular cross section of the steel liner as opposed to the entire cross section. The depth of the current penetration (δ) is estimated as (Fink):

$$\delta = 1/\sqrt{\pi\mu f\sigma}\ \text{(m)}$$

where:

μ = permeability of the conductor = $100\mu_0$ (Summer)
and μ_0 = 4πE-7 Henries/m
σ = electrical conductivity (seimens/meter) = $1/\rho$
= 1/resistivity = 1/9.78E-08 (ohm-m) (Fink)
f = frequency of the field (Hz)

The pulse is represented conservatively as a half sine form, so that the equivalent $f = 2 \times \tau$, where τ is the referenced pulse duration. There are two skin depths to be computed, corresponding to different pulse duration. The larger effective frequency will result in a smaller effective area to conduct the current. The effective resistance is computed as (Fink):

$$R = \frac{\rho l}{a}$$

where:

R = resistance (ohms)
ρ = resistivity = 9.78E-08 (ohm-m)
l = length of conductor path
a = area of conductor (m^2)
= $(R_{shell})(\delta)(\pi/4)$
R_{shell} = 35.75 inches = 0.9081 m

Using the current level of the pulse and the duration in conjunction with the carbon steel liner, the resulting energy into the shell is:

	Peak	Continuous	Expression
Time (s) τ	2.60 E-06	2.0	----------
Peak Current (KA)	250	2	----------
Frequency (Hz)	2000(conservative)	2.5E-01	$1/(2\tau)$
Skin depth (m) δ	3.52E-04	3.15E-02	$1/\sqrt{\pi\mu f\sigma}$
Conductor length (m) L	4.1	4.1	----------
Conductor area (m^2) A_c	2.51E-4	2.24E-2	$R_{shell}\,\delta(\pi/4)$
Resistance (ohm) Ω	1.60E-03	1.79E-5	$(L/A)\rho$
Q (Btu)	24.6	.14	$R = \frac{\rho\, l}{a}$

It is conservatively assumed that this thermal energy dissipation occurs in the localized volume of the carbon steel involved in the current flow path through the flange to the inner liner. Assuming no heat loss or thermal diffusion beyond the current flow boundary, the maximum temperature increase in the flange due to this thermal energy dissipation is calculated as (Black):

$$\Delta T = \frac{Q}{mc}$$

where:

ΔT = temperature change (°F)
Q = thermal energy (BTU)
c = 0.113 Btu/lb °F
m = mass (lbm)

The ΔT_1 for the peak current (250KA, 260 μsec) for the region of the current is computed based on the mass associated with this region.

$$m = (.284\ lb/in^3) \times A_c \times L = (.284)(2.51E\text{-}4)(159.92)/C_f = 17.7\ lbm$$

$$C_f = (.0254^2)\ \text{(converts } m^2 \text{ to } in^2\text{)}$$

$$\Delta T_1 = 24.6/(17.7 \times .113) = 12.3°F$$

The ΔT_2 for the continuous current (2KA, 2 sec) for the region of the current is computed based on the mass associated with this region.

$$m = (.284\ lb/in^3) \times A_c \times L = (.284)(2.24E\text{-}2)(159.92)/(.0254^2) = 1577\ lbm$$

$$\Delta T_2 = .14/(1577 \times .113) = 0.001°F$$

The ΔT_1 would correspond to the increase in the maximum temperature of the steel. For the concrete to experience an increase in temperature, the heat must disperse from the steel liner surface throughout the steel. Using the total thickness of the steel, over the 90 degree sector, the increase in temperature is:

$$m = (.284\ lb/in^3) \times (39.25^2 - 35.75^2)\pi/4 \times L = 9{,}364\ lbm$$

$$\Delta T_1 = (24.6+.14)/(9{,}364 \times .113) = 0.02\ F$$

Therefore, the increase in temperature of the concrete is not significant.

11.2.9.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.9.4 NAC-MPC Performance

This analysis shows that the Yankee-MPC vertical concrete cask's performance is not affected by a lightning strike. When lightning strikes the cask and travels through the 3.5-inch thick carbon steel storage cask liner, the maximum increases in the steel and concrete temperatures are 12.3°F and 0.0°F, respectively. Since the concrete cask liner in the CY-MPC system is longer, the increase in temperature in the CY-MPC liner and concrete is less.

11.2.9.5 Recovery and/or Corrective Actions

There are no recovery or corrective actions required for this accident event.

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11.2.10 Maximum Anticipated Heat Load (125°F Ambient Temperature)

This analysis evaluates the NAC-MPC response to storage operation with an ambient temperature of 125°F. The NAC-MPC is evaluated at steady state conditions.

11.2.10.1 Cause of Accident

The cause of this condition is a weather event that causes the NAC-MPC to be subject to a 125°F ambient temperature with full solar insolance.

The condition is analyzed in accordance with the requirements of ANSI/ANS 57.9 to evaluate a credible worse case thermal loading. This condition is considered in the load combinations described in Chapter 2.

Detection of the ambient high temperature condition would occur during measurement of site ambient temperatures.

11.2.10.2 Analysis of the 125°F Ambient Temperature Event

11.2.10.2.1 Analysis of the 125°F Ambient Temperature Event for the Yankee-MPC

The severe high temperature condition is evaluated using the thermal models described in Section 4.4.1. A contents heat load of 12.5 kW is assumed. The principal component temperatures for this ambient condition are:

Component	125°F Ambient Max Temp. (°F)	Allowable Max Temp. (°F)
Fuel Cladding	607	806
Support Disks	575	800
Heat Transfer Disks	574	700
Canister Shell	372	800
Concrete	228	350

This evaluation shows that the component temperatures are within the allowable temperature for the severe high ambient temperature conditions.

This event is considered an "accident condition" for the purpose of this evaluation. Consequently, the thermal stress (secondary) occurring in the canister due to this thermal loading is not evaluated.

However, the thermal stresses for the concrete cask are calculated using the same methodology as shown in Section 3.4.4.2 for the stress calculation for normal conditions of storage. The same finite element model is used with the boundary temperatures based on concrete cask thermal analysis results (Section 4.4.4.1). The maximum vertical and circumferential (compressive) stresses at the concrete inside surface are calculated to be 660.1 psi and 127.5 psi, respectively. These stresses are included in the load combination (No. 4) as presented in Table 3.4.4.2-1. The maximum tensile forces in the vertical and hoop reinforcing bars are 19,380 lbs. and 23,196 lbs., respectively. Comparison of these forces and the allowable forces is shown in Table 3.4.4.2-2. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined concrete stress and reinforcing bar force for the load combination of dead (D), live (L) and accident temperature (T_a) are below the allowable stress and force, respectively.

11.2.10.2.2 Analysis of the 125°F Ambient Temperature Event for the CY-MPC

The severe high temperature condition is evaluated using the thermal models described in Section 4.5.1. The principal component temperatures for this ambient condition are:

Component	125°F Ambient Max Temp. (°F)	Allowable Max Temp. (°F)
Fuel Cladding	670	806
Support Disks	583	800
Heat Transfer Disks	579	700
Canister Shell	363	800
Concrete	235	350

This evaluation shows that the component temperatures are within the allowable temperature for the severe high ambient temperature conditions.

This event is considered an "accident condition" for the purpose of this evaluation. Consequently, the thermal stress (secondary) in the canister due to this thermal load is not evaluated.

The thermal stresses for the concrete cask are calculated using the same methodology as shown in Section 3.4.4.4 for the stress calculation for normal conditions of storage. The same finite element model is used with the boundary temperatures based on the concrete cask thermal analysis results (Section 4.5.1.1). The maximum vertical and circumferential (compressive) stresses at the concrete inside surface for the 125°F ambient accident condition are calculated to be 583 psi and 106 psi, respectively. This is the bounding thermal stress for the off-normal accident temperature (T_a) as defined in Table 2.2-1. These stresses are included in the load combination (Number 4) as presented in Table 3.4.4.4-1. The maximum tensile stresses in the vertical and hoop reinforcing bars are 5675 psi and 6647 psi, respectively. Comparison of these stresses and the allowable stresses is shown in Table 3.4.4.4-2. As shown in Tables 3.4.4.4-1 and 3.4.4.4-2, the maximum combined concrete stress and reinforcing bar stress for the load combination of dead (D), live (L) and accident temperature (T_a) are below the allowable stress and force, respectively.

11.2.10.3 Radiological Consequences

There are no radiological consequences for this event.

11.2.10.4 NAC-MPC Performance

There are no adverse consequences for this accident condition. The maximum component temperatures are less than the allowable temperatures for accident conditions and are also less than the temperature limits for normal conditions of storage.

11.2.10.5 Corrective Actions

No corrective actions are required for this accident condition.

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11.2.11 Storage Cask 6-Inch Drop

This analysis evaluates a loaded concrete storage cask for a 6-inch drop onto a concrete storage pad. This evaluation shows that neither the concrete storage cask nor the canister experience significant adverse effects due to the 6-inch drop accident.

11.2.11.1 Cause of Accident

The concrete storage cask, containing the loaded canister, must be raised approximately 4 inches in order to install the inflatable air-pads beneath it. The air pads use pressurized air to allow the cask to be moved across the surfaces of the transporter and the ISFSI pad to the designated positions. The cask is raised using hydraulic jacks installed at jack-points in the air inlets.

This accident assumes the failure of one or more of the jacks or of the air pad system, resulting in a drop of the cask. A lift of about 4 inches is required to install and remove the air pads. This analysis conservatively evaluates the consequences of a 6-inch drop.

This accident would be detected by persons jacking or moving the storage cask.

11.2.11.2 Analysis of the 6-Inch Drop Event

A bottom end impact is assumed to occur normal to the concrete pad surface, transmitting the maximum g-load to the concrete storage cask and the canister. The energy absorption is computed as the product of the compressive force acting on the storage cask and its displacement. Conservatively assuming the storage pad is an infinitely rigid surface, exhibiting a uniform isotropic crush strength, the concrete body of the storage cask will crush until the impact energy is absorbed.

A compressive strength of 4,000 psi is used for the storage cask concrete. This is conservative, since it is the minimum specified value and it ignores any energy absorption by the internal friction of the aggregate as crushing proceeds.

11.2.11.2.1 Analysis of the Yankee-MPC 6-Inch Drop Event

The Yankee-MPC canister rests upon a stand/inlet system, shown in Figure 11.2.11-1, designed to allow cooling of the canister. Following the initial impact, the inlet system will partially

collapse, providing an energy absorption mechanism that somewhat reduces the deceleration force on the canister. The weight of the empty Yankee-MPC concrete storage cask is 151,364 pounds. The loaded Yankee-MPC canister weight is 54,730 pounds.

In the 6-inch bottom drop, the cylindrical portion of the concrete is in contact with the steel bottom baseplate that also supports the stand/inlet system. The baseplate is assumed to be part of an infinitely rigid storage pad. No credit is taken for the crush properties of the storage pad or the underlying soil layer. Therefore, energy absorbed by the crushing of the cylindrical concrete region of the storage cask equals the product of the compressive strength of the concrete, the crush depth of the concrete, and the projected area of the concrete cylinder. Crushing of the concrete continues until the energy absorbed equals the potential energy of the storage cask at the initial drop height. The canister is not rigidly attached to the concrete cask, so it is not considered to contribute to the concrete crushing. The energy balance equation is:

$$w(h+\delta) = P_o A\delta,$$

where:

h = 6 in., the drop height
δ = the crush depth of the concrete cask
P_o = 4000 psi, the compressive strength of the concrete
A = $\pi(R_1^2 - R_2^2)$
= 7,059 in^2, the projected area of the concrete shield wall
w = 151,364 lb $\times$ 1.1, the weight of the concrete cask, conservatively multiplied by 1.1 to account for variations in the concrete

It is assumed that the maximum force that can be exerted on the concrete cask is the compressive strength of the concrete multiplied by the area of the concrete being crushed. Therefore, the deceleration of the storage cask is dependent upon the compressive strength of the concrete, the cross-sectional area of the storage cask cylindrical body, and the weight of the empty storage cask with lid. The deceleration due to crush is:

$$a_{vcc} = \frac{P_o A}{w} = 169.6 \text{ g}$$

The crush distance computed from the energy balance equation is:

$$\delta = \frac{hw}{P_oA - w} = \frac{(6)(151{,}364 \times 1.1)}{(4000)(7{,}059) - (151{,}364 \times 1.1)} = 0.036 \text{ inch}$$

Evaluation of the Yankee-MPC Canister for the Storage Cask 6-inch Bottom-End Drop

Upon a bottom-end impact of the concrete storage cask on the storage pad, the canister produces a force on the stand/inlet system located near the bottom of the storage cask. It is expected that the steel plate above the air inlet channels will yield. Calculating the flow stress, σ_f, for the material:

$$\sigma_f = \frac{\sigma_y + \sigma_u}{2}$$
$$= 45{,}400 \text{ psi},$$

where:

σ_u = 58,000 psi, ASTM A36 carbon steel ultimate strength at 200°F,
σ_y = 32,800 psi, ASTM A36 carbon steel yield strength at 200°F.

The flow stress results in the deformation of the steel plate above the air inlets, and produces a force through the section. The total force is:

$$F = 8(\sigma_f bt),$$
$$= 1.092 \times 10^6 \text{ pounds}$$

where:

b = 1.5 in., the width of the load bearing area
t = 2.0 in., the thickness of the stand

This force results in an acceleration to the loaded canister (weighing w_c = 54,730 pounds) of:

$$g = \frac{F}{w_C} = 19.95$$

The area of contact between the canister bottom and stand is twice as large as the cross-sectional area of the region that yields; therefore, the stand's platform will not be perforated. The expected crush distance, δ, of the crush area is computed by an energy balance equation. The crush distance is:

$$\delta = \frac{hw_c}{P_oA - w_c} = \frac{(6)(54{,}730\times1.1)}{(45{,}400)(8)(2)(1.5)-(54{,}730\times1.1)} = 0.35 \text{ in.}$$

Thus, reducing the height of the air inlet region by only 0.35 inches.

11.2.11.2.2 Analysis of the CY-MPC 6-Inch Drop Event

The CY-MPC canister rests upon a stand/inlet system designed to allow cooling of the canister. The stand/inlet system is similar to that for the Yankee-MPC system. Following the initial impact, the inlet system will partially collapse, providing an energy absorption mechanism that somewhat reduces the deceleration force on the canister. The weight of the empty CY-MPC concrete storage cask is 185,950 pounds. The loaded CY-MPC canister weight is 65,821 pounds. A weight of 66,000 is conservatively used in the analysis.

In the 6-inch bottom end drop, the cylindrical portion of the concrete is in contact with the steel bottom baseplate that also supports the stand/inlet system. The baseplate is assumed to be part of an infinitely rigid storage pad. No credit is taken for the crush properties of the storage pad or the underlying soil layer. Therefore, energy absorbed by the crushing of the cylindrical concrete region of the storage cask equals the product of the compressive strength of the concrete, the crush depth of the concrete, and the projected area of the concrete cylinder. Crushing of the concrete continues until the energy absorbed equals the potential energy of the storage cask at the initial drop height. The canister is not rigidly attached to the concrete cask, so it is not considered to contribute to the concrete crushing. The energy balance equation is:

$$w(h+\delta) = P_oA\delta,$$

where:

h = 6 in., the drop height
δ = the crush depth of the concrete cask
P_o = 4000 psi, the compressive strength of the concrete
A = $\pi(R_1^2 - R_2^2)$
= 7,059 in^2, the projected area of the concrete shield wall

w = 185,950 lb × 1.1, the weight of the concrete cask, conservatively multiplied by 1.1 to account for variations in the concrete

It is assumed that the maximum force that can be exerted on the concrete cask is the compressive strength of the concrete multiplied by the area of the concrete being crushed. Therefore, the deceleration of the storage cask is dependent upon the compressive strength of the concrete, the cross-sectional area of the storage cask cylindrical body, and the weight of the empty storage cask with lid. The deceleration due to crush is:

$$a_{vcc} = \frac{P_o A}{w} = 138.0\ g$$

The crush distance computed from the energy balance equation is:

$$\delta = \frac{hw}{P_o A - w} = \frac{(6)(185{,}950 \times 1.1)}{(4000)(7{,}059) - (185{,}950 \times 1.1)} = 0.044\ \text{inch}$$

Upon a bottom-end impact of the concrete storage cask on the storage pad, the canister produces a force on the stand/inlet system located near the bottom of the storage cask. It is expected that the steel plate above the air inlet channels will yield. Calculating the flow stress, σ_f, for the material:

$$\sigma_f = \frac{\sigma_y + \sigma_u}{2}$$

$$= 47{,}000\ \text{psi},$$

where:

σ_u = 58,000 psi, ASTM A36 carbon steel ultimate strength at 100°F,
σ_y = 36,000 psi, ASTM A36 carbon steel yield strength at 100°F.
(Note: 100°F is used to determine material properties based on the air temperature of 75°F at the air inlets.)

The flow stress results in the deformation of the steel plate above the air inlet vents, and produces a force through the section. The total force is:

$$F = 8(\sigma_f bt),$$

$$= 1.128 \times 10^6 \text{ pounds}$$

where:

b = 1.5 in., the width of the load bearing area

t = 2.0 in., the thickness of the stand

This force results in an acceleration (a_{can}) to the loaded canister (weighing w_c = 66,000 pounds) of:

$$a_{can} = \frac{F}{w_C} = 18 \text{ g}$$

The area of contact between the canister bottom and stand is twice as large as the cross-sectional area of the region that yields; therefore, the stand's platform will not be perforated. The expected crush distance, δ, of the crush area is computed by an energy balance equation. The crush distance is:

$$\delta = \frac{hw_c}{P_o A - w_c} = \frac{(6)(66{,}000 \times 1.1)}{(47{,}000)(8)(2)(1.5) - (66{,}000 \times 1.1)} = 0.36 \text{ in.}$$

Thus, reducing the height of the air inlet region by only 0.36 inch.

Evaluation of the CY-MPC Canister and Basket for the Storage Cask 6-inch Bottom-End Drop

The CY-MPC canister is evaluated using the ANSYS finite element model described in Section 3.4.4.3. An acceleration of 60g is conservatively applied to the model to simulate this bottom end drop condition. The design internal pressure of 15 psig is also applied.

Tables 11.2.11-1 and 11.2.11-2 provide the maximum primary membrane stress (P_m) and primary membrane plus bending stress (P_m+P_b) stress intensities for locations 1 through 16 (see Figure 3.4.4.3-1). The maximum P_m stress intensity occurs at location 2 with a margin of safety of +5.09. The maximum P_m+P_b stress intensity occurs at location 11 with a margin of safety of +3.58.

The CY-MPC canister basket support disk and weldments are evaluated using ANSYS finite element models described in Sections 3.4.4.3.8 and 3.4.4.3.9. An acceleration of 60g is conservatively applied to the models to simulate this bottom end drop condition. The analysis results are summarized in Table 11.2.11-3. Note that the P_m stresses are essentially zero, since there are no loads in the plane of the support disk and the weldment plates.

These results show that the CY-MPC canister and basket maintain a positive margin of safety for the accident condition 6-inch bottom end drop.

11.2.11.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.11.4 NAC-MPC Performance

Evaluations of the Yankee-MPC concrete storage cask for a 6-inch bottom end drop accident results in a maximum deceleration of 169.6 g for the storage cask, which does not reduce the shielding effectiveness of the cask. The base support, which contains the air inlets, is crushed approximately 0.35 inch. The effect of the reduction of the inlet area by the 6-inch drop is to reduce cooling air flow. The consequences of the loss of one-half of the air inlets is evaluated in Section 11.1.1, which bounds this condition.

The maximum deceleration of 19.95 g for the Yankee-MPC canister and its internals, as a result of the 6-inch storage cask drop, is bounded by the 56.1 g loading evaluated in Section 11.3, where the adequacy of the canister is demonstrated.

Evaluations of the CY-MPC concrete storage cask for a 6-inch bottom end drop accident results in a maximum deceleration of 138 g for the storage cask, which does not reduce the shielding effectiveness of the cask. The base support, which contains the air inlets, is crushed

approximately 0.36 inch. The effect of the reduction of the inlet area by the 6-inch drop is to reduce cooling air flow. The consequences of the loss of one-half of the air inlets is evaluated in Section 11.1.1, which bounds this condition.

The maximum deceleration of 18 g for the CY-MPC canister and its internals, as a result of the 6-inch storage cask drop, is bounded by the 60 g loading evaluation described in Section 11.2.11.2.2, where the adequacy of the canister is demonstrated.

The NAC-MPC storage cask system is structurally adequate to withstand a 6-inch drop accident.

11.2.11.5 Recovery and/or Corrective Actions

Even though the storage cask system remains functional and no immediate recovery steps are required, the canister should be moved to a new concrete storage cask as soon as one is available. The damaged storage cask should be inspected for stability, and repaired as required prior to continued use.

Figure 11.2.11-1 Yankee-MPC Storage Cask Base Plate

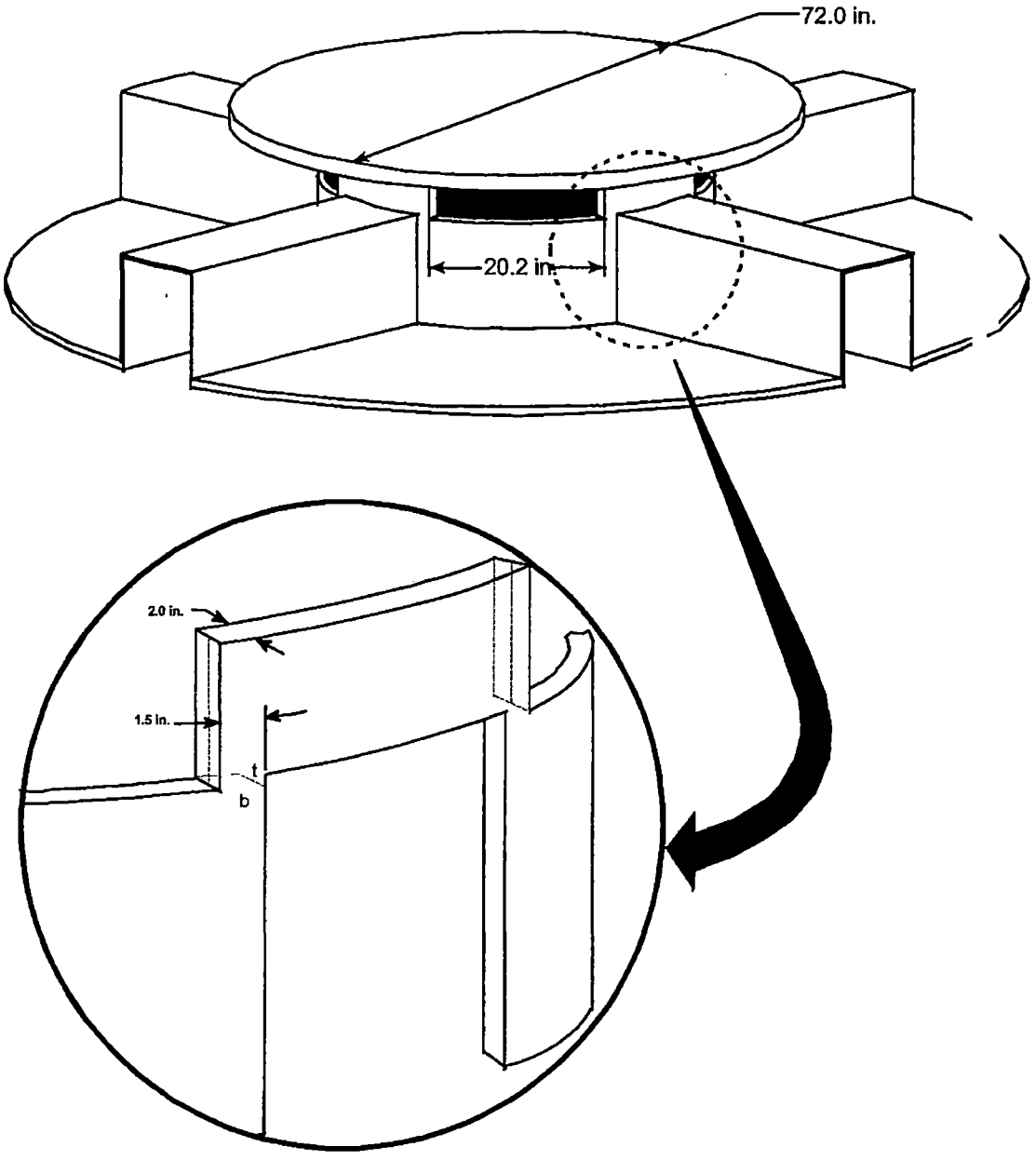

Table 11.2.11-1 CY-MPC Canister 6-inch Bottom End-Drop (60g) with Normal Internal Pressure (15 psig) Primary Membrane (P_m) Stresses (ksi)

Location No.[2]	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Stress Allowable	Margin of Safety
1	0.1	0	-1.2	0	0.1	0.3	1.43	40.08	27.03
2	0.6	-1.6	-5.9	0.2	0	-0.1	6.58	40.08	5.09
3	-0.1	-1.9	-6	0.2	0	0.2	5.86	40.08	5.84
4	0	0.8	-5.5	-0.1	0	0	6.32	39.67	5.28
5	0	0.8	-5	0.1	0	0	5.83	36.9	5.33
6	0	0.8	-4.5	0.1	0	0	5.34	36.58	5.85
7	0	0.8	-4	0.1	0	0	4.85	38.6	6.96
8	0	0.1	-3.5	0	0	0	3.6	40.08	10.13
9	-0.4	-1.9	-2.9	-0.1	0	-0.3	2.62	40.08	14.3
10	1.5	-1.2	-1.9	0.2	0	0.7	3.78	40.08	9.6
11	-3.1	-2.5	1.1	0	0	-0.7	4.48	40.08	7.95
12	1	-0.5	1.2	0.2	-0.1	0.7	2.32	40.08	16.28
13	0.5	-3.5	-3.2	-0.4	0.3	-0.3	4.22	32.06[3]	6.60
14	0.2	0.2	-0.6	0	0.1	0.1	0.86	40.08	45.6
15	0.2	0.2	0	0	0	0	0.24	40.08	+large
16	-0.3	-0.3	0	0	0	-0.1	0.39	40.08	+large

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

Table 11.2.11-2 CY-MPC Canister 6-inch Bottom End-Drop (60g) with Normal Internal Pressure (15 psig) Primary Membrane + Primary Bending (P_m+P_b) Stresses (ksi)

Location No.[2]	SX[1]	SY[1]	SZ[1]	SXY	SYZ	SXZ	Stress Intensity	Stress Allowable	Margin of Safety
1	1.3	0.9	-1.3	0	-0.2	0.5	2.8	60.12	20.47
2	0.6	-2.9	-10.8	0.3	0	-0.2	11.49	60.12	4.23
3	0.1	-3	-10.3	0.3	0	0.2	10.36	60.12	4.8
4	0	0.8	-5.5	0.1	0	0	6.33	59.5	8.4
5	0	0.8	-5	-0.1	0	0	5.84	55.35	8.48
6	0	0.8	-4.5	-0.1	0	0	5.35	54.86	9.25
7	0	0.8	-4	0.1	0	0	4.86	57.89	10.91
8	0	-0.2	-4.3	0	0	0	4.36	60.12	12.79
9	-0.4	-2.8	-6.2	0.2	-0.1	-0.7	5.95	60.12	9.1
10	0.9	-2.3	-5.4	0.2	0.1	0.2	6.3	60.12	8.54
11	-2.5	0.1	10.3	-0.2	-0.1	-1.5	13.12	60.12	3.58
12	2.4	-0.1	1.5	-0.2	0.1	1.3	3.48	60.12	16.28
13	4.5	-2.4	-0.8	0.6	-0.5	-0.7	7.24	48.10[3]	5.54
14	0.5	0.2	-0.6	-0.1	0.1	0.1	1.13	60.12	52.2
15	3.7	3.7	0	0	0	0	3.76	60.12	14.99
16	-8.3	-8.3	0	0	0	-0.1	8.35	60.12	6.2

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 3.4.4.3-1 for definition of locations of stress sections.
3. Allowable multiplied by a weld stress reduction factor of 0.8.

Table 11.2.11-3 Summary of Maximum Stresses for the CY-MPC Fuel Basket Weldments and Support Disks – Concrete Cask 6-inch Drop Accident (60 g)

Component	Load Condition	Stress Intensity		Allowable Stress		Margin of Safety
		Reported	Value (ksi)	Criteria	Value (ksi)	
Top Weldment	Dead Load + Handling	$P_m + P_b$	56.9	$3.6S_m$	63.0	+0.11
Bottom Weldment	Dead Load + Handling	$P_m + P_b$	47.2	$3.6S_m$	63.0	+0.34
Support Disks	Dead Load + Handling	$P_m + P_b$	74.7	$1.0S_u$	131.2	+0.76

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11.2.12 Tip Over of the Vertical Concrete Cask

This is a hypothetical accident condition that presents a bounding case for evaluation. There are no design basis accidents that result in the tip over of the vertical concrete cask (concrete cask).

11.2.12.1 Cause of Tip Over

A tip over event is possible in an earthquake that exceeds the design basis described in Section 11.2.2. There are no other events that are expected to result in a tip over of the concrete cask.

A tip over of the concrete storage cask would be observed during a survey of the site following the earthquake or other catastrophic event. The tipped over orientation of the concrete cask would be obvious by inspection.

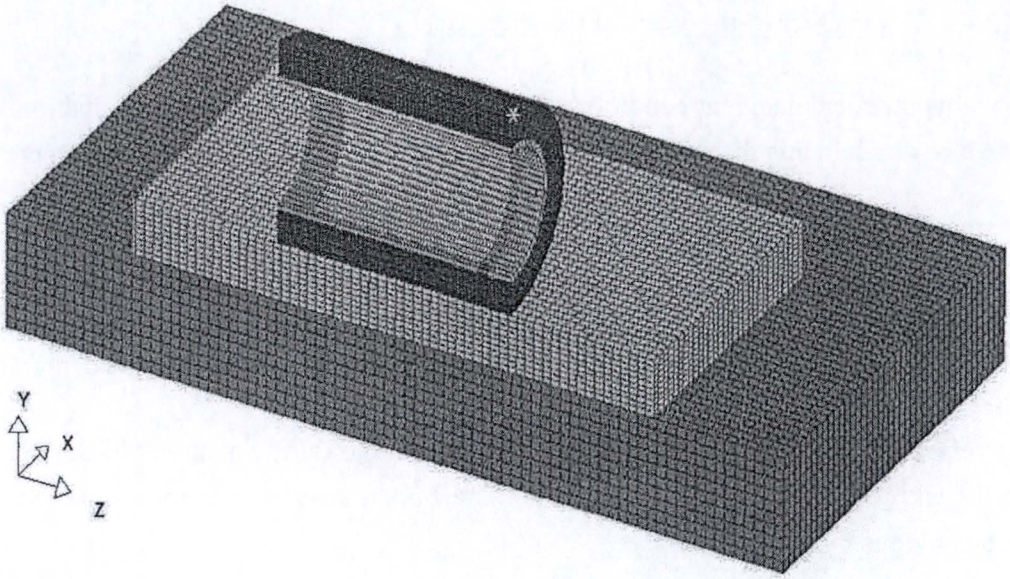
11.2.12.2 Analysis of the Yankee-MPC Tip Over Event

For a tip over event to occur, the center of gravity of the concrete cask and loaded canister must be displaced beyond the outer radius of the concrete cask, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the concrete cask and canister will be converted to kinetic energy as the concrete cask and canister rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, ISFSI pad, and underlying soil.

The objective of the evaluation of the response of the concrete cask during the tip over event is to determine the maximum acceleration to be used in the structural evaluation of the loaded canister and basket. The methodology to determine the concrete cask response follows the methodology contained in NUREG/CR-6608 ("Summary and Evaluation of Low-Velocity Impact Tests of Solid Steel Billet Onto Concrete Pads"). The LS-DYNA program is used in this evaluation.

11.2.12.2.1 Analysis of the Yankee-MPC Vertical Concrete Cask

The Yankee-MPC tip over event is evaluated using a finite element model. As shown in the following, the model includes a half section of the concrete cask, the concrete ISFSI pad and soil subgrade. The concrete pad in the model corresponds to a pad 30-feet by 30-feet square and 3-feet thick, supporting one concrete cask in the center of the pad. The soil under the concrete pad is considered to be 45-feet by 45-feet square and 6-feet thick. Only one-half of the concrete cask, pad and soil configuration is modeled due to symmetry.



Material Properties

The concrete is represented as a homogeneous isotropic material. The concrete cask (outer shell) and the pad are modeled as material Type Number 16 in LS-DYNA. The required input data is:

Property	Concrete Cask	Concrete Pad
Density, ρ (pcf)	146	125
Compressive Strength, f'_c (psi)	4,000	4,000
Poisson's Ratio, ν	0.22	0.22
Modulus of Elasticity, E (psi)	3.682E6	2.917E6
Bulk Modulus, K (psi)	2.192E6	1.736E6

where:

$$E = 33\rho^{1.5}\sqrt{f'_c}$$

and

$$K = \frac{E}{3(1-2\nu)}$$

The design density for the pad is between 125 pcf and 150 pcf. A density of 125 pcf is used in the model for the pad. The design strength is 4,000 psi for the concrete cask and ≤ 4,000 psi for the concrete pad. By modeling the compressive strength of the pad to be equal to that of the concrete cask, the evaluation is bounding.

The design density for the soil beneath the ISFSI pad is between 85 lbs/ft^3 and 130 lbs/ft^3.

The material properties used in this model for the soil below the ISFSI pad are:

Density = 100 pcf
Poisson's Ratio (υ) = 0.4

$$\text{Modulus of Elasticity} = \frac{1-\upsilon^2}{\alpha} k \sqrt{A_{pad}} \text{ psi} \qquad \text{(EPRI-TR-108760)}$$

where:

A_{pad} = the area of the concrete pad in square inches
k = the soil stiffness
α = 1.08 for a square area

A soil stiffness of 250 psi/inch is used in this model and analysis. For the 30 x 30 square foot pad, the modulus of elasticity of the soil in this model is calculated as 70,000 psi. Analyses show that there is no significant effect on the calculated impact load using soil stiffness values up to 300 psi/inch. The concrete cask steel liner has the properties:

Density = 0.284 lb/in^3
Poisson's ratio = 0.31
Modulus of elasticity = 2.9E7 psi

To account for the weight of the shield plug, the loaded canister, and the concrete cask pedestal, effective densities are used for the elements in the first row of the steel liner model adjacent to the impact plane of symmetry. These densities represent the regions (6° in the circumferential direction) of the steel liner subjected to the weight of the shield plug, the loaded canister and the pedestal, during the side impact (tip over) condition. The contact angle (6°) is determined based on the canister/basket analysis for the tip over condition (Section 11.2.12.2.2). Based on the status of the gap elements at the outer surface of the canister shell (representing the interface between the canister shell and the concrete cask steel liner) in the finite element model used in Section 11.2.12.2.2, the contact angle between the canister shell and the concrete cask liner is between 4.5° and 9° for the half-symmetry model.

Boundary Conditions and Initial Conditions

A friction coefficient of 0.25 is used at the interface between the steel liner and the concrete shell, between the concrete cask and the pad, and between the pad and the soil. For all the embedded faces (three side surfaces and the bottom surface) of the soil in the model, the displacements in the direction normal to the surface are restrained. The symmetry boundary conditions are applied for all nodes at the plane of symmetry.

The initial condition corresponds to the concrete cask in a horizontal position with an initial vertical velocity into the concrete pad. The pad and soil are initially at rest.

The initial velocity is simulated by applying an angular velocity (ω) of 1.516 radians/sec to the entire cask. The angular velocity value is computed by considering energy conservation at the cask "center of gravity over corner" tip condition versus the side impact condition.

From energy conservation:

$$mgh = \frac{I\omega^2}{2}$$

where:

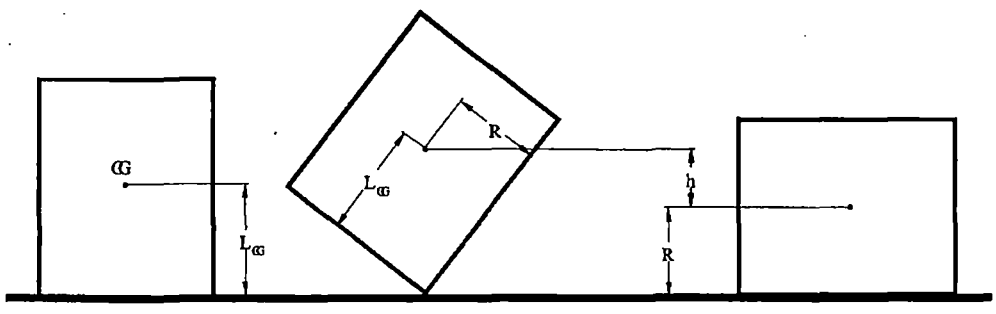
mg = total weight of the loaded concrete cask = 206,094 lbs

h = height change of the concrete cask center of gravity (L_{CG}) = $\sqrt{R^2 + \left(\frac{L_{CG}}{2}\right)^2} - R$

= 40.97 inches

where:

L_{CG} = location of the center of gravity above the pad for the concrete cask = 83.2 inches
R = radius of the concrete cask = 64 inches
I = total mass moment of inertia of the concrete cask about the pivot point
= 7,352,751 lb-sec^2-inch



Concrete Cask Tip Over Height Change

The mass moment of inertia for the concrete shell and the steel liner is calculated using the formula for a hollow right circular cylinder (Blevins).

$$I = \frac{m}{12}(3R_1^2 + 3R_2^2 + 4L^2) + md^2$$

where:

m = mass
R_1 and R_2 = the outer and inner radius of the cylinder
L = height of the cylinder
d = distance between the center of gravity and the pivot point

For the mass of the shield plug, loaded canister and the pedestal, the formula for the moment of inertia for a solid cylinder is used:

$$I = \frac{m}{12}(3R^2 + 4L^2) + md^2$$

where:

m = mass of the cylinder
R = radius of the cylinder
L = height of the cylinder
d = distance between the two pivot axes

The angular velocity is given by $\omega = \sqrt{\frac{2mgh}{I}}$ = 1.516 radians/sec

Filter Frequency

The accelerations are evaluated at the inner surface of the cask liner, which physically corresponds to the interface of the liner and the loaded canister nearest the plane of impact. Following the methodology contained in NUREG/CR-6608, the Butterworth filter is applied to the nodal accelerations. The filter frequency is based on the fundamental mode of the cask.

The fundamental natural frequency of a beam in transverse vibration due to flexure only is given by Blevins as:

$$f = \frac{\lambda^2}{2\pi}\sqrt{\frac{EI}{\rho AL^4}}$$

where:

$\lambda = 3.92660231$ for a pin-free beam

The frequencies of the concrete (f_c) and the steel liner (f_s) are computed as:

Area of concrete cask = $\pi \{(64)^2 - (43)^2\} = 2{,}247\pi \text{ in}^2$

Moment of inertia of concrete cask = $\frac{\pi}{4}\{(64)^4 - (43)^4\} = 3{,}339{,}603.75\pi \text{ in}^4$

$f_c = 31.1\ \lambda^2 = 479.5 \text{ Hz}$

Area of steel liner = $\pi \{(43)^2 - (39.5)^2\} = 288.75\pi \text{ in}^2$

Moment of inertia of steel liner = $\frac{\pi}{4}\{(43)^4 - (39.5)^4\} = 246{,}105.23\pi \text{ in}^4$

$f_s = 36.1\ \lambda^2 = 556.6 \text{ Hz}$

Since the concrete cask is short compared to its diameter, the contribution of the flexibility due to shear is also incorporated. This is accomplished by using Dunkerley's formula (Blevins). The system frequency is:

$$\frac{1}{f^2} = \frac{1}{f_c^2} + \frac{1}{f_s^2}$$

Thus, the system frequency is: f = 363.3 Hz. A cut-off frequency of 375 Hz is conservatively applied to filter the analysis results and measure the peak accelerations.

Results of the Transient Analysis

The accelerations at key locations of the concrete cask liner, which are required in the evaluation of the loaded canister/basket model (Section 11.2.12.2.2) are:

Location on Component	Position Measured from the bottom of the Concrete Cask (inches)	Acceleration (g)
Top support disk	126.2	27.5
Top of the canister structural lid	145.6	31.4

Validation of the Analysis Methodology

Tip over tests of a steel billet onto a concrete pad were conducted and reported in NUREG/CR-6608. The purpose of the test was to provide data, against which, analysis methodology could be validated. Using the geometry described in the benchmark along with the modeling methodology, these analyses were performed using the soil input data presented in this Section.

Using the filter frequency reported in the benchmark, the results obtained are compared to the accelerations in the NUREG/CR-6608 benchmark:

Nodes / Gauge Location	Maximum Experiment (g)	NAC Analysis (g)
16115 / A1	237.5	237.1
17265 / A5	231.5	229.4

11.2.12.2.2 Analysis of the Yankee-MPC Canister and Basket

Structural evaluations are performed for the transportable storage canister and fuel basket support disks for tip over accident conditions. An ANSYS finite element model is used to evaluate this side impact loading condition. Based on the evaluation presented in this section, the bounding basket drop angle of 45° is used for the evaluation of tip over accident. Thermal conditions are bounded by evaluating the canister and basket using material properties at 75°F and applying the stress allowables for the maximum temperatures at the extreme heat thermal accident condition. Evaluation of the canister and basket with damaged fuel cans is presented in Section 11.2.12.3.

Yankee-MPC Canister and Basket Model

A finite element analysis, using the ANSYS program, is performed to evaluate the canister and support disks for the tip over accident condition. Output is in the form of linearized stresses taken across component sections. Additionally, a buckling evaluation is performed on the support disk in accordance with NUREG/CR-6322.

A symmetric one-half (180°) model is used to represent the upper portion of the canister and basket assembly, which is subject to the highest g-load during the tip over accident. As shown in Figure 11.2.12.2.2-1, the model consists of the upper portion of the canister, the top weldment and the five support disks. The canister is constructed using ANSYS solid (SOLID45) elements. ANSYS SHELL63 elements are used to model the top weldment and the support disks. The model for the canister assembly includes the shield and structural lids. Figure 11.2.12.2.2-2 shows the basket top weldment and five support disks. A detailed view of the basket support disk showing applied loads is shown in Figure 11.2.12.2.2-3. For the evaluation of the basket support disk, a basket angle of 45° is considered. This orientation is the most critical during side impact conditions. The weights of the fuel assembly, aluminum heat transfer disks, rods and spacers, and fuel tube (factored by appropriate g-load) are conservatively represented as concentrated forces at mid-span of the ligaments of the support disks. Two loading cases are considered for the evaluation of the canister and the basket support disks, respectively. The first case evaluates the canister stresses using a fuel weight of 32,400 pounds (900 lb/fuel assembly × 36 loading positions) to bound the maximum load applied to the canister shell. The second case

evaluates the basket support disk using 950 lb/fuel assembly × 36 loading positions for a total 34,200 pounds of fuel, which accounts for possible asymmetric loading of the basket. In both cases, the analyzed weights are greater than the limiting total fuel weight of 30,600 pounds.

The canister and basket model use ANSYS CONTAC52 and COMBIN40 elements to simulate contact between adjacent components. Interaction between the basket and canister is modeled using three-dimensional gap elements (CONTAC52) along the periphery of the support disks. Contact between the canister and concrete cask liner is also modeled using CONTAC52 elements. Contact between the canister's structural lid and shield lid is modeled using COMBIN40 combination elements in the axial (UY) degree of freedom. The backing ring is modeled using a ring of COMBIN40 spring gap elements connecting the shield lid and the canister in the axial direction at the lid lower outside radius. In addition, CONTAC52 elements are used to model interaction between the structural lid and canister shell, and the shield lid and canister shell, just below the respective lid weld joints. The size of the CONTAC52 gaps is determined from the nominal dimensions of contacting components. The COMBIN40 elements between the structural and shield lids are assigned a gap size of 0.08 inch, based on the flatness tolerances of the structural and shield lids. A gap of 1E-8 in. is used between the backing ring and shield lid. Note that the gap sizes in the axial direction do not have a significant effect on the side impact analysis results. All gap-spring elements are assigned a stiffness of 1E6 lb/in.

Symmetry boundary conditions are applied at the plane of symmetry of the model, as well as at the cut boundary of the model (canister shell near the 5th support disk). All nodes on the concrete cask side gap elements at the outer surface of the canister shell are fixed in all degrees of freedom (UX, UY, and UZ). In addition, the axial (UY) and in-plane rotational degrees of freedom (ROTX and ROTZ) of the basket nodes are fixed.

Loading of the model includes an internal pressure of 11.5 psig (normal condition of storage) applied to the canister, concentrated loads are applied to all slots (except the central slot where there is no fuel assembly) and the inertial loads.

For the inertial loads, a maximum acceleration of 45 g is conservatively applied to the entire model. The maximum acceleration of the steel liner at the locations of the top support disk and the top of the canister lid during the tip over event is determined to be 27.5 g and 31.4 g, respectively. The main pulse of deceleration lasts for 30 milliseconds. To determine the effect of the rapid application of the inertia loading for the top support disk, a dynamic load factor (DLF) is computed using the mode shapes of a loaded support disk. The mode shapes are

extracted using ANSYS for the first four modes. Using the acceleration time history developed from Section 11.2.12.2.1, the DLFs for each modal frequency are computed using a single degree of freedom model. The maximum DLF and corresponding frequencies are:

Mode Number	Frequency (Hz)	DLF
1	44	1.61
2	169	1.09
3	234	1.02
4	273	1.03

Applying the maximum DLF to the 27.5 g results in a peak acceleration of 44.4 g. The canister lid region is significantly stiffer than the basket disk due to its monolithic structure. Applying the DLF of 1.09 to the maximum acceleration time history value of 31.4 g results in a maximum of 34.2 g. Therefore, applying 45 g to the entire canister/basket model is conservative.

A uniform temperature of 75°F is applied to the model to determine material properties during solution. During post processing, temperatures of 575°F and 372°F are conservatively used for the support disks and the canister, respectively, to determine the allowable stresses. These temperatures are the maximum calculated temperatures for the accident (extreme heat) thermal condition (ambient temperature = 125°F).

Analysis Results for the Yankee-MPC Canister

The stress results of the canister for the tip over accident condition are summarized in Tables 11.2.12.2.2-1 and 11.2.12.2.2-2 for primary membrane and primary membrane plus bending stresses, respectively. The sectional stresses at 14 axial locations are obtained for each angular division of the model (a total of 41 angular locations for each axial location). The locations for the stress sections are shown in Figure 11.2.12.2.2-4.

The stress evaluation for the canister is performed in accordance with the ASME Code, Section III, Subsection NB, by comparing the linearized stresses of cross sections of the structure against the allowable stresses. Allowable stresses are conservatively taken at a temperature of 372°F (maximum canister temperature is 319°F for normal condition of storage). The allowable stresses for accident conditions are taken from Subsection NB as shown below. S_m and S_u are 16.05 ksi and 59.17 ksi, respectively, for Type 304L stainless steel (canister shell and structural lid). S_m and S_u are 19.06 ksi and 64.85 ksi, respectively, for Type 304 stainless steel (shield lid).

	Accident (Level D) Allowable Stress
P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

During the tip-over accident, the canister shell at the structural and shield lids is subjected to the inertial load of the lids, which results in highly localized bearing stresses (Sections 8 through 12 at angular locations of 0 and 4.5 degrees). This stress is predominant because the weights of the structural and shielding lids are transferred to the canister shell through the thickness of the weld (7/8-inch weld for structural lid and 1/2-inch weld for shield lid). According to ASME Code Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions. Therefore, the P_m stresses are not presented for the region local to the impact (angular locations of 0 and 4.5 degree) for Sections 8, 9, and 10 in Table 11.2.12.2.2-1. Stresses are conservatively presented for all locations (including bearing region) for Section 11.

The inertial load of the shield lid also results in localized bending stresses at the canister shell (at the shield lid weld, i.e., Section 8). This stress state is identified as the case of a cylindrical shell at the junction with a head, as shown in Table NB-3217-1 of the ASME Code, Section III, Subsection NB. The localized bending stress at the structural discontinuity is classified as secondary (Q) stress. In accordance with ASME Code Section III, Appendix F, secondary stresses are not considered for the stress evaluation for Level D (accident) conditions. Therefore, the P_m+P_b stresses are not presented for the region local to the impact for Section 8 (angular locations of 0 and 4.5 degree) in Table 11.2.12.2.2-2.

The stress evaluation results for tip over accident conditions show that the minimum margin of safety in the canister is +0.02 for P_m (Section 12) and +0.10 for P_m+P_b (Section 10).

Analysis Results for the Yankee-MPC Support Disk

To evaluate the most critical regions of the support disk, a series of cross sections are considered. To aid in the identification of these sections, Figure 11.2.12.2.2-5 shows the locations on a support disk. Table 11.2.12.2.2-3 lists the cross sections versus Point 1 and Point 2, which spans the cross section of the ligament in the plane of the support disk.

The stress evaluation for the support disk is performed according to ASME Code Section III, Subsection NG. According to this subsection, linearized stresses of cross sections of the structure are to be compared against the allowable stresses. The allowable stresses for tip over accident conditions are taken from Subsection NG as shown below at the maximum support disk

temperature of 575°F (accident-extreme heat). The S_m and S_u are 42.3 ksi and 127.1 ksi, respectively, for 17-4 PH stainless steel.

	Accident (Level D) Allowable Stresses
P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

The stress evaluation results for the support disks for tip-over impact condition are presented in Tables 11.2.12.2.2-4 through 11.2.12.2.2-13. The tables list the 40 highest P_m and P_m+P_b stress intensities for Disks 1 through 5. The minimum margin of safety is +0.17, which occurs in Disk 5 (See Figure 11.2.12.2.2-4 for identification of support disks). The highest P_m and P_m+P_b stresses occur in Disk 5, with the minimum margin of safety of 1.42 and 0.17, respectively. Locations of the 10 highest P_m and P_m+P_b linearized stresses for Disk 5 are given in Figures 11.2.12.2.2-6 and 11.2.12.2.2-7.

Yankee-MPC Support Disk Buckling Evaluation

The fuel basket support disks are subjected to compressive and/or inertial loads during impact conditions. For the tip over accident, the support disks experience in-plane loads. The in-plane loads apply compressive forces and in-plane bending moments on the support disk. Buckling of the support disk is evaluated in accordance with the methods and acceptance criteria of NUREG/CR-6322. Because the ASME Code identifies 17-4PH disk material as ferritic steel, the formulas for non-austenitic steel are used.

The buckling evaluation of the support disk web is based on the Interaction Equations 31 and 32 in NUREG/CR-6322. These two equations adopt the "Limit Analysis Design" approach for structural members subjected to stresses beyond the yield limit of the material, i.e., for members deformed elastically as a result of axial load or bending moment. Other equations applicable to the calculations are noted as they are applied. The maximum forces and moments for the tip over accident are based on the finite element analysis stress results.

Symbols and Units

P = applied axial compressive loads, kips
M = applied bending moment, kips-inch
P_a = allowable axial compressive load, kips
P_{cr} = critical axial compression load, kips
P_e = Euler buckling loads, kips

P_y = average yield load, equal to profile area times specified minimum yield stress, kips (for normal operating condition)

C_c = column slenderness ratio separating elastic and inelastic buckling

C_m = coefficient applied to bending term in interaction equation

M_m = critical moment that can be resisted by a plastically designed member in the absence of axial load, kip-inch

M_p = plastic moment, kip-inch

F_a = axial compressive stress permitted in the absence of bending moment, ksi

F_e = Euler stress for a prismatic member divided by factor of safety, ksi

k = ratio of effective column length to actual unsupported length

l = unsupported length of member, inch

r = radius of gyration, inch

S_y = yield stress, ksi

A = cross sectional area of member, in^2

Z_x = plastic section modulus, in^3

λ = allowable reduction factor, dimensionless

From NUREG/CR-6322, the following equations are used to evaluate the support disk:

$$\frac{P}{P_{cr}} + \frac{C_m M}{M_m\left[1 - \frac{P}{P_e}\right]} \leq 1.0 \qquad \text{(Equation 31)}$$

$$\frac{P}{P_y} + \frac{M}{1.18\,M_p} \leq 1.0 \qquad \text{(Equation 32)}$$

where:

$$P_{cr} = 1.7 \times A \times F_a$$

$$F_a = \frac{P_a}{A} \quad \text{for} \quad P_a = P_y\left[\frac{1 - \frac{\lambda^2}{4}}{1.11 + 0.5\lambda + 0.17\lambda^2 - 0.28\lambda^3}\right]$$

$$\text{and} \quad \lambda = \frac{1}{\pi}\left(\frac{kl}{r}\right)\sqrt{\frac{S_y}{E}} \qquad \text{(accident conditions)}$$

$$Pe = 1.92 \times A \times Fe$$

$$F_e = \frac{\pi^2 \cdot E}{1.3\left(\frac{k \cdot l}{r}\right)^2} \qquad \text{(Level D–Accident)}$$

$$P_y = S_y \times A$$

$C_m =$ 0.85 for members with joint translation (sideways)

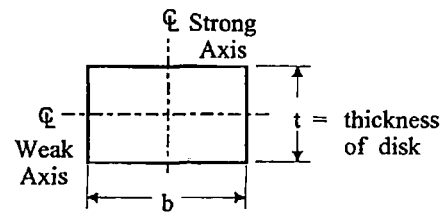
$$M_p = S_y \times Z_x$$

$$M_m = M_p \cdot \left(1.07 - \frac{\left(\frac{l}{r}\right) \cdot \sqrt{S_y}}{3160}\right) \leq M_p$$

Buckling evaluation is performed in all sections in the disk ligaments defined in Figure 11.2.12.2.2-5. Using the cross-sectional stresses calculated at each section located in the web for each loading condition the maximum corresponding compressive forces (P) and bending moment (M) are determined as:

$$P = \sigma_m A$$

$$M = \sigma_b S$$



where, σ_m is the membrane stress, σ_b is the bending stress, A is the area (b × t), and S is the section modulus ($tb^2/6$).

To determine the margin of safety:

$$P_1 = P/P_{cr} \qquad M_1 = \frac{C_m M}{(1 - P/P_e)M_m} \qquad (P_1 + M_1 \leq 1)$$

and

$$P_2 = P/P_y \qquad M_2 = \frac{M}{1.18\,M_p} \qquad (P_1 + M_1 \leq 1)$$

The Margins of Safety are:

$$MS1 = \frac{1}{P_1 + M_1} - 1$$

and

$$MS2 = \frac{1}{P_2 + M_2} - 1$$

Buckling evaluation results are provided in Tables 11.2.12.2.2-14 through 11.2.12.2.2-18. As the tables demonstrate, the support disks meet the requirements of NUREG/CR-6322.

Yankee-MPC Basket Impact Orientation Evaluation

This section presents the justification for considering the 45° basket impact orientation as the bounding case for the support disk evaluation for the concrete cask tip over accident.

Due to the symmetry of the basket, three basket impact angles, 0°, 22.9° and 45° (shown in Figure 11.2.12.2.2-8) with two side impact conditions (20g and 55g) are considered in the evaluation. The orientation angles of 22.9° and 45° are selected because a minimal ligament between the corner of the fuel assembly slot and the disk outer radius occurs at those orientations. The evaluation in this section shows that the maximum stresses occur for the 45° impact orientation and, thus, the 45° impact orientation is the bounding case for the support disk evaluation.

As shown in Figure 11.2.12.2.2-9, a finite element model for the support disk is generated using the ANSYS program to perform analyses for six side impact cases:

Case No.	Side Impact Acceleration (g)	Basket Orientation (Degree)
1	20	0
2	20	22.9
3	20	45
4	55	0
5	55	22.9
6	55	45

The model consists of a support disk and a section of the canister shell, as shown in Figure 11.2.12.2.2-9. ANSYS SHELL63 elements are used to model the disk and canister. As shown in Figure 11.2.12.2.2-10, CONTAC52 elements are used to simulate the interface between the

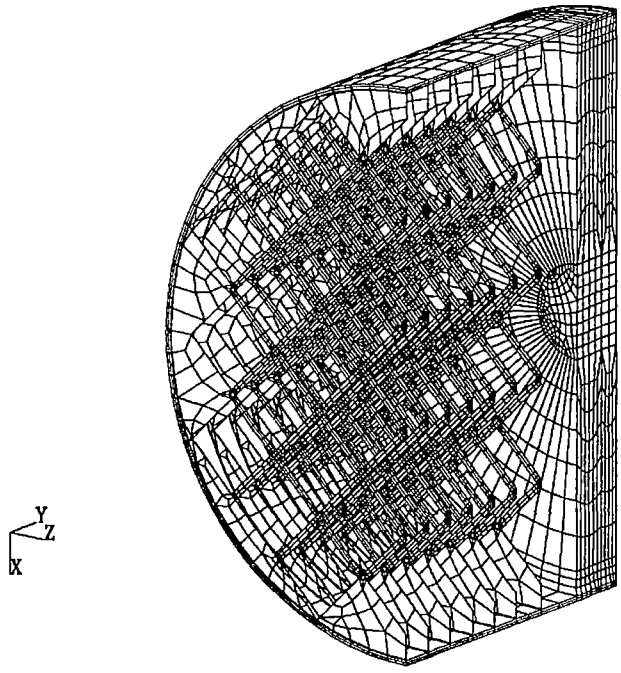
support disk and the canister shell. A value of 1.0 x 10^6 lb/inch is used for the stiffness of CONTAC52 elements. BEAM3 elements with very small properties (Area = 5 x 10^{-4} inch^2, I_{zz} = 5 x 10^{-2} inch^4, Modulus of Elasticity = 1 psi) are applied at the same locations as the CONTAC52 elements to prevent rigid body motion of the model. The canister shell outer diameter is constrained to prevent translation of the canister. Applying a concentrated load (with the acceleration factor) simulates the fuel assembly and tube weight at the mid-span of each ligament. The value of the force varies according to the impact orientation. There is no fuel assembly in the center slot of the basket; therefore, no forces are applied at the ligaments of the center slot.

The maximum nodal stress intensity for each basket impact orientation angle (0°, 22.9° and 45° [20 g and 55 g]) is summarized as:

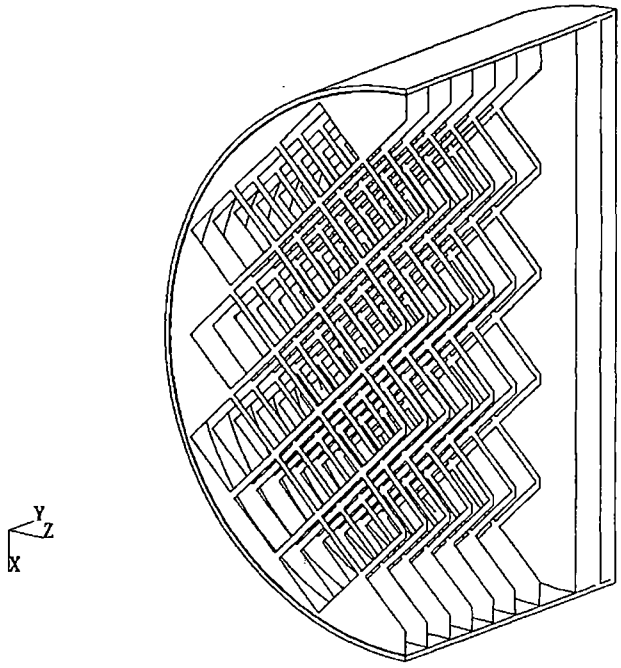
Basket Side Impact Orientation	Maximum Stress Intensity (ksi)	
	20 g	55 g
0°	33.3	84.1
22.9°	48.1	81.8
45°	48.9	85.3

The maximum stress intensity occurs in the 45° orientation case. Therefore, it is concluded that the 45° orientation is the bounding case for the support disk evaluations for the concrete cask tip over event.

Figure 11.2.12.2.2-1 Three-Dimensional Yankee-MPC Canister and Basket Model



Model With Element Edges Displayed



Model Without Element Edges Displayed

Figure 11.2.12.2.2-2 Yankee-MPC Basket Assembly

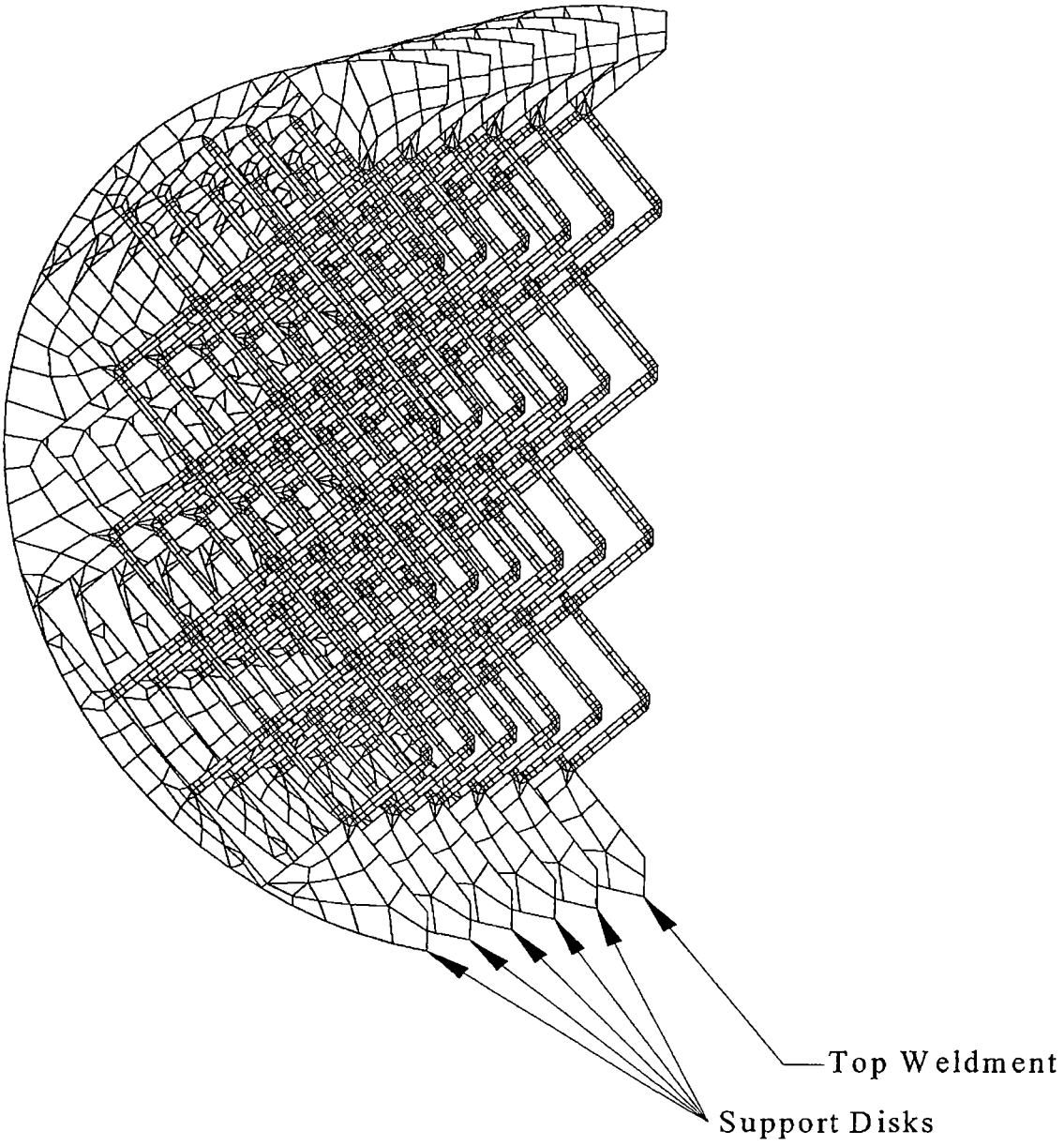


Figure 11.2.12.2.2-3 Yankee-MPC Support Disk Detail

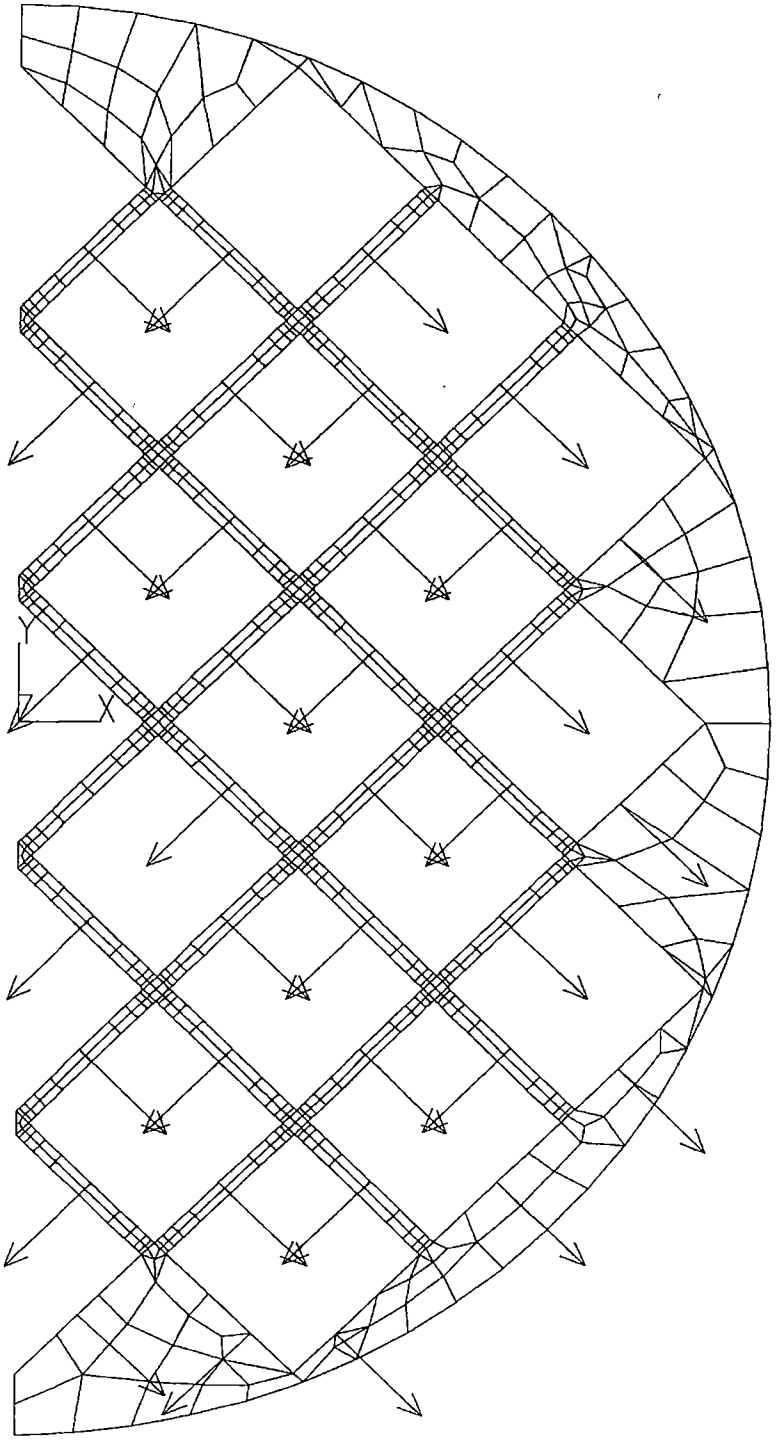


Figure 11.2.12.2.2-4 Yankee-MPC Canister Stress Sections Locations

Section	Node 1		Node 2	
	X	Y	X	Y
1	34.695	84.720	35.320	84.720
2	34.695	89.130	35.320	89.130
3	34.695	93.540	35.320	93.540
4	34.695	97.950	35.320	97.950
5	34.695	102.360	35.320	102.360
6	34.695	107.250	35.320	107.250
7	34.695	114.500	35.320	114.500
8	34.695	118.500	35.320	118.500
9	34.695	119.500	35.320	119.500
10	34.695	121.620	35.320	121.620
11	34.695	118.500	34.695	119.500
12	34.695	121.620	34.695	122.500
13	0.000	114.500	0.000	119.480
14	0.000	119.520	0.000	122.500

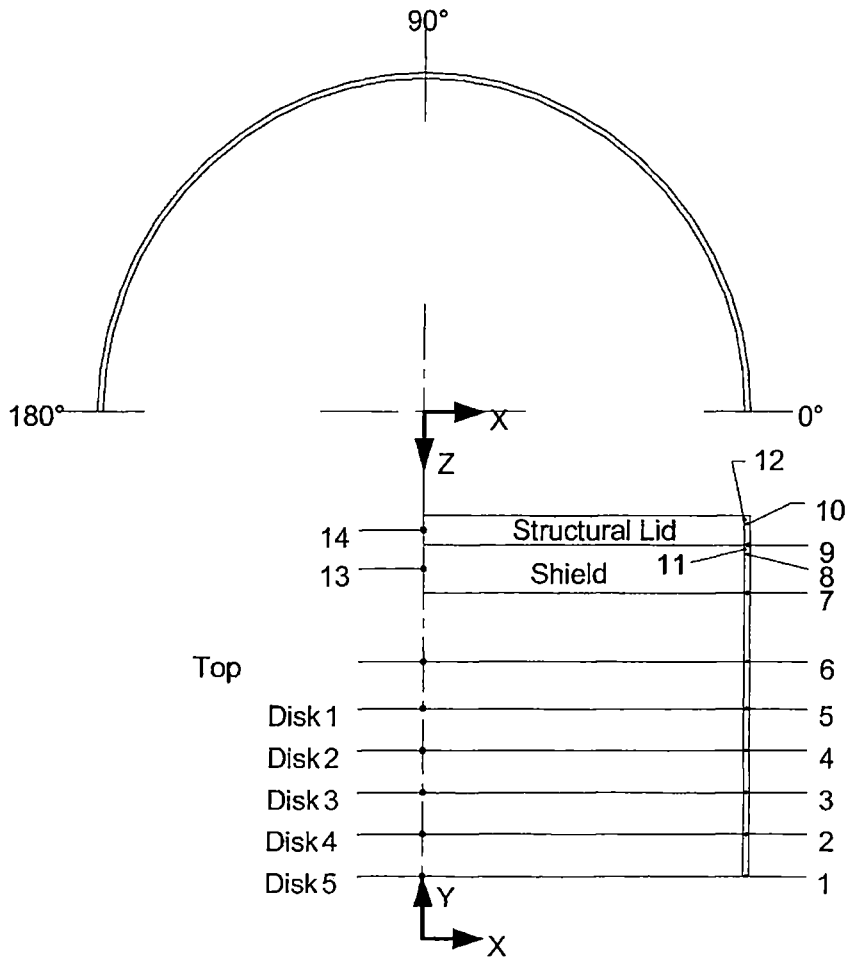


Figure 11.2.12.2.2-5 Location of Yankee-MPC Support Disk Sections to Obtain Linearized Stresses

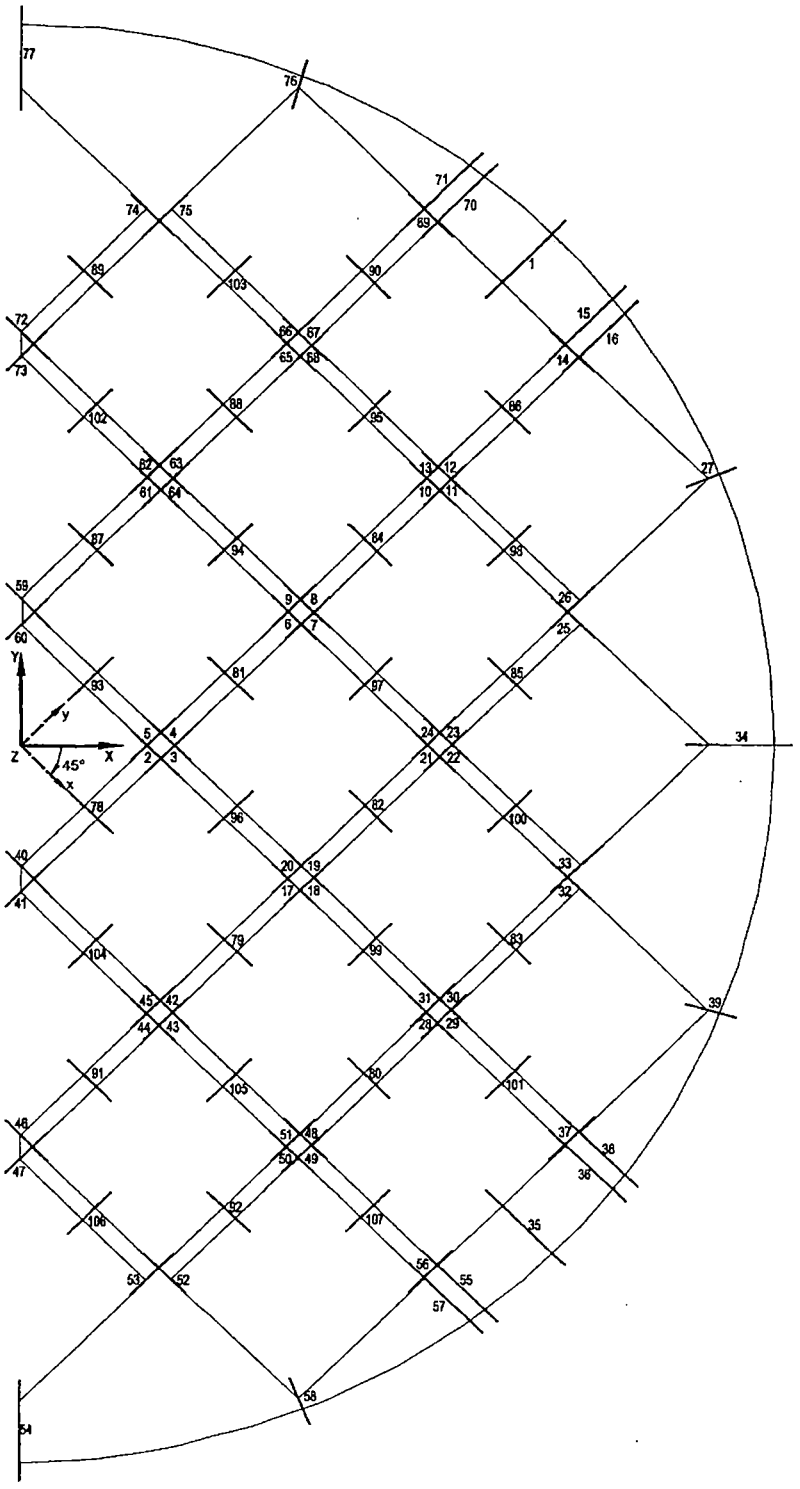


Figure 11.2.12.2.2-6 Locations of the 10 Highest P_m Yankee-MPC Support Disk Linearized Stress Sections

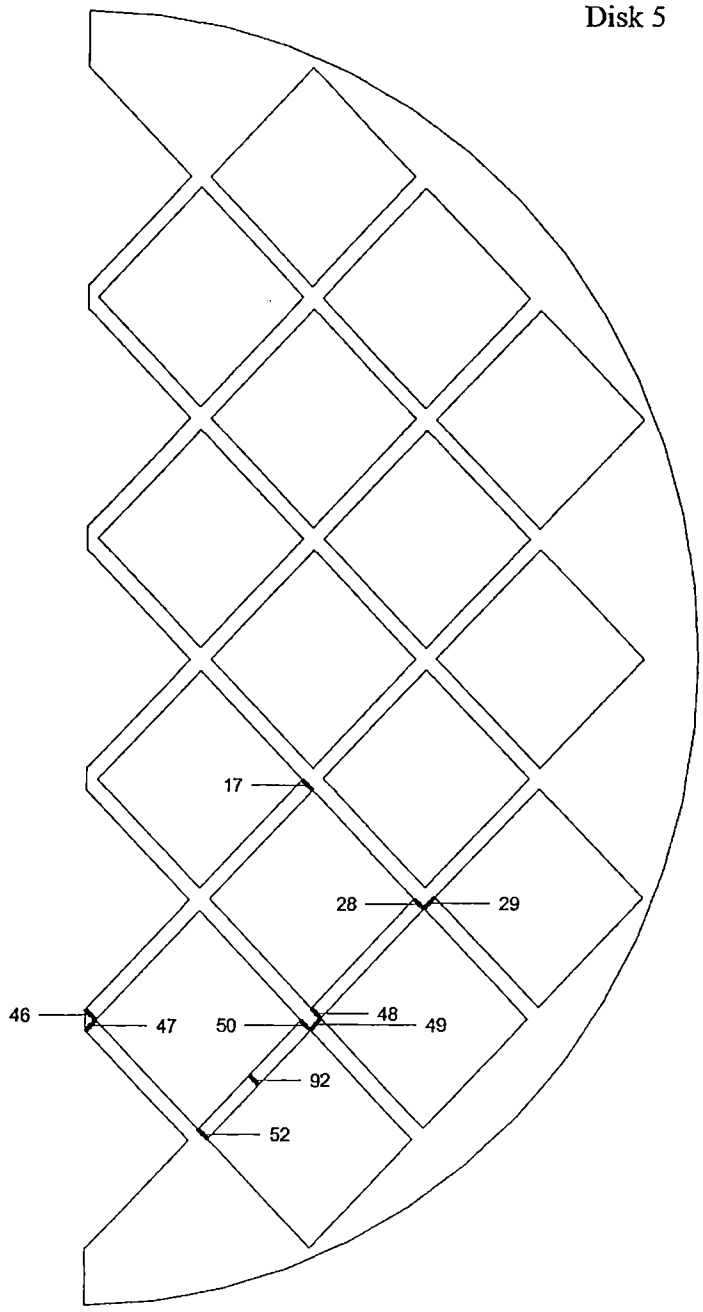


Figure 11.2.12.2.2-7 Locations of the 10 Highest P_m+P_b Yankee-MPC Support Disk Linearized Stress Sections

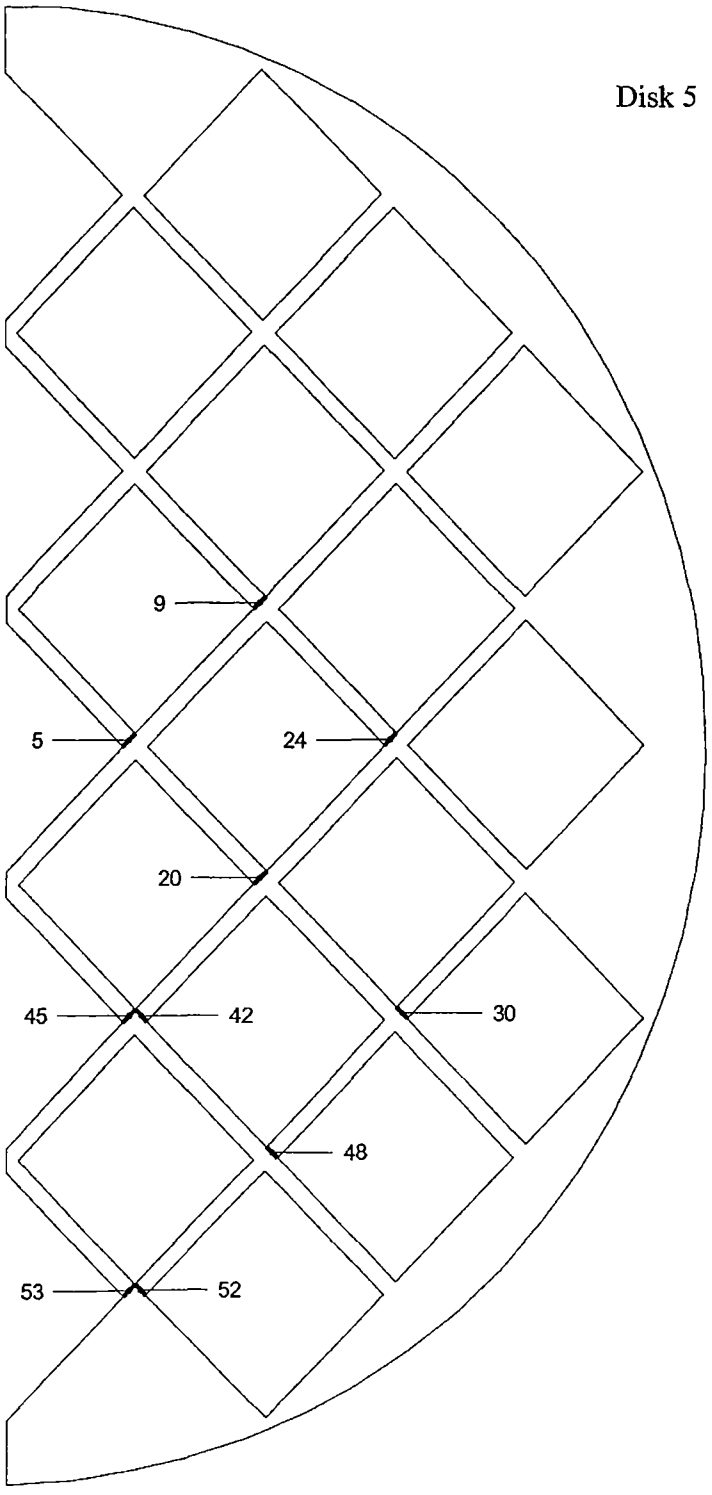


Figure 11.2.12.2.2-8 Evaluated Yankee-MPC Basket Impact Orientations

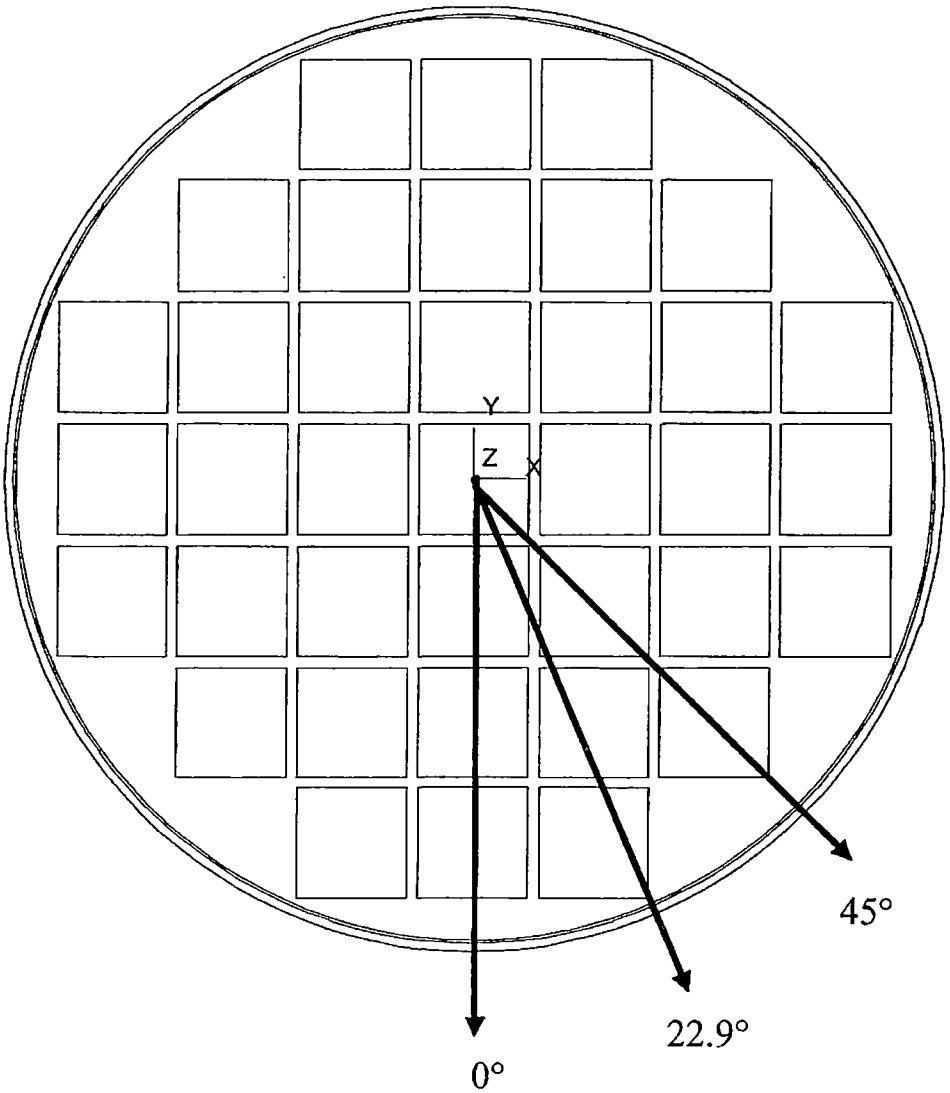


Figure 11.2.12.2.2-9 ANSYS Model for the Yankee-MPC Support Disk

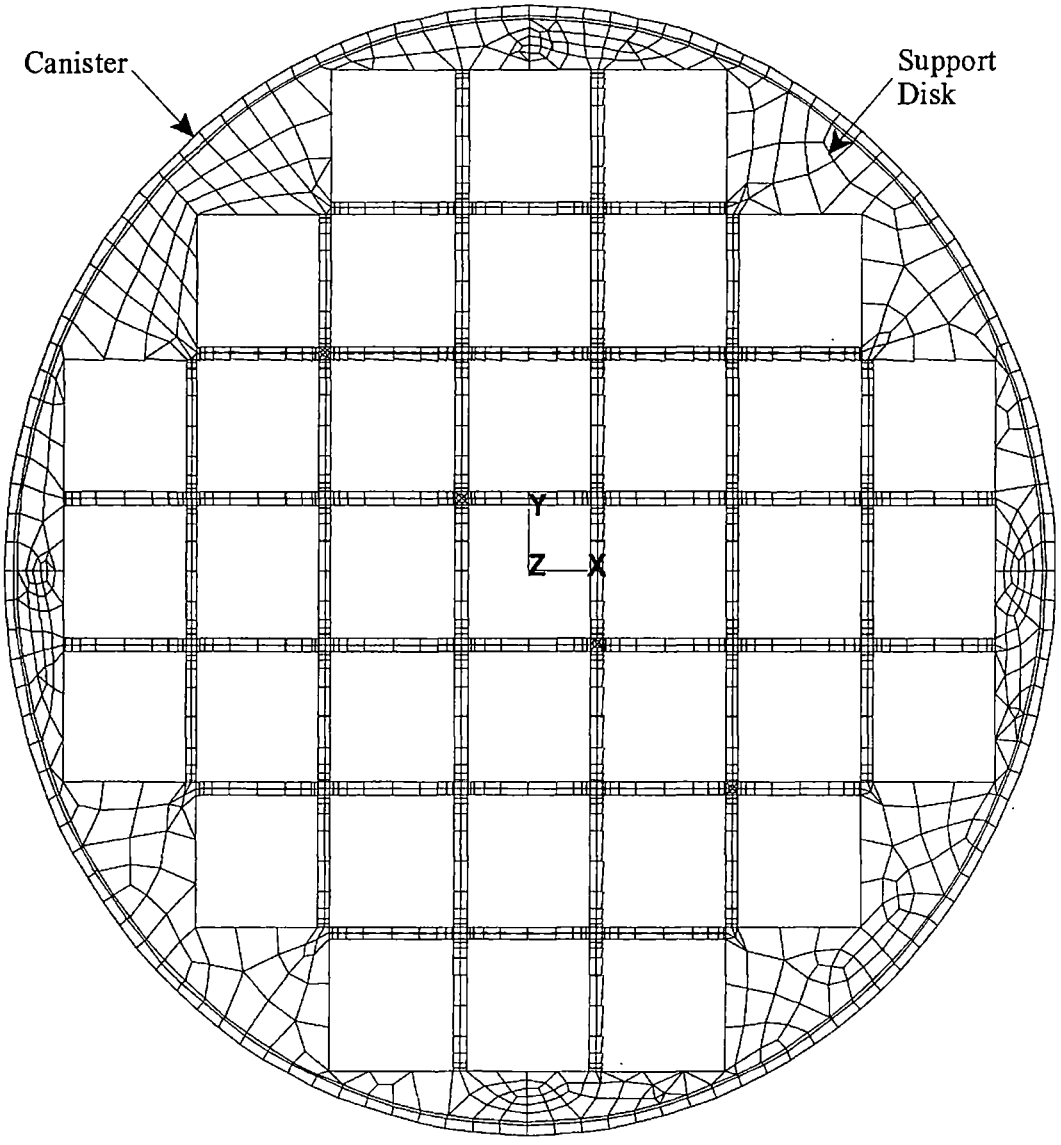


Figure 11.2.12.2.2-10 Yankee-MPC Support Disk ANSYS Model Detail

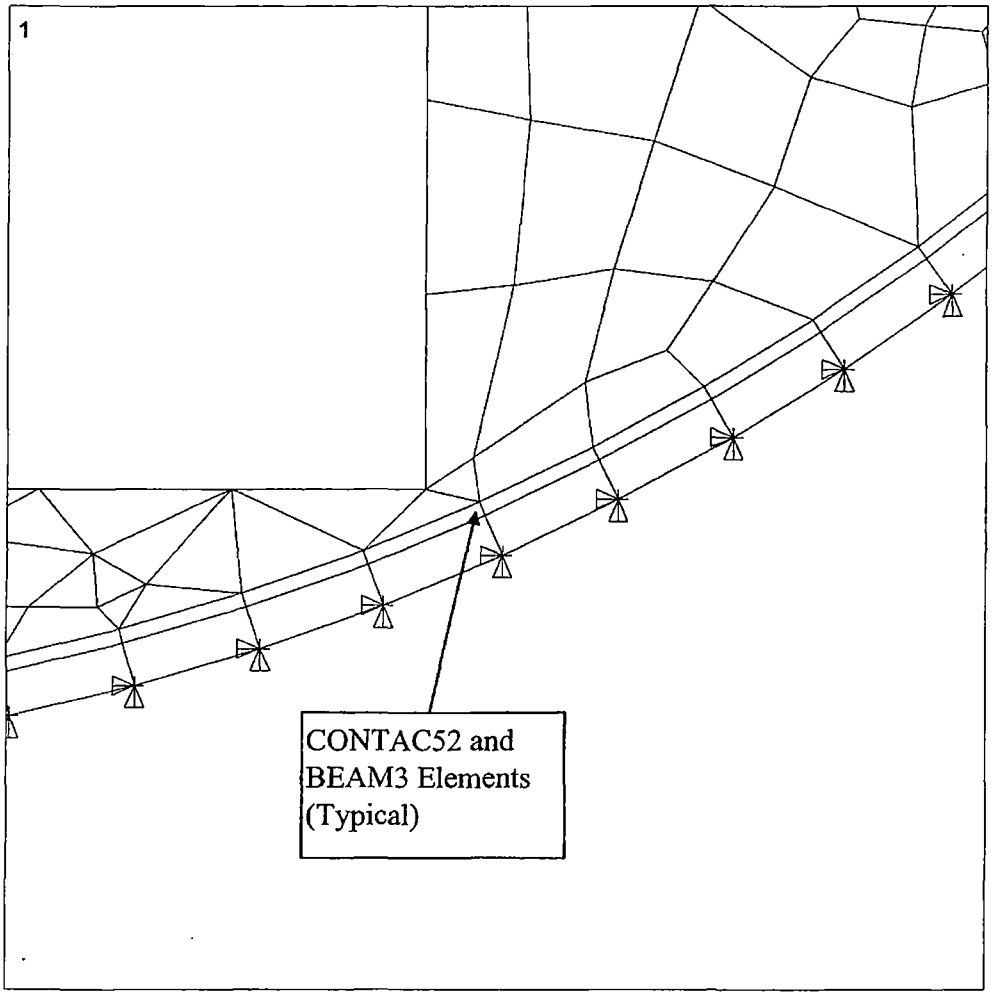


Table 11.2.12.2.2-1 Yankee-MPC Canister Primary Membrane Stresses[1] for Tip-Over Accident

Section[1]	Angle (deg)	Sx (ksi)	Sy (ksi)	Sz (ksi)	Sxy (ksi)	Syz (ksi)	Sxz (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	0.00	-4.10	16.60	-3.80	1.70	-0.10	0.90	21.67	38.52	0.78
2	0.00	-1.20	15.20	-3.30	0.00	-0.20	0.60	18.67	38.52	1.06
3	0.00	-1.80	12.50	-2.80	-0.30	-0.20	0.30	15.40	38.52	1.50
4	99.00	0.00	4.10	-3.90	0.00	7.20	0.20	16.43	38.52	1.34
5	94.50	0.10	3.80	-2.00	0.00	9.40	0.00	19.63	38.52	0.96
6	90.00	0.00	1.40	-0.50	-0.10	11.50	0.00	23.08	38.52	0.67
7	85.50	0.00	-0.40	-0.40	0.00	11.40	0.00	22.85	38.52	0.69
8[2]	9.00	-0.07	0.79	8.71	3.16	-5.83	-1.10	16.13	38.52	1.39
9[2]	9.00	4.42	-0.51	5.04	0.45	-3.07	-1.77	9.36	38.52	3.12
10[2]	9.00	4.81	-3.21	1.56	1.88	-3.33	0.50	10.53	38.52	2.66
11	0.00	-37.60	-22.30	-37.70	0.60	-2.40	-9.70	25.84	38.52	0.49
12	0.0-4.5	-31.18	-15.03	-8.88	4.89	-1.41	-1.22	24.25	24.65[3]	0.02
13	0.00	-1.10	0.40	0.00	0.00	0.00	-0.10	1.55	45.74	28.51
14	0.00	-1.50	0.40	0.00	0.00	0.00	0.00	1.97	38.52	18.57

Notes: 1 Stresses are in cylindrical coordinate system (x-radial, y-circumferential, z-axial).
2 Stresses are not presented for the region with localized bearing stresses. Per ASME Code Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
3 Includes two stress reduction factors for weld = 0.8 x 0.8 = 0.64 (See Section 11.5.1).

Table 11.2.12.2.2-2 Yankee-MPC Canister Primary Membrane + Bending Stresses[1] for Tip-Over Accident

Section[1]	Angle (deg)	Sx (ksi)	Sy (ksi)	Sz (ksi)	Sxy (ksi)	Syz (ksi)	Sxz (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	0.00	-4.40	32.20	-0.50	1.20	-0.30	0.90	36.87	57.79	0.57
2	0.00	-1.90	29.50	0.70	-0.60	-0.50	-0.60	31.63	57.79	0.83
3	0.00	-2.70	25.90	1.60	-0.80	-0.20	0.40	28.72	57.79	1.01
4	0.00	-2.10	24.90	-0.20	-0.60	0.00	-0.10	26.96	57.79	1.14
5	0.00	-2.90	22.60	2.00	0.40	0.10	0.00	25.51	57.79	1.27
6	90.00	0.00	1.80	2.00	-0.10	14.40	0.00	28.89	57.79	1.00
7	0.00	-1.50	-42.70	-27.80	5.20	-2.20	-1.10	42.76	57.79	0.35
8[2]	9.00	0.43	10.41	29.77	0.37	-2.53	0.86	45.14	57.79	0.28
9	0.00	-16.50	-11.60	27.90	-1.80	-2.80	-10.2	49.72	57.79	0.16
10	0.00	-30.60	-17.90	21.20	-2.10	-2.30	3.00	52.62	57.79	0.10
11	0.00	-21.60	-13.00	-19.10	0.90	-0.90	-15.00	30.23	57.79	0.91
12	0.0-4.5	-30.92	-13.32	-6.14	5.70	-0.80	1.30	26.66	36.99[3]	0.37
13	0.00	-1.30	0.70	0.00	0.00	0.00	-0.10	1.94	57.79	28.76
14	0.00	-0.90	1.50	0.00	0.00	0.00	0.00	2.44	57.79	22.73

Notes: 1 Stresses are in cylindrical coordinate system (x-radial, y-circumferential, z-axial).
2 Stresses are not presented for the region with bearing stress (membrane) and secondary (Q) stress (bending). Per ASME Code Section III, Appendix F, both bearing stresses and secondary stresses are not required for evaluation for Level D service (accident) conditions.
3 Includes two stress reduction factors for weld = 0.8 x 0.8 = 0.64 (See Section 11.5.1).

Table 11.2.12.2.2-3 Listing of Cross Sections for Stress Evaluation of the Yankee-MPC Support Disk

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
1	1	2	22.15	22.15	24.39	24.39
2	3	4	5.84	0	6.46	-0.62
3	5	6	6.46	-0.62	7.07	0
4	7	8	7.07	0	6.46	0.62
5	9	10	6.46	0.62	5.84	0
6	11	12	12.29	6.46	12.91	5.84
7	13	14	12.91	5.84	13.48	6.41
8	15	16	13.48	6.41	12.86	7.03
9	17	18	12.86	7.03	12.29	6.46
10	19	20	18.7	12.86	19.32	12.25
11	21	22	19.32	12.25	19.85	12.78
12	23	24	19.85	12.78	19.23	13.4
13	25	26	19.23	13.4	18.7	12.86
14	27	28	25.07	19.23	25.69	18.61
15	29	30	25.07	19.23	27.13	21.3
16	31	32	25.69	18.61	27.67	20.59
17	33	34	12.29	-6.46	12.86	-7.03
18	35	36	12.86	-7.03	13.48	-6.41
19	37	38	13.48	-6.41	12.91	-5.84
20	39	40	12.91	-5.84	12.29	-6.46
21	41	42	18.75	0	19.32	-0.57
22	43	44	19.32	-0.57	19.89	0
23	45	46	19.89	0	19.32	0.57
24	47	48	19.32	0.57	18.75	0
25	49	50	25.16	6.41	25.73	5.84
26	51	52	25.16	6.41	25.69	6.94
27	53	54	31.52	12.78	31.97	12.96
28	55	56	18.7	-12.86	19.23	-13.4
29	57	58	19.23	-13.4	19.85	-12.78
30	59	60	19.85	-12.78	19.32	-12.25
31	61	62	19.32	-12.25	18.7	-12.86
32	63	64	25.16	-6.41	25.69	-6.94
33	65	66	25.16	-6.41	25.73	-5.84
34	67	68	31.57	0	34.49	0
35	69	70	22.15	-22.15	24.39	-24.39
36	71	72	25.07	-19.23	27.13	-21.3
37	73	74	25.07	-19.23	25.69	-18.61
38	75	76	25.69	-18.61	27.67	-20.59
39	77	78	31.52	-12.78	31.95	-12.9
40	79	80	0	-5.84	0.62	-6.46
41	81	82	0.62	-6.46	0	-7.07
42	83	84	6.46	-12.29	7.03	-12.86
43	85	86	7.03	-12.86	6.41	-13.48
44	87	88	6.41	-13.48	5.84	-12.91

Table 11.2.12.2.2-3 Listing of Cross Sections for Stress Evaluation of the Yankee-MPC Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
45	89	90	5.84	-12.91	6.46	-12.29
46	91	92	0	-18.75	0.57	-19.32
47	93	94	0.57	-19.32	0	-19.89
48	95	96	12.86	-18.7	13.4	-19.23
49	97	98	13.4	-19.23	12.78	-19.85
50	99	100	12.78	-19.85	12.25	-19.32
51	101	102	12.25	-19.32	12.86	-18.7
52	103	104	6.41	-25.16	6.94	-25.69
53	105	106	6.41	-25.16	5.84	-25.73
54	107	108	0	-31.57	0	-34.49
55	109	110	19.23	-25.07	21.3	-27.13
56	111	112	19.23	-25.07	18.61	-25.69
57	113	114	18.61	-25.69	20.59	-27.67
58	115	116	12.78	-31.52	12.96	-31.97
59	117	118	0	7.07	0.62	6.46
60	119	120	0.62	6.46	0	5.84
61	121	122	6.46	12.29	5.84	12.91
62	123	124	5.84	12.91	6.41	13.48
63	125	126	6.41	13.48	7.03	12.86
64	127	128	7.03	12.86	6.46	12.29
65	129	130	12.86	18.7	12.25	19.32
66	131	132	12.25	19.32	12.78	19.85
67	133	134	12.78	19.85	13.4	19.23
68	135	136	13.4	19.23	12.86	18.7
69	137	138	19.23	25.07	18.61	25.69
70	139	140	19.23	25.07	21.3	27.13
71	141	142	18.61	25.69	20.59	27.67
72	143	144	0	19.89	0.57	19.32
73	145	146	0.57	19.32	0	18.75
74	147	148	6.41	25.16	5.84	25.73
75	149	150	6.41	25.16	6.94	25.69
76	151	152	12.78	31.52	12.9	31.95
77	153	154	0	31.57	0	34.49
78	155	156	2.92	-2.92	3.54	-3.54
79	157	158	9.37	-9.37	9.95	-9.95
80	159	160	15.78	-15.78	16.31	-16.31
81	161	162	9.37	3.54	9.99	2.92
82	163	164	15.83	-2.92	16.4	-3.49
83	165	166	22.24	-9.33	22.77	-9.86
84	167	168	15.78	9.95	16.4	9.33
85	169	170	22.24	3.49	22.81	2.92
86	171	172	22.15	16.31	22.77	15.69
87	173	174	3.54	9.37	2.92	9.99
88	175	176	9.95	15.78	9.33	16.4
89	177	178	3.49	22.24	2.92	22.81

Table 11.2.12.2.2-3 Listing of Cross Sections for Stress Evaluation of the Yankee-MPC Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
90	179	180	16.31	22.15	15.69	22.77
91	181	182	2.92	-15.83	3.49	-16.4
92	183	184	9.33	-22.24	9.86	-22.77
93	185	186	2.92	2.92	3.54	3.54
94	187	188	9.37	9.37	9.95	9.95
95	189	190	15.78	15.78	16.31	16.31
96	191	192	9.37	-3.54	9.99	-2.92
97	193	194	15.83	2.92	16.4	3.49
98	195	196	22.24	9.33	22.77	9.86
99	197	198	15.78	-9.95	16.4	-9.33
100	199	200	22.24	-3.49	22.81	-2.92
101	201	202	22.15	-16.31	22.77	-15.69
102	203	204	2.92	15.83	3.49	16.4
103	205	206	9.33	22.24	9.86	22.77
104	207	208	3.54	-9.37	2.92	-9.99
105	209	210	9.95	-15.78	9.33	-16.4
106	211	212	3.49	-22.24	2.92	-22.81
107	213	214	16.31	-22.15	15.69	-22.77

Table 11.2.12.2.2-4 Yankee-MPC Support Disk 5 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.70	-33.40	3.50	36.80	89.00	1.42
48	6.80	-28.40	3.30	35.80	89.00	1.49
49	-16.50	-35.40	-1.00	35.40	89.00	1.51
50	-34.30	-33.30	-0.80	34.80	89.00	1.56
92	-1.40	-33.40	-0.80	33.40	89.00	1.66
47	-20.00	-33.20	-0.60	33.20	89.00	1.68
46	2.70	-21.50	-9.90	31.30	89.00	1.84
17	-30.90	-10.30	0.00	30.90	89.00	1.88
28	-30.50	-28.30	-0.90	30.80	89.00	1.89
29	-15.50	-30.60	-1.00	30.70	89.00	1.90
44	-29.80	-15.40	0.10	29.80	89.00	1.99
21	-29.70	-4.80	-0.40	29.70	89.00	2.00
30	5.30	-23.70	3.00	29.70	89.00	2.00
25	-28.70	0.40	-1.20	29.20	89.00	2.05
80	-1.40	-28.30	-0.90	28.40	89.00	2.14
32	-26.40	-23.70	-1.20	26.80	89.00	2.32
59	0.40	-10.10	-11.50	25.40	89.00	2.51
83	-1.40	-23.70	3.00	24.10	89.00	2.69
42	11.80	-10.30	4.00	23.60	89.00	2.77
40	-4.20	-11.50	-10.90	23.00	89.00	2.86
43	-12.90	-22.60	-0.40	22.60	89.00	2.94
19	15.10	-4.90	3.60	21.20	89.00	3.21
53	-20.10	-7.20	3.40	20.90	89.00	3.25
106	-20.10	-1.40	-0.50	20.10	89.00	3.43
39	-10.10	-18.70	-3.40	19.90	89.00	3.48
37	-15.60	-16.80	2.70	18.90	89.00	3.70
2	-18.10	-7.40	2.20	18.50	89.00	3.81
56	-16.50	-13.80	2.70	18.20	89.00	3.89
10	-17.90	0.00	-0.80	18.00	89.00	3.95
23	17.10	0.30	2.70	17.70	89.00	4.04
6	-17.20	-3.70	0.10	17.20	89.00	4.17
13	-2.70	12.70	3.30	16.80	89.00	4.28
26	-7.30	8.00	3.30	16.60	89.00	4.35
107	-16.50	-1.40	-0.90	16.60	89.00	4.38
27	-7.00	-0.40	7.60	16.50	89.00	4.40
18	-12.00	-16.30	-0.70	16.40	89.00	4.43
101	-15.50	-1.40	-1.00	15.60	89.00	4.70
20	-8.70	4.30	4.30	15.60	89.00	4.71
58	-1.30	-11.70	-5.70	15.40	89.00	4.76
91	-1.40	-15.40	0.10	15.40	89.00	4.78

Table 11.2.12.2.2-5 Yankee-MPC Support Disk 5 Primary Membrane + Bending Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-17.40	-108.00	6.70	108.50	127.10	0.17
45	-98.20	-28.10	3.00	98.30	127.10	0.29
5	-97.20	-33.90	4.80	97.50	127.10	0.30
48	-11.90	-96.70	2.70	96.80	127.10	0.31
20	-96.50	-25.40	3.00	96.70	127.10	0.32
42	-15.40	-95.20	0.60	95.20	127.10	0.33
53	-93.00	-27.40	7.90	93.90	127.10	0.35
24	-86.20	-18.00	2.70	86.30	127.10	0.47
30	-10.80	-82.70	2.50	82.80	127.10	0.54
9	-78.50	-20.00	2.80	78.60	127.10	0.62
51	-78.10	-29.90	4.70	78.60	127.10	0.62
19	-8.90	-78.20	-1.00	78.20	127.10	0.63
26	-77.40	-1.30	-0.30	77.50	127.10	0.64
4	-23.50	-74.80	1.60	74.80	127.10	0.70
56	-70.50	-23.20	9.30	72.20	127.10	0.76
13	-71.50	-5.70	0.00	71.50	127.10	0.78
37	-68.40	-29.90	9.50	70.60	127.10	0.80
2	-44.90	-66.50	7.90	69.10	127.10	0.84
31	-67.90	-24.90	4.00	68.30	127.10	0.86
62	-65.40	-17.60	2.30	65.50	127.10	0.94
92	-3.00	-62.50	-0.80	62.50	127.10	1.03
66	57.30	27.30	6.40	58.60	127.10	1.17
80	-2.90	-58.10	-1.00	58.10	127.10	1.19
33	-57.10	-15.50	4.00	57.50	127.10	1.21
44	-46.50	-48.30	9.30	56.70	127.10	1.24
47	-29.10	-51.70	9.60	55.20	127.10	1.30
17	-46.30	-42.90	9.30	54.10	127.10	1.35
12	30.60	51.50	7.30	53.80	127.10	1.36
54	-11.40	-42.90	-21.00	53.40	127.10	1.38
3	-52.60	-30.90	3.40	53.10	127.10	1.39
50	-41.30	-43.00	10.30	52.50	127.10	1.42
41	-50.50	-37.90	4.30	51.80	127.10	1.45
8	30.80	50.00	6.10	51.80	127.10	1.46
60	-48.60	-40.20	4.50	50.50	127.10	1.51
23	33.70	45.60	8.30	49.80	127.10	1.55
46	30.10	1.00	-19.00	47.90	127.10	1.65
67	27.80	44.90	6.70	47.20	127.10	1.69
91	-3.80	-46.70	0.10	46.70	127.10	1.72
49	-8.40	-43.80	9.70	46.20	127.10	1.75
63	28.20	44.50	5.60	46.20	127.10	1.75

Table 11.2.12.2.2-6 Yankee-MPC Support Disk 4 Primary Membrane Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.40	-32.50	3.40	35.60	89.00	1.50
49	-16.60	-34.90	-1.00	34.90	89.00	1.55
48	6.50	-27.50	3.30	34.60	89.00	1.57
50	-34.00	-32.50	-0.80	34.30	89.00	1.59
47	-19.90	-33.00	-0.60	33.00	89.00	1.70
92	-1.40	-32.50	-0.80	32.50	89.00	1.74
17	-30.80	-10.10	0.00	30.80	89.00	1.88
46	2.90	-21.20	-9.60	30.80	89.00	1.89
28	-30.20	-27.40	-1.00	30.60	89.00	1.91
29	-15.70	-30.20	-1.00	30.30	89.00	1.94
44	-29.70	-15.20	0.00	29.70	89.00	1.99
21	-29.60	-4.60	-0.40	29.60	89.00	2.01
25	-28.60	0.50	-1.30	29.20	89.00	2.05
30	5.00	-22.90	3.00	28.60	89.00	2.11
80	-1.40	-27.50	-0.90	27.50	89.00	2.23
32	-26.20	-22.80	-1.20	26.60	89.00	2.35
59	0.40	-10.10	-11.30	25.00	89.00	2.56
83	-1.40	-22.90	3.00	23.30	89.00	2.82
42	11.70	-10.20	3.90	23.20	89.00	2.83
43	-13.00	-22.60	-0.40	22.60	89.00	2.94
40	-4.10	-11.50	-10.60	22.50	89.00	2.96
19	14.80	-4.70	3.60	20.80	89.00	3.29
53	-19.90	-6.70	3.30	20.70	89.00	3.29
106	-19.90	-1.40	-0.60	19.90	89.00	3.47
39	-10.20	-18.80	-3.20	19.90	89.00	3.48
37	-15.80	-16.70	2.70	18.90	89.00	3.70
2	-18.20	-7.50	2.20	18.60	89.00	3.77
56	-16.70	-13.70	2.70	18.20	89.00	3.88
10	-18.10	-0.10	-0.80	18.10	89.00	3.92
6	-17.40	-3.80	0.10	17.40	89.00	4.13
23	16.90	0.40	2.70	17.30	89.00	4.14
26	-7.50	8.20	3.30	17.00	89.00	4.24
13	-2.90	12.70	3.30	17.00	89.00	4.24
107	-16.60	-1.40	-1.00	16.70	89.00	4.33
18	-12.20	-16.30	-0.80	16.40	89.00	4.42
27	-6.80	-0.30	7.40	16.10	89.00	4.51
20	-8.90	4.50	4.20	15.80	89.00	4.62
101	-15.70	-1.40	-1.00	15.80	89.00	4.64
58	-1.30	-11.80	-5.80	15.70	89.00	4.68
45	-9.40	3.60	4.20	15.40	89.00	4.77

Table 11.2.12.2.2-7 Yankee-MPC Support Disk 4 Primary Membrane + Bending Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-17.40	-106.10	6.70	106.60	127.10	0.19
45	-96.80	-27.20	2.90	96.90	127.10	0.31
5	-96.20	-33.40	4.70	96.60	127.10	0.32
20	-95.40	-24.70	2.90	95.50	127.10	0.33
48	-11.90	-95.10	2.70	95.20	127.10	0.34
42	-15.10	-93.80	0.60	93.80	127.10	0.36
53	-91.10	-26.50	7.70	92.00	127.10	0.38
24	-85.30	-17.50	2.60	85.40	127.10	0.49
30	-10.90	-81.50	2.50	81.60	127.10	0.56
9	-77.70	-19.60	2.80	77.90	127.10	0.63
51	-77.00	-28.80	4.50	77.40	127.10	0.64
19	-8.80	-77.10	-1.00	77.10	127.10	0.65
26	-76.80	-0.90	-0.40	76.80	127.10	0.66
4	-23.10	-73.90	1.60	73.90	127.10	0.72
56	-70.20	-23.00	9.30	71.90	127.10	0.77
13	-71.00	-5.40	0.00	71.00	127.10	0.79
37	-68.40	-29.80	9.50	70.60	127.10	0.80
2	-44.60	-65.20	7.90	67.90	127.10	0.87
31	-67.20	-23.90	3.80	67.50	127.10	0.88
62	-64.90	-17.30	2.30	65.00	127.10	0.96
92	-3.00	-61.30	-0.80	61.30	127.10	1.07
66	56.80	27.10	6.40	58.10	127.10	1.19
80	-2.90	-57.00	-1.00	57.10	127.10	1.23
33	-56.50	-14.80	3.90	56.90	127.10	1.23
44	-45.80	-46.40	9.20	55.40	127.10	1.30
47	-27.60	-50.70	9.50	54.10	127.10	1.35
12	30.20	51.10	7.20	53.30	127.10	1.38
17	-45.80	-41.40	9.20	53.10	127.10	1.39
3	-51.50	-30.60	3.40	52.00	127.10	1.44
8	30.40	49.30	6.10	51.00	127.10	1.49
50	-40.70	-41.10	10.10	51.00	127.10	1.49
54	-11.00	-40.70	-20.20	51.00	127.10	1.49
41	-49.10	-37.30	4.30	50.50	127.10	1.52
60	-47.60	-39.80	4.50	49.70	127.10	1.56
23	33.20	45.10	8.20	49.30	127.10	1.58
67	27.50	44.60	6.70	46.90	127.10	1.71
46	29.50	0.80	-18.50	46.90	127.10	1.71
91	-3.70	-46.10	0.00	46.10	127.10	1.75
63	27.90	44.00	5.50	45.70	127.10	1.78
49	-8.50	-43.00	9.50	45.50	127.10	1.79

Table 11.2.12.2.2-8 Yankee-MPC Support Disk 3 Primary Membrane Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.60	-31.20	3.40	34.50	89.00	1.58
49	-16.70	-34.20	-1.00	34.20	89.00	1.60
50	-33.70	-31.20	-0.90	34.00	89.00	1.62
48	6.30	-26.30	3.20	33.20	89.00	1.68
47	-19.00	-32.10	-0.70	32.10	89.00	1.77
92	-1.40	-31.20	-0.90	31.20	89.00	1.85
17	-30.80	-9.30	-0.10	30.80	89.00	1.89
28	-30.30	-26.20	-1.00	30.50	89.00	1.92
46	3.40	-20.40	-9.20	30.10	89.00	1.96
25	-28.50	1.20	-1.30	29.80	89.00	1.98
29	-16.20	-29.60	-1.00	29.70	89.00	1.99
21	-29.70	-3.90	-0.40	29.70	89.00	2.00
44	-29.40	-14.30	-0.10	29.40	89.00	2.03
30	4.70	-21.70	3.00	27.00	89.00	2.29
32	-26.20	-21.60	-1.20	26.50	89.00	2.36
80	-1.40	-26.20	-1.00	26.20	89.00	2.39
59	0.40	-10.40	-11.00	24.50	89.00	2.63
42	11.40	-9.40	3.90	22.20	89.00	3.01
43	-13.10	-22.10	-0.50	22.10	89.00	3.02
83	-1.40	-21.60	3.00	22.10	89.00	3.03
40	-4.00	-11.30	-10.10	21.60	89.00	3.12
53	-19.10	-6.30	3.30	19.90	89.00	3.48
39	-10.30	-18.90	-2.90	19.80	89.00	3.50
19	14.30	-3.90	3.50	19.60	89.00	3.55
106	-19.00	-1.40	-0.60	19.10	89.00	3.67
37	-16.20	-16.40	2.60	18.90	89.00	3.70
2	-18.60	-7.60	2.10	18.90	89.00	3.70
10	-18.20	-0.10	-0.80	18.20	89.00	3.88
56	-16.80	-13.40	2.60	18.20	89.00	3.89
26	-7.70	8.80	3.30	17.70	89.00	4.02
6	-17.70	-3.80	0.00	17.70	89.00	4.04
13	-3.10	12.70	3.30	17.10	89.00	4.20
23	16.40	1.20	2.70	16.90	89.00	4.26
107	-16.70	-1.40	-1.00	16.80	89.00	4.30
20	-9.30	5.20	4.10	16.70	89.00	4.32
101	-16.20	-1.40	-1.00	16.30	89.00	4.47
18	-12.70	-16.00	-0.80	16.20	89.00	4.49
45	-9.40	4.20	4.10	15.90	89.00	4.58
58	-1.40	-12.20	-5.90	15.90	89.00	4.61
27	-6.30	-0.30	7.10	15.50	89.00	4.75

Table 11.2.12.2.2-9 Yankee-MPC Support Disk 3 Primary Membrane + Bending Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-16.70	-102.80	6.50	103.30	127.10	0.23
5	-94.90	-32.50	4.70	95.30	127.10	0.33
45	-94.40	-25.50	2.60	94.50	127.10	0.34
20	-93.90	-23.20	2.60	94.00	127.10	0.35
48	-11.50	-92.30	2.60	92.40	127.10	0.38
42	-14.50	-90.90	0.60	90.90	127.10	0.40
53	-88.30	-25.60	7.50	89.20	127.10	0.42
24	-84.50	-16.40	2.40	84.60	127.10	0.50
30	-11.00	-79.70	2.50	79.80	127.10	0.59
9	-77.00	-19.10	2.70	77.10	127.10	0.65
26	-76.00	-0.10	-0.50	76.00	127.10	0.67
51	-75.40	-27.10	4.30	75.80	127.10	0.68
19	-8.70	-75.10	-1.00	75.10	127.10	0.69
4	-22.70	-72.60	1.60	72.60	127.10	0.75
56	-68.60	-22.40	9.10	70.30	127.10	0.81
13	-70.30	-5.20	0.00	70.30	127.10	0.81
37	-67.80	-29.20	9.40	70.00	127.10	0.82
31	-66.50	-22.40	3.60	66.80	127.10	0.90
2	-44.10	-63.00	7.90	65.90	127.10	0.93
62	-64.70	-17.20	2.40	64.80	127.10	0.96
92	-2.90	-59.60	-0.90	59.60	127.10	1.13
66	56.30	26.80	6.30	57.60	127.10	1.21
33	-56.20	-13.70	3.70	56.50	127.10	1.25
80	-2.80	-55.30	-1.00	55.30	127.10	1.30
44	-44.60	-43.10	9.00	52.90	127.10	1.40
12	29.70	50.40	7.20	52.70	127.10	1.41
47	-25.20	-48.80	9.10	51.90	127.10	1.45
17	-45.00	-38.40	9.10	51.40	127.10	1.47
3	-50.00	-30.10	3.40	50.60	127.10	1.51
8	29.70	48.50	6.00	50.30	127.10	1.53
23	32.50	45.40	8.10	49.30	127.10	1.58
54	-10.70	-38.90	-19.50	48.90	127.10	1.60
50	-39.80	-37.80	9.90	48.70	127.10	1.61
60	-46.20	-39.50	4.60	48.50	127.10	1.62
41	-46.70	-36.10	4.20	48.20	127.10	1.64
67	27.30	43.90	6.70	46.20	127.10	1.75
46	28.80	1.00	-17.80	45.20	127.10	1.81
63	-10.90	-45.10	-0.10	45.10	127.10	1.82
25	-37.10	5.60	7.10	45.00	127.10	1.83
91	-3.60	-44.70	-0.10	44.70	127.10	1.84

Table 11.2.12.2.2-10 Yankee-MPC Support Disk 2 Primary Membrane Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	3.90	-30.40	3.30	35.00	89.00	1.54
50	-34.00	-30.40	-1.00	34.20	89.00	1.60
49	-16.60	-33.70	-1.10	33.80	89.00	1.64
48	6.90	-25.40	3.20	32.90	89.00	1.70
28	-31.00	-25.30	-1.10	31.20	89.00	1.85
25	-28.20	2.60	-1.30	30.80	89.00	1.89
17	-30.80	-7.90	-0.10	30.80	89.00	1.89
47	-17.50	-30.40	-0.70	30.40	89.00	1.92
92	-1.40	-30.40	-0.90	30.40	89.00	1.93
21	-29.90	-2.50	-0.50	29.90	89.00	1.97
29	-16.90	-29.40	-1.10	29.50	89.00	2.02
46	4.10	-19.00	-9.00	29.30	89.00	2.04
44	-28.70	-12.90	-0.10	28.70	89.00	2.10
32	-26.80	-20.60	-1.30	27.10	89.00	2.29
30	4.70	-20.70	3.00	26.00	89.00	2.42
80	-1.40	-25.30	-1.00	25.40	89.00	2.51
59	0.30	-10.80	-10.80	24.20	89.00	2.67
43	-13.00	-21.20	-0.50	21.20	89.00	3.19
83	-1.40	-20.70	3.00	21.10	89.00	3.22
40	-3.80	-11.10	-9.70	20.70	89.00	3.30
42	11.20	-8.00	3.80	20.60	89.00	3.31
39	-10.30	-18.80	-2.60	19.50	89.00	3.55
2	-18.90	-7.50	2.00	19.30	89.00	3.61
37	-16.90	-15.80	2.60	19.00	89.00	3.69
53	-17.60	-6.50	3.30	18.40	89.00	3.82
20	-10.00	6.40	4.10	18.30	89.00	3.87
26	-7.60	9.40	3.20	18.20	89.00	3.89
6	-18.10	-3.70	0.00	18.10	89.00	3.91
10	-18.10	-0.10	-0.80	18.10	89.00	3.92
56	-16.70	-13.10	2.50	18.00	89.00	3.95
19	13.70	-2.60	3.50	17.70	89.00	4.02
106	-17.50	-1.40	-0.60	17.50	89.00	4.07
101	-16.90	-1.40	-1.10	17.00	89.00	4.24
13	-3.10	12.50	3.20	16.90	89.00	4.27
24	-8.80	6.40	3.60	16.80	89.00	4.29
107	-16.70	-1.40	-1.10	16.80	89.00	4.31
45	-9.40	5.20	4.00	16.70	89.00	4.34
23	15.80	2.50	2.70	16.40	89.00	4.44
58	-1.50	-12.40	-5.80	16.00	89.00	4.57
18	-13.30	-15.50	-0.80	15.80	89.00	4.65

Table 11.2.12.2.2-11 Yankee-MPC Support Disk 2 Primary Membrane + Bending Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-15.00	-99.40	5.90	99.80	127.10	0.27
5	-93.90	-31.50	4.50	94.20	127.10	0.35
20	-92.80	-21.50	2.30	92.90	127.10	0.37
45	-91.90	-23.60	2.30	92.00	127.10	0.38
48	-10.30	-89.60	2.30	89.60	127.10	0.42
42	-14.10	-87.80	0.50	87.80	127.10	0.45
53	-86.80	-25.50	7.40	87.70	127.10	0.45
24	-84.80	-15.10	2.20	84.80	127.10	0.50
30	-10.70	-78.00	2.40	78.10	127.10	0.63
9	-76.90	-18.50	2.60	77.00	127.10	0.65
26	-75.40	0.50	-0.70	76.00	127.10	0.67
51	-74.60	-25.80	4.10	74.90	127.10	0.70
19	-9.00	-73.20	-0.90	73.20	127.10	0.74
4	-22.50	-71.60	1.60	71.60	127.10	0.77
13	-69.60	-5.20	0.00	69.60	127.10	0.83
37	-66.20	-28.00	9.30	68.30	127.10	0.86
31	-66.90	-21.10	3.40	67.10	127.10	0.89
56	-65.20	-21.60	8.90	66.90	127.10	0.90
62	-65.50	-17.30	2.40	65.70	127.10	0.94
2	-43.60	-60.60	7.90	63.80	127.10	0.99
92	-2.80	-58.30	-1.00	58.30	127.10	1.18
66	56.40	26.20	6.20	57.60	127.10	1.21
33	-57.30	-12.70	3.50	57.50	127.10	1.21
80	-2.70	-53.90	-1.10	53.90	127.10	1.36
12	29.40	49.60	7.10	51.90	127.10	1.45
23	31.90	47.30	8.10	50.80	127.10	1.50
44	-43.20	-39.70	8.60	50.30	127.10	1.53
8	28.90	48.70	5.80	50.20	127.10	1.53
54	-11.00	-39.80	-19.90	50.00	127.10	1.54
17	-44.40	-35.20	8.90	49.80	127.10	1.55
3	-49.10	-29.80	3.50	49.70	127.10	1.56
47	-23.80	-46.80	8.60	49.60	127.10	1.56
60	-45.10	-39.50	4.80	47.80	127.10	1.66
50	-39.30	-34.70	9.80	47.10	127.10	1.70
41	-44.40	-34.80	4.10	45.90	127.10	1.77
63	-11.10	-45.70	0.00	45.70	127.10	1.78
67	27.20	42.80	6.60	45.20	127.10	1.81
25	-36.70	6.20	6.90	45.00	127.10	1.82
46	28.80	1.80	-17.30	43.90	127.10	1.90
91	-3.60	-42.90	-0.10	42.90	127.10	1.97

Table 11.2.12.2.2-12 Yankee-MPC Support Disk 1 Primary Membrane Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	6.20	-29.30	3.10	36.00	89.00	1.47
50	-34.90	-29.20	-1.10	35.10	89.00	1.54
49	-16.80	-33.20	-1.30	33.30	89.00	1.67
48	7.90	-24.00	3.10	32.50	89.00	1.74
28	-32.20	-23.90	-1.20	32.40	89.00	1.75
25	-27.00	4.10	-1.20	31.30	89.00	1.85
17	-30.20	-6.10	-0.20	30.20	89.00	1.94
21	-29.90	-0.90	-0.50	29.90	89.00	1.98
92	-1.40	-29.20	-1.10	29.30	89.00	2.04
29	-17.80	-28.90	-1.20	29.00	89.00	2.06
32	-28.20	-19.10	-1.30	28.40	89.00	2.14
46	4.60	-17.00	-8.60	27.70	89.00	2.22
47	-15.30	-27.60	-0.60	27.60	89.00	2.22
44	-27.50	-10.90	-0.30	27.50	89.00	2.24
30	4.90	-19.20	2.90	24.90	89.00	2.58
80	-1.40	-24.00	-1.10	24.00	89.00	2.70
59	0.20	-11.30	-10.20	23.50	89.00	2.79
20	-10.80	7.90	4.00	20.30	89.00	3.38
43	-13.10	-20.20	-0.60	20.20	89.00	3.39
2	-19.60	-7.60	1.80	19.90	89.00	3.47
83	-1.40	-19.20	2.90	19.60	89.00	3.53
24	-10.00	8.20	3.50	19.50	89.00	3.55
37	-17.90	-15.00	2.40	19.30	89.00	3.61
40	-3.50	-10.90	-8.80	19.00	89.00	3.67
6	-18.90	-3.80	-0.10	18.90	89.00	3.71
39	-10.10	-18.40	-1.90	18.80	89.00	3.73
26	-7.20	9.80	3.20	18.10	89.00	3.90
42	10.20	-6.20	3.70	17.90	89.00	3.96
101	-17.90	-1.40	-1.20	17.90	89.00	3.96
45	-9.50	6.70	3.80	17.90	89.00	3.96
10	-17.90	-0.10	-0.80	17.90	89.00	3.97
56	-16.90	-12.10	2.30	17.80	89.00	3.99
107	-16.90	-1.40	-1.30	17.00	89.00	4.25
53	-15.40	-7.30	3.30	16.60	89.00	4.37
13	-2.80	11.90	3.20	16.00	89.00	4.56
58	-1.80	-12.70	-5.70	15.80	89.00	4.62
106	-15.40	-1.40	-0.60	15.40	89.00	4.78
18	-14.20	-14.80	-0.80	15.40	89.00	4.78
61	-15.10	-5.70	-0.10	15.10	89.00	4.88
23	14.30	4.10	2.70	15.00	89.00	4.92

Table 11.2.12.2.2-13 Support Disk 1 Primary Membrane + Bending Stresses for Tip-Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-12.20	-93.10	5.00	93.50	127.10	0.36
5	-91.60	-29.80	4.40	91.90	127.10	0.38
20	-89.80	-18.70	1.90	89.90	127.10	0.41
45	-86.80	-20.30	1.80	86.90	127.10	0.46
53	-85.40	-25.80	7.60	86.40	127.10	0.47
48	-8.30	-85.50	1.90	85.50	127.10	0.49
24	-84.10	-12.90	1.70	84.20	127.10	0.51
42	-13.90	-83.00	0.60	83.00	127.10	0.53
9	-76.40	-17.30	2.50	76.50	127.10	0.66
30	-9.80	-75.20	2.10	75.20	127.10	0.69
51	-73.80	-23.50	3.70	74.00	127.10	0.72
26	-72.80	0.90	-0.70	73.80	127.10	0.72
19	-9.70	-70.00	-0.70	70.00	127.10	0.81
4	-21.80	-69.20	1.70	69.30	127.10	0.83
31	-67.50	-19.20	3.10	67.70	127.10	0.88
13	-67.70	-5.30	0.10	67.70	127.10	0.88
62	-66.20	-17.10	2.50	66.30	127.10	0.92
37	-63.10	-26.20	9.10	65.30	127.10	0.95
56	-59.50	-19.70	8.40	61.20	127.10	1.08
2	-42.80	-56.40	8.00	60.10	127.10	1.12
33	-59.80	-10.90	3.10	60.00	127.10	1.12
66	56.10	25.00	5.90	57.20	127.10	1.22
92	-2.70	-56.30	-1.10	56.30	127.10	1.26
23	30.60	50.10	7.90	52.90	127.10	1.40
54	-11.40	-42.00	-20.90	52.60	127.10	1.42
80	-2.60	-51.70	-1.20	51.70	127.10	1.46
8	27.70	48.50	5.60	49.90	127.10	1.55
12	28.80	47.20	7.10	49.60	127.10	1.56
3	-46.50	-28.90	3.60	47.20	127.10	1.69
17	-42.90	-30.10	8.50	47.10	127.10	1.70
63	-11.20	-46.50	0.10	46.50	127.10	1.74
60	-42.50	-39.00	5.00	46.00	127.10	1.76
47	-22.30	-43.40	7.80	46.00	127.10	1.77
44	-40.60	-33.70	8.00	45.90	127.10	1.77
50	-38.90	-29.10	9.80	45.00	127.10	1.83
25	-35.40	6.00	6.40	43.40	127.10	1.93
67	27.10	40.50	6.70	43.20	127.10	1.94
49	-32.40	-28.40	-11.50	42.10	127.10	2.02
21	-39.40	-16.60	7.90	41.90	127.10	2.03
41	-39.80	-32.60	4.00	41.60	127.10	2.06

Table 11.2.12.2.2-14 Buckling Evaluation Summary for Disk 5

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	12.53	35.92	32.00	3.50	6.00	5.75	0.10	0.13
48	10.65	35.92	32.00	3.20	6.00	5.75	0.24	0.27
53	8.15	39.79	34.56	3.99	7.00	6.77	0.37	0.39
45	4.04	43.95	37.31	5.67	8.16	7.95	0.41	0.43
42	4.19	39.75	34.53	4.64	6.99	6.76	0.42	0.46
20	3.82	43.95	37.31	5.60	8.16	7.95	0.44	0.46
5	3.11	44.00	37.34	5.75	8.17	7.96	0.44	0.47
30	8.90	35.87	31.97	2.76	5.99	5.74	0.47	0.50
24	3.00	39.79	34.56	4.31	7.00	6.77	0.60	0.64
92	12.52	35.92	32.00	1.37	6.00	5.75	0.76	0.71
51	5.65	43.95	37.31	4.16	8.16	7.95	0.71	0.71
26	2.74	35.92	32.00	3.29	6.00	5.75	0.75	0.82
9	1.75	39.75	34.53	4.05	6.99	6.76	0.79	0.85
19	1.97	39.79	34.56	4.01	7.00	6.77	0.79	0.84
56	7.23	43.95	37.31	3.44	8.16	7.95	0.84	0.81
37	6.82	43.95	37.31	3.37	8.16	7.95	0.90	0.88
80	10.62	35.87	31.97	1.39	5.99	5.74	0.93	0.89
4	1.64	44.00	37.34	4.54	8.17	7.96	0.91	0.94
31	5.29	43.95	37.31	3.56	8.16	7.95	0.96	0.96
13	1.03	35.92	32.00	3.22	6.00	5.75	0.97	1.05
2	3.24	44.00	37.34	3.77	8.17	7.96	1.08	1.09
50	12.49	35.87	31.97	0.45	5.99	5.74	1.37	1.20
62	0.54	39.79	34.56	3.50	7.00	6.77	1.20	1.27
33	4.28	39.79	34.56	2.55	7.00	6.77	1.30	1.31
46	8.71	39.79	34.56	1.23	7.00	6.77	1.63	1.49
44	6.22	39.79	34.56	1.80	7.00	6.77	1.56	1.51
3	3.79	44.00	37.34	2.81	8.17	7.96	1.56	1.55
91	6.23	39.75	34.53	1.71	6.99	6.76	1.63	1.58
106	8.13	39.79	34.56	1.23	7.00	6.77	1.73	1.60
41	4.02	44.00	37.34	2.64	8.17	7.96	1.65	1.62
28	10.62	35.92	32.00	0.32	6.00	5.75	1.88	1.65
83	8.89	35.92	32.00	0.67	6.00	5.75	1.84	1.69
60	3.08	44.00	37.34	2.65	8.17	7.96	1.80	1.80
8	0.03	44.00	37.34	3.20	8.17	7.96	1.93	2.01
17	4.16	39.75	34.53	1.78	6.99	6.76	1.99	1.97
79	4.17	39.79	34.56	1.76	7.00	6.77	2.02	2.00
63	0.23	44.00	37.34	2.88	8.17	7.96	2.20	2.28
47	8.11	39.75	34.53	0.50	6.99	6.76	2.71	2.39
32	8.88	35.92	32.00	0.09	6.00	5.75	2.83	2.45
105	5.64	43.95	37.31	1.32	8.16	7.95	2.67	2.47

Table 11.2.12.2.2-15 Buckling Evaluation Summary for Disk 4

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	12.20	35.92	32.00	3.45	6.00	5.75	0.12	0.15
48	10.33	35.92	32.00	3.17	6.00	5.75	0.26	0.30
53	8.08	39.79	34.56	3.90	7.00	6.77	0.40	0.42
45	4.10	43.95	37.31	5.58	8.16	7.95	0.43	0.45
42	4.12	39.75	34.53	4.56	6.99	6.76	0.45	0.49
20	3.89	43.95	37.31	5.51	8.16	7.95	0.45	0.48
5	3.17	44.00	37.34	5.68	8.17	7.96	0.46	0.48
30	8.59	35.87	31.97	2.74	5.99	5.74	0.49	0.52
24	3.06	39.79	34.56	4.25	7.00	6.77	0.61	0.66
51	5.71	43.95	37.31	4.07	8.16	7.95	0.73	0.73
92	12.18	35.92	32.00	1.35	6.00	5.75	0.80	0.75
26	2.80	35.92	32.00	3.25	6.00	5.75	0.76	0.83
9	1.80	39.75	34.53	4.00	6.99	6.76	0.81	0.86
19	1.91	39.79	34.56	3.96	7.00	6.77	0.82	0.87
56	7.29	43.95	37.31	3.41	8.16	7.95	0.84	0.82
37	6.89	43.95	37.31	3.35	8.16	7.95	0.90	0.88
4	1.68	44.00	37.34	4.47	8.17	7.96	0.93	0.97
80	10.30	35.87	31.97	1.38	5.99	5.74	0.97	0.93
31	5.37	43.95	37.31	3.50	8.16	7.95	0.98	0.97
13	1.09	35.92	32.00	3.19	6.00	5.75	0.98	1.06
2	3.29	44.00	37.34	3.68	8.17	7.96	1.11	1.13
62	0.59	39.79	34.56	3.47	7.00	6.77	1.21	1.29
50	12.16	35.87	31.97	0.40	5.99	5.74	1.47	1.29
33	4.34	39.79	34.56	2.51	7.00	6.77	1.32	1.33
46	8.60	39.79	34.56	1.20	7.00	6.77	1.67	1.53
3	3.86	44.00	37.34	2.72	8.17	7.96	1.61	1.59
44	6.15	39.79	34.56	1.71	7.00	6.77	1.66	1.60
91	6.16	39.75	34.53	1.69	6.99	6.76	1.67	1.61
106	8.06	39.79	34.56	1.22	7.00	6.77	1.76	1.63
41	4.07	44.00	37.34	2.54	8.17	7.96	1.71	1.68
83	8.59	35.92	32.00	0.67	6.00	5.75	1.91	1.75
28	10.30	35.92	32.00	0.29	6.00	5.75	2.01	1.76
60	3.14	44.00	37.34	2.58	8.17	7.96	1.85	1.84
8	0.07	44.00	37.34	3.16	8.17	7.96	1.95	2.04
79	4.11	39.79	34.56	1.74	7.00	6.77	2.06	2.03
17	4.09	39.75	34.53	1.71	6.99	6.76	2.10	2.07
63	0.28	44.00	37.34	2.85	8.17	7.96	2.22	2.30
105	5.69	43.95	37.31	1.31	8.16	7.95	2.66	2.46
47	8.04	39.75	34.53	0.42	6.99	6.76	2.88	2.52
32	8.57	35.92	32.00	0.10	6.00	5.75	2.93	2.55

Table 11.2.12.2.2-16 Buckling Evaluation Summary for Disk 3

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	11.72	35.92	32.00	3.36	6.00	5.75	0.16	0.19
48	9.85	35.92	32.00	3.10	6.00	5.75	0.31	0.34
53	7.73	39.79	34.56	3.79	7.00	6.77	0.45	0.47
45	4.13	43.95	37.31	5.42	8.16	7.95	0.46	0.48
5	3.34	44.00	37.34	5.57	8.17	7.96	0.47	0.50
20	4.08	43.95	37.31	5.39	8.16	7.95	0.47	0.49
42	3.80	39.75	34.53	4.45	6.99	6.76	0.50	0.54
30	8.11	35.87	31.97	2.72	5.99	5.74	0.54	0.57
24	3.25	39.79	34.56	4.18	7.00	6.77	0.62	0.67
51	5.75	43.95	37.31	3.97	8.16	7.95	0.77	0.77
26	2.88	35.92	32.00	3.21	6.00	5.75	0.78	0.84
92	11.70	35.92	32.00	1.33	6.00	5.75	0.86	0.81
9	1.98	39.75	34.53	3.94	6.99	6.76	0.82	0.87
56	7.33	43.95	37.31	3.30	8.16	7.95	0.88	0.85
19	1.60	39.79	34.56	3.89	7.00	6.77	0.88	0.93
37	7.10	43.95	37.31	3.28	8.16	7.95	0.91	0.88
4	1.71	44.00	37.34	4.39	8.17	7.96	0.96	1.00
31	5.56	43.95	37.31	3.43	8.16	7.95	0.99	0.98
13	1.17	35.92	32.00	3.15	6.00	5.75	0.99	1.08
80	9.82	35.87	31.97	1.36	5.99	5.74	1.04	1.00
2	3.32	44.00	37.34	3.54	8.17	7.96	1.18	1.19
62	0.76	39.79	34.56	3.44	7.00	6.77	1.21	1.28
33	4.54	39.79	34.56	2.46	7.00	6.77	1.32	1.33
50	11.68	35.87	31.97	0.31	5.99	5.74	1.67	1.44
46	8.25	39.79	34.56	1.17	7.00	6.77	1.77	1.63
3	4.05	44.00	37.34	2.60	8.17	7.96	1.67	1.64
91	5.82	39.75	34.53	1.66	6.99	6.76	1.77	1.71
106	7.71	39.79	34.56	1.20	7.00	6.77	1.85	1.71
44	5.81	39.79	34.56	1.57	7.00	6.77	1.86	1.79
41	4.10	44.00	37.34	2.38	8.17	7.96	1.84	1.80
83	8.11	35.92	32.00	0.68	6.00	5.75	2.01	1.86
60	3.31	44.00	37.34	2.47	8.17	7.96	1.92	1.90
28	9.82	35.92	32.00	0.21	6.00	5.75	2.26	1.97
8	0.10	44.00	37.34	3.11	8.17	7.96	1.99	2.07
79	3.78	39.79	34.56	1.71	7.00	6.77	2.18	2.16
63	0.43	44.00	37.34	2.82	8.17	7.96	2.22	2.29
17	3.77	39.75	34.53	1.59	6.99	6.76	2.35	2.31
105	5.73	43.95	37.31	1.29	8.16	7.95	2.68	2.47
107	7.32	44.00	37.34	0.82	8.17	7.96	2.90	2.56
93	3.33	44.00	37.34	1.85	8.17	7.96	2.63	2.56

Table 11.2.12.2.2-17 Buckling Evaluation Summary for Disk 2

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	11.41	35.92	32.00	3.24	6.00	5.75	0.20	0.23
48	9.51	35.92	32.00	3.01	6.00	5.75	0.35	0.38
5	3.61	44.00	37.34	5.47	8.17	7.96	0.48	0.51
20	4.36	43.95	37.31	5.28	8.16	7.95	0.48	0.50
53	7.11	39.79	34.56	3.79	7.00	6.77	0.49	0.50
45	4.09	43.95	37.31	5.26	8.16	7.95	0.50	0.52
42	3.24	39.75	34.53	4.36	6.99	6.76	0.56	0.61
30	7.75	35.87	31.97	2.69	5.99	5.74	0.57	0.61
24	3.57	39.79	34.56	4.16	7.00	6.77	0.61	0.65
51	5.72	43.95	37.31	3.92	8.16	7.95	0.79	0.78
26	2.84	35.92	32.00	3.18	6.00	5.75	0.79	0.86
9	2.28	39.75	34.53	3.89	6.99	6.76	0.81	0.86
92	11.39	35.92	32.00	1.31	6.00	5.75	0.90	0.85
37	7.41	43.95	37.31	3.14	8.16	7.95	0.94	0.91
56	7.31	43.95	37.31	3.09	8.16	7.95	0.97	0.93
19	1.06	39.79	34.56	3.86	7.00	6.77	0.94	1.01
31	5.86	43.95	37.31	3.41	8.16	7.95	0.97	0.96
4	1.67	44.00	37.34	4.33	8.17	7.96	0.99	1.03
13	1.15	35.92	32.00	3.12	6.00	5.75	1.01	1.10
80	9.48	35.87	31.97	1.34	5.99	5.74	1.10	1.06
62	1.05	39.79	34.56	3.44	7.00	6.77	1.17	1.24
2	3.28	44.00	37.34	3.39	8.17	7.96	1.26	1.27
33	4.88	39.79	34.56	2.47	7.00	6.77	1.26	1.27
50	11.37	35.87	31.97	0.20	5.99	5.74	1.86	1.60
3	4.33	44.00	37.34	2.51	8.17	7.96	1.70	1.66
46	7.71	39.79	34.56	1.14	7.00	6.77	1.92	1.77
106	7.09	39.79	34.56	1.21	7.00	6.77	1.98	1.85
91	5.24	39.75	34.53	1.63	6.99	6.76	1.91	1.86
41	4.06	44.00	37.34	2.24	8.17	7.96	1.98	1.93
60	3.57	44.00	37.34	2.36	8.17	7.96	1.97	1.94
83	7.75	35.92	32.00	0.68	6.00	5.75	2.11	1.96
8	0.06	44.00	37.34	3.12	8.17	7.96	1.99	2.08
44	5.23	39.79	34.56	1.46	7.00	6.77	2.12	2.04
63	0.67	44.00	37.34	2.82	8.17	7.96	2.15	2.22
28	9.48	35.92	32.00	0.11	6.00	5.75	2.55	2.20
79	3.22	39.79	34.56	1.68	7.00	6.77	2.38	2.37
101	7.40	44.00	37.34	0.84	8.17	7.96	2.83	2.50
105	5.70	43.95	37.31	1.28	8.16	7.95	2.70	2.50
93	3.59	44.00	37.34	1.82	8.17	7.96	2.59	2.51
107	7.30	44.00	37.34	0.81	8.17	7.96	2.92	2.58

Table 11.2.12.2.2-18 Buckling Evaluation Summary for Disk 1

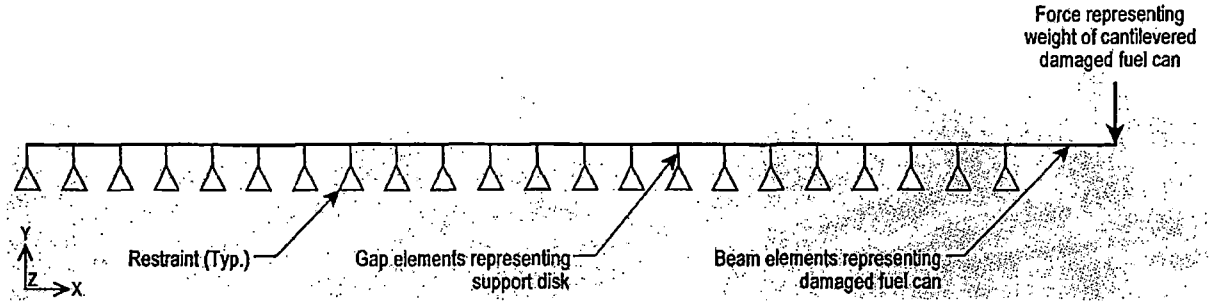
Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	10.98	35.92	32.00	3.00	6.00	5.75	0.28	0.31
48	9.01	35.92	32.00	2.88	6.00	5.75	0.42	0.45
5	3.96	44.00	37.34	5.27	8.17	7.96	0.51	0.53
20	4.74	43.95	37.31	5.04	8.16	7.95	0.52	0.54
53	6.24	39.79	34.56	3.83	7.00	6.77	0.53	0.55
45	4.14	43.95	37.31	4.93	8.16	7.95	0.59	0.60
24	4.07	39.79	34.56	4.05	7.00	6.77	0.61	0.64
30	7.20	35.87	31.97	2.62	5.99	5.74	0.64	0.68
42	2.51	39.75	34.53	4.20	6.99	6.76	0.67	0.72
51	5.78	43.95	37.31	3.86	8.16	7.95	0.80	0.80
9	2.74	39.75	34.53	3.80	6.99	6.76	0.80	0.85
26	2.70	35.92	32.00	3.08	6.00	5.75	0.86	0.93
92	10.96	35.92	32.00	1.27	6.00	5.75	0.97	0.92
31	6.26	43.95	37.31	3.39	8.16	7.95	0.94	0.92
37	7.83	43.95	37.31	2.88	8.16	7.95	1.01	0.96
4	1.69	44.00	37.34	4.18	8.17	7.96	1.05	1.09
19	0.38	39.79	34.56	3.78	7.00	6.77	1.06	1.13
13	1.05	35.92	32.00	3.05	6.00	5.75	1.07	1.16
56	7.39	43.95	37.31	2.72	8.16	7.95	1.14	1.08
62	1.48	39.79	34.56	3.42	7.00	6.77	1.13	1.19
80	8.98	35.87	31.97	1.30	5.99	5.74	1.20	1.15
33	5.42	39.79	34.56	2.54	7.00	6.77	1.15	1.15
2	3.31	44.00	37.34	3.12	8.17	7.96	1.42	1.42
3	4.71	44.00	37.34	2.28	8.17	7.96	1.81	1.76
50	10.94	35.87	31.97	0.00	5.99	5.74	2.27	1.92
8	0.09	44.00	37.34	3.11	8.17	7.96	1.99	2.08
46	6.89	39.79	34.56	1.08	7.00	6.77	2.18	2.03
60	3.93	44.00	37.34	2.14	8.17	7.96	2.11	2.05
106	6.23	39.79	34.56	1.21	7.00	6.77	2.19	2.06
63	0.98	44.00	37.34	2.82	8.17	7.96	2.08	2.13
83	7.19	35.92	32.00	0.69	6.00	5.75	2.25	2.10
91	4.44	39.75	34.53	1.59	6.99	6.76	2.16	2.11
41	4.11	44.00	37.34	1.94	8.17	7.96	2.29	2.21
49	7.36	44.00	37.34	0.99	8.17	7.96	2.61	2.33
101	7.82	44.00	37.34	0.82	8.17	7.96	2.72	2.39
29	7.80	44.00	37.34	0.81	8.17	7.96	2.75	2.41
93	3.94	44.00	37.34	1.76	8.17	7.96	2.56	2.47
105	5.76	43.95	37.31	1.27	8.16	7.95	2.70	2.49
28	8.98	35.92	32.00	0.03	6.00	5.75	2.93	2.51
44	4.43	39.79	34.56	1.24	7.00	6.77	2.69	2.59

11.2.12.3 Basket Impact Orientation Evaluation Analysis of Canister and Basket with Damaged Fuel Cans

This section presents the justification for considering the 45° basket impact orientation as the bounding case for the support disk evaluation for the concrete cask tip-over accident.To determine the effect of the damaged fuel cans on the canister and fuel basket, an analysis was performed that calculates the additional weight applied to a support disk corner fuel loading position from a damaged fuel can. The ANSYS program was used to determine the additional load applied to the basket support disk by the damaged fuel can using a beam model. The beam model shown in Figure 11.2.12.3-1 represents a single damaged fuel can supported by 22 basket support disks. The disks are modeled by gap elements. The stiffness of the gap elements was determined by using the support disk model (see Figure 11.2.12.2.2-9) in conjunction with a unit load in the direction of the 45° drop.

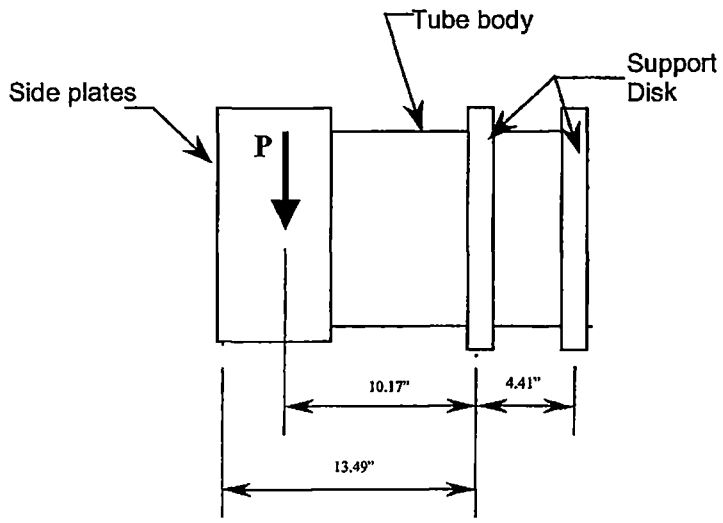
The results of the beam model show that the maximum load increase due to the damaged fuel can is 4.2 pounds per corner loading position. The total load increase to the support disk is 16.8 pounds. The resulting total load on each support disk includes the weight of the fuel (30,600 lb), fuel tubes, damaged fuel can, aluminum heat transfer disks, tie rods, and tie rod hardware. The evaluation of the support disk for thirty-six 950 lb fuel assemblies includes the weight of the fuel tubes, aluminum heat transfer disks, tie rods and tie rod hardware. This 950 lb fuel assembly configuration is conservatively used in the basket analysis for the tip-over conditions. Therefore, the evaluation of the damaged fuel can configuration is bounded by the evaluation for the 950 lb fuel assembly configuration.

Figure 11.2.12.3-1 ANSYS Beam Model of Damaged Fuel Can with Boundary Conditions



11.2.12.4 Basket Impact Orientation Evaluation Analysis of the Damaged Fuel Can Body

The damaged fuel can body is evaluated as a cantilevered beam with the combined weight (P) of the overhanging tube body and side plates conservatively concentrated at the top end of the side plates, multiplied by a deceleration factor of 60g. Note that the maximum g-load for the basket is 40g for the tip-over accident.



The maximum bending moment (M) is:

$$M = P \times g \times L = 13{,}678 \text{ lbs·in.}$$

where:

P = 21.815 lbs. (weight of the overhanging tube and side plates)

g = 60 (conservative g-load that bounds the tip-over condition)

L = 10.45 in. (the total overhanging length of the tube body and side plates)

The maximum bending stress, f_b, is:

$$f_b = \frac{M \times c}{I} = 3{,}202 \text{ psi}$$

where:

c = half of the outer dimension of the tube = 4.04 in.

I = the moment of inertia = 17.26 in^4.

The shear stress (τ) is:

$$\tau = \frac{Pg}{A} = 815 \text{ psi}$$

where:

A = the cross-sectional area of the tube = 1.606 in^2

The principal stresses are calculated to be 3,398 psi and -196 psi, and the corresponding maximum stress intensity (σ_{max}) is determined to be 3,594 psi.

The margin of safety (MS) is calculated based on the allowable primary membrane plus bending stress (1.0 S_u, S_u = 63.3 ksi) at a bounding temperature of 600°F for Type 304 stainless steel:

$$MS = \frac{1.0S_u}{\sigma_{max}} - 1 = +16.6$$

Therefore, the damaged fuel can maintains its integrity for the accident conditions.

Lid

During a bottom end impact, the top lid will be subjected to bending stresses caused by the weight of the top lid. The maximum bending stress (f_b) for the lid is calculated by conservatively assuming a one-inch-wide, simply supported beam that is 7.98-inches long and is 0.5-inch thick. The top lid assembly conservatively weighs 11.5 pounds.

Under a 60g load, the load on the plate is 11.5 lb × 60g = 690 pounds. The load to consider acting on the beam is w = ($690/7.98^2$) ≅ 10.86 psi.

$$M = \frac{wl^2}{8} = 86.3 \text{ in - lbs}$$

where l = 7.98 in.

$$f_b = \frac{Mc}{I} = 2{,}071 \text{ psi}$$

where I = 0.0104 in^4.

$c = 0.25$ in.

The Margin of Safety (MS) is:

$$MS = \frac{2.4S_m}{f_b} - 1 = +18.4$$

Weld Evaluation

The welds joining the tube body to the side plates are full-penetration welds. The weld quality factor (n) for a Type III weld with visual surface inspection is 0.5.

The Margin of Safety (MS) for the welds is:

$$MS = \frac{(1.0)n \cdot S_u}{\sigma_{max}} - 1 = +7.8$$

where S_u = 63.3 ksi

σ_{max} = 3,594 psi

n = 0.5

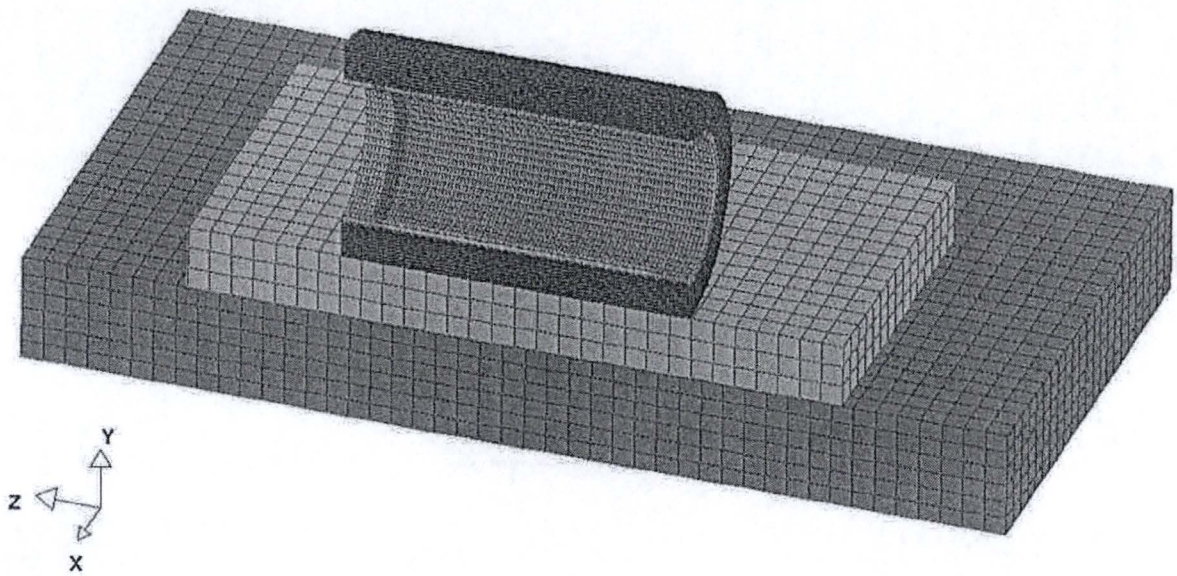
11.2.12.5 Analysis of the CY-MPC Tip Over Event

For a tip over event to occur, the center of gravity of the concrete cask and loaded canister must be displaced beyond the outer radius of the concrete cask, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the concrete cask and canister will be converted to kinetic energy as the concrete cask and canister rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, ISFSI pad, and underlying soil.

The objective of the evaluation of the response of the concrete cask during the tip over event is to determine the maximum acceleration to be used in the structural evaluation of the loaded canister and basket. The methodology to determine the concrete cask response follows the methodology contained in NUREG/CR-6608 ("Summary and Evaluation of Low-Velocity Impact Tests of Solid Steel Billet Onto Concrete Pads"). The LS-DYNA program is used in this evaluation.

11.2.12.5.1 Analysis of the CY-MPC Tip Over Event

The CY-MPC tip over event is evaluated using a finite element model. As shown below, the model includes a half section of the concrete cask, the concrete ISFSI pad and soil subgrade.



The concrete pad in the model corresponds to a pad 30-feet by 30-feet square and 3-feet thick, supporting one concrete cask in the center of the pad. The soil under the concrete pad is considered to be 45-feet by 45-feet square and 5-feet thick. Only one-half of the concrete cask, pad and soil configuration is modeled due to symmetry.

Material Properties

The concrete is represented as a homogeneous isotropic material. The concrete cask (outer shell) and the pad are modeled as material Type Number 16 in LS-DYNA. The required input data is:

Property	Concrete Cask	Concrete Pad	
Density, ρ (pcf)	147	140	160
Compressive Strength, f'_c (psi)	4,000	4,000	4,000
Poisson's Ratio, ν	0.22	0.22	0.22
Modulus of Elasticity, E (psi)	3.715E6	3.457E6	4.224E6
Bulk Modulus, K (psi)	2.211E6	2.058E6	2.514E6

where:

$$E = 33\rho^{1.5}\sqrt{f_c'}$$

and

$$K = \frac{E}{3(1-2v)}$$

The design density for the concrete cask is 140 pcf. To account for the weight of the steel components, 147 pcf is used in the model. The design density for the concrete pad is between 135 pcf and 150 pcf. To account for the weight rebar, 140 pcf and 160 pcf are used in the model (two cases).

The material properties used in the model for the soil below the ISFSI pad are:

Density	= 85 pcf and 130 pcf (two cases considered)
Poisson's Ratio (υ)	= 0.4
Modulus of Elasticity	= 30,000 psi

The concrete cask steel liner has the properties:

Density	= 0.284 lb/in^3
Poisson's ratio	= 0.31
Modulus of elasticity	= 2.9E7 psi

To account for the weight of the shield plug, the loaded canister, and the concrete cask pedestal, effective densities are used for the elements in the first row of the steel liner model adjacent to the impact plane of symmetry. These densities represent the regions (6° in the circumferential direction) of the steel liner subjected to the weight of the shield plug, the loaded canister and the pedestal, during the side impact (tip over) condition. The contact angle (6°) is determined based on the canister/basket analysis for the tip over condition (Section 11.2.12.5.2). Based on the status of the gap elements at the outer surface of the canister shell (representing the interface between the canister shell and the concrete cask steel liner) in the finite element model used in Section 11.2.12.5.2, the contact angle between the canister shell and the concrete cask liner is between 4.5° and 9° for the half-symmetry model.

Boundary Conditions and Initial Conditions

A friction coefficient of 0.25 is used at the interface between the steel liner and the concrete shell, between the concrete cask and the pad, and between the pad and the soil. For all the embedded faces (three side surfaces and the bottom surface) of the soil in the model, the displacements in the direction normal to the surface are restrained. The symmetry boundary conditions are applied for all nodes at the plane of symmetry.

The initial condition corresponds to the concrete cask in a horizontal position with an initial vertical velocity into the concrete pad. The pad and soil are initially at rest.

The initial velocity is simulated by applying an angular velocity (ω) of 1.55 radians/sec to the entire cask. The angular velocity value is computed by considering energy conservation at the cask "center of gravity over corner" tip condition versus the side impact condition.

From energy conservation:

$$mgh = \frac{I\omega^2}{2}$$

where:

mg = total weight of the loaded concrete cask = 251,771 lbs

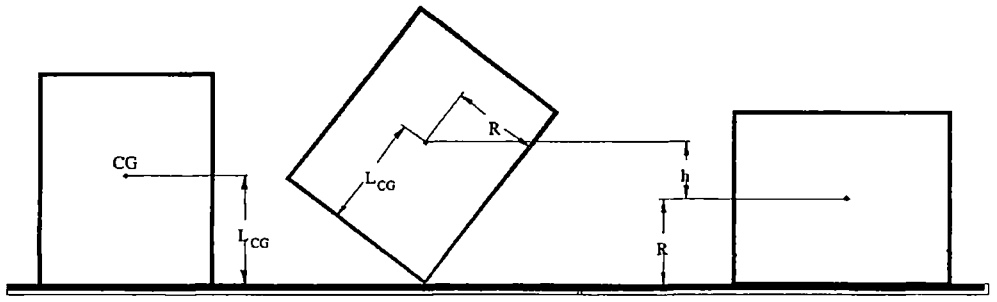
h = height change of the concrete cask center of gravity (L_{CG}) = $\sqrt{R^2 + \left(\frac{L_{CG}}{2}\right)^2} - R$

= 53.47 inches

where:

L_{CG} = location of the center of gravity above the pad for the concrete cask = 98.5 inches
R = radius of the concrete cask = 64.0 inches
I = total mass moment of inertia of the concrete cask about the pivot point

= 11,169,679 lb-sec^2-inch



Concrete Cask Tip Over Height Change

The mass moment of inertia for the concrete shell and the steel liner is calculated using the formula for a hollow right circular cylinder (Blevins).

$$I = \frac{m}{12}(3R_1^2 + 3R_2^2 + 4L^2) + md^2$$

where:

m	= mass
R_1 and R_2	= the outer and inner radius of the cylinder
L	= height of the cylinder
d	= distance between the center of gravity and the pivot point

For the mass of the shield plug, loaded canister and the pedestal, the formula for the moment of inertia for a solid cylinder is used:

$$I = \frac{m}{12}(3R^2 + L^2) + md^2$$

where:

m = mass of the cylinder
R = radius of the cylinder
L = height of the cylinder
d = distance between the two pivot axes

The angular velocity is given by $\omega = \sqrt{\frac{2mgh}{I}}$ = 1.55 radians/sec

Filter Frequency

The accelerations are evaluated at the inner surface of the cask liner, which physically corresponds to the interface of the liner and the loaded canister nearest the plane of impact. Following the methodology contained in NUREG/CR-6608, the Butterworth filter is applied to the nodal accelerations. The filter frequency is based on the fundamental mode of the cask.

The fundamental natural frequency of a beam in transverse vibration due to flexure only is given by Blevins as:

$$f = \frac{\lambda^2}{2\pi}\sqrt{\frac{EI}{\rho AL^4}}$$

where:

λ = 3.92660231 for a pin-free beam

The frequencies of the concrete (f_c) and the steel liner (f_s) are computed as:

Area of concrete cask = $\pi\ \{(64)^2 - (43)^2\} = 2{,}247\pi$ in^2
Density of concrete cask = 147 pcf
Modulus of elasticity of concrete cask = 3.715E6
Moment of inertia of concrete cask = $\frac{\pi}{4}\{(64)^4 - (43)^4\} = 3{,}339{,}603.75\pi$ in^4
Length of cask = 190.6 in

f_c = 338.4 Hz

Area of steel liner = $\pi\ \{(43)^2 - (39.5)^2\} = 288.75\pi$ in^2
Density of steel liner = 490 pcf
Modulus of elasticity of steel liner = 29.0E6
Moment of inertia of steel liner = $\frac{\pi}{4}\{(43)^4 - (39.5)^4\} = 246{,}105.23\pi$ in^4

$f_s = 25.41 \quad \lambda^2 = 391.78$ Hz

Since the concrete cask is short compared to its diameter, the contribution of the flexibility due to shear is also incorporated. This is accomplished by using Dunkerley's formula (Blevins). The system frequency is:

$$\frac{1}{f^2} = \frac{1}{f_c^2} + \frac{1}{f_s^2}$$

Thus, the system frequency is: f = 256.1 Hz. A cut-off frequency of 275.0 Hz is conservatively applied to filter the analysis results and measure the peak accelerations.

Results of the Transient Analysis

The accelerations at key locations of the concrete cask liner for the governing case are listed below. These accelerations are required in the evaluation of the loaded canister/basket for the tip-over event (Section 11.2.12.5.2).

Acceleration at Specific Locations at the Concrete Cask Liner

Location on Component	Position Measured from the bottom of the Concrete Cask (inches)	Acceleration (g)
Top support disk	155.5	25.3
Top of the canister structural lid	175.23	28.4

1.2.12.5.2 Analysis of the CY-MPC Canister and Basket Tip Over Event

Structural evaluations are performed for the transportable storage canister and fuel basket support disks for tip over accident conditions. An ANSYS finite element model is used to evaluate this side impact loading condition.

Comparison of maximum stress results to the allowable stress intensities shows that the canister and support disks are structurally adequate for the concrete cask tip over condition and satisfies the stress criteria in accordance with the ASME Code, Section III, Division I, Subsection NB and NG, respectively.

The structural response of the canister and fuel basket to the tip over condition is evaluated using an ANSYS three-dimensional finite element model consisting of the top portion of the canister, the top five fuel basket support disks, and the fuel basket top weldment disk. The structural analysis is performed for fuel basket drop orientations of 0°, 38°, 63°, and 90° in order to ensure that the maximum primary membrane (P_m) and primary membrane plus primary bending (P_m+P_b) stresses are evaluated.

CY-MPC Canister and Basket Model

A three-dimensional model of the canister and basket is evaluated for side loading conditions that conservatively simulate a tip-over event while inside the concrete cask. To ensure structural stability, a buckling evaluation is performed on the support disk in accordance with NUREG/CR-6322.

Model Description

The finite element model used to evaluate the CY-MPC canister and fuel basket for the tip over event is presented in Figures 11.2.12.5.2-1 through 11.2.12.5.2-3. As shown in Figure 11.2.12.5.2-1, the model consists of the upper portion of the canister, the top weldment and the five support disks. Only half of the canister is shown to present the view of the fuel basket. This full model is used in the evaluation for the 38° and 63° tip-over cases. Due to symmetry, a half symmetry model is used in the 0° and 90° cases, as shown in Figure 11.2.12.5.2-6. For the 0° orientation, the left half of the model of the weldment, support disks and canister is used for the solution. Similarly, the bottom half of the model is used for the 90° case. Symmetry boundary conditions are applied at the plane of symmetry.

The canister, shield lid, and structural lid are constructed using ANSYS solid (SOLID45) elements. ANSYS shell elements (SHELL63) are used to model the top weldment and the support disks. The canister and basket model use gap-spring elements to simulate contact between adjacent components. Interaction between the basket and canister is modeled using three-dimensional gap elements (CONTAC52) along the periphery of the support disks and inner radius of the canister. Contact between the canister and concrete cask shell is also modeled using CONTAC52 elements with a gap size based on nominal dimensions. A gap stiffness of 1×10^6 lb/in. is assigned to all CONTAC52 elements.

Contact between the canister's structural lid and shield lid is modeled using combination spring element (COMBIN40) elements in the axial (UY) degree-of-freedom. The backing ring is modeled using a ring of COMBIN40 spring gap elements connected to the shield lid and canister

with a gap size of 1×10^{-8} inch. The COMBIN40 elements between the structural and shield lids are assigned a gap size of 0.08 inch. The gap is determined from the structural and shield lids flatness tolerance of 0.03 inch per lid, which results in a total gap of 0.06 inch. An additional 25% is added to the gap to maximize bending stresses that may occur in the weld region due to internal pressurization. A gap stiffness of 1×10^{6} lb/in. is assigned to all COMBIN40 elements.

Restraints are applied to all gap elements between the canister and concrete cask inner liner. Nodes representing the concrete cask inner liner are fixed in all degrees of freedom (UX, UY, UX, ROTX, ROTY, ROTZ). For the basket nodes, axial (UY) and in-plane rotational degrees of freedom (ROTX and ROTZ) are fixed. The bottom of the canister shell is restrained in the axial direction (UY). The global coordinate system for the model is shown in Figures 11.2.12.5.2-1 and 11.2.12.5.2-4 and is used in the post-processing of the canister results. It should be noted, however, that in post-processing of the stress results for the support disks, a local coordinate system is used as shown in Figures 11.2.12.5.2-3 and 11.2.12.5.2-5.

The tip-over inertial load of 40g is conservatively applied to the entire model in the X-direction to simulate the side impact during the cask tip-over event. A pressure load of 15 psig (design internal pressure for normal condition of storage) is applied to the inner surface of the canister shell and the underside of the shield lid. Pressure loads are also applied to the support disk slots to represent the weight of the fuel assemblies, fuel tubes, and aluminum heat transfer disks multiplied by the appropriate acceleration (see Figure 11.2.12.5.2-3). The load per slot is calculated using an assumed weight of 1,500 lbs in 22 fuel positions and 1,600 lbs in the 4 corner positions. In addition, following weights are used:

Heat transfer disk	= 74 lb.
4 sided BORAL standard fuel tube	= 117 lb.
4 sided BORAL oversized fuel tube	= 122 lb.

The slot line load (lbs/in) for a standard size fuel assembly (F_s) is:

$$F_s = \frac{\left[\left(74\times27\right)/26 + 1{,}500 + 117\right]}{\left(28\times9.17\right)} = 6.60\ \text{lb/in}$$

The slot line load (lb./in) for an oversized fuel assembly (F_o) is:

$$F_o = \frac{\left[\left(74\times27\right)/26 + 1{,}600 + 122\right]}{\left(28\times9.57\right)} = 6.71\,\text{lb/in}$$

Therefore, the total load applied to a support disk (F_t) is:

$$F_t = 22\times9.17\times6.60 + 4\times6.71\times9.57 = 1{,}588\,\text{lb. per support disk (Analyzed load).}$$

By comparison, the basket maximum contents weight of 35,100 lb. gives an average fuel assembly weight of 1,350 lb. The load applied to a support disk (F_{ta}) using the average fuel assembly weight, standard size fuel tube weight (127 lb.), and an oversized fuel tube weight (133 lb.) is:

$$F_{ta} = \frac{26\times1350 + 22\times127 + 4\times133}{28} = 1{,}372\,\text{lb. per support disk (Max. design load).}$$

The analyzed load per support disk is 13.6% greater than the design basis support disk load. Therefore, the basket/canister analyses accounts for the possible variations in fuel weight without relying on administrative controls.

For the inertial loads, a maximum acceleration of 40 g is conservatively applied to the entire model. The maximum acceleration of the steel liner at the locations of the top support disk and the top of the canister lid during the tip over event is determined to be 25.3 g and 28.4 g, respectively. The main pulse of deceleration lasts for 30 milliseconds. To determine the effect of the rapid application of the inertia loading for the top support disk, a dynamic load factor (DLF) is computed using the mode shapes of a loaded support disk. The mode shapes are extracted using ANSYS for the first ten modes. The DLFs are computed using the SRSS (square root of sum of the squares) method and a single degree of freedom model.

Applying the maximum DLF, 1.07, to the 25.3 g results in a peak acceleration of 27.1 g. The canister lid region is significantly stiffer than the basket disk due to its monolithic structure. Therefore, applying 40 g to the entire canister/basket model is conservative.

An ambient uniform temperature of 75°F is applied to the model during solution. For post-processing a thermal run on the support disks was performed to generate a temperature gradient from the center (maximum temperature location) of the disk to the outer edge of the disk (minimum disk temperature). The canister was post-processed using a constant temperature of 350°F. The support disk modal frequencies and mass participation factors are:

Mode	Frequency (Hz)	Effective Mass (lb-sec^2/in^4)	Mass Participation Factor
1	61.5	3.583	0.871
2	83.6	0.000	0.102
3	159.6	0.419	0.000
4	201.3	0.000	0.000
5	206.7	0.000	0.000
6	251.7	0.000	0.000
7	330.9	0.051	0.013
8	338.9	0.000	0.000
9	339.7	0.000	0.000
10	344.2	0.000	0.000
		Total	0.986

Analysis Results for the CY-MPC Canister

The results of the canister drop analyses for tip over accident conditions are summarized in Tables 11.2.12.5.2-1 through 11.2.12.5.2-8 for primary membrane and primary membrane plus bending stresses. The section stresses at axial locations are obtained for each angular division of the models. The angular location at which the maximum sectional stress intensity occurs for each axial location is identified in these tables. The locations for the stress sections are shown in Figure 11.2.12.5.2-4.

The stress evaluation for the CY-MPC canister is performed in accordance with ASME Code, Section III Subsection NB. According to this subsection, linearized stresses of cross sections of the structure are to be compared against allowable stresses. Allowable stresses are conservatively taken at a temperature of 350°F. The allowable stresses for accident conditions are taken from Subsection NB and are:

P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

The S_m and S_u are 16.3 ksi and 59.7 ksi, respectively, for Type 304L stainless steel (canister shell and structural lid). The S_m and S_u are 19.4 ksi and 65.2, respectively, for Type 304 stainless steel (shield lid). However, all margins of safety for all sections are conservatively evaluated using the Type 304L stainless steel properties.

During the tip-over accident, the canister shell at the structural and shield lids is subjected to the inertial load of the lids and results in highly localized bearing stresses (sections 7 through 9 at angular locations of approximately ± 4.5 degrees). This stress is predominant because the weights of the structural and shielding lids are transferred to the canister shell through the thickness of the weld (0.75-inch weld for structural lid and 0.375-inch weld for shield lid). According to ASME Code Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions. Therefore, the P_m stresses are not presented for the region local to the impact for sections 7 through 9 in Tables 11.2.12.5.2-1 through 11.2.12.5.2-8. Stresses for Section 11 are presented as the average of the compression radial stresses in the weld region.

The inertial load of the shield and structural lids also results in localized bending stresses at the canister shell (at the shield lid and structural lid welds, i.e., sections 7, through 11). This stress state is identified as the case of a cylindrical shell at the junction with head, as shown in Table NB-3217-1 of the ASME Code, Section III, Subsection NB. The localized bending stress at the structural discontinuity is classified as secondary (Q) stress. In accordance with ASME Code Section III, Appendix F, secondary stresses are not considered for the stress evaluation for Level D (accident) conditions. Therefore, the $P_m + P_b$ stresses are not presented for the region local to the impact for sections 7 through 9 in Tables 11.2.12.5.2-1 through 11.2.12.5.2-8. Stresses for Section 11 are presented as the average of the compression radial stresses in the weld region. In accordance with NRC ISG-4, Revision 1, a 0.8 reduction factor is applied to the stress allowable for the structural lid/canister shell weld. Use of the 0.8 factor is valid because the ultimate strength of the weld material exceeds the base metal strength.

The stress evaluation results for tip over accident conditions show that the minimum margin of safety in the canister is +0.03 for P_m (Section 11 at 63°) and +0.14 for P_m+P_b (Section 10 at 63°).

Analysis Results for the CY-MPC Support Disk

To evaluate the most critical regions of the support disk, a series of cross sections are considered. To aid in identification of these sections, Figure 11.2.12.5.2-5 shows the locations on a support disk. Additionally, Table 11.2.12.5.2-9 lists the sections versus Point 1 and Point 2, which span the cross section of the ligament in the plane of the support disk.

The stress evaluation for the support disk is performed according to the ASME Code, Section III, Subsection NG. According to this subsection, linearized stresses of cross-sections of the structure are compared against allowable stresses. A thermal conduction analysis is performed on the support disks to determine the temperature distribution for the evaluation of the allowable stresses. A temperature of 650°F is held fixed at the center of the support disk while the outer

edge of the support disk is held fixed at 350°F. The temperature distribution in the remainder of the support disk is then solved for using ANSYS. The allowable stresses for tip over accident conditions are taken from Subsection NG and are:

	Accident (Level D) Allowable Stresses
P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

The stress evaluation results for the tip over impact conditions are presented in Tables 11.2.12.5.2-10 through 11.2.12.5.2-17 for the 5th support disk for fuel basket drop orientations of 0°, 38°, 63°, and 90° (see Figure 11.2.12.5.2-6). The tables list the 30 lowest margins of safety for P_m and $P_m + P_b$ stress intensities. Note that the maximum stress intensities occur at the 5th support disk from the top for each case evaluated. Therefore, only the results for the 5th support disk from the top are presented for each case.

The minimum margin of safety for membrane stresses is 0.84 (section number 2), which occurs for a 0° basket orientation. For membrane plus bending stresses, the minimum margin of safety is 0.13 (section number 1) which occurs for a 38° basket orientation.

The support disk evaluation using intact fuel bounds the support disk evaluation for the damaged fuel can containing a complete fuel assembly, a fuel assembly lattice holding individual fuel rods, or a failed rod storage canister, which may hold one or more damaged rods. The governing case for the configuration with the damaged fuel cans is the case with 100% failure of the fuel rods in a complete fuel assembly. Using a 50% volume compaction ratio of the failed fuel rods, the most critically loaded support disk is the 19th support disk as counted from the bottom of the basket. At this disk, the applied g-load is 31g and the resulting disk load is 52,850 pounds. For the intact fuel case, the maximum loading occurred on the top (28th) support disk and is 63,520 lbs (1,588 x 40), resulting from a g-load of 40g. Therefore, the support disk analysis for the intact fuel bounds the support disk analysis for 100% failed fuel in the damaged fuel can.

CY-MPC Support Disk Buckling Evaluation

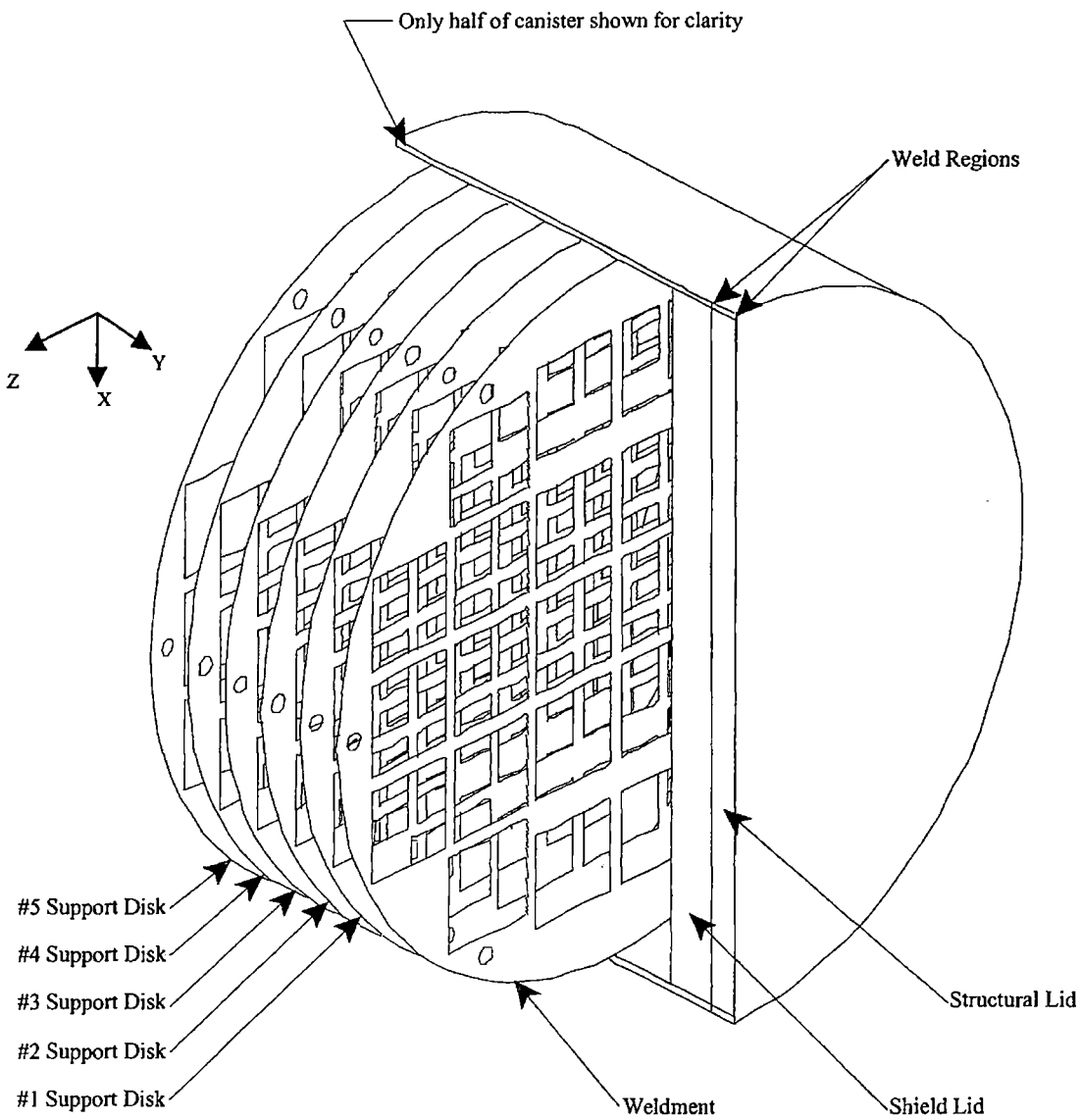
The fuel basket support disks are subjected to compressive and/or inertial loads during impact conditions. For the tip over accident, the support disks experience in-plane loads. The in-plane loads apply compressive forces and in-plane bending moments on the support disk. Buckling of the support disk is evaluated in accordance with the methods and acceptance criteria of

NUREG/CR-6322. Because the ASME Code identifies 17-4PH disk material as ferritic steel, the formulas for non-austenitic steel are used.

The buckling evaluation of the support disk web is based on the Interaction Equations 31 and 32 in NUREG/CR-6322. These two equations adopt the "Limit Analysis Design" approach for structural members subjected to stresses beyond the yield limit of the material, i.e., for members deformed elastically as a result of axial load or bending moment. Other equations applicable to the calculations are noted as they are applied (See Section 11.2.12.2.2). The maximum forces and moments for the tip-over accident are based on the finite element analysis stress results.

Buckling evaluation results for the 5th support disk are provided in Tables 11.2.12.5.2-18 through 11.2.12.5.2-21. As the tables demonstrate, the support disks meet the requirements of NUREG/CR-6322. The minimum margin of safety is 0.26 (section number 1) for a 38° basket orientation.

Figure 11.2.12.5.2-1 Three-Dimensional CY-MPC Canister and Basket Model



Note: Element edges are not shown for clarity. See Figures 11.2.12.5.2-2 and 11.2.12.5.2-3 for the finite element mesh.

Figure 11.2.12.5.2-2 Three-Dimensional CY-MPC Canister and Basket Model – Canister Portion

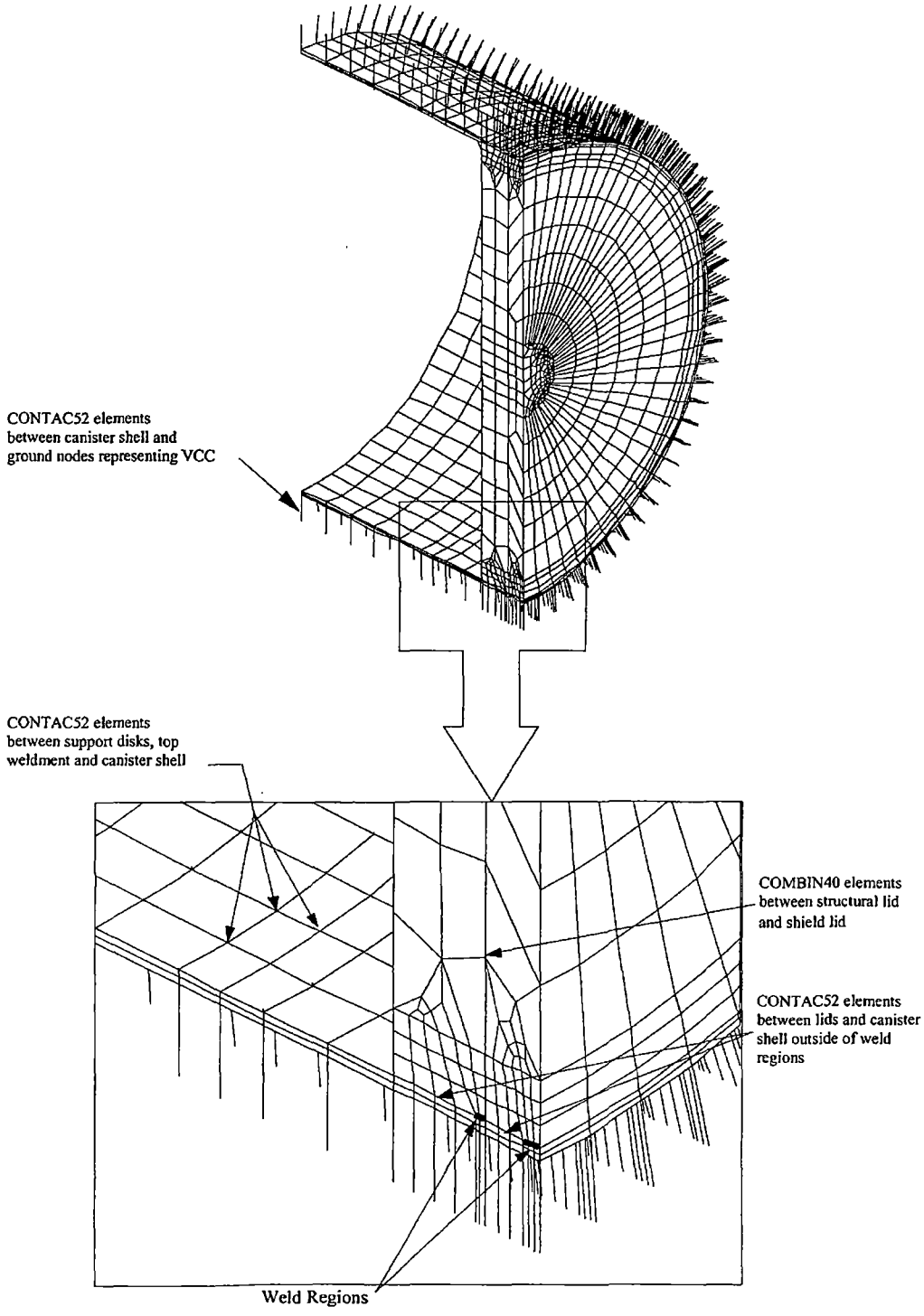


Figure 11.2.12.5.2-3 Three-Dimensional CY-MPC Canister and Basket Model - Support Disk Detail

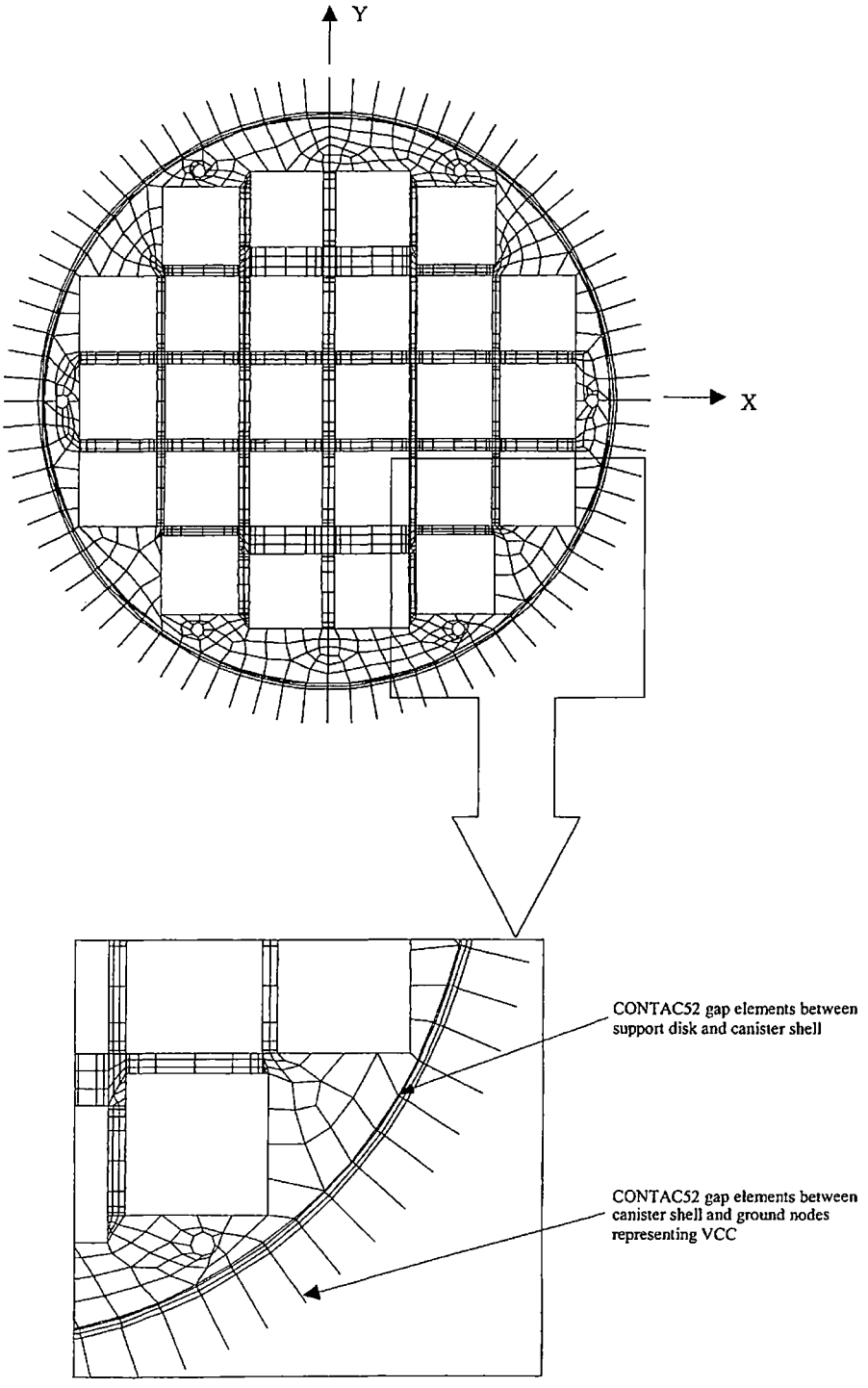
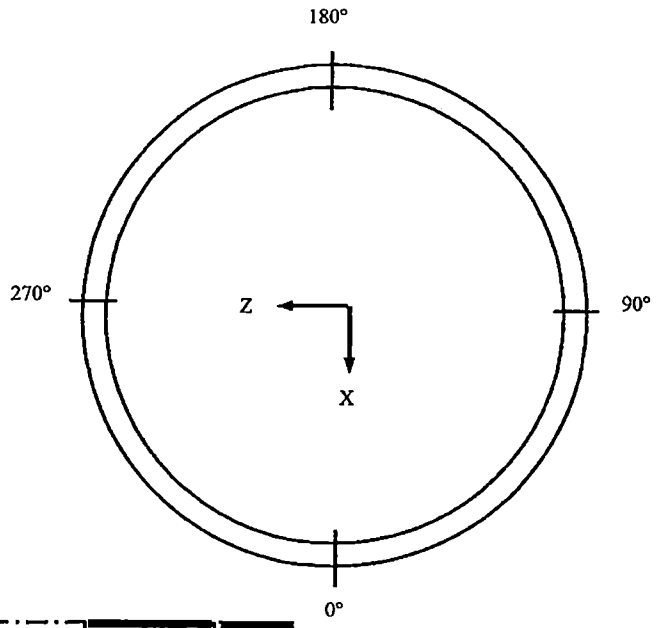
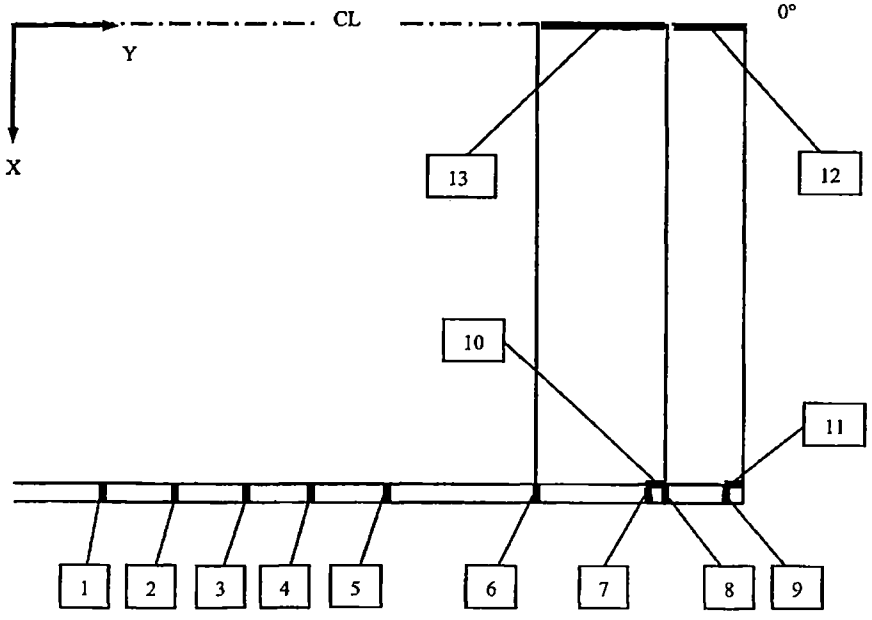


Figure 11.2.12.5.2-4 CY-MPC Canister Stress Sections Locations

	Point 1		Point 2	
Location	X inches	Y inches	X inches	Y inches
1	34.695	113.66	35.320	113.66
2	34.695	118.25	35.320	118.25
3	34.695	122.84	35.320	122.84
4	34.695	127.43	35.320	127.43
5	34.695	132.02	35.320	132.02
6	34.695	143.75	35.320	143.75
7	34.695	148.25	35.320	148.25
8	34.695	148.75	35.320	148.75
9	34.695	150.87	35.320	150.87
10	34.695	148.25	34.695	148.75
11	34.695	150.87	34.695	151.75
12	0.1	148.75	0.1	151.75
13	0.1	143.75	0.1	148.75





Note: The left half of the model (180° to 360°) is used for the evaluation of the 0° tip-over impact orientation. The bottom half of the model (270° to 90°) is used for the 90° orientation. The full model is used for the 38° and 63° orientations. Impact orientations are shown in Figure 11.2.12.3.2-6.

Figure 11.2.12.5.2-5 Location of CY-MPC Support Disk Sections to Obtain Linearized Stresses

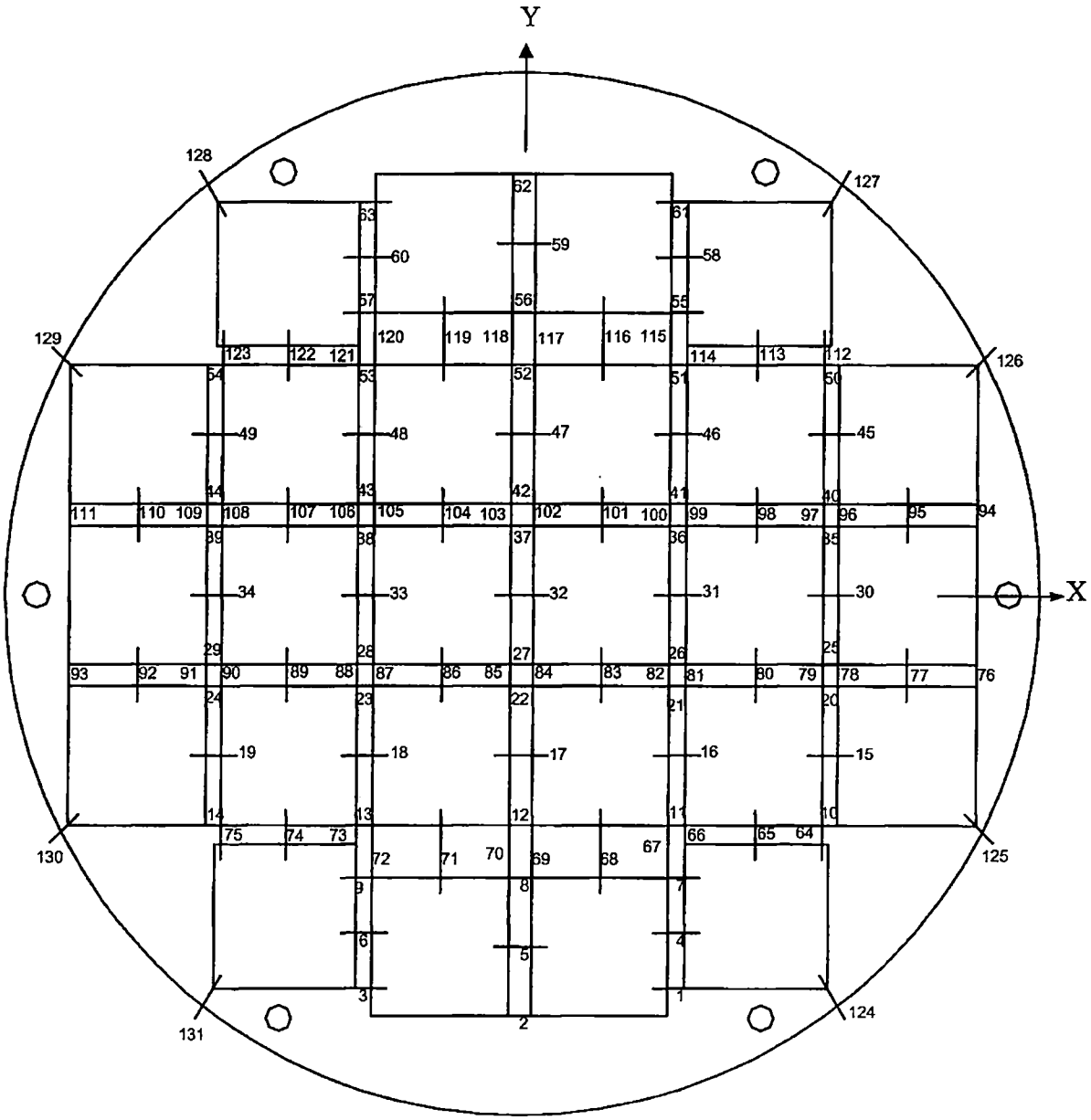


Figure 11.2.12.5.2-6 Evaluated CY-MPC Basket Impact Orientations

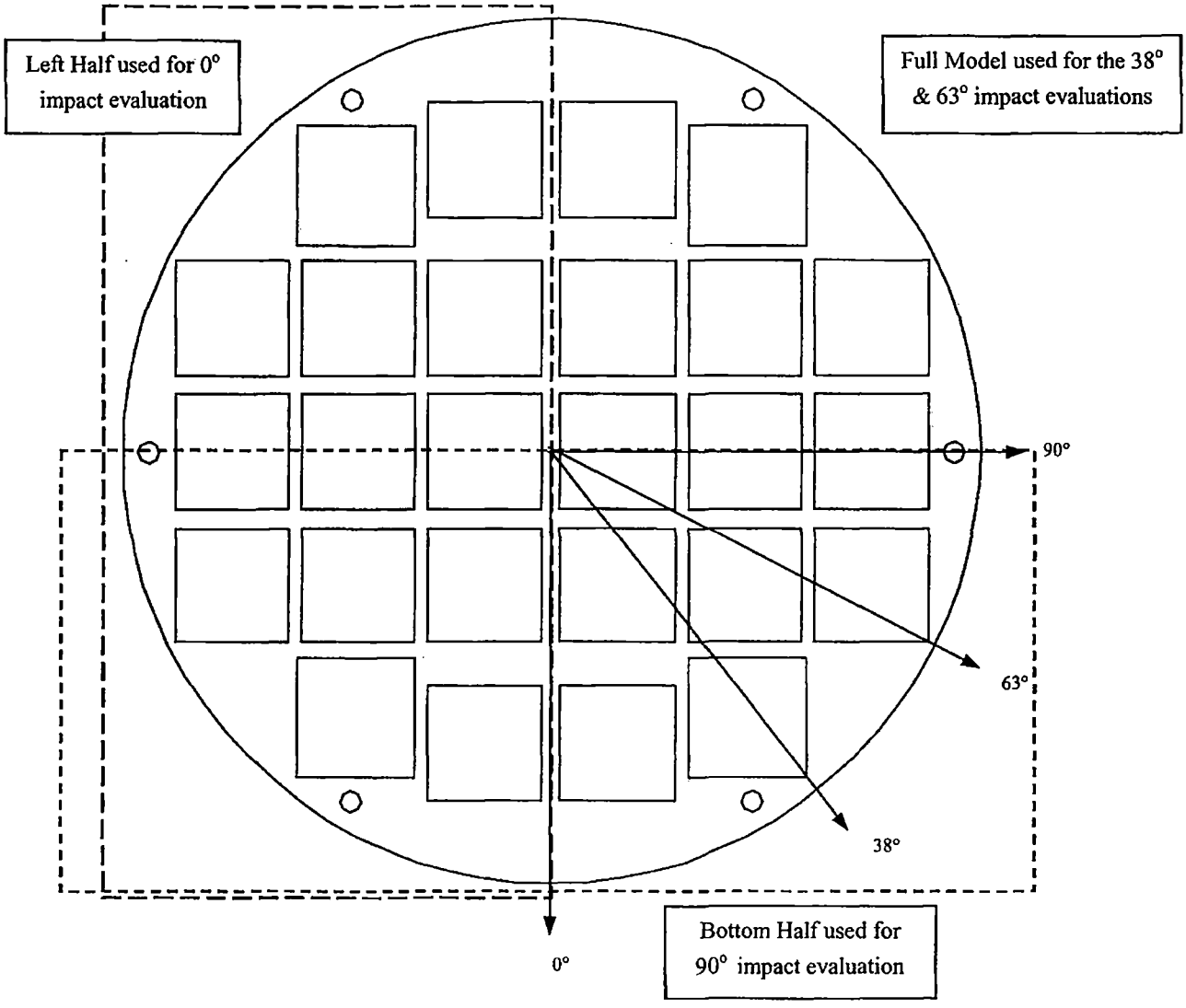


Table 11.2.12.5.2-1 CY-MPC Canister Primary Membrane Stresses, 0° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-2.1	5.0	4.0	-0.8	0.1	-0.4	7.35	39.00	4.31
2	0	-2.4	8.4	4.0	-0.6	0.0	0.5	10.96	39.00	2.56
3	0	-2.3	7.2	3.9	-1.6	-0.1	-0.2	10.01	39.00	2.90
4	0	-2.2	8.4	3.2	-0.6	-0.2	0.0	10.69	39.00	2.65
5	0	-2.7	5.8	2.7	-2.0	-0.3	0.1	9.37	39.00	3.16
6	0	-1.1	-8.1	2.6	-2.0	0.6	-0.6	11.48	39.00	2.40
7[3]	351	1.6	-0.8	3.4	-1.3	3.2	-0.5	8.09	39.00	3.82
8[3]	351	4.2	-0.8	3.2	0.3	2.2	0.3	6.41	39.00	5.08
9[3]	351	3.5	-1.1	0.9	-1.3	2.4	-0.2	6.92	39.00	4.64
10[4]	355.5 - 0	-36.5	-17.5	-29.4	-1.6	0.6	-10.4	26.91	39.00	0.45
11[5]	355.5 - 0	-30.9	-12.5	-7.6	-4.1	1.3	-3.8	25.97	31.20	0.20
12	0	-0.7	0.2	0.0	0.0	0.0	-0.1	1.01	39.00	37.73
13	0	-1.0	0.3	0.0	0.0	0.0	-0.1	1.37	39.00	27.45

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 0° and -4.5° stress results.
5. Average of 0° and -4.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-2 CY-MPC Canister Primary Membrane + Bending Stresses, 0° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-3.0	29.0	9.3	0.1	0.4	-0.3	32.09	58.50	0.82
2	0	-3.1	31.5	6.4	0.3	-0.1	0.4	34.60	58.50	0.69
3	0	-4.2	31.9	11.9	-0.6	-0.1	-0.2	36.07	58.50	0.62
4	0	-3.1	31.5	6.6	0.3	-0.2	0.1	34.58	58.50	0.69
5	0	-3.2	29.5	8.0	-1.1	-0.2	0.1	32.85	58.50	0.78
6	0	-0.4	-31.6	-14.2	-2.9	0.8	-0.6	31.79	58.50	0.84
7[3]	351	2.3	-5.8	-3.4	-3.0	5.0	-0.9	14.29	58.50	3.09
8[3]	351	5.9	-5.1	-1.4	-0.5	2.1	2.2	12.76	58.50	3.58
9[3]	351	4.3	-3.4	1.9	-2.5	2.4	-0.5	10.29	58.50	4.69
10[4]	355.5 - 0	-30.8	-14.7	-26.0	-1.2	-0.8	-16.4	33.13	58.50	0.77
11[5]	355.5 - 0	-31.2	-11.5	-6.5	-4.4	1.4	-3.7	27.36	46.80	0.71
12	0	-0.9	0.3	0.0	0.0	0.0	-0.1	1.20	58.50	47.67
13	0	-1.1	0.4	0.0	0.0	0.0	-0.1	1.49	58.50	38.31

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 0° and -4.5° stress results.
5. Average of 0° and -4.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-3 CY-MPC Canister Primary Membrane Stresses, 38° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	36	-1.3	9.1	1.8	-0.5	0.0	0.2	10.48	39.00	2.72
2	36	-1.5	12.3	1.6	-0.2	0.2	0.0	13.87	39.00	1.81
3	0	-0.2	12.9	6.9	0.0	-0.9	0.0	13.24	39.00	1.95
4	351	-0.1	13.3	6.1	0.0	-2.2	0.1	14.05	39.00	1.78
5	324	-0.1	6.0	1.2	0.0	-7.4	-0.1	15.56	39.00	1.51
6	324	0.0	-0.2	-0.6	0.0	-9.1	0.0	18.12	39.00	1.15
7[3]	27	-1.6	9.1	-7.2	-4.0	-4.0	3.1	20.57	39.00	0.90
8[3]	27	1.5	6.3	-2.3	-4.8	-1.1	-1.7	13.19	39.00	1.96
9[3]	27	0.5	2.3	-6.9	-2.1	-3.6	-0.4	12.74	39.00	2.06
10[4]	32.5-41.5	-40.5	-21.7	-35.2	1.4	-0.6	-13.5	30.57	39.00	0.27
11[5]	32.5-41.5	-36.8	-15.7	-10.3	1.9	-0.8	-4.5	28.25	31.20	0.10
12	0	-0.4	-0.2	-0.1	-0.7	0.0	-0.4	1.57	39.00	23.87
13	0	-0.8	-0.2	-0.1	-0.9	0.0	-0.5	2.10	39.00	17.62

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 33.5°, 38° and 42.5° stress results.
5. Average of 33.5°, 38° and 42.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-4 CY-MPC Canister Primary Membrane + Bending Stresses, 38° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	36	-1.8	25.1	5.7	-0.7	-0.2	0.3	26.98	58.50	1.17
2	36	-1.8	29.1	4.0	-0.4	0.0	0.0	30.97	58.50	0.89
3	36	-2.5	29.4	6.8	-0.7	0.6	-0.1	32.02	58.50	0.83
4	36	-1.9	28.3	4.6	-0.8	1.1	0.0	30.32	58.50	0.93
5	36	-2.3	25.0	6.0	-0.7	1.6	-0.1	27.46	58.50	1.13
6	36	-0.3	-30.1	-12.5	-0.7	3.6	-0.6	30.58	58.50	0.91
7[3]	27	-0.3	32.8	3.7	-1.9	-2.9	5.7	37.60	58.50	0.56
8[3]	27	0.8	22.8	4.7	-7.2	-1.3	1.9	26.8	58.50	1.18
9[3]	27	1.1	0.6	-12.21	-3.2	-3.8	-0.7	17.67	58.50	2.31
10[4]	32.5-41.5	-33.9	-18.8	-33.7	1.7	-0.9	-18.3	37.51	58.50	0.56
11[5]	32.5-41.5	-33.5	-12.1	-5.1	1.9	-1.0	-4.2	29.97	46.80	0.56
12	0	-0.7	-0.5	-0.2	-0.7	-0.1	-0.8	2.26	58.50	24.86
13	0	-0.8	-0.5	-0.2	-0.8	-0.1	-0.9	2.51	58.50	22.29

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 33.5°, 38° and 42.5° stress results.
5. Average of 33.5°, 38° and 42.5°stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-5 CY-MPC Canister Primary Membrane Stresses, 63° Basket Drop Orientation

Location[1]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	162	0.0	1.4	-9.0	0.1	0.9	0.0	10.57	39.00	2.69
2	81	-0.1	13.5	6.5	0.0	0.2	-0.2	13.62	39.00	1.86
3	108	-0.3	13.1	9.1	0.1	2.2	0.0	14.39	39.00	1.71
4	108	-0.3	14.2	8.1	0.1	3.2	0.2	15.85	39.00	1.46
5	144	0.0	2.2	-3.4	-0.3	8.5	-0.1	17.84	39.00	1.19
6	126	0.0	-0.7	-0.6	0.0	10.9	0.0	21.80	39.00	0.79
7[3]	72	-3.4	6.6	3.6	5.4	1.9	2.3	16.02	39.00	1.43
8[3]	72	-0.9	5.6	7.9	2.3	1.7	-1.9	11.05	39.00	2.53
9[3]	72	-3.6	1.6	6.5	3.0	1.1	-0.9	11.89	39.00	2.28
10[4]	58.5-67.5	-43.9	-23.3	-30.3	0.8	0.6	-14.7	32.44	39.00	0.20
11[5]	58.5-67.5	-39.8	-16.7	-11.3	-0.9	0.3	-4.9	30.22	31.20	0.03
12	0	0.1	-0.7	-0.1	-0.5	-0.1	-0.3	1.47	39.00	25.48
13	0	0.0	-1.0	-0.1	-0.7	0.0	-0.4	1.98	39.00	18.74

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 90° and 85.5° stress results.
5. Average of 90° and 85.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-6 CY-MPC Canister Primary Membrane + Bending Stresses, 63° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	162	0.0	10.0	-5.4	0.2	0.9	0.0	15.47	58.50	2.78
2	81	-0.3	18.3	10.2	0.0	0.4	-0.1	18.62	58.50	2.14
3	81	0.2	18.1	7.8	0.0	0.3	0.0	17.88	58.50	2.27
4	144	0.0	10.5	-1.0	-0.2	9.1	0.0	21.54	58.50	1.72
5	144	0.0	8.4	0.0	-0.3	11.1	-0.1	23.64	58.50	1.47
6	126	0.0	-0.7	-0.3	0.0	13.8	0.0	27.65	58.50	1.12
7[3]	72	-13.3	-9.1	4.1	6.5	3.4	2.3	23.78	58.50	1.46
8[3]	72	-8.5	-6.6	10.6	2.1	-1.5	-3.5	21.51	58.50	1.72
9[3]	72	-7.7	2.9	8.0	3.4	1.7	-0.6	17.34	58.50	2.37
10[4]	58.5-67.5	-33.4	-19.3	-35.4	0.7	0.8	-20.3	40.66	58.50	0.14
11[5]	58.5-67.5	-36.4	-14.2	-7.5	-1.1	-0.9	-4.8	30.55	46.80	0.53
12	0	-0.1	-1.2	-0.2	-0.6	-0.2	-0.6	2.11	58.50	26.71
13	0	-0.1	-1.4	-0.2	-0.7	-0.2	-0.6	2.35	58.50	23.84

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 90° and 85.5° stress results.
5. Average of 90° and 85.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-7 CY-MPC Canister Primary Membrane Stresses, 90° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	90	-1.7	6.7	5.2	-0.5	0.0	-0.1	8.47	39.00	3.60
2	90	-2.0	10.1	5.0	-0.6	-0.1	0.3	12.12	39.00	2.22
3	90	-1.9	9.1	4.6	-1.2	-0.2	-0.2	11.26	39.00	2.46
4	90	-1.8	9.9	3.8	-0.5	-0.2	0.1	11.83	39.00	2.30
5	36	0.0	3.2	-0.3	0.0	-5.3	0.0	11.08	39.00	2.52
6	40.5	0.0	0.2	0.0	0.0	-6.5	0.0	12.96	39.00	2.01
7[3]	81	-0.8	4.3	1.0	-3.2	-0.1	-1.9	9.02	39.00	3.32
8[3]	81	-1.2	3.9	4.8	-2.2	-0.3	-0.9	7.00	39.00	4.57
9[3]	81	-1.0	1.1	3.2	-2.5	-0.2	2.3	7.81	39.00	3.99
10[4]	85.5 - 90	-38.6	-19.2	-31.4	-1.3	0.6	-11.2	27.99	39.00	0.39
11[5]	85.5 - 90	-32.66	-13.7	-8.0	-3.8	1.2	-4.0	27.08	31.20	0.15
12	0	0.2	-0.8	0.0	0.0	-0.1	0.0	1.03	39.00	36.97
13	0	0.4	-1.2	0.0	0.0	-0.1	0.0	1.56	39.00	23.94

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 90° and 85.5° stress results.
5. Average of 90° and 85.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-8 CY-MPC Canister Primary Membrane + Bending Stresses, 90° Basket Drop Orientation

Location[2]	Section Angle (deg)	Sx[1]	Sy[1]	Sz[1]	Sxy	Syz	Sxz	Stress Intensity	Allowable Stress	Margin of Safety
1	90	-2.5	31.6	10.9	0.4	0.2	0.0	34.05	58.50	0.72
2	90	-2.6	34.6	8.3	0.4	-0.2	0.2	37.14	58.50	0.58
3	90	-3.5	34.9	12.7	-0.2	-0.1	-0.2	38.45	58.50	0.52
4	90	-2.5	34.3	8.0	0.4	-0.2	0.1	36.87	58.50	0.59
5	90	-2.6	31.4	9.5	-0.6	0.0	0.0	33.99	58.50	0.72
6	90	-0.4	-32.0	-13.2	-2.9	0.8	-0.7	32.19	58.50	0.82
7[3]	81	-5.6	-4.2	0.5	-5.3	0.2	-4.6	15.26	58.50	2.83
8[3]	81	-5.5	-2.3	6.0	-1.5	-2.4	-2.7	14.04	58.50	3.17
9[3]	81	-3.0	-2.2	3.4	-2.6	0.1	-4.1	11.51	58.50	4.08
10[4]	85.5 - 90	-32.4	-16.2	-27.9	-0.8	-0.7	-17.2	34.79	58.50	0.68
11[5]	85.5 - 90	-32.4	-12.8	-7.1	-4.1	1.4	-4.0	27.83	46.80	0.68
12	0	0.3	-1.0	0.0	0.0	-0.1	0.0	1.33	58.50	43.12
13	0	0.4	-1.3	0.0	0.0	0.0	0.0	1.75	58.50	32.43

1. Stresses are in the cylindrical coordinate system (x – radial, y – circumferential, z – axial).
2. See Figure 11.2.12.3.2-4 for definition of locations of stress sections.
3. Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.
4. Average of 90° and 85.5° stress results.
5. Average of 90° and 85.5° stress results. Allowable includes stress reduction factor for weld: 0.8(ISG) × stress allowable.

Table 11.2.12.5.2-9 Listing of Cross Sections for Stress Evaluation of the CY-MPC Support Disk

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
1	1	2	9.92	-26.07	11.02	-26.07
2	3	4	-0.75	-27.93	0.75	-27.93
3	5	6	-9.92	-26.07	-11.02	-26.07
4	7	8	9.92	-22.41	11.02	-22.41
5	9	10	-0.75	-23.34	0.75	-23.34
6	11	12	-9.92	-22.41	-11.02	-22.41
7	13	14	9.92	-18.75	11.02	-18.75
8	15	16	-0.75	-18.75	0.75	-18.75
9	17	18	-9.92	-18.75	-11.02	-18.75
10	19	20	20.19	-15.26	21.19	-15.26
11	21	22	9.92	-15.26	11.02	-15.26
12	23	24	-0.75	-15.26	0.75	-15.26
13	25	26	-9.92	-15.26	-11.02	-15.26
14	27	28	-20.19	-15.26	-21.19	-15.26
15	29	30	20.19	-10.67	21.19	-10.67
16	31	32	9.92	-10.67	11.02	-10.67
17	33	34	-0.75	-10.67	0.75	-10.67
18	35	36	-9.92	-10.67	-11.02	-10.67
19	37	38	-20.19	-10.67	-21.19	-10.67
20	39	40	20.19	-6.08	21.19	-6.08
21	41	42	9.92	-6.08	11.02	-6.08
22	43	44	-0.75	-6.08	0.75	-6.08
23	45	46	-9.92	-6.08	-11.02	-6.08
24	47	48	-20.19	-6.08	-21.19	-6.08
25	49	50	20.19	-4.58	21.19	-4.58
26	51	52	9.92	-4.58	11.02	-4.58
27	53	54	-0.75	-4.58	0.75	-4.58
28	55	56	-9.92	-4.58	-11.02	-4.58
29	57	58	-20.19	-4.58	-21.19	-4.58
30	59	60	20.19	0	21.19	0
31	61	62	9.92	0	11.02	0
32	63	64	-0.75	0	0.75	0
33	65	66	-9.92	0	-11.02	0
34	67	68	-20.19	0	-21.19	0
35	69	70	20.19	4.58	21.19	4.58
36	71	72	9.92	4.58	11.02	4.58
37	73	74	-0.75	4.58	0.75	4.58
38	75	76	-9.92	4.58	-11.02	4.58
39	77	78	-20.19	4.58	-21.19	4.58
40	79	80	20.19	6.08	21.19	6.08
41	81	82	9.92	6.08	11.02	6.08
42	83	84	-0.75	6.08	0.75	6.08
43	85	86	-9.92	6.08	-11.02	6.08
44	87	88	-20.19	6.08	-21.19	6.08

Table 11.2.12.5.2-9 Listing of Cross Sections for Stress Evaluation of the CY-MPC Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
45	89	90	20.19	10.67	21.19	10.67
46	91	92	9.92	10.67	11.02	10.67
47	93	94	-0.75	10.67	0.75	10.67
48	95	96	-9.92	10.67	-11.02	10.67
49	97	98	-20.19	10.67	-21.19	10.67
50	99	100	20.19	15.26	21.19	15.26
51	101	102	9.92	15.26	11.02	15.26
52	103	104	-0.75	15.26	0.75	15.26
53	105	106	-9.92	15.26	-11.02	15.26
54	107	108	-20.19	15.26	-21.19	15.26
55	109	110	9.92	18.75	11.02	18.75
56	111	112	-0.75	18.75	0.75	18.75
57	113	114	-9.92	18.75	-11.02	18.75
58	115	116	9.92	22.41	11.02	22.41
59	117	118	-0.75	23.34	0.75	23.34
60	119	120	-9.92	22.41	-11.02	22.41
61	121	122	9.92	26.07	11.02	26.07
62	123	124	-0.75	27.93	0.75	27.93
63	125	126	-9.92	26.07	-11.02	26.07
64	127	128	20.19	-16.5	20.19	-15.26
65	129	130	15.76	-16.5	15.76	-15.26
66	131	132	11.02	-16.5	11.02	-15.26
67	133	134	9.92	-18.75	9.92	-15.26
68	135	136	5.33	-18.75	5.33	-15.26
69	137	138	0.75	-18.75	0.75	-15.26
70	139	140	-0.75	-18.75	-0.75	-15.26
71	141	142	-5.33	-18.75	-5.33	-15.26
72	143	144	-9.92	-18.75	-9.92	-15.26
73	145	146	-11.02	-16.5	-11.02	-15.26
74	147	148	-15.76	-16.5	-15.76	-15.26
75	149	150	-20.19	-16.5	-20.19	-15.26
76	151	152	30.36	-6.08	30.36	-4.58
77	153	154	25.77	-6.08	25.77	-4.58
78	155	156	21.19	-6.08	21.19	-4.58
79	157	158	20.19	-6.08	20.19	-4.58
80	159	160	15.76	-6.08	15.76	-4.58
81	161	162	11.02	-6.08	11.02	-4.58
82	163	164	9.92	-6.08	9.92	-4.58
83	165	166	5.33	-6.08	5.33	-4.58
84	167	168	0.75	-6.08	0.75	-4.58
85	169	170	-0.75	-6.08	-0.75	-4.58
86	171	172	-5.33	-6.08	-5.33	-4.58
87	173	174	-9.92	-6.08	-9.92	-4.58
88	175	176	-11.02	-6.08	-11.02	-4.58
89	177	178	-15.76	-6.08	-15.76	-4.58

Table 11.2.12.5.2-9 Listing of Cross Sections for Stress Evaluation of the CY-MPC Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
90	179	180	-20.19	-6.08	-20.19	-4.58
91	181	182	-21.19	-6.08	-21.19	-4.58
92	183	184	-25.77	-6.08	-25.77	-4.58
93	185	186	-30.36	-6.08	-30.36	-4.58
94	187	188	30.36	6.08	30.36	4.58
95	189	190	25.77	6.08	25.77	4.58
96	191	192	21.19	6.08	21.19	4.58
97	193	194	20.19	6.08	20.19	4.58
98	195	196	15.76	6.08	15.76	4.58
99	197	198	11.02	6.08	11.02	4.58
100	199	200	9.92	6.08	9.92	4.58
101	201	202	5.33	6.08	5.33	4.58
102	203	204	0.75	6.08	0.75	4.58
103	205	206	-0.75	6.08	-0.75	4.58
104	207	208	-5.33	6.08	-5.33	4.58
105	209	210	-9.92	6.08	-9.92	4.58
106	211	212	-11.02	6.08	-11.02	4.58
107	213	214	-15.76	6.08	-15.76	4.58
108	215	216	-20.19	6.08	-20.19	4.58
109	217	218	-21.19	6.08	-21.19	4.58
110	219	220	-25.77	6.08	-25.77	4.58
111	221	222	-30.36	6.08	-30.36	4.58
112	223	224	20.19	16.5	20.19	15.26
113	225	226	15.76	16.5	15.76	15.26
114	227	228	11.02	16.5	11.02	15.26
115	229	230	9.92	18.75	9.92	15.26
116	231	232	5.33	18.75	5.33	15.26
117	233	234	0.75	18.75	0.75	15.26
118	235	236	-0.75	18.75	-0.75	15.26
119	237	238	-5.33	18.75	-5.33	15.26
120	239	240	-9.92	18.75	-9.92	15.26
121	241	242	-11.02	16.5	-11.02	15.26
122	243	244	-15.76	16.5	-15.76	15.26
123	245	246	-20.19	16.5	-20.19	15.26
124	247	248	20.59	-26.07	21.27	-27.23
125	249	250	30.36	-15.26	30.8	-15.69
126	251	252	30.36	15.26	30.8	15.69
127	253	254	20.59	26.07	21.27	27.23
128	255	256	-20.59	26.07	-21.27	27.23
129	257	258	-30.36	15.26	-30.8	15.69
130	259	260	-30.36	-15.26	-30.8	-15.69
131	261	262	-20.59	-26.07	-21.27	-27.23

Table 11.2.12.5.2-10 CY-MPC Support Disk Primary Membrane Stresses (P_m)
0° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
2	15.3	-33.2	-0.1	48.5	93.1	0.92
12	12	-22.5	2.2	34.8	91.7	1.64
5	0	-33.1	0	33.1	92.5	1.8
13	11.4	-17.3	1	28.8	92.1	2.2
27	8.6	-18.2	2	27.1	89.6	2.3
9	7.9	-18.5	1.9	26.7	92.2	2.45
3	7.9	-18.6	1.9	26.8	93	2.47
8	-21	-22.1	4.4	25.9	92	2.54
17	0	-22.4	0	22.4	90.8	3.05
42	6	-14.2	1.5	20.4	89.9	3.4
28	8.3	-11.7	0.6	20.1	91.2	3.55
70	2.1	-16.6	2.2	19.2	91.8	3.78
22	-11.7	-18	2.1	18.6	89.9	3.82
32	0	-18.2	0	18.2	88	3.85
6	0.1	-18.6	1.9	19	92.6	3.87
23	-9.8	-17.2	1	17.3	91.2	4.27
18	0	-17.2	1	17.3	91.7	4.3
85	2.1	-14	2	16.6	89.7	4.41
73	5	-9.8	3	16	92.1	4.76
37	-12.3	-14.4	1.9	15.5	89.6	4.78
47	0	-14.1	0	14.1	90.8	5.44
56	6.4	-6.9	1.6	13.7	92	5.72
52	-12.5	-9.1	1.9	13.4	91.7	5.86
88	1.9	-10.3	2.6	13.3	91.3	5.88
43	6.9	-6.2	0.6	13.2	91.2	5.92
38	-10.6	-11.6	0.6	11.9	91.2	6.66
103	-0.8	-11.3	1.9	11.7	89.7	6.68
33	0	-11.6	0.6	11.7	91.2	6.8
53	-11.7	-6.1	0.6	11.7	92.1	6.86
87	2.1	-7.9	-1.2	10.3	91.2	7.81

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-11 CY-MPC Support Disk Primary Membrane + Primary Bending Stresses ($P_m + P_b$) 0° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
2	15.3	-47.9	-0.1	63.2	132.9	1.1
3	-2	-58.4	-2.4	58.5	132.9	1.27
9	-1.2	-53.6	-2.4	53.8	131.7	1.45
13	6.4	-42.9	-1	49.3	131.5	1.67
23	-18.4	-38.5	6.5	40.4	130.3	2.23
12	12	-25.8	2.2	38	131	2.45
70	25	-11.1	-5.5	37.7	131.1	2.48
73	33.6	5.1	0.7	33.6	131.6	2.91
5	0	-33.4	0	33.4	132.2	2.96
85	20.3	-8.6	-2.7	29.4	128.1	3.35
8	-23.6	-23.8	6.3	30.1	131.4	3.37
88	-22.7	-24	6.2	29.6	130.4	3.4
38	-16.8	-26.5	5.8	29.2	130.3	3.46
121	-28	-14.4	3.9	29.1	131.6	3.52
28	1.2	-27.2	-1.4	28.6	130.3	3.56
27	8.6	-19	2	27.9	128	3.58
6	-2.3	-27.1	1.9	27.3	132.3	3.85
106	-22.8	-17.6	4.6	25.4	130.4	4.13
131	-12.7	-22.7	6.1	25.6	133.2	4.21
53	-15.8	-20.8	5.2	24	131.5	4.47
103	-16.7	-16.2	5.9	22.4	128.1	4.73
17	0	-22.6	0	22.6	129.7	4.75
57	-9.8	-21.8	3.4	22.7	131.7	4.8
75	22.8	1.5	-1.2	22.8	132.7	4.81
18	-1.5	-21.9	1	22	131	4.96
43	0.8	-20.7	-1.6	21.7	130.3	5
22	-14.5	-19.1	3.8	21.3	128.4	5.04
42	6	-14.5	1.5	20.7	128.4	5.19
87	6.8	-12.8	1.2	19.8	130.3	5.58
37	-15.2	-15.9	3.4	18.9	128	5.76

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-12 CY-MPC Support Disk Primary Membrane Stresses (P_m)
38° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
10	16.90	-27.30	3.50	44.70	92.90	1.08
66	-9.30	-34.00	0.40	34.00	92.10	1.71
25	10.70	-20.30	3.50	31.80	92.30	1.91
20	-27.70	-27.20	0.50	28.00	92.30	2.30
15	-0.20	-27.20	1.60	27.30	92.60	2.39
50	-25.60	-13.80	0.00	25.60	92.90	2.63
35	-24.30	-20.20	0.50	24.30	92.30	2.79
1	-17.30	-19.40	5.50	24.00	93.00	2.88
40	9.00	-13.90	3.00	23.60	92.30	2.90
4	-0.30	-19.40	4.10	20.80	92.60	3.46
30	-0.20	-20.20	1.60	20.30	92.30	3.54
78	-7.60	-20.20	-0.60	20.20	92.30	3.57
73	-1.00	17.20	2.70	19.00	92.10	3.85
124	10.20	-9.90	-7.70	17.80	93.20	4.24
3	9.80	-4.90	3.40	16.10	93.00	4.76
114	-4.30	11.60	-0.20	15.80	92.10	4.81
2	-11.70	-8.70	4.20	14.70	93.10	5.34
96	-7.80	-13.80	-0.60	13.80	92.30	5.67
45	-0.10	-13.80	1.10	13.90	92.60	5.67
11	-2.60	-11.90	4.50	13.70	92.10	5.70
75	-0.90	-13.40	-0.30	13.40	92.90	5.92
9	8.20	-4.80	1.20	13.20	92.20	6.00
55	11.90	3.30	3.50	13.10	92.20	6.02
16	-0.20	-11.80	2.80	12.90	91.70	6.09
79	-5.50	-11.00	3.90	13.00	92.30	6.10
7	-10.00	-8.10	-3.60	12.70	92.20	6.24
21	-7.60	-11.80	1.80	12.50	91.20	6.31
121	2.00	-9.70	2.40	12.60	92.10	6.33
64	-9.30	0.90	3.50	12.40	92.90	6.51
57	-8.80	1.10	2.80	11.40	92.20	7.12

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-13 CY-MPC Support Disk Primary Membrane + Primary Bending Stresses ($P_m + P_b$), 38° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
1	-39.50	-112.80	18.80	117.40	132.90	0.13
11	-32.90	-100.30	6.00	100.80	131.50	0.30
10	5.00	-91.90	2.90	97.10	132.70	0.37
12	-23.90	-90.10	6.80	90.80	131.10	0.44
26	-34.50	-86.70	5.20	87.30	130.30	0.49
13	-28.70	-84.70	5.80	85.30	131.50	0.54
25	-6.30	-83.30	1.70	83.30	131.80	0.58
21	-35.70	-76.90	5.70	77.60	130.30	0.68
41	-30.00	-72.80	4.20	73.20	130.30	0.78
2	-25.80	-71.70	8.50	73.20	133.00	0.82
28	-30.20	-70.20	4.40	70.70	130.30	0.84
20	-39.70	-68.50	9.50	71.40	131.90	0.85
36	-33.40	-67.70	5.10	68.50	130.30	0.90
64	-66.70	-12.20	0.50	66.70	132.70	0.99
40	-5.40	-65.50	1.20	65.60	131.90	1.01
85	-60.80	-38.90	6.10	62.40	128.10	1.05
35	-35.70	-61.50	8.10	63.90	131.80	1.06
79	-60.80	-43.90	7.50	63.60	131.80	1.07
43	26.20	60.80	4.00	61.30	130.30	1.13
22	-31.20	-59.30	5.30	60.20	128.40	1.13
23	-26.00	-59.60	2.60	59.80	130.30	1.18
52	-12.50	-59.30	2.00	59.40	131.10	1.21
66	-35.60	-50.60	14.60	59.60	131.60	1.21
29	-17.10	-59.10	3.60	59.40	131.80	1.22
51	-23.10	-57.90	4.00	58.30	131.50	1.26
8	-14.40	-57.70	3.40	58.00	131.40	1.27
55	26.20	53.30	11.30	57.40	131.70	1.30
97	-54.30	-38.10	6.60	56.70	131.80	1.33
14	-16.40	-56.20	2.20	56.30	132.70	1.36
103	-53.50	-28.80	2.70	53.80	128.10	1.38

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-14 CY-MPC Support Disk Primary Membrane Stresses (P_m)
63° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
64	-23.80	15.60	1.90	39.60	92.90	1.34
66	-23.70	-36.00	0.10	36.00	92.10	1.56
73	-5.10	21.50	2.00	26.90	92.10	2.43
65	23.80	-0.20	1.20	23.90	92.50	2.88
76	-14.50	-18.90	3.90	21.20	93.20	3.40
75	-5.00	-18.50	0.30	18.50	92.90	4.03
10	-15.30	-9.70	4.90	18.10	92.90	4.13
125	-4.70	-14.10	-7.00	17.80	93.20	4.23
78	-14.40	-13.90	2.40	16.60	92.30	4.57
94	-10.40	-14.90	3.20	16.60	93.20	4.63
114	-5.20	11.00	-0.20	16.20	92.10	4.69
77	14.50	-0.30	3.30	15.70	92.70	4.90
25	-10.20	-9.40	4.90	14.70	92.30	5.27
69	-6.70	-14.50	0.10	14.50	91.80	5.33
21	-12.60	-7.30	1.10	12.80	91.20	6.13
79	11.40	0.40	2.50	12.80	92.30	6.19
70	-4.10	8.10	1.80	12.70	91.80	6.24
126	-10.00	-9.60	2.80	12.60	93.20	6.38
82	-8.50	1.10	3.50	12.00	91.20	6.63
11	-6.40	-7.40	5.00	12.00	92.10	6.69
80	11.40	-0.20	2.00	11.90	91.80	6.70
81	-11.30	-9.70	1.10	11.80	91.30	6.72
112	-2.50	-10.90	-3.10	11.90	92.90	6.79
1	-7.50	-9.80	3.00	11.90	93.00	6.85
96	-10.30	-8.90	1.80	11.50	92.30	7.06
121	1.40	-9.50	1.60	11.40	92.10	7.08
95	10.30	-0.20	2.70	11.50	92.70	7.09
50	-11.40	-8.20	-0.20	11.40	92.90	7.12
40	-5.80	-8.30	4.10	11.30	92.30	7.15
20	-10.80	-9.70	0.60	11.00	92.30	7.36

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-15 CY-MPC Support Disk Primary Membrane + Primary Bending Stresses ($P_m + P_b$), 63° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
25	-34.10	-99.10	7.80	100.00	131.80	0.32
11	-36.20	-98.90	7.20	99.70	131.50	0.32
10	-35.80	-97.20	9.80	98.80	132.70	0.34
76	-92.80	-44.50	13.70	96.40	133.10	0.38
12	-22.40	-88.70	6.50	89.30	131.10	0.47
13	-35.50	-88.20	7.60	89.30	131.50	0.47
26	-36.20	-84.40	5.50	85.00	130.30	0.53
28	-36.10	-78.90	5.90	79.70	130.30	0.63
29	20.50	79.00	4.70	79.30	131.80	0.66
14	-21.10	-78.90	2.20	79.00	132.70	0.68
40	-24.80	-75.60	5.80	76.20	131.90	0.73
94	-73.40	-35.10	10.40	76.00	133.10	0.75
35	-25.10	-66.10	3.50	66.40	131.80	0.99
41	-28.50	-65.20	4.00	65.60	130.30	0.99
21	-37.90	-64.00	6.00	65.30	130.30	1.00
85	-63.10	-34.80	4.20	63.80	128.10	1.01
20	-27.10	-65.30	3.60	65.60	131.90	1.01
43	-27.50	-63.60	4.20	64.10	130.30	1.03
44	19.00	62.80	4.70	63.30	131.90	1.08
84	-59.60	-34.50	4.10	60.30	128.10	1.13
66	-35.60	-49.50	16.90	60.80	131.60	1.16
36	-32.10	-58.50	4.30	59.20	130.30	1.20
78	-46.00	-49.80	9.40	57.50	131.90	1.30
23	-27.40	-56.00	2.20	56.10	130.30	1.32
27	-30.00	-53.90	5.00	54.90	128.10	1.33
22	-31.70	-53.10	4.60	54.00	128.40	1.38
82	-54.00	-36.10	2.90	54.50	130.30	1.39
38	-22.60	-53.00	1.10	53.10	130.30	1.45
103	-51.50	-27.80	2.30	51.70	128.10	1.48
64	-53.20	-3.00	-3.50	53.50	132.70	1.48

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-16 CY-MPC Support Disk Primary Membrane Stresses (P_m)
90° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
79	23.3	17.9	-0.2	41.2	92.3	1.24
76	28	10.2	-1.8	38.3	93.2	1.43
82	18.7	13	-0.8	31.7	91.2	1.88
85	13	14.3	-0.7	27.3	89.7	2.28
78	-27.9	-15.9	-1.8	28.1	92.3	2.28
77	-27.9	-0.1	-1.8	28.1	92.7	2.3
20	-22.7	2.4	-4.3	26.6	92.3	2.47
81	-23.1	-16.1	-0.2	23.2	91.3	2.94
80	-23.2	0	-0.2	23.2	91.8	2.95
88	-8.6	12.7	-0.3	21.3	91.3	3.28
84	-18.5	-16.2	-0.8	18.8	89.7	3.77
83	-18.6	0	-0.8	18.7	90.4	3.85
25	-11.3	4.7	2.4	16.7	92.3	4.52
26	-16.2	-0.7	2.2	16.5	91.2	4.53
125	-14.2	-10.7	-3.6	16.4	93.2	4.67
90	-8.5	-15.7	-0.3	15.7	92.3	4.89
91	-4.4	11	-0.6	15.4	92.3	4.98
21	-12.5	0.1	-3.8	14.7	91.2	5.21
87	-12.9	-13.4	-0.7	13.9	91.2	5.56
22	-10.6	0.7	-3.8	13.6	89.9	5.6
86	-13	0	-0.7	13	90.4	5.95
93	-4.3	-13.1	-0.6	13.1	93.2	6.12
27	-10.1	0.8	1.6	11.4	89.7	6.88
23	-8.7	0.3	-3.5	11.4	91.2	7.02
66	-5.4	5.7	-0.1	11.1	92.1	7.3
89	-8.5	0	-0.3	8.6	91.8	9.73
28	-5.9	0.9	2.2	8.1	91.2	10.27
29	-6.3	-3.4	2.4	7.6	92.3	11.08
1	-4.4	1.9	2.1	7.5	93	11.34
24	-3.8	-2.9	-3.6	7.2	92.3	11.84

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-17 CY-MPC Support Disk Primary Membrane + Primary Bending Stresses ($P_m + P_b$), 90° Basket Drop Orientation (ksi)

Section Number	Sx	Sy	Sxy	Stress Intensity	Allowable Stress	M.S.
20	-7.3	70.6	0.5	77.9	131.9	0.69
76	-69.6	-2	-2.7	69.7	133.1	0.91
21	-29.8	-51.9	-7.3	54	130.3	1.41
78	-48	-30.6	-11.4	53.6	131.9	1.46
125	-31.9	-37.4	-18.8	53.6	133.2	1.49
79	-21.8	28.3	-7.4	52.2	131.8	1.53
24	-14.6	-50.5	-4.5	51	131.9	1.58
77	-47.7	-2	-1.7	47.8	132.5	1.77
23	-23.8	-45.1	-6.1	46.7	130.3	1.79
22	-24.4	-41.7	-6.6	43.9	128.4	1.92
84	-34.1	-25.2	-9.9	40.6	128.1	2.16
81	-29.7	-24	-9.4	36.6	130.4	2.56
82	-31.4	3.5	4.2	35.9	130.3	2.63
85	-27.6	5.6	4.8	34.6	128.1	2.71
10	4.2	34.7	-0.1	34.7	132.7	2.83
12	5.5	33.2	-0.5	33.2	131.1	2.95
25	-9.7	22.2	0.8	32	131.8	3.12
26	-13.8	17.2	-2.8	31.5	130.3	3.14
87	-23.1	-21.3	-8	30.2	130.3	3.31
90	-12.9	-22.3	-8.2	27.1	131.8	3.87
27	-10.6	15.5	-1	26.2	128.1	3.89
88	-3.1	19.4	-5.8	25.3	130.4	4.16
80	-24.5	0.2	-0.3	24.7	131.1	4.3
93	-18	-16.4	-7	24.2	133.1	4.49
11	1.6	23.4	2.2	23.6	131.5	4.58
29	-9.1	-22.4	4	23.6	131.8	4.6
83	-21.3	-0.9	-0.8	21.4	129.2	5.05
28	-3.2	17.6	0.7	20.8	130.3	5.26
91	4.1	18.6	-6.1	20.8	131.9	5.35
86	-18.8	-0.8	-0.7	18.8	129.2	5.86

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-18 CY-MPC Summary of NUREG/CR-6322 Support Disk Ligament Buckling Analysis 0° Basket Drop Orientation

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
2	12.44	36.13	34.12	0.69	6.4	5.99	1.2	1.19
3	10.25	60.17	50.04	4.01	13.76	13.47	1.32	1.22
9	10.19	59.45	49.4	3.54	13.58	13.31	1.47	1.34
5	12.41	35.86	33.84	0.01	6.35	5.95	1.87	1.71
13	9.51	59.34	49.3	2.58	13.56	13.28	2.03	1.82
23	9.45	58.64	48.71	2.15	13.4	13.13	2.29	2.03
12	8.44	35.47	33.44	0.15	6.27	5.88	2.82	2.66
6	10.21	59.82	49.73	0.86	13.68	13.39	3.4	2.86
8	8.29	35.59	33.56	0.08	6.29	5.9	3.08	2.88
17	8.41	35.01	33.01	0.01	6.19	5.81	3.15	2.91
28	6.45	58.61	48.69	1.56	13.39	13.12	3.7	3.33
38	6.37	58.61	48.69	1.5	13.39	13.12	3.81	3.42
18	9.47	59	49.01	0.47	13.48	13.21	4.21	3.48
32	6.81	33.34	31.35	0.01	5.88	5.54	3.88	3.59
27	6.84	34.38	32.39	0.04	6.07	5.71	3.88	3.62
22	6.74	34.56	32.57	0.05	6.11	5.74	3.91	3.66
121	1.29	69.63	56.05	3.38	17.51	17.35	4.42	4.36
37	5.39	34.38	32.39	0.07	6.07	5.71	4.96	4.67
42	5.32	34.56	32.57	0.02	6.11	5.74	5.4	5.05
43	3.4	58.64	48.71	1.46	13.4	13.13	5.52	5.16
47	5.28	35.01	33.01	0.01	6.19	5.81	5.59	5.22
53	3.33	59.34	49.3	1.48	13.56	13.28	5.58	5.24
33	6.4	58.65	48.72	0.42	13.4	13.13	6.31	5.33
57	1.52	59.45	49.4	1.92	13.58	13.31	5.72	5.64
106	0.61	85.8	66.47	4.12	24.93	24.93	5.78	5.71
103	0.59	83.75	64.87	2.98	24.33	24.33	8	7.87
52	3.41	35.47	33.44	0.05	6.27	5.88	8.61	8.16
111	0.75	88.14	68.35	2.64	25.63	25.63	9.41	9.19
48	3.36	59	49.01	0.44	13.48	13.21	10.72	9.42
118	1.52	223.34	156.14	12.75	136.62	136.62	10.61	10.25

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-19 CY-MPC Summary of NUREG/CR-6322 Support Disk Ligament Buckling Analysis 38° Basket Drop Orientation

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
1	10.69	60.17	50.04	9.41	13.76	13.47	0.27	0.26
10	13.63	53.15	45.40	5.38	11.35	11.01	0.44	0.42
11	6.54	59.34	49.30	8.91	13.56	13.28	0.45	0.45
25	10.13	52.68	44.96	5.25	11.24	10.91	0.62	0.61
12	4.90	86.37	66.92	15.67	25.09	25.09	0.69	0.66
26	4.50	58.61	48.69	7.92	13.39	13.12	0.68	0.68
13	2.58	59.34	49.30	8.07	13.56	13.28	0.77	0.80
20	13.58	52.69	44.98	3.44	11.24	10.91	0.85	0.78
21	6.48	58.64	48.71	6.56	13.40	13.13	0.84	0.82
41	2.39	58.64	48.71	6.90	13.40	13.13	1.04	1.06
2	6.55	88.05	68.28	11.81	25.60	25.60	1.13	1.05
35	10.08	52.68	44.96	3.45	11.24	10.91	1.13	1.07
40	6.93	52.69	44.98	4.31	11.24	10.91	1.10	1.09
36	4.44	58.61	48.69	6.02	13.39	13.12	1.13	1.12
28	1.28	58.61	48.69	6.84	13.39	13.12	1.14	1.18
64	5.84	70.45	56.75	7.47	17.73	17.56	1.23	1.18
15	13.60	52.94	45.21	1.70	11.30	10.97	1.53	1.33
22	4.82	84.09	65.14	9.90	24.43	24.43	1.48	1.39
85	2.17	83.75	64.87	10.86	24.33	24.33	1.46	1.43
79	4.14	87.02	67.44	10.36	25.29	25.29	1.52	1.45
8	6.47	86.63	67.12	9.20	25.17	25.17	1.58	1.46
23	2.53	58.64	48.71	5.55	13.40	13.13	1.47	1.48
51	2.33	59.34	49.30	5.41	13.56	13.28	1.58	1.60
29	0.18	52.68	44.96	4.90	11.24	10.91	1.60	1.68
52	0.61	86.37	66.92	10.97	25.09	25.09	1.64	1.63
14	1.97	53.15	45.40	4.35	11.35	11.01	1.66	1.72
4	10.66	59.82	49.73	2.56	13.68	13.39	1.90	1.68
97	4.58	87.02	67.44	9.04	25.29	25.29	1.79	1.70
3	2.68	60.17	50.04	4.93	13.76	13.47	1.79	1.80
103	1.07	83.75	64.87	9.77	24.33	24.33	1.82	1.80

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12. 5.2-20 CY-MPC Summary of NUREG/CR-6322 Support Disk Ligament Buckling Analysis 63° Basket Drop Orientation

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
25	4.68	52.68	44.96	7.48	11.24	10.91	0.47	0.50
11	4.06	59.34	49.30	9.23	13.56	13.28	0.50	0.52
10	4.86	53.15	45.40	7.29	11.35	11.01	0.50	0.53
13	1.46	59.34	49.30	8.63	13.56	13.28	0.73	0.76
12	2.26	86.37	66.92	16.06	25.09	25.09	0.75	0.74
26	2.16	58.61	48.69	8.12	13.39	13.12	0.77	0.79
40	4.15	52.69	44.98	5.61	11.24	10.91	0.92	0.94
28	0.97	58.61	48.69	7.78	13.39	13.12	0.92	0.95
14	1.18	53.15	45.40	6.38	11.35	11.01	0.93	0.99
35	4.65	52.68	44.96	4.73	11.24	10.91	1.16	1.17
20	4.83	52.69	44.98	4.64	11.24	10.91	1.18	1.19
85	4.94	83.75	64.87	10.61	24.33	24.33	1.32	1.24
21	4.03	58.64	48.71	5.71	13.40	13.13	1.26	1.25
84	6.31	83.75	64.87	9.60	24.33	24.33	1.42	1.32
41	0.44	58.64	48.71	6.49	13.40	13.13	1.33	1.38
43	0.35	58.64	48.71	6.35	13.40	13.13	1.39	1.44
36	2.13	58.61	48.69	5.51	13.39	13.12	1.53	1.55
82	6.39	85.69	66.39	8.53	24.90	24.90	1.72	1.59
23	1.43	58.64	48.71	5.38	13.40	13.13	1.67	1.70
22	2.22	84.09	65.14	9.40	24.43	24.43	1.82	1.78
27	1.15	83.75	64.87	9.81	24.33	24.33	1.80	1.78
38	0.93	58.61	48.69	5.17	13.39	13.12	1.84	1.88
103	1.47	83.75	64.87	9.29	24.33	24.33	1.92	1.89
102	3.83	83.75	64.87	8.09	24.33	24.33	2.04	1.94
1	5.38	60.17	50.04	3.54	13.76	13.47	2.16	2.07
93	0.34	88.14	68.35	9.63	25.63	25.63	2.09	2.09
24	1.15	52.69	44.98	3.72	11.24	10.91	2.20	2.27
50	4.12	53.15	45.40	2.95	11.35	11.01	2.24	2.22
100	3.91	85.69	66.39	7.35	24.90	24.90	2.36	2.24
87	4.86	85.69	66.39	6.84	24.90	24.90	2.43	2.27

See Figure 11.2.12.5.2-5 for section locations.

Table 11.2.12.5.2-21 CY-MPC Summary of NUREG/CR-6322 Support Disk Ligament Buckling Analysis 90° Basket Drop Orientation

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
24	1.45	52.7	44.98	3.96	11.24	10.91	1.96	2.02
29	1.71	52.68	44.96	1.58	11.24	10.91	5.38	5.35
88	6.45	85.8	66.47	1.04	24.93	24.93	8.02	6.55
93	3.19	88.14	68.35	2.58	25.63	25.63	7.2	6.58
26	0.37	58.61	48.69	1.8	13.39	13.12	7.13	7.23
90	6.36	87.02	67.44	0.83	25.29	25.29	8.9	7.2
14	1.45	53.16	45.4	1.12	11.35	11.01	7.77	7.66
91	3.28	87.1	67.51	1.59	25.31	25.31	9.96	8.82
89	6.4	86.39	66.93	0.09	25.1	25.1	11.95	9.13
3	0.65	60.17	50.04	1.21	13.76	13.47	10.47	10.44
34	1.71	52.7	44.98	0.64	11.25	10.91	11.12	10.61
66	3.39	69.63	56.05	0.52	17.51	17.35	12.44	10.66
65	3.44	70.07	56.42	0.11	17.63	17.46	17.31	14.07
64	3.47	70.45	56.75	0.1	17.73	17.56	17.52	14.2
6	0.65	59.82	49.73	0.74	13.68	13.39	16.35	16.05
92	3.25	87.62	67.93	0.13	25.47	25.47	23.2	18.21
67	2.16	224.37	156.87	5.65	137.26	137.26	21.42	19.56
9	0.65	59.45	49.4	0.43	13.58	13.31	24.97	23.99
19	1.45	52.95	45.21	0.05	11.3	10.97	31.07	26.99
31	0.37	58.65	48.72	0.44	13.4	13.13	27.77	27.26
69	1.94	223.34	156.14	3.37	136.62	136.62	32.72	29
70	1.25	223.34	156.14	3.38	136.62	136.62	36.57	33.52
68	2.08	224.09	156.66	2.46	137.08	137.08	39.77	34.12
72	1.03	224.38	156.87	3.42	137.26	137.26	37.81	35.12
71	1.17	224.09	156.67	1.07	137.08	137.08	82.99	69.72
7	0.66	59.45	49.4	0.09	13.58	13.31	99	99
27	0.6	83.75	64.87	2.76	24.33	24.33	99	99
28	0.47	58.61	48.69	1.68	13.39	13.12	99	99
8	0.27	86.63	67.12	0.22	25.17	25.17	99	99
30	2.36	52.7	44.98	0.77	11.25	10.91	99	99

See Figure 11.2.12.5.2-5 for section locations.

11.2.12.6 Radiological Consequences

There is an adverse radiological consequence in the hypothetical tip-over event, since the bottom end of the storage cask and the canister have significantly less shielding than the sides and tops of these same components. For the Yankee-MPC, the dose rate at 1 meter is calculated to be approximately 156 rem/hour, and the dose rate at 5 meters is calculated to be approximately 32 rem/hour. The CY-MPC concrete cask contains a 4-inch pedestal plate, compared to the 2-inch plate employed in the Yankee-MPC cask. Concrete cask bottom dose rates for the CY-MPC system are, therefore, going to be lower than those calculated for the Yankee-MPC system. Regardless of the MPC system configuration, high dose rates expected at the cask bottom following the tip-over event would dictate the use of supplemental shielding until the concrete cask can be righted. Stringent access controls must be applied to ensure that personnel do not enter the area of radiation shine from the exposed bottom of the tipped over concrete cask. As previously noted in the tip-over analysis, tip-over is not a credible event.

11.2.12.7 NAC-MPC Performance

Functionally the NAC-MPC does not suffer significant adverse consequences from the tip-over event. The storage cask and canister maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

Damage to the edges or surface of the concrete cask may occur in the tip-over, which could result in marginally higher dose rates at the bottom edge or at surface cracks in the concrete. This increased dose rate is not expected to be significant, but would be dependent on the specific damage incurred.

11.2.12.8 Recovery and/or Corrective Actions

The most important recovery step required following a cask tip over accident is the uprighting of the concrete cask to eliminate the high dose rate from the exposed bottom end. The uprighting operation will require a heavy lift capability and rigging expertise. The concrete cask must be returned to the vertical by rotation around a convenient bottom edge. The concrete cask should be returned to the vertical using a method and rigging that controls the rotation to vertical.

Surface and top and bottom edges of the concrete cask would be expected to exhibit cracking and possibly loss of concrete down to the layer of reinforcing bar. If only minor damage occurs, the concrete may be repairable using grout. Otherwise, it may be necessary to remove the canister and install it in a new storage cask.

The storage pad must be repaired to preclude the intrusion of water that could cause further deterioration of the pad in freeze-thaw cycles.

11.2.13 Tornado and Tornado Driven Missiles

This analysis evaluates the strength and stability of the concrete storage cask for a maximum tornado wind loading and for the impacts of tornado generated missiles. The design basis tornado characteristics have been selected in accordance with Regulatory Guide 1.76.

Classical techniques are used to evaluate the loading conditions. Cask stability analysis for the maximum tornado wind loading is based on NUREG-0800, Section 3.3.1, "Wind Loadings," and Section 3.3.2, "Tornado Loadings." Loads, due to tornado generated missiles, are based on NUREG-0800, Section 3.5.3, "Barrier Design Procedures."

11.2.13.1 Cause of Tornado Event

A tornado is a random weather event having a higher probability of occurrence at certain times of the year and in certain geographical areas.

Wind loading and tornado driven missiles have the potential for causing damage from pressure differential loading and from impact loadings.

A tornado event is expected to be visually observed. Warning of a tornado probability and of a tornado sighting may be received from the National Weather Service, local radio and television, local law enforcement officials, and site personnel.

11.2.13.2 Analysis of the Tornado Event

Classical analysis is applied to the evaluation of the consequences of tornado wind and missile events.

The concrete cask stability in a maximum tornado wind is evaluated based on the design wind pressure calculated in accordance with ANSI/ASCE 7-93 and using classical free body stability analysis methods.

Local damage to the concrete shell is assessed using a formula developed by the National Defense Research Committee. This formula has been selected as the basis for predicting depth of missile penetration and minimum concrete thickness requirements to prevent scabbing of the

concrete. Penetration depths calculated using this formula have been shown to provide reasonable correlation with test results (EPRI Report NP-440).

The local shear strength of the concrete shell is evaluated based on ACI 349-85, Section 11.11.2.1, discounting the reinforcing and steel shell.

The concrete shell shear capacity and shear-friction reinforcing steel area requirements are also evaluated for missile loading using ACI 349-85, Section 11.7.

11.2.13.2.1 Analysis of the Tornado Event for the Yankee-MPC

The Yankee-MPC concrete cask has the following properties that are considered in this evaluation:

H	=	Height = 160 in
D_o	=	Outside Diameter = 128 in
D_i	=	Inside Diameter0 of concrete shell = 86 in
W_{VCC}	=	Weight of the storage cask with canister, basket and full fuel load
	=	206,100 lbs
A_c	=	Cross section area of concrete shell = 7,059 in^2
I_c	=	Moment of inertia of concrete shell = 10.49×10^6 in^4
f_c'	=	Compressive strength of concrete shell = 4,000 psi

11.2.13.2.1.1 Tornado Wind Loading of the Yankee-MPC Storage Cask

The tornado wind velocity is transformed into an effective pressure applied to the cask using procedures delineated in ANSI/ASCE 7-93 Building Code Requirements for Minimum Design Loads in Buildings and Other Structures. The maximum pressure, q, is determined from the maximum tornado wind velocity as follows:

$$q = (0.00256)\ V^2 \text{ psf}$$

where:

V = Maximum tornado wind speed = 360 mph

The velocity pressure exposure coefficient for local terrain effects, K, Importance Factor, I, and the Gust Factor, G, may be taken as unity (1) for evaluating the effects of tornado wind velocity pressure.

Then:

$$q = (0.00256)(360)^2 = 331.8 \text{ psf}$$

Considering the cask is small with respect to the tornado radius, the velocity pressure is assumed uniform over the projected area of the cask.

Then the total wind loading on the projected area of the cask, F_w, is then computed as:

$$F_w = q \times G \times C_f \times A_p$$

where:

q = Effective velocity pressure (psf)
C_f = Force Coefficient = 0.50 (ASCE 7-93, Table 12 with $D\,q^{1/2} = 194$ for a moderately smooth surface, h/D = 13.33 ft /10.66 ft = 1.25)
A_f = Projected area of cask = 10.67 ft x 13.33 ft = 142.2 ft^2
F_w = 331.8 x 0.50 x 142.2 = 23,590 lbs

The wind overturning moment, M_w, is computed as:

$M_w = F_w \times H/2$, where, H, is the cask height

M_w = 23,590 lbs x 160. in/12 x 1/2 = 157,267. ft -lbs

The stability moment, M_s, of the cask with the canister, basket and full fuel load about an edge of the base is:

$$M_s = W_{VCC} \times D_o/2$$

where:

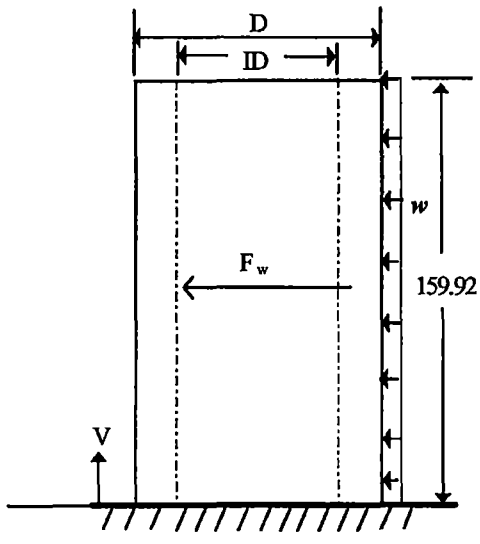
D_o = Diameter of the cask = 128 in

W_{VCC} = Weight of the cask with canister
= 206,100 lbs

M_s = 206,100 lbs x 128. In /12 x 1/2 = 1.099×10^6 ft-lbs

Thus, the cask has a Safety Factor of approximately +7 (1.099×10^6 /1.573×10^5) against overturning with respect to the maximum tornado wind loading and requires only a coefficient of friction of about 0.12 (23.6×10^3 / $206. \times 10^3$) to be developed between the concrete cask base and ISFSI support deck to inhibit sliding via friction.

The stresses in the concrete due to the tornado wind load are conservatively calculated as below. The concrete cask is considered to be fixed at its base.



F_W	= 23,590 lb		
D	= 128 in. (concrete exterior diameter)		
ID	= 86 in. (concrete interior diameter)		
A	$= \pi (D^2 - ID^{2)} / 4$	= 7,059.2 in.^{2}	
I	$= \pi (D^4 - ID^{4)} / 64$	= 10.492×10^6 in.^{4}	(Moment of Inertia)
S_{outer}	= 2I /D	= 163,937.5 in.^{3}	(Section Modulus for inner surface)
S_{inner}	= 2I / (ID)	= 244,000.0 in.^{3}	(Section Modulus for outer surface)
w	$= F_w$ / 159.92	= 147.5 lbf / in	
V	$= F_w/A$	= 3.34 psi	(Shear stress at the base)
M	$= w (159.92)^2 / 2$	= 1.886×10^6 in.-lb	(Bending Moment at the base)

Maximum stresses at the base surface:

$\sigma_{v\ outer} = M / S_{outer} = 11.5$ psi (tension or compression)
$\sigma_{v\ inner} = M / S_{inner} = 7.7$ psi (tension or compression)

The compressive stresses are included in the load combination No. 8 in Table 3.4.4.2-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined stresses for the load combination of dead, live, thermal and tornado wind are below the allowable stress.

11.2.13.2.1.2 Tornado Missile Loading on the Yankee-MPC Storage Cask

The Yankee-MPC concrete cask is designed to withstand the effects of impacts associated with postulated tornado generated missiles identified in NUREG-0800, Section 3.5.1.4.III.4, Spectrum I missiles. Consisting of: 1) a high kinetic energy missile (3,960 lb automobile, with a frontal area of 20 square feet that deforms on impact); 2) a 275 lb, 8-inch diameter armor piercing artillery shell; and 3) a small 1-inch diameter solid steel sphere. All of these missiles are assumed to impact in a manner that produces the maximum damage at a velocity of 126 mph (35 percent of the maximum tornado wind speed of 360 mph). The cask has been evaluated for impact effects associated with each of the above missiles.

The principal dimensions and moment arms used in this evaluation are shown in the following figure.

The concrete cask has no openings, except for the four outlets at the top and four inlets at the bottom of the cask. These openings are configured such that a 1-inch diameter solid steel missile cannot directly enter the concrete cask interior. In addition, the canister is protected from the inlet (bottom) openings by a steel pedestal (bottom plate), and from the outlet (top) openings by the canister structural and shield lids. Therefore, a detailed analysis of the impact of a 1-inch diameter steel missile is not required.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Yankee-MPC Concrete Shell Local Damage Prediction (Penetration Missile)

Local damage to the cask body has been assessed using the National Defense Research Committee (NDRC) formula. This formula has been selected as the basis for predicting depth of penetration and minimum concrete thickness requirements to prevent scabbing. Penetration depths calculated using this formula have been shown to provide reasonable correlation with test results (EPRI Report NP-440, Section 4 "Local Response Evaluation").

Concrete shell penetration depths are calculated as follows:

For $x/2d \leq 2.0$:

where:

x = Missile penetration depth
d = Missile diameter = 8 in
$x = [4KNWd^{-0.8}(V/1000)^{1.8}]^{0.5}$

where:

K = Coefficient depending on concrete strength
= $180/(f_c')^{1/2} = 180/(4000)^{1/2} = 2.846$
N = 1.14 Shape factor for sharp nosed missiles
W = Missile weight = 275 lb
V = Missile velocity = 126 mph = 185 ft/sec
x = $[(4)(2.846)(1.14)(275)(8^{-0.8})(185/1000)^{1.8}]^{0.5}$
= 5.68 inches
$x/2d$ = $5.68/(2)(8) = 0.355 < 2.0$

The minimum concrete shell thickness required to prevent scabbing is three times the predicted penetration depth of 5.68 inches based on the NDRC formula, or 17.04 inches. The concrete cask wall thickness includes 21 inches of concrete, which is more than the thickness required to prevent damage due to the penetration missile. This analysis conservatively neglects the 3.5-inch steel shell at the inside face of the concrete shell.

Yankee-MPC Closure Plate Local Damage Prediction (Penetration Missile)

The concrete cask is closed with a 1.5-inch thick steel plate bolted in place. The following missile penetration analysis shows that the 1.5-inch steel closure plate is adequate to withstand the impact of the 275 lb armor piercing missile, impacting at 126 mph.

The perforation thickness of the closure steel plate is calculated by the Ballistic Research Laboratories Formula with K = 1, formula number 2-7, in Section 2.2 of Topical Report BC-TOP-9A, Revision 2.

$$T = [0.5M_mV^2]^{2/3}/672d$$
$$= 0.516 \text{ inch}$$

where:

T = Perforation thickness
M_m = Missile mass = W/g = 275 lbs/32.2 ft/sec^2 = 8.54 slugs
g = Acceleration of gravity = 32.2 ft/sec^2
W, V and d are as defined above

BC-TOP-9A, recommends that the plate thickness be 25 percent greater than the calculated perforation thickness, T, to prevent perforation.

Thus, the recommended plate thickness is: 1.25 x 0.516 in. = 0.645 in.

The closure plate is 1.5 inches thick; therefore, the plate is adequate to withstand the local impingement damage due to the specified armor piercing missile.

Overall Damage Prediction for a Yankee-MPC Tornado Missile Impact (High Energy Missile)

The concrete cask is a freestanding structure. Therefore, the principal consideration in overall damage response is the potential of upsetting or overturning the cask as a result of the impact of a high energy missile. Based on the following analysis, it is concluded that the cask can sustain an impact from the defined high energy missile and does not overturn.

From the principle of conservation of momentum, the impulse of the force from the missile impact on the cask must equal the change in angular momentum of the cask. Also, the impulse force due to the impact of the missile must equal the change in linear momentum of the missile. These relationships may be expressed as follows:

Change in momentum of the missile, during the deformation phase:

$$\int_{t_1}^{t_2} (F)(dt) = M_M (v_2 - v_1)$$

where:

F	=	Impact Impulse force on missile
M_M	=	Mass of missile = 3960 lbs/g = 123 slugs/12 =
	=	10.25 lbm (lb sec^2 /in)
t_1	=	Time at missile impact
t_2	=	Time at conclusion of deformation phase
v_1	=	Velocity of missile at impact = 126 mph = 185 ft/sec
v_2	=	Velocity of missile at time t_2

The change in angular momentum of the cask, about the bottom outside edge/rim, opposite the side of impact is:

$$\int_{t_1}^{t_2} (M_c)(dt) = \int_{t_1}^{t_2} (H)(F)\, dt = I_m(\varpi_1 - \varpi_2)$$

Thus, $\int (F)(dt) = M_M(v_2 - v_1) = I_m(\varpi_1 - \varpi_2)/H$

where:

M_c = Moment of the impact force on the cask

I_m = Storage cask mass moment of inertia, about point of rotation on the bottom rim

ϖ_1 = Angular velocity at time t_1

ϖ_2 = Angular velocity at time t_2

M_{VCC} = Mass of the VCC cask = W_{VCC}/g

= 6,400 slugs/12 = 533.4 lbm (lb sec^2 /in)

I_{mx} = Mass moment of inertia of VCC cask about x axis through center of gravity

$\cong 1/12(M_{VCC})(3r^2 + H^2)$

$\cong (1/12)(533.4)\,[(3)(64)^2 + (160)^2] = 1.684 \times 10^6$ in^2 lbm

I_m = $I_{mx} + (M_{VCC})(d_{CG})^2$, where: d_{CG} is the distance (105 inches) between the cask CG and a rotation point on base rim

Thus, $I_m \cong 1.684 \times 10^6 + (533.4)(105)^2$

$= 7.565 \times 10^6$ in^2 lbm

Based on conservation of momentum, the impulse of the impact force on the missile is equated to the impulse of the force on the cask.

$M_M(v_2 - v_1) = I_m(\varpi_1 - \varpi_2)/H$,

at time t_1, v_1 = 185 ft/sec and ϖ_1 = 0 rad/sec

at time t_2, = v_2 = 0 ft/sec based on the following:

During the restitution phase, the final velocity of the missile will depend upon the coefficient of restitution of the missile, the geometry of the missile and target, the angle of incidence, and on the amount of energy dissipated in deforming the missile and target. It is assumed, based on tests conducted by EPRI (Ref. EPRI Report NP-440), that the final velocity of the missile, v_f,

following the impact is zero. If it is conservatively assumed that all of the missile energy is transferred to the cask:

Then: $(10.25)(v_2 - 185 \text{ ft/sec} \times 12 \text{ in/ ft}) = 7.565 \times 10^6 \text{ in}^2\text{-lbm } (0 - \varpi_2)/160$

Setting $v_2 = 0$ and solving for ϖ_2,

$\varpi_2 = 0.481$ rad/sec

and $v_2 = 205\, \varpi_2$

Then, $v_2 = (205)(0.481) = 98.6$ in/sec

Equating the impulse of the force on the missile during restitution to the impulse of the force on the cask yields:

$-[M(v_f - v_2] = I_m(\varpi_f - \varpi_2)/H$

With: $v_f = 0$, $v_2 = 98.6$ in/sec and $\varpi_2 = 0.481$ rad/sec

Then: $-[10.25(0 - 98.6)] = 7.565 \times 10^6 \text{ in}^2\text{-lbm } (\varpi_f - 0.481)/160$

$\varpi_f = 0.502$ rad/sec

Thus, the final energy of the cask following the impact, E_k, is:

$E_k = (I_m)(\varpi_f)^2/(2)$

$= (7.565 \times 10^6)(0.502)^2/(2)$

$E_k = 9.53 \times 10^5$ in-lb_f

The energy required to overturn cask must be equal to or greater than its potential energy, E_p:

$E_p = (W_{VCC})(h_{PE})$

$E_p = 206{,}100$ lbs $\times$ 21.77 in

$E_p = 4.487 \times 10^6$ in-lb_f

The high energy tornado generated missile imparts insufficient kinetic energy to produce a cask overturning due to the missile impact.

Combined Tornado Wind and Missile Yankee-MPC Loading (High Energy Missile)

The cask rotation due to the heavy missile impact is calculated as:

$$h_{EK} = E_k / W_{VCC} = 9.53 \times 10^5 \text{ in-lb}_f / 20\,6{,}100. \text{ lbs} = 4.63 \text{ in}$$

Then:

$$\cos\beta = (h_{CG} + h_{KE}) / d_{CG}$$
$$\cos\beta = (83.2 + 4.63) / 104.97 = 0.8367$$
$$\beta = 33.21 \text{ deg}$$

$$\cos\alpha = 83.2 / 104.97 = 0.7926$$
$$\alpha = 37.57 \text{ deg}$$

$$e = d_{CG} \sin\beta$$
$$e = 104.97 \sin 33.21 = 57.49 \text{ in}$$

Thus, cask rotation after impact = $\alpha - \beta = 37.57 - 33.21 = 4.36$ deg

Available gravity restoration moment after missile impact = $(W_{VCC})(e)$

= 206,100 lb x 57.49 in / 12 =
987,391 ft-lb >> Tornado Wind Moment = 157,267. ft-lb

Therefore, the combined effects of tornado wind loading and the high energy missile impact loading will not overturn the cask.

Local Shear Strength Capacity of the Yankee-MPC Concrete Shell (High Energy Missile)

This section evaluates the shear strength of the concrete at the top edge of the concrete shell due to a high energy missile impact based on ACI 349-85, Chapter 11, Section 11.11.2.1, on concrete punching shear strength.

The force developed by the missile using the methodology presented in Topical Report, BC-TOP-9A, is:

$$F = 0.625(v)(W_M)$$

$F = 0.625(185\ ft/sec)(3960\ lbs) = 457.8\ kips$

$F_u = LF \times F = 1.1 \times 457.8 = 503.6\ kips$

Based on a rectangular missile contact area, having proportions of 2 horizontal to 1 vertical and the top of the area flush with the top of the concrete cask, the required missile contact area based on the concrete punching shear strength, neglecting reinforcing is:

$V_c = (2+4/\beta_c)\,(f_c')^{1/2} b_o\, d$, where $\beta_c = 2/1 = 2$

$V_c = 4\,(f_c')^{1/2} b_o\, d$

$d = 21in - 3\ in = 18\ in$

$(f_c')^{1/2} = 63.24$ psi, where $f_c' = 4{,}000$ psi

b_o = perimeter of punching shear area at d/2 from missile contact area

$b_o = (2b + 18) + 2(b + 9) = 4b + 36$

$V_u = \Phi(V_c + V_s)$, where $V_s = 0$, assuming no steel shear

$V_u = \Phi V_c = \Phi\, 4\,(f_c')^{1/2} b_o\, d = (.85)(4)(63.24)(4b + 36)(18)$

$= 15{,}481\ b + 139{,}330.$

Setting, V_u equal to F_u and solving for b:

$503.6 \times 10^3 = 15{,}481\ b + 139{,}330$

$b = 23.53$ inches (say 2.0 ft)

The implied missile impact area required $= 2b \times b = 2 \times 2 \times 2 = 8.0$ sq ft < 20.0 sq ft.

Thus, the concrete shell alone, based on the concrete conical punching strength and discounting the steel reinforcement and shell, has sufficient capacity to react to the high energy missile impact force.

The effects of tornado winds and missiles have been considered both separately and combined in accordance with NUREG-800, Section 3.3.2 II.3.d. For the case of tornado wind plus missile loading, the stability of the cask has been assessed and found to be acceptable. Equating the kinetic energy of the cask following missile impact to the potential energy yields a maximum postulated rotation of the cask, as a result of the impact, of 4.36 degrees. Applying the total tornado wind load to the cask in this configuration results in an available restoring moment considerably greater than the tornado wind overturning moment. Therefore, overturning of the

cask under the combined effects of tornado winds, plus tornado-generated missiles, does not occur.

11.2.13.2.1.3 Tornado Effects on the Yankee-MPC Canister

The postulated tornado wind loading and missile impacts are not capable of overturning the cask, or penetrating the boundary established by the concrete cask. Consequently, there is no effect on the canister.

11.2.13.2.2 Analysis of the Tornado Event for the CY-MPC

The CY-MPC concrete cask has the following properties that are considered in this evaluation:

h	=	Height = 190.6 in
D_o	=	Outside diameter of cask = 128 in
D_b	=	Base diameter of cask = 128 in
D_i	=	Inside diameter of concrete shell = 86 in
W_{VCC}	=	Weight of the fully loaded concrete cask = 251,771 lb
A_c	=	Cross section area of concrete shell = 7,059 in^2
I_c	=	Moment of inertia of concrete shell = 10.49×10^6 in^4
f_c'	=	Compressive strength of concrete shell = 4,000 psi
V	=	Maximum tornado wind speed = 360 mph
K	=	Velocity pressure exposure coefficient = 1.0
I	=	Importance factor = 1.0
G	=	Gust factor = 1.0

11.2.13.2.2.1 Tornado Wind Loading of the CY-MPC Storage Cask

The tornado wind velocity is transformed into an effective pressure applied to the cask using procedures delineated in ANSI/ASCE 7-93 Building Code Requirements for Minimum Design Loads in Buildings and Other Structures. The maximum pressure, q, is determined from the maximum tornado wind velocity as follows:

$$q = 0.00256 \cdot K \cdot (I \cdot V)^2$$
$$q = 0.00256(1.0)(1.0 \times 360)^2 = 331.8 \text{ lb/ft}^2 .$$

Considering the cask is small with respect to the tornado radius, the velocity pressure is assumed uniform over the projected area of the cask. The total wind loading, F_w, on the projected area of the cask is:

$$F_w = q \times G \times C_f \times A_f = 29{,}230 \text{ lb},$$

where:

$$A_f = \text{Projected area of cask} = (187 \times 128) / 144 = 166.2 \text{ ft}^2,$$
$$C_f = \text{Force Coefficient} = 0.53.$$
$$\left(\begin{array}{l} \text{ASCE 7-93, Table 12 by interpolation:} \\ D \times q^{1/2} = \frac{128}{12} \times \sqrt{331.8} = 194.3 > 2.5 \text{ and } \frac{h}{D} = \frac{190.6}{128} = 1.49 \end{array} \right)$$

The wind overturning moment, M_w, is:

$$M_w = F_w \times \frac{h}{2} = 29{,}230 \times \frac{190.6}{2} \cong 2.8 \times 10^6 \text{ in-lb}$$

The stability moment, M_s, about the edge of the cask base is:

$$M_s = W_{vcc} \times \frac{D_b}{2} = 251{,}771 \times \frac{120}{2} \cong 15.1 \times 10^6 \text{ in-lb}$$

ASCE 7-93 requires that the overturning moment due to wind load shall not exceed two-thirds of the dead load stabilizing moment unless the structure is anchored. Therefore, the Factor of Safety, FS, against overturning is:

$$FS = \frac{(0.67)(15.1\times10^6)}{2.8\times10^6} = 3.61 > 1.1$$

with respect to the maximum tornado wind loading. A coefficient of friction of about 0.12 (29,230/251,771) between the concrete cask base and ISFSI support deck is required to inhibit sliding via friction.

The stresses in the concrete that result from tornado wind load are conservatively calculated. The maximum shear stress at the base surface is:

$$Fs = Fw/Ac = 29{,}230/7{,}059 = 4.14 \text{ psi}$$

Maximum stresses (tension or compression) occur at the base surface:

$$f_b = \frac{\left(M_w \times {}^{D_o}\!/_2\right)}{I_c} = \frac{\left(2.8e6 \times {}^{128}\!/_2\right)}{10.49e6} = 17.1 \text{ psi} \approx 20 \text{ psi}$$

where:

$$I_c = \frac{\pi}{64}\left(D_o^4 - D_i^4\right) = \frac{\pi}{64}\left(128^4 - 86^4\right) = 10.49\times10^6 \text{ in}^4$$

The compressive stresses are included in the load combination No. 8 in Table 3.4.4.4-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.4-1 and 3.4.4.4-2, the maximum combined stresses for the load combination of dead, live, thermal and tornado wind are below the allowable stress.

11.2.13.2.2.2 Tornado Missile Loading on the CY-MPC Storage Cask

The CY-MPC concrete cask is designed to withstand the effects of impacts associated with postulated tornado generated missiles identified in NUREG-0800, Section 3.5.1.4.III.4, Spectrum I missiles. Consisting of: 1) a high kinetic energy missile (4,000 lb automobile, with a frontal area of 20 square feet that deforms on impact); 2) a 275 lb, 8-inch diameter armor piercing artillery shell; and 3) a small 1-inch diameter solid steel sphere. All of these missiles are

assumed to impact in a manner that produces the maximum damage at a velocity of 126 mph (35 percent of the maximum tornado wind speed of 360 mph). The cask has been evaluated for impact effects associated with each of the above missiles.

The principal dimensions and moment arms used in this evaluation are shown in the following figure.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Overall Damage Prediction for a Tornado Missile Impact (High Energy Missile) on the CY-MPC

The concrete cask is a freestanding structure. Therefore, the principal consideration in overall damage response is the potential of upsetting or overturning the cask as a result of the impact of a high-energy missile. Based on the following analysis, it is concluded that the cask can sustain an impact from the defined high-energy missile and does not overturn.

From the principle of conservation of momentum, the impulse of the force from the missile impact on the cask must equal the change in angular momentum of the cask. Also, the impulse force due to the impact of the missile must equal the change in linear momentum of the missile. These relationships may be expressed as follows:

$$\int_{t1}^{t2} F(dt) = m_m(v_2 - v_1),$$

where:

F = impact impulse force on the missile,
m_m = mass of missile (4000 lb) =10.4 lb-sec^2/in,
t_1 = time at missile impact,
t_2 = time at conclusion of deformation phase,
v_1 = velocity of missile at impact = 126 mph = 185 ft/sec,
v_2 = velocity of missile at time t_2.

The change in angular momentum of the cask, about the bottom outside edge, opposite the side of impact is:

$$\int_{t1}^{t2} M_c(dt) = \int_{t1}^{t2} h \cdot F(dt) = I_m(\omega_1 - \omega_2),$$

$$m_m(v_2 - v_1) = \frac{I_m(\omega_1 - \omega_2)}{h},$$

where:

M_c = moment of the impact force on the cask,
I_m = cask mass moment of inertia about the point of rotation on the bottom edge,
ω_1 = angular velocity at time t_1,
ω_2 = angular velocity at time t_2,
m_c = mass of the cask (251,771 lbs) = 651.6 lb sec^2/in,
I_{mx} = mass moment of inertia of the cask about the x-axis through the cask C.G,

$$= \frac{1}{12} m_c(3r^2 + h^2) \cong \frac{1}{12}(651.6)(3(64)^2 + 190.6^2) = 2.64 \times 10^6 \text{ lb sec}^2/\text{in}.$$

Solving for the mass moment of inertia about the point of rotation on the bottom edge:

$$I_m = I_{mx} + m_c(d_{cg})^2 = 2.64e6 + 651.6 \times 115.3^2 = 11.31 \times 10^6 \text{ lb-sec}^2/\text{in.}$$

where:

d_{cg} = the distance between the cask CG and rotation point on its base rim

$= \sqrt{60^2 + 98.5^2} = 115.3 \text{ in.}$

Conservatively assuming the missile impacts in line with the top edge of the cask, the impulse of the missile impact force is equal to the impulse of the force on the cask to yield:

$$m_m(v_2 - v_1) = I_m(\omega_1 - \omega_2)/h.$$

At time t_1: $v_1 = 185$ ft/sec and $\omega_1 = 0$ rad/sec.

At time t_2: $v_2 = 0$ ft/sec based on the following.

During the restitution phase, the final velocity of the missile depends upon the coefficient of restitution of the missile, the geometry of the missile and target, the angle of incidence, and upon the amount of energy dissipated in deforming the missile and target. Based upon tests conducted at EPRI, the final velocity of the missile, v_f, following the impact is zero. Conservatively assuming that all the missile's energy is transferred to the cask:

$$10.4(v_2 - 185 \times 12) = {11.31e6(0 - \omega_2)}/{190.6}$$

Setting $v_2 = 0$ and solving for ω_2:

$$\omega_2 = 0.389 \text{ rad/sec.}$$

The distance from the point of missile impact to the point of cask rotation is:

$$d_m = \sqrt{124^2 + 190.6^2} = 227.4 \text{ in.}$$

Therefore,

$$v_2 = d_{mr} \times \omega_2 = 227.4 \times 0.389 = 88.5 \text{ in/sec}.$$

Equating the impulse of the force on the missile during restitution to the impulse of the force on the cask yields:

$$-[m_m \times (v_f - v_2)] = {I_m(\omega_f - \omega_2)}/{h}$$

$$-[10.4(0 - 88.5)] = {11.31e6(\omega_f - 0.389)}/{190.6}$$

$$\omega_f = 0.404 \text{ rad/sec}$$

where:

v_f = 0

v_2 = 88.5 in/sec

ω_2 = 0.389 rad/sec

The final energy, E_k, of the cask following the impact is:

$$E_k = {I_m(\omega_f)^2}/{2} = {11.31e6(0.404)^2}/{2} = 9.23 \times 10^5 \text{ in - lb}.$$

The change in potential energy, E_p, of the cask due to rotating it until its center of gravity is above the point of rotation (the condition where the cask will begin to tip over) is:

$$E_p = (W_c)(h_{PE}) = (251{,}771 \text{ lb})(16.8 \text{ in}) = 4.23 \times 10^6 \text{ in - lb},$$

where:

$$h_p = d_{cg} - VCC_{cg} = 115.3 - 98.5 = 16.8 \text{ in}.$$

The massive high kinetic energy tornado-generated missile imparts less kinetic energy than the change in potential energy of the cask at the tip over point. Therefore, cask overturning from missile impact is not postulated to occur. Considering that the overturning moment must not exceed two-thirds the restoring stability moment, the factor of safety is:

$$FS = \frac{0.67 \times 4.23E6}{9.23E5} = 3.07.$$

Local Shear Strength Capacity of the CY-MPC Concrete Shell (High Energy Missile)

The shear strength of the concrete shell required to react the force of the high kinetic energy missile impact, is evaluated in accordance with ACI-349-85, Chapter 11, Section 11.11.2.1.

The force, F, developed by the missile having a frontal area of 20 ft^2 is determined by using the methodology presented in Topical Report, BC-TOP-9A. For conservatism, a 10% load factor is added to the calculated value.

$$F = 0.625(v)(W_m) = 0.625(185 \text{ ft/sec})(4{,}000 \text{ lb}) = 462.5 \text{ kip}$$
$$F_u = LF \times F = 1.1 \times 462.5 = 508.8 \text{ kip}$$

Based on a rectangular missile contact area, having proportions of 2 horizontal to 1 vertical and the top of the area flush with the top of the concrete cask, the required missile contact area based on the concrete punching shear strength, neglecting reinforcing is:

$$V_c = (2+4/\beta_c)\,(f_c')^{1/2} b_o\, d, \text{ where } \beta_c = 2/1 = 2$$
$$= 4\,(f_c')^{1/2} b_o\, d$$
$$d = 21 \text{ in} - 3 \text{ in} = 18 \text{ in}$$
$$(f_c')^{1/2} = 63.24 \text{ psi, where } f_c' = 4{,}000 \text{ psi}$$
$$b_o = \text{perimeter of punching shear area at d/2 from missile contact area}$$
$$= (2b + 18) + 2(b + 9) = 4b + 36$$
$$V_u = \Phi(V_c + V_s), \text{ where } V_s = 0, \text{ assuming no steel shear}$$
$$\Phi V_c = \Phi\, 4\,(f_c')^{1/2} b_o\, d = (0.85)(4)(63.24)(4b + 36)(18) = 15{,}481\, b + 139{,}330.$$

Setting V_u equal to F_u and solving for b:

$$508{,}800 = 15{,}483\, b + 139{,}343$$
$$= 23.86 \text{ in.} \approx 2.0 \text{ ft.}$$

The concrete area, A, required to resist shearing by the missile impact is:

$$A = 2b(b) = 8.0 \text{ ft}^2 < 20 \text{ ft}^2.$$

Thus, the concrete shell alone, based on the concrete conical punching strength and discounting the steel reinforcement and shell, has sufficient capacity to react to the high energy missile impact force.

CY-MPC Concrete Shell Local Damage Prediction (Penetration Missile)

Local damage to the cask body has been assessed using the National Defense Research Committee (NDRC) formula. This formula has been selected as the basis for predicting depth of penetration and minimum concrete thickness requirements to prevent scabbing. Penetration depths calculated using this formula have been shown to provide reasonable correlation with test results (EPRI Report NP-440, Section 4 "Local Response Evaluation").

Missile penetration depth, x, into the concrete shell is calculated using the following equation, which is valid for $x/2d \leq 2.0$.

$$x = \sqrt{4KNW(d)^{-0.8}(V/1000)^{1.8}} = 5.75 \text{ in}$$

where:

d = missile diameter = 8.0 inch,
K = coefficient depending on concrete strength $= 180/(f_c')^{1/2} = 2.846$,
N = shape factor for sharp nosed missiles = 1.14,
W = missile weight = 280 lb,
V = missile velocity = 126 mph = 185 ft/sec,
f_c' = concrete compressive strength = 4000 psi

Since

$$\frac{x}{2d} = \frac{5.75}{2(8.0)} = 0.359 < 2.0,$$

The minimum concrete shell thickness required to prevent scabbing is three times the penetration depth of 5.75 inch or 3(5.75) = 17.25 inch. The concrete shell wall thickness is 21.0 inch, which is greater than the thickness required to prevent damage due to the tornado-generated missile. This analysis conservatively neglects the 3.5-inch steel shell at the inside face of the concrete shell. The factor of safety is:

$$FS = \frac{21.0}{17.25} = 1.22 > 1.10$$

CY-MPC Closure Plate Local Damage Prediction (Penetration Missile)

The concrete cask is closed with a 1.5-inch thick steel plate bolted in place. The following missile penetration analysis shows that the 1.5-inch steel closure plate is adequate to withstand the impact of the 275 lb armor piercing missile, impacting at 126 mph.

The perforation thickness of the closure steel plate is calculated by the Ballistic Research Laboratories Formula with K=1, formula number 2-7, in Section 2.2 of Topical Report BC-TOP-9A, Revision 2.

$$t = \frac{\left[0.5(m_m)v^2\right]^{2/3}}{672d} = \frac{\left[0.5(8.70)(185)^2\right]^{2/3}}{672(8)} = 0.523 \text{ in.}$$

where:

m_m = missile mass = W/g = 280 lbs / 32.174 ft/sec^2 = 8.70 slugs.

BC-TOP-9A recommends that the plate thickness be 25% greater than the calculated thickness, t, to prevent perforation. Therefore, the recommended plate thickness is 1.25 x 0.523 in. = 0.654 in.

Since the closure plate is 1.5 inches thick, the plate is adequate to prevent perforation by the specified armor piercing missile with a factor of safety, FS, of:

$$FS = \frac{1.5}{0.654} = 2.29.$$

Small Missile Impact on Barrier Openings

The concrete cask has no openings except for the four outlets at the top and four inlets at the bottom of the cask. These openings are configured such that a 1-inch diameter solid steel missile cannot directly enter the concrete cask interior. In addition, the canister is protected from the inlet (bottom) openings by a steel pedestal (bottom plate), and from the outlet (top) openings by

the canister structural and shield lids. Therefore, a detailed analysis of the impact of a 1-inch diameter steel missile is not required.

Combined Tornado Wind and Missile Loading (High Energy Missile) on the CY-MPC

The cask rotation due to the heavy missile impact is calculated as:

$$h_{EK} = E_k / W_{VCC} = 9.23 \times 10^5 \text{ in-lbf} / 251{,}771 \text{ lb} = 3.67 \text{ in.}$$

Then,

$$\cos\beta = (h_{CG} + h_{KE}) / d_{CG} = (98.5 + 3.67) / 115.3,$$
$$\beta = 27.6°,$$
$$\cos\alpha = 98.5 / 115.3,$$
$$\alpha = 31.3°,$$
$$e = d_{CG} \sin\beta = 115.3 \times \sin 27.6° = 53.4 \text{ in.}$$

Therefore, the cask rotation after impact $= \alpha - \beta = 31.3 - 27.6 = 3.7°$.

Available deadweight restoration moment, M_{dr}, after missile impact, $M_{dr} = W_c \times e$

$$M_{dr} = 251{,}771 \times 53.4 = 13.44 \times 10^6 \text{ in-lb}$$
$$M_w = \text{tornado wind moment} = 2.8 \times 10^6 \text{ in-lb}$$

Since $M_{dr} > M_w$, the combined effects of tornado wind loading and the high energy missile impact loading will not overturn the cask.

The effects of tornado winds and missiles have been considered both separately and combined in accordance with NUREG-800, Section 3.3.2 II.3.d. For the case of tornado wind plus missile loading, the stability of the cask has been assessed and found to be acceptable. Equating the kinetic energy of the cask following missile impact to the potential energy yields a maximum postulated rotation of the cask, as a result of the impact of 3.7 degrees. Applying the total tornado wind load to the cask in this configuration results in an available restoring moment considerably greater than the tornado wind overturning moment. Therefore, overturning of the cask under the combined effects of tornado winds, plus tornado-generated missiles, does not occur.

11.2.13.2.2.3 Tornado Effects on the CY-MPC Canister

The postulated tornado wind loading and missile impacts are not capable of overturning the cask, or penetrating the boundary established by the concrete cask. Consequently, there is no effect on the canister.

11.2.13.3 Radiological Consequences

This evaluation shows that there is little potential for significant damage to the concrete cask, which provides radiation shielding.

Under the worst tornado missile impact for the Yankee-MPC, a penetration of 5.68 inches into the concrete shield is possible. This would result in a local surface radiation dose rate at the point of penetration of 314 mrem/hr. Since the area of reduced shielding is very small, there would not be a noticeable increase in the dose rate at the site boundary. Repair of the damage would likely require two persons to setup forms in the damaged area and apply grout. This is estimated to require 30 minutes. The estimated extremity dose is 314 mrem. The whole body dose would be less. The extremity dose rate of clearing inlets and outlets has been estimated in Section 11.2.8.3 at a total of 336 mrem.

For the CY-MPC, the worst tornado missile impact is expected to result in a penetration of 5.75 inches into the concrete shield. This would result in a local surface radiation dose rate at the point of penetration of approximately 1,000 mrem/hr. This dose rate is based on multiplying the maximum side dose rate by a scaling factor equal to the Yankee-MPC accident to normal condition side dose rates (314/47.3). Since both systems have similar missile impact penetration and concrete material removed, the use of the scaling factor is appropriate. The CY-MPC penetration depth is 0.07 inches larger, but the conservatism inherent in the assumption of the removal of concrete from the entire surface of the storage cask compared to the small surface area actually impacted by the missile more than compensates for this difference. Since the area of reduced shielding is very small, there would not be a noticeable increase in the dose rate at the site boundary. Repair of the damage would likely require two persons to form the damaged area and apply grout. This is estimated to require 30 minutes. The estimated extremity dose is 1,000 mrem. The whole body dose would be less.

11.2.13.4 NAC-MPC Performance

The concrete cask is demonstrated to be stable in tornado wind loading in conjunction with impact from a high energy tornado missile. The performance of the NAC-MPC is not significantly affected by the tornado event.

The Yankee-MPC storage cask has a safety factor of 7.0 against overturning under the sustained maximum wind loading. The maximum concrete shell stresses under maximum tornado wind loading are 3.34 psi in shear and 11.51 psi in bending, which are well below their respective ACI 349-85 code allowables of 107.5 psi and 1,904 psi, respectively.

The concrete shell of the Yankee-MPC storage cask is more than three times thicker than the calculated missile penetration depth, which is adequate to prevent significant scabbing of the concrete.

The CY-MPC storage cask has a safety factor of 3.61 against overturning under the sustained maximum wind loading. The maximum concrete shell stresses under maximum tornado wind loading are 4.14 psi in shear and 20 psi in bending, which are well below their respective ACI 349-85 code allowables of 107 psi and 1,904 psi, respectively.

The concrete shell of the CY-MPC storage cask is more than three times thicker than the calculated missile penetration depth, which is adequate to prevent significant scabbing of the concrete.

11.2.13.5 Recovery and/or Corrective Actions

A tornado event is not expected to result in the need to take any corrective action other than an inspection of the ISFSI. This inspection would be directed at ensuring that inlets and outlets had not become blocked by wind-blown debris and at checking for obvious (concrete) surface damage.

As shown in the evaluation, in the worse case, a missile could dislodge concrete to a depth of approximately 6 inches. To repair the cask surface this area would need to be filled with grout. As noted, penetration to 6 inches is unlikely, since the reinforcing bar cage is encountered at a depth of 2 to 3 inches, depending on the location on the cask surface.

11.3 Design Basis Loading of the Yankee-MPC Transportable Storage Canister

The Transportable Storage Canister (canister) is designed to be stored in the Yankee-MPC storage cask and transported in the NAC Storage Transport Canister (NAC-STC). The NAC-STC is licensed to transport spent fuel in accordance with 10 CFR 71 and has been issued Certificate of Compliance Number 71-9235. An amendment to the Safety Analysis Report (SAR) for the NAC-STC has been approved, in conjunction with this Safety Analysis Report for storage of Yankee class fuel, to include the loaded Yankee-MPC canister as authorized contents.

The load condition imposed on the canister and its basket by the transport conditions—including the 30 foot end and side impacts and the fire accident—are more rigorous than those imposed by design basis storage normal, off-normal and accident conditions.

Sections 11.1.2 and 11.2.11 use the results of analysis performed for transport end and side impact conditions to show adequate performance of the canister in the off-normal handling condition (Section 11.1.2) and of the canister and basket in the 6-inch concrete cask drop accident (Section 11.2.11). This section summarizes the transport analysis upon which the results of Sections 11.1.2 and 11.2.11 are based. The canister and basket are evaluated in accordance with ASME Code Section III, Subsection NB, and Subsection NG, respectively.

The complete evaluation of the transport normal and accident conditions loading on the canister and basket is presented in the NAC-STC SAR, Docket Number 71-9235. The design basis loading of the MPC-LACBWR transportable storage canister is evaluated in Section 11.A.3 of Appendix 11.A.

11.3.1 Yankee-MPC Canister Impact Analysis

The canister is a right-circular shell fabricated from rolled 5/8-inch thick, Type 304L stainless steel plate and closed by a 1-inch thick, Type 304L stainless steel plate that is welded to one end of the shell. The canister is closed at the top end by the installation and welding of the 5-inch thick, Type 304 stainless steel shield lid and the 3-inch thick, Type 304L stainless steel structural lid.

11.3.1.1 Yankee-MPC Canister Finite Element Model Description

A finite element model of the canister was constructed using ANSYS solid (SOLID45) elements. The model represents a one-half (180°) section of the canister and basket. The basket support discs were modeled with three-dimensional shell (SHELL63) elements. The model uses gap-spring elements to simulate contact between adjacent components. Interaction between the basket and canister were accomplished using three-dimensional gap elements (CONTACT52) along the periphery of the support disks. Contact between the canister and the cask inner shell is also modeled using CONTACT52 gap elements. Contact between the canister structural lid and shield lid is modeled using COMBIN40 combination elements in the axial degree of freedom. Simulation of the backing ring is accomplished using a ring of COMBIN40 spring gap elements connecting the shield lid and the canister in the axial direction at the lid lower outside radius. In addition, CONTACT52 elements are used to model interaction between the structural lid and canister shell and the shield lid and canister shell just below the respective lid weld joints. The size of the CONTACT52 gaps were determined from the nominal dimensions of contacting components. The COMBIN40 elements used between the structural and shield lids and for the backing ring were assigned small gap sizes of 1E-8 inches. All gap-spring elements are assigned a stiffness of 1E8 lb/in.

Boundary conditions were applied to enforce symmetry at the plane of symmetry of the model. All nodes on the cask shell side of the canister to cask spring gap elements were fixed in all degrees of freedom. In addition, the axial and inplane rotational degrees of freedom of the basket nodes were fixed.

Figure 11.3.1.1-1 is a plot of the entire canister finite element model. An isolated view of the canister shield and structural lids portion of the model is presented in Figure 11.3.1.1-2 and an enlarged view of the model in the structural lid and shield lid weld regions is shown in Figure 11.3.1.1-3. The canister bottom plate portion of the model is shown in Figure 11.3.1.1-4. Identification of the sections for evaluating the linearized stresses in the canister is shown in Figure 11.3.1.1-5.

In the bottom end impact orientation, the fuel weight as well as the basket weight are transferred to the canister bottom plate. In the finite element model, the canister content weight is represented by applying a pressure load to the surface of the canister bottom plate. The support

disks inside the canister as shown in Figure 11.3.1.1-1 are set to be in-active for the bottom end impact analysis. The canister bottom plate is considered to be fully supported.

For the side impact condition, the loads from the canister contents weight is transferred through the support disks into the canister wall, which is considered to be backed by a rigid shell support of 71.0 inside diameter. The basket, canister and the assumed support shell have different radii, which implies that the contact angle between the components is dependent on the loading. Gap elements between the basket and the canister allow the interface to be dependent on the loading. The interface between the canister and the support shell is also represented by gap elements. The load due to the contents is applied to the basket via pressure acting in the plane of the disks. The weight is assumed to act over the effective width of 8.254 inches in which the disk is 0.5 inches thick. The content weight includes the 900 pounds per fuel assembly (for 36 fuel assemblies) plus the fuel tube weight (58.6 pounds/tube). This weight is distributed over the 22 support disks.

Use of the minimum size gap between the transportable storage canister structural and shield lids, 1×10^{-8} inch, results in the maximum stress and minimum margin of safety for the transportable storage canister impact analysis. Use of the maximum gap size (0.08 inches) results in a reduced margin of safety in some section locations, but does not result in the maximum stress / lowest margin of safety condition.

Figure 11.3.1.1-1 Yankee-MPC Canister Assembly Finite Element Model

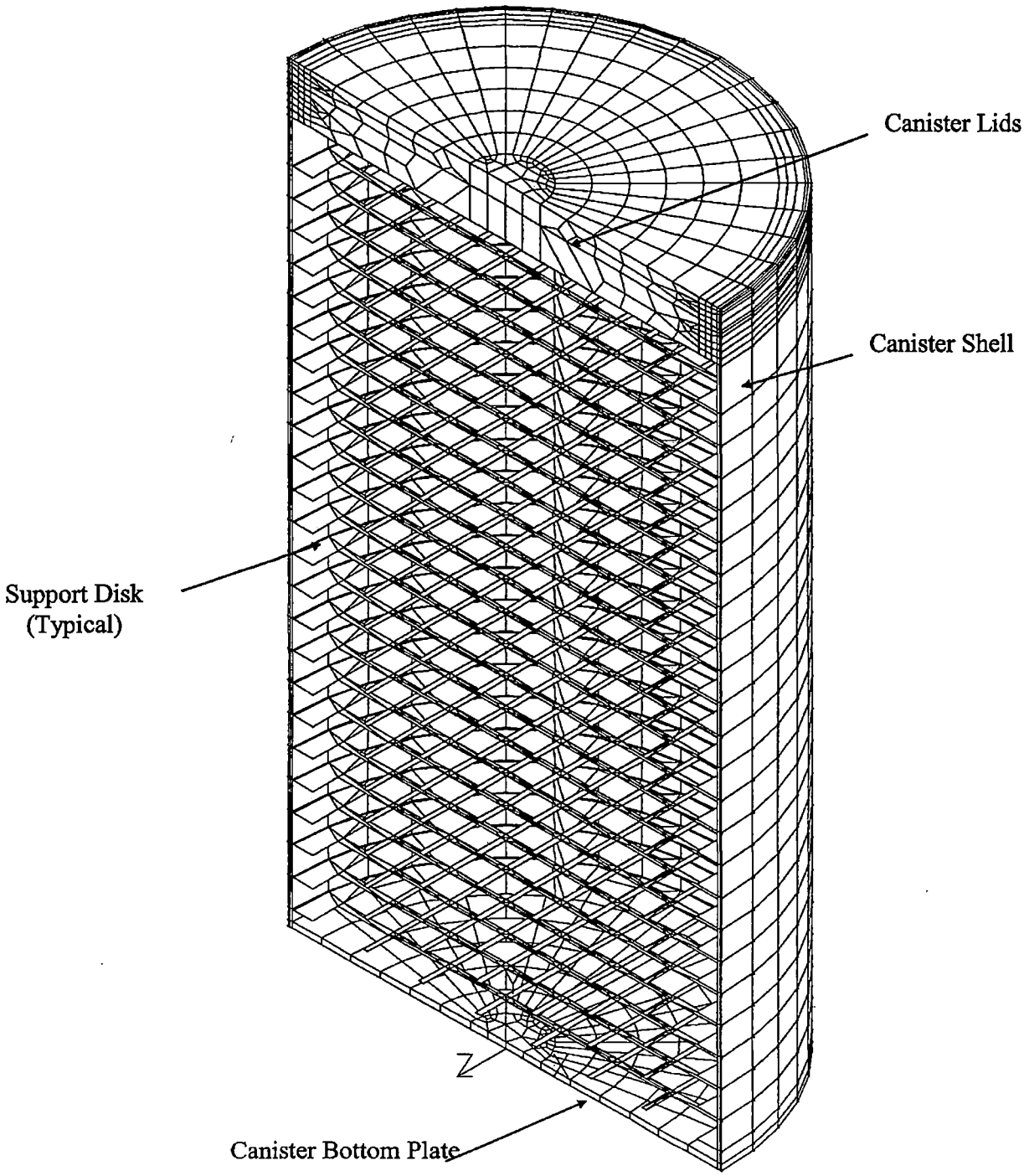


Figure 11.3.1.1-2 Yankee-MPC Canister Structural and Shield Lid Finite Element Mesh

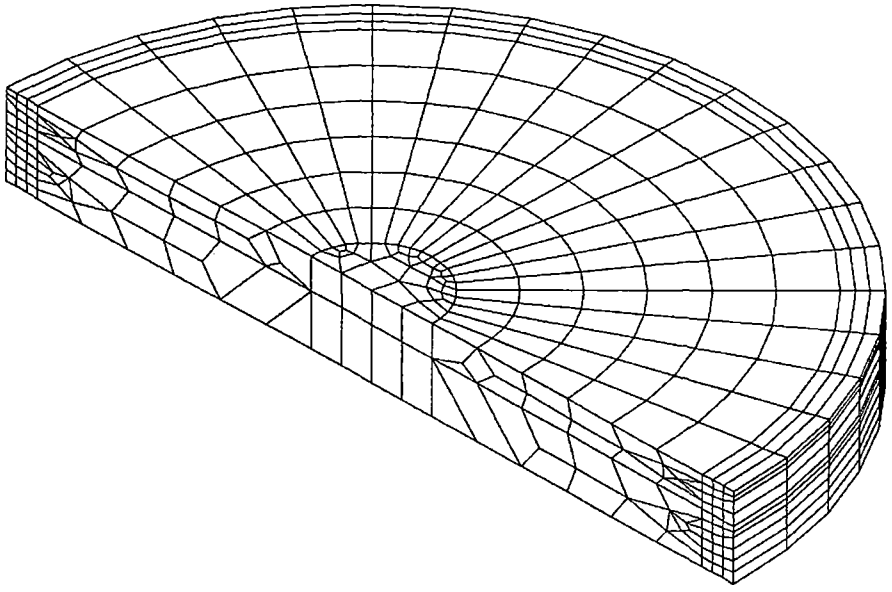


Figure 11.3.1.1-3 Structural and Shield Lid Weld Regions Finite Element Mesh

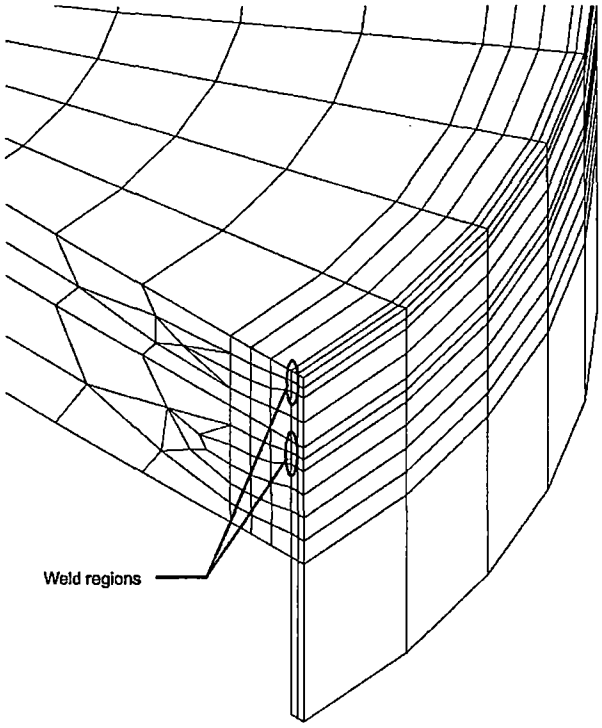


Figure 11.3.1.1-4 Canister Bottom Plate Finite Element Mesh

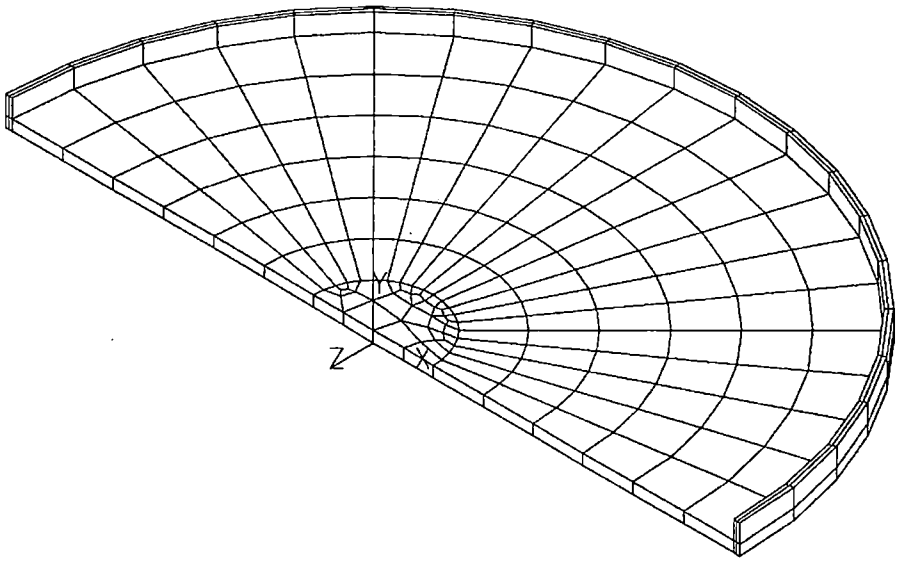
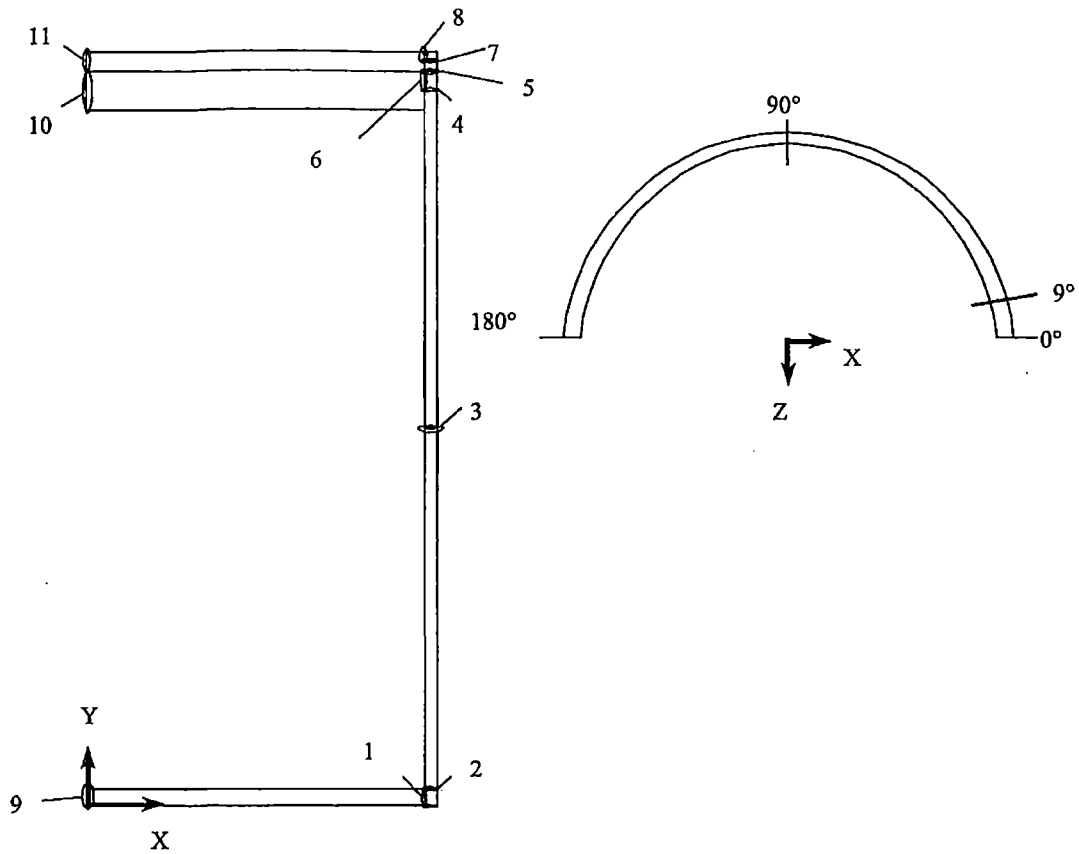


Figure 11.3.1.1-5 Identification of the Sections for Evaluating the Linearized Stresses in the Canister



Section	Node 1		Node 2	
	X (in.)	Y (in.)	X (in.)	Y (in.)
1	34.695	0.000	34.695	1.000
2	34.695	1.000	35.320	1.000
3	34.695	57.269	35.320	57.269
4	34.695	118.000	35.320	118.000
5	34.695	119.000	35.320	119.000
6	34.695	118.000	34.695	119.000
7	34.695	121.120	35.320	121.120
8	34.695	121.120	34.695	122.000
9	0.000	0.000	0.000	1.000
10	0.000	114.000	0.000	119.000
11	0.000	119.000	0.000	122.000[1]

1. The actual length of the canister is 122.5 inches. There is no significant effect on the analysis results due to the 0.5-inch difference in the evaluated length and the actual canister length.

11.3.1.2 Yankee-MPC Canister Bottom and Side Impact Analysis

This section documents the evaluation of the canister for the 56.1 g bottom end impact and 55 g side impact load conditions. In addition to the impact loads, a 20 psig pressure load internal to the canister is considered. Note that the use of 20 psig is conservative, since the maximum internal pressure for the canister is 7.9 psi for normal conditions of storage. To determine the effect of the 20 psig pressure load, analyses with and without the pressure load were performed. The maximum nodal stresses are summarized as:

Impact Orientation	Internal Pressure (psi)	Maximum Stress Intensity (ksi)
Bottom End	0	4.6
Bottom End	20	3.0
Side	0	24.5
Side	20	27.1

It is concluded that the impact loading without pressure is the limiting condition for the bottom end impact case. For the side impact case, the addition of pressure to the impact loading is limiting. Therefore, a 20 psig pressure is conservatively applied to the inner surface of the canister model for the side impact conditions, while no internal pressure is used for the bottom end impact analyses.

The analysis results of the 56.1 g bottom impact conditions are presented in Tables 11.3.1.2-1 and 11.3.2-2. Results for the 55 g side impact condition are shown in Tables 11.3.1.2-3 and 11.3.1.2-4. The section stresses presented in the tables are identified by a section number. A cross-section of the canister showing the section numbers is presented in Figure 11.3.1.1-5. A summary of the canister minimum Margins of Safety for the evaluated impact conditions are shown in Table 11.3.1.2-5. The margins of safety are calculated as: M.S. = (allowable stress/S.I.) –1, where S.I. is the calculated stress intensity.

For the bottom end impacts, the stresses are essentially uniform around the circumference. For the side impact, the stresses vary around the circumference. Therefore, the circumferential angle at which the maximum stress occurs is noted in the table, in parentheses beside the section number. The allowable stresses presented in the tables are for Type 304L stainless steel, except for section 10, which is for Type 304 stainless steel. These allowables are evaluated at 350°F (maximum calculated temperature in the canister is 319°F for normal conditions of storage).

Additionally, stress results for a 20 g bottom end impact and a 20 g side impact are listed in Table 11.3.1.2-6 through 11.3.1.2-9. Since the results are bounded by those of the 56.1 g bottom end impact and the 55 g side impact conditions, the stresses are listed without showing the Margin of Safety.

Table 11.3.1.2-1 Canister Analysis Results for the 56.1 g Bottom End Impact (Primary Membrane Stress)

Section[1]	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1	-70.7	-1971.0	-361.1	176.2	70.3	22.4	-51.8	-360.9	-1990.0	1938.0	39000	19.12
2	289.7	-5185.0	-1182.0	91.4	54.3	94.4	297.4	-1187.0	-5187.0	5485.0	39000	6.11
3	2.1	-4867.0	0.9	0.0	0.2	0.0	2.1	0.9	-4867.0	4869.0	39000	7.01
4	-2131.0	-2251.0	-1084.0	0.0	734.3	0.0	-729.3	-2131.0	-2605.0	1876.0	39000	19.79
5	2510.0	-2096.0	-1535.0	-310.9	-0.9	278.1	2549.0	-1553.0	-2117.0	4667.0	39000	7.36
6	551.9	1897.0	-676.0	15.4	84.7	-106.6	1900.0	561.0	-688.0	2588.0	39000	14.07
7	-3028.0	979.9	-1533.0	-368.1	39.6	55.9	1014.0	-1531.0	-3063.0	4077.0	39000	8.57
8	588.3	-3496.0	-2019.0	466.6	119.6	210.4	659.5	-2031.0	-3554.0	4214.0	39000	8.25
9	82.5	-682.0	94.2	6.5	58.3	-0.5	98.5	82.5	-686.4	785.0	39000	48.68
10	183.8	-98.9	168.1	43.7	-77.1	5.7	195.2	183.5	-125.7	320.9	45640	141.22
11	-469.6	-9.4	-467.5	48.0	-75.2	-1.2	7.4	-470.1	-483.8	491.2	39000	78.40

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-2 Canister Analysis Results for the 56.1 g Bottom End Impact (Primary Membrane Plus Primary Bending Stress)

Section[1]	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1	398.0	-2678.0	-380.7	125.9	67.7	37.0	405.2	-380.8	-2685.0	3090.0	58500	17.93
2	-1988.0	-7553.0	85.1	0.0	-32.4	0.0	85.2	-1988.0	-7553.0	7638.0	58500	6.66
3	2.1	-4867.0	2.9	1.1	0.4	-0.1	3.0	2.1	-4867.0	4870.0	58500	11.01
4	-2259.0	-3096.0	-704.5	0.0	805.1	0.0	-458.8	-2259.0	-3342.0	2883.0	58500	19.29
5	1450.0	-10380.0	-4379.0	304.5	3.7	410.7	1486.0	-4407.0	-10390.0	11880.0	58500	3.92
6	3324.0	5269.0	932.2	817.6	53.3	-170.6	5567.0	3041.0	917.1	4650.0	58500	11.58
7	-2361.0	8380.0	938.8	-472.4	41.6	196.1	8401.0	950.4	-2393.0	10790.0	58500	4.42
8	4403.0	-1585.0	-491.6	605.7	160.4	345.7	4490.0	-503.9	-1659.0	6149.0	58500	8.51
9	105.1	-686.4	100.3	8.1	60.4	-1.7	106.1	104.0	-691.1	797.2	58500	72.38
10	6941.0	230.8	6895.0	28.2	-72.6	35.9	6960.0	6876.0	229.9	6730.0	65200	8.69
11	-4093.0	-195.3	-4098.0	47.4	-79.5	-18.6	-193.1	-4079.0	-4115.0	3922.0	58500	13.92

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-3 Canister Analysis Results for the 55 g Side Impact + Internal Pressure (20 psi) (Primary Membrane Stress)

Section[1]	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1(0°)	-14680.4	1080.1	-9311.6	-235.5	-21.1	-904.6	1083.2	-9163.7	-14827.2	15917.7	39000	1.45
2(0°)	-3395.4	62.4	-7415.7	-314.3	-438.9	-478.6	111.6	-3358.7	-7501.7	7612.8	39000	4.12
3(180°)	-4.6	-1213.2	586.7	0.1	-4.0	-45.8	590.3	-8.1	-1213.2	1802.5	39000	20.64
4(9°)	-16945.4	3043.0	-4750.2	-336.0	2851.1	2020.7	3978.4	-5329.0	-17301.9	21276.1	39000	0.83
5(0°)	-10863.5	1232.1	-7804.7	-1756.4	1333.8	92.4	1662.0	-7961.0	-11146.6	12803.4	39000	2.05
6(0°)	-23467.7	-3813.8	-11125.6	-2768.3	1168.1	38.0	-3262.2	-11293.4	23855.7	20594.5	39000	0.89
7(9)	-11503.1	654.7	-4158.7	-31.6	1865.5	961.7	1299.2	-4673.6	-11639.5	12939.7	39000	2.01
8(0°)	-19367.6	-4979.8	-8614.2	-982.6	865.8	-756.5	-4697.7	-8785.2	-19472.5	14774.8	39000	1.64
9	-2146.5	-15.3	1105.2	-2.9	-14.7	-78.0	1107.3	-15.5	-2148.6	3255.9	39000	10.98
10	-1032.3	-8.4	331.8	-59.4	-2.9	-27.1	332.3	-4.9	-1036.3	1368.4	45640	32.35
11	-1131.4	-1.3	373.3	-25.5	-5.1	-32.8	374.1	-0.7	-1132.5	1506.8	39000	24.88

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-4 Canister Analysis Results for the 55 g Side Impact + Internal Pressure (20 psi) (Primary Membrane Plus Primary Bending Stress)

Section[1]	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1(0°)	-24841.3	457.1	-12761.5	-195.8	106.1	-824.5	459.5	-12709.0	-24904.3	25365.6	58500	1.31
2(0°)	-2630.9	-1326.5	-8993.8	-290.8	-641.0	-126.3	-1218.5	-2682.3	-9050.5	7832.0	58500	6.47
3(0°)	89.9	2039.5	3198.2	2.7	38.7	156.9	3207.7	2038.5	81.9	3125.9	58500	17.71
4(9°)	-13894.0	9446.8	-2019.6	93.3	2241.9	2829.1	9886.2	-1813.0	-14533.6	24421.9	58500	1.40
5(0°)	-14261.0	2077.3	-6923.9	-2052.1	1046.5	-15.1	2446.4	-7037.2	-14512.6	16966.3	58500	2.45
6(0°)	-32968.0	-7832.0	-15215.2	-4140.9	1477.5	185.3	-6920.8	-15456.4	-33639.1	26718.3	58500	1.19
7(9°)	-9079.8	4969.3	-1993.4	53.6	1402.0	1674.6	5250.3	-1894.8	-9460.5	14711.9	58500	2.98
8(0°)	-28144.4	-7245.8	-12646.1	-2107.7	1351.6	-307.9	-6716.3	-12971.2	-28354.1	21643.1	58500	1.70
9	-2172.7	-33.2	1088.4	-2.9	-14.9	-75.6	1089.5	-33.5	-2174.8	3264.3	58500	16.92
10	-1360.0	-10.9	297.9	-63.0	-2.9	-40.8	299.0	-8.0	-1364.2	1663.1	65200	38.20
11	-1344.3	-1.2	354.1	-25.6	-5.0	-39.5	355.1	-0.7	-1346.4	1700.8	58500	33.40

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-5 Summary of Minimum Margin of Safety for Canister Impact Analysis

Drop Orientation	Loading Condition	Stress Evaluated	Minimum Margin of Safety	Section No.*
Bottom end	56.1 g impact	P_m	6.11	2
Bottom end	56.1 g impact	$P_m + P_b$	3.92	5
Side	55 g impact + internal pressure (20 psi)	P_m	0.83	4
Side	55 g impact + internal pressure (20 psi)	$P_m + P_b$	1.19	6

* See Figure 11.3.1.1-5 for section locations.

Table 11.3.1.2-6 Bottom End Impact (20 g) - Primary Membrane Stresses[1]

Section	P_m Stresses (psi)						Principal Stresses (psi)			
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	-25.3	-704.5	-129.2	63.1	25.1	8.0	-18.5	-129.1	-711.3	692.8
2	103.7	-1854.0	-422.7	32.7	19.4	33.8	106.4	-424.7	-1855.0	1961.0
3	0.8	-1740.0	0.3	0.0	0.1	0.0	0.8	0.3	-1740.0	1741.0
4	-760.4	-800.7	-389.0	0.0	263.2	0.0	-260.7	-760.4	-929.1	668.4
5	905.9	-756.4	-546.9	-107.1	0.2	99.9	919.5	-553.5	-763.5	1683.0
6	196.5	704.2	-233.2	5.1	30.5	-37.5	705.2	199.7	-237.4	942.6
7	-1072.0	339.2	-546.8	-127.7	13.9	19.5	350.9	-546.2	-1084.0	1435.0
8	207.7	-1240.0	-718.6	162.8	42.2	74.7	232.4	-723.0	-1260.0	1493.0
9	29.5	-243.2	33.7	2.3	20.8	-0.2	35.3	29.5	-244.7	280.0
10	70.7	23.7	69.5	16.0	-20.2	0.7	80.9	71.0	12.1	68.8
11	-161.1	50.4	-157.0	16.1	-39.4	-1.4	58.9	-161.5	-165.1	223.9

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-7 Bottom End Impact (20 g)-Primary Membrane Plus Primary Bending Stresses[1]

Section	$P_m + P_b$ Stresses (psi)						Principal Stresses (psi)			
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	142.5	-957.2	-136.2	45.1	24.2	13.3	145.1	-136.2	-959.7	1105.0
2	-711.1	-2701.0	30.4	0.0	-11.5	0.0	30.5	-711.1	-2701.0	2731.0
3	0.8	-1741.0	1.0	0.4	0.1	0.0	1.053	0.8	-1741.0	1742.0
4	-808.8	-1111.0	-254.6	0.0	290.6	0.0	-165.3	-808.8	-1200.0	1035.0
5	522.1	-3735.0	-1569.0	111.2	1.6	147.5	535.4	-1580.0	-3738.0	4273.0
6	1194.0	1910.0	344.1	288.9	19.6	-60.7	2012.0	1097.0	338.7	1674.0
7	-838.6	2970.0	331.1	-166.6	14.8	69.5	2977.0	335.2	-850.0	3827.0
8	1555.0	-560.8	-178.8	213.3	56.8	122.6	1586.0	-183.1	-587.0	2173.0
9	37.6	-244.7	35.9	2.9	21.5	-0.6	38.0	37.2	-246.4	284.4
10	2529.0	140.9	2515.0	13.6	-17.2	12.0	2536.0	2508.0	140.7	2395.0
11	-1383.0	-19.4	-1389.0	14.6	-41.9	-6.1	-17.9	-1380.0	-1393.0	1375.0

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-8 Side Impact (20 g) + Internal Pressure (20 psi) - Primary Membrane Stresses[1]

Section	P_m Stresses (psi)						Principal Stresses (psi)			
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	-10227.0	856.0	-4685.1	375.9	199.7	-908.3	873.9	-4543.6	-10386.4	11262.0
2	5431.7	1884.3	-732.0	-276.8	-292.7	-442.5	5481.0	1902.2	-800.0	6281.1
3	-692.7	765.9	1360.0	4.7	-5.3	114.9	1367.4	765.9	-699.1	2065.7
4	-292.6	2090.9	659.1	159.2	1019.3	427.2	2660.3	279.9	-482.3	3142.7
5	-9019.0	-32.9	-3701.6	-1049.6	954.2	-599.5	345.1	-3914.4	-9184.7	9529.7
6	-15561.2	-2614.2	-4803.6	-1996.5	811.3	-748.8	-2010.2	-5071.0	-15896.8	13883.5
7	1925.2	1097.9	814.8	69.9	485.8	-45.5	1931.5	1460.7	446.1	1484.8
8	-14051.2	-2852.2	-3555.8	-677.4	842.2	-1202.7	-2161.2	-4080.1	-14219.0	12058.9
9	-478.9	-198.6	806.7	71.4	22.0	-22.2	807.5	-181.7	-496.6	1304.5
10	-425.3	-1.7	78.9	-25.7	6.7	-10.9	79.7	-0.7	-427.1	506.8
11	-382.5	-2.7	174.5	-16.4	2.8	-13.3	174.9	-2.1	-383.6	558.5

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

Table 11.3.1.2-9 Side Impact (20 g) + Internal Pressure (20 psi) - Primary Membrane Plus Primary Bending Stresses[1]

Section	$P_m + P_b$ Stresses (psi)						Principal Stresses (psi)			
No.	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	-26047.2	-2107.7	-10104.3	413.8	217.7	-1116.8	-2095.1	-10030.9	-26131.1	24044.4
2	-4429.3	-11241.0	1092.6	364.4	886.8	-75.4	1156.6	-4409.4	-11324.9	12478.3
3	-759.6	1198.5	2829.1	7.8	-5.9	227.3	2842.8	1198.5	-774.0	3617.7
4	599.0	4274.1	2236.7	208.0	755.2	1088.4	4603.4	2456.9	50.1	4553.0
5	-11146.6	26.7	-3044.1	-1644.2	728.4	-827.9	466.5	-3185.6	-11450.7	11912.1
6	-19996.8	-4548.8	-6797.0	-2643.5	1026.7	-594.2	-3707.8	-7185.0	-20447.7	16735.7
7	2385.6	321.5	419.3	86.5	664.6	-648.9	1677.8	651.1	-962.1	2639.3
8	-18046.4	-4398.9	-5819.7	-1420.9	1203.8	-864.6	-3522.2	-6506.6	-18235.2	14711.9
9	-956.6	-172.7	869.4	75.4	9.5	10.3	869.6	-165.6	-963.9	1833.0
10	-1095.8	-29.5	-493.6	-25.3	7.2	-18.4	-28.7	-493.2	-1096.8	1068.5
11	-814.4	-19.7	-190.1	-16.0	3.0	-15.9	-19.4	-189.8	-815.2	795.8

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions, respectively.

11.3.1.3 Yankee-MPC Canister Buckling Evaluation for the Bottom End Impact

The canister shell is axially loaded by the weights of the structural lid, the shield lid, and the inertial weight of the shell during a bottom end impact. The impact load amplification factor is 56.1g. The shell is evaluated as an unsupported, right circular cylinder using a critical buckling load per Blake, 2nd Edition, "Practical Stress Analysis in Engineering Design."

$$S_{cr} = \frac{E\left(0.605 - 10^{-7} M^2\right)}{M\left(1 + 0.004\phi\right)}$$

$$= 40.3 \text{ ksi}$$

The canister material is Type 304L stainless steel. Conservatively assume the material temperature to be at 400°F for this impact condition.

$E = 26.5E{+}03$ ksi $\quad R = (69.39 + 0.625)/2$

$= 35.01$ inches (mid-radius of the canister shell)

$S_y = 17.5$ ksi $\quad t = 0.625$ inches (thickness of the canister)

$\phi = E/S_y$ and $m = R/t$

$= 1514.3$ $\quad = 56.0$

The axial compression load in the canister shell is:

$$P_a = [\,(\pi/4)\,(69.03^2)\,(8)(0.291) + (\pi/4)(70.64^2 - 69.39^2)(121.5)(0.291)\,]\ (56.1)$$

$$P_a = 761{,}457 \text{ pounds}$$

and the axial compression stress is:

$$S_a = \frac{P_A}{\left(\pi/4\right)\left(70.64^2 - 69.39^2\right)}$$

$$S_a = 5{,}540 \text{ psi}$$

The margin of safety is:

$$(S_{cr}/S_a) - 1 = +\ 6.3$$

11.3.2 Yankee-MPC Canister Fuel Basket End Impact Analysis

Section 11.2.11 uses the results of analysis performed for the transport end impact condition to show adequate performance of the basket for the 6-inch concrete cask end drop accident. This section presents the transport end impact analysis upon which the results of Section 11.2.11 are based.

The fuel basket in the transportable storage canister is designed to contain up to 36 Yankee class fuel assemblies. The basket structure has a right circular cylinder configuration and consists of 36 square tubes supported by 22 circular support disks, and a circular top and bottom plate, which are retained by eight axial tie rods. The support disks and top and bottom plates are seperated and supported by split spacers at the tie rods. The configuration of the basket is shown in Figure 11.3.2-1.

Each fuel tube has an 7.8-inch square inside dimension, a 0.048-inch thick wall, and can hold one intact fuel assembly. The fuel assemblies together with the tubes are laterally supported in square holes in the stainless steel support disks. Each circular support disk is 0.5 inches thick and 69.15 inches in diameter. There are three different web widths in the support disks. One web width is 0.750 inches between the holes, one web width is 0.810 inches between the holes, and one web width is 0.875 inches between holes. The top and bottom plates are both 0.5 inch thick and have the same diameter as the support disks. The disks are spaced and retained by tie rods and split spacers (spacers) at eight locations near the periphery of each disk to form an integral basket assembly. The fuel basket contains the fuel and is enclosed by the canister. The canister has a 70.64-inch outer diameter and 5/8-inch thick walls. The overall length of the canister cavity is 122.5 inches, which encompasses the entire fuel assembly length and the thickness of the shield lid and structural lid. The canister shell is fabricated from Type 304L stainless steel.

The material of the support disks is 17-4 PH stainless steel. The top plate and the bottom plate are fabricated from Type 304 stainless steel. The fuel tubes are made from Type 304 stainless steel, which also encases the BORAL neutron absorbing material. The tie rods and spacers are fabricated from Type 304 stainless steel. The fuel tubes are not structural components and are not considered in the basket evaluation. The tie rods and spacers locate and structurally assemble the circular support disks, heat transfer disks, and the top and bottom plates to form an integral assembly. The spacers carry the weight of the support disks, heat transfer disks, endplate and

their own weight in the end impact loading condition. The end impact analysis uses classical closed form methods that are evaluated independent of the finite element basket model. The support disk structural evaluation is performed using a finite element model of a single disk.

The structural analysis of the basket components is in accordance with ASME Code, Section III, Division 1, Subsection NG, "Core Support Structures." In addition, the stainless steel/BORAL composite fuel tube has been evaluated for a postulated impact load.

11.3.2.1 Stress Evaluation of Support Disk in the End Impact

To determine the structural adequacy of the support disks in the end drop event, a load equal to the weight of the fuel and tubes multiplied by an amplification factor is applied to the support disk structure to simulate an end impact. For accident conditions, the amplification factor for the end impact is 56.1 g.

A finite element analysis is performed, utilizing the ANSYS computer code, to calculate the stresses in a support disk in accordance with ASME Code Section III, Subsection NG. In this subsection, linearized stresses of cross sections of the structure are compared to the allowable stresses. The maximum primary membrane stress intensity calculated in the support disk is compared to the allowable stress limits for accident conditions is, 0.7 S_u or 2.4 S_m, whichever is less.

11.3.2.1.1 Finite Element Model Description

A finite element model is used to evaluate the basket support disk for the end impact accident condition in which the loads are perpendicular to the plane of the disk.

The model for the end drop condition is constructed using ANSYS SHELL63 elements. It consists of a single support disk with a thickness of 0.5 inches. The shell elements accommodate the out-of-plane bending, which is present in the end-drop condition. In the end drop, the support disk is restrained by the split spacers on the eight tie rods. The nodes corresponding to the location of the tie rods are restrained in the out of plane direction (the cask axial direction). Four additional in-plane transitional restraints are specified at the outer edge of the model (located 90° apart from each other) in the tangential direction to prohibit rigid body displacements. The only loading is the inertial weight (56.1 g) of the support disk in the out-of-plane direction. The finite element model is shown in Figure 11.3.2-2.

Three thermal conditions are considered:

Thermal Condition	Ambient Temperature	Solar Insolence Applied to Cask Surface	12.5 kW Fuel Load
1	100°F	yes	yes
2	-40°F	no	yes
3	-40°F	no	no

The temperature distribution of the support disk for these Thermal Conditions are determined by the thermal analysis. The bounding thermal conditions (2 and 3) are used in the analysis to determine the material properties. Allowable stresses are determined based on conservative temperatures of 539° F for Thermal Condition 2 and -40° F for Thermal Condition 3.

To determine the most critical regions, a series of cross sections are considered. The section locations are identified in Figure 11.3.2-3. Table 11.3.2-1 shows the coordinate location of the cross section end points.

11.3.2.1.2 Support Disk End Impact Analysis Results

A structural analysis is performed using ANSYS to evaluate the effect of a 56.1 g end impact which corresponds to the most severe out-of-plane loading. Linearized stresses at the cross sections identified in Figure 11.3.2-3 are compared to stress allowables in accordance with the ASME Code, Section III, Subsection NG.

The stress evaluation results for the 56.1 g end impact condition are:

Thermal Condition	P_m Stress Intensity (ksi)	M.S.	P_m+P_b Stress Intensity (ksi)	M.S.
2	0	N/A	52.9	1.42
3	0	N/A	53.9	1.51

The margin of safety (M.S.) is:

M.S. = (Allowable Stress/Stress Intensity) –1,

where the allowable stress is 1.0 S_u for 17-4PH Type 630 stainless steel.

The minimum margin of safety is +1.42. The P_m stresses in the support disk for end drop conditions are essentially zero because there is no in-plane loading. Tables 11.3.2-2 and 11.3.2-3 list the 40 highest P_m+P_b stress intensities for thermal conditions 2 and 3, respectively.

11.3.2.2 Evaluation of Tie Rods and Spacers for an End Impact Condition

The design end impact loading for the basket is 56.1 g. The structural capacity of the spacers supporting the basket is evaluated using classical analysis. Accident loading due to the 56.1 g impact of the fuel basket was compared to the stress limit of 0.7 S_u in accordance with Subarticle NF 1440 of the ASME Code.

No detailed evaluation of the tie rods is required. The tie rods serve basket assembly purposes and are not part of the load path for the condition evaluated. The tie rods are loaded during fabrication by a 190 ft-lbs preload. Under impact conditions, the preload will be reduced. The tie rod design is, therefore, acceptable by inspection.

During the end impact, the spacers are loaded with the weight of 22 support disks, the aluminum heat transfer disks, one end plate, and the weight of the spacers. The load is resisted by the effective area of 8 spacers. The compressive stresses are calculated on the effective area of the spacer.

The material allowable stress is conservatively selected at a temperature of 500°F. The analysis input is:

stress limits	=	0.7 S_u (accident condition) (more limiting than 2.4 S_m)
loading criteria (g)	=	56.1g (accident condition)
evaluation temperature	=	500°F

Canister Basket Parameters

fuel basket weight	=	9,530 lbs
bottom weldment weight	=	438 lbs
fuel tube weight (36 tubes)	=	2,164 lbs
rod diameter	=	1.13 in
spacer outer diameter	=	2.50 in

Materials

tie rod	=	ASME SA 479 Type 304 Stainless Steel
spacer	=	ASTM A511 Type 304 Stainless Steel

Material Allowable

Type 304 SS	=	S_m = 17,500 psi (500°F)
	=	S_u = 63,500 psi (500°F)

The spacer load is calculated as follows:

Total weight of basket	=	9,530 lbs
Less weight of bottom weldment	=	-438 lbs
Less weight of fuel tubes	=	-2,164 lbs
Therefore,		
1 g load on spacers	=	6,928 lbs
Applied g level	=	56.1g
End impact load on spacers	=	6,928 x 56.1
	=	388,661 lbs

The effective area of one spacer at each of eight locations supporting the weight of the support disks is equal to the net area of the spacer and is calculated as:

$$A = \frac{3.14 \times \left(2.5^2 - 1.25^2\right)}{4}$$

$$= 3.68 \text{ in}^2$$

The average compressive stress, S_c, in the spacer is:

$$S_c = \frac{388{,}661}{8 \times 3.68}$$

$$= 13{,}202 \text{ psi}$$

The allowable stress for Type 304 stainless steel under accident conditions is 0.7 S_u.

$$S_u = 63{,}500 \text{ psi}$$
$$0.7\,S_u = 0.7 \times 63{,}500$$
$$= 44{,}500 \text{ psi}$$

The margin of safety (MS), which is defined as $\frac{0.7S_u}{S_c} - 1$, is calculated as:

$$\frac{44{,}450}{13{,}202} - 1 = 2.37$$

Therefore, the spacers are structurally adequate for a 56.1 g end impact under accident conditions.

Figure 11.3.2-1 Canistered Yankee Class Fuel Basket Assembly

Security-Related Information Figure Withheld Under 10 CFR 2.390.

Figure 11.3.2-2 Fuel Basket Support Disk Finite Element Model

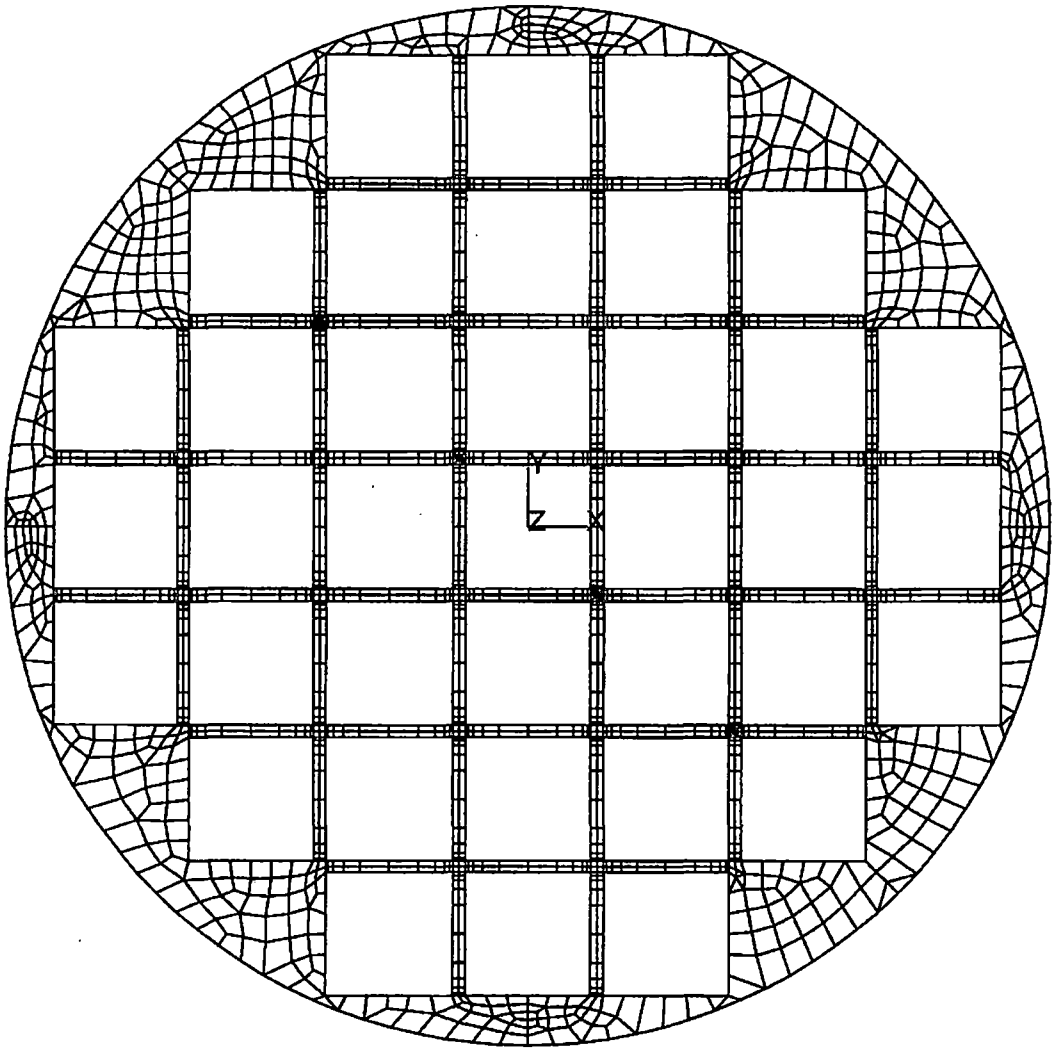


Figure 11.3.2-3 Location of the Support Disk Sections to Obtain Linearized Stresses

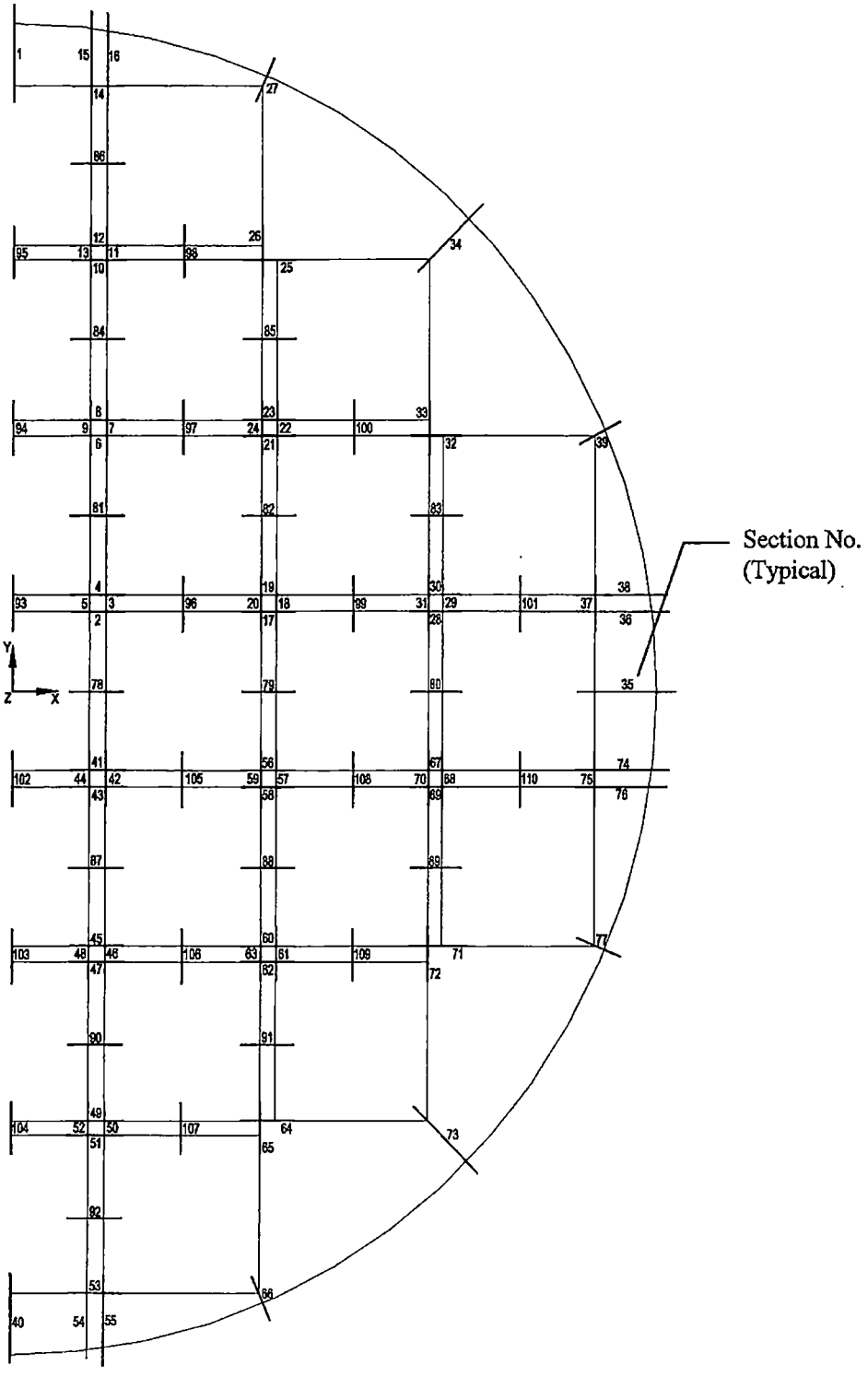


Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of the Support Disk (0° Basket Drop Orientation)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
1	1	2	0.00	31.32	0.00	34.49
2	3	4	4.13	4.13	5.00	4.13
3	5	6	5.00	4.13	5.00	5.00
4	7	8	5.00	5.00	4.13	5.00
5	9	10	4.13	5.00	4.13	4.13
6	11	12	4.13	13.26	5.00	13.26
7	13	14	5.00	13.26	5.00	14.07
8	15	16	5.00	14.07	4.13	14.07
9	17	18	4.13	14.07	4.13	13.26
10	19	20	4.13	22.32	5.00	22.32
11	21	22	5.00	22.32	5.00	23.07
12	23	24	5.00	23.07	4.13	23.07
13	25	26	4.13	23.07	4.13	22.32
14	27	28	4.13	31.32	5.00	31.32
15	29	30	4.13	31.32	4.13	34.24
16	31	32	5.00	31.32	5.00	34.13
17	33	34	13.26	4.13	14.07	4.13
18	35	36	14.07	4.13	14.07	5.00
19	37	38	14.07	5.00	13.26	5.00
20	39	40	13.26	5.00	13.26	4.13
21	41	42	13.26	13.26	14.07	13.26
22	43	44	14.07	13.26	14.07	14.07
23	45	46	14.07	14.07	13.26	14.07
24	47	48	13.26	14.07	13.26	13.26
25	49	50	13.26	22.32	14.07	22.32
26	51	52	13.26	22.32	13.26	23.07
27	53	54	13.26	31.32	13.44	31.76
28	55	56	22.32	4.13	23.07	4.13
29	57	58	23.07	4.13	23.07	5.00
30	59	60	23.07	5.00	22.32	5.00
31	61	62	22.32	5.00	22.32	4.13
32	63	64	22.32	13.26	23.07	13.26
33	65	66	22.32	13.26	22.32	14.07
34	67	68	22.32	22.32	24.39	24.39
35	69	70	31.32	0.00	34.49	0.00

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk (0° Basket Drop Orientation) (Continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
36	71	72	31.32	4.13	34.24	4.13
37	73	74	31.32	4.13	31.32	5.00
38	75	76	31.32	5.00	34.13	5.00
39	77	78	31.32	13.26	31.71	13.47
40	79	80	0.00	-31.32	0.00	-34.49
41	81	82	4.13	-4.13	5.00	-4.13
42	83	84	5.00	-4.13	5.00	-5.00
43	85	86	5.00	-5.00	4.13	-5.00
44	87	88	4.13	-5.00	4.13	-4.13
45	89	90	4.13	-13.26	5.00	-13.26
46	91	92	5.00	-13.26	5.00	-14.07
47	93	94	5.00	-14.07	4.13	-14.07
48	95	96	4.13	-14.07	4.13	-13.26
49	97	98	4.13	-22.32	5.00	-22.32
50	99	100	5.00	-22.32	5.00	-23.07
51	101	102	5.00	-23.07	4.13	-23.07
52	103	104	4.13	-23.07	4.13	-22.32
53	105	106	4.13	-31.32	5.00	-31.32
54	107	108	4.13	-31.32	4.13	-34.24
55	109	110	5.00	-31.32	5.00	-34.13
56	111	112	13.26	-4.13	14.07	-4.13
57	113	114	14.07	-4.13	14.07	-5.00
58	115	116	14.07	-5.00	13.26	-5.00
59	117	118	13.26	-5.00	13.26	-4.13
60	119	120	13.26	-13.26	14.07	-13.26
61	121	122	14.07	-13.26	14.07	-14.07
62	123	124	14.07	-14.07	13.26	-14.07
63	125	126	13.26	-14.07	13.26	-13.26
64	127	128	13.26	-22.32	14.07	-22.32
65	129	130	13.26	-22.32	13.26	-23.07
66	131	132	13.26	-31.32	13.44	-31.76

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk (0° Basket Drop Orientation) (Continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
67	133	134	22.32	-4.13	23.07	-4.13
68	135	136	23.07	-4.13	23.07	-5.00
69	137	138	23.07	-5.00	22.32	-5.00
70	139	140	22.32	-5.00	22.32	-4.13
71	141	142	22.32	-13.26	23.07	-13.26
72	143	144	22.32	-13.26	22.32	-14.07
73	145	146	22.32	-22.32	24.39	-24.39
74	147	148	31.32	-4.13	34.24	-4.13
75	149	150	31.32	-4.13	31.32	-5.00
76	151	152	31.32	-5.00	34.13	-5.00
77	153	154	31.32	-13.26	31.76	-13.44
78	155	156	4.13	0.00	5.00	0.00
79	157	158	13.26	0.00	14.07	0.00
80	159	160	22.32	0.00	23.07	0.00
81	161	162	4.13	9.13	5.00	9.13
82	163	164	13.26	9.13	14.07	9.13
83	165	166	22.32	9.13	23.07	9.13
84	167	168	4.13	18.19	5.00	18.19
85	169	170	13.26	18.19	14.07	18.19
86	171	172	4.13	27.20	5.00	27.20
87	173	174	4.13	-9.13	5.00	-9.13
88	175	176	13.26	-9.13	14.07	-9.13
89	177	178	22.32	-9.13	23.07	-9.13
90	179	180	4.13	-18.19	5.00	-18.19
91	181	182	13.26	-18.19	14.07	-18.19
92	183	184	4.13	-27.20	5.00	-27.20
93	185	186	0.00	4.13	0.00	5.00
94	187	188	0.00	13.26	0.00	14.07
95	189	190	0.00	22.32	0.00	23.07
96	191	192	9.13	4.13	9.13	5.00
97	193	194	9.13	13.26	9.13	14.07
98	195	196	9.13	22.32	9.13	23.07

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk (0° Basket Drop Orientation) (Continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
99	197	198	18.19	4.13	18.19	5.00
100	199	200	18.19	13.26	18.19	14.07
101	201	202	27.20	4.13	27.20	5.00
102	203	204	0.00	-4.13	0.00	-5.00
103	205	206	0.00	-13.26	0.00	-14.07
104	207	208	0.00	-22.32	0.00	-23.07
105	209	210	9.13	-4.13	9.13	-5.00
106	211	212	9.13	-13.26	9.13	-14.07
107	213	214	9.13	-22.32	9.13	-23.07
108	215	216	18.19	-4.13	18.19	-5.00
109	217	218	18.19	-13.26	18.19	-14.07
110	219	220	27.20	-4.13	27.20	-5.00
105	209	210	-10.02	-16.16	-11.52	-16.16
106	211	212	-20.29	-10.02	-20.29	-11.52
107	213	214	-10.02	-31.18	-10.02	-30.44
108	215	216	-31.18	-10.02	-30.44	-10.02
109	217	218	5.39	-11.02	5.39	-10.02
110	219	220	5.39	-20.29	5.39	-21.17

Table 11.3.2-2 P_m+P_b Stresses for Support Disk—56.1 g End Impact Thermal Condition 2

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
50	-52.7	-5.6	-3.3	52.9	127.8	1.42
46	-52.6	-17.9	1.3	52.6	127.8	1.43
19	-18.3	-52.5	-0.3	52.5	127.8	1.44
5	-52.4	-27.8	0.1	52.4	127.8	1.44
30	-6.1	-51.5	2.9	51.7	127.8	1.47
56	-18.3	-51.6	0.5	51.6	127.8	1.48
9	-51.3	-19.0	-0.1	51.3	127.8	1.49
7	-51.2	-18.8	-0.6	51.3	127.8	1.49
4	-27.4	-51.2	-0.2	51.2	127.8	1.49
42	-50.8	-27.6	1.0	50.9	127.8	1.51
11	-50.6	-5.9	2.7	50.8	127.8	1.52
3	-50.3	-27.8	-0.2	50.3	127.8	1.54
67	-6.4	-46.7	-1.8	46.8	127.8	1.73
79	-0.1	-46.5	0.3	46.5	127.8	1.75
103	-46.4	0.0	0.3	46.4	127.8	1.75
13	-45.7	-6.6	1.3	45.8	127.8	1.79
94	-45.6	-0.1	-0.1	45.6	127.8	1.80
80	-0.1	-45.5	-0.2	45.5	127.8	1.81
104	-45.5	-0.1	-0.2	45.5	127.8	1.81
95	-44.5	-0.1	-0.2	44.5	127.8	1.87
78	-0.1	-44.0	0.3	44.0	127.8	1.90
102	-44.0	-0.1	0.3	44.0	127.8	1.90
93	-43.8	-0.1	0.1	43.8	127.8	1.92
77	-6.3	-35.1	-10.2	38.3	127.8	2.34
66	-35.1	-6.3	-10.2	38.3	127.8	2.34
89	-0.6	-37.7	-3.3	38.0	127.8	2.36
88	-0.5	-37.5	1.4	37.5	127.8	2.41
20	-37.2	-28.2	0.0	37.2	127.8	2.43
45	-28.1	-36.9	1.0	37.0	127.8	2.46
87	-0.3	-36.0	0.8	36.0	127.8	2.55
82	0.3	-35.7	-0.5	36.0	127.8	2.55
37	8.8	-25.9	3.9	35.5	127.8	2.60
81	0.2	-35.2	-0.3	35.4	127.8	2.61
53	-26.3	8.1	-4.3	35.4	127.8	2.61
106	-34.8	0.4	1.4	35.3	127.8	2.62
107	-34.0	0.5	-3.3	35.1	127.8	2.64
83	0.5	-33.9	2.9	34.9	127.8	2.66
97	-34.4	0.3	-0.7	34.7	127.8	2.68
105	-34.4	0.2	0.8	34.6	127.8	2.69
96	-34.4	0.2	-0.2	34.6	127.8	2.69

Note: See Figure 11.3.2-3 for section locations and definition of coordinate system.

Table 11.3.2-3 P_m+P_b Stresses for Support Disk—56.1 g End Impact Thermal Condition 3

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
5	-53.9	-28.5	0.0	53.9	135.0	1.51
46	-53.1	-18.3	1.6	53.1	135.0	1.54
19	-18.8	-52.9	-0.6	52.9	135.0	1.55
50	-52.6	-5.8	-3.1	52.8	135.0	1.56
4	-28.1	-52.4	-0.4	52.4	135.0	1.58
42	-52.0	-28.3	1.2	52.1	135.0	1.59
56	-18.7	-52.0	0.6	52.0	135.0	1.60
9	-51.7	-19.5	-0.2	51.7	135.0	1.61
7	-51.7	-19.2	-0.9	51.7	135.0	1.61
30	-6.3	-51.4	2.7	51.6	135.0	1.62
3	-51.5	-28.5	-0.3	51.5	135.0	1.62
11	-50.5	-6.1	2.5	50.7	135.0	1.66
79	-0.1	-46.7	0.3	46.7	135.0	1.89
103	-46.7	0.0	0.3	46.7	135.0	1.89
67	-6.6	-46.5	-1.7	46.6	135.0	1.90
94	-45.8	-0.1	-0.1	45.8	135.0	1.95
13	-45.6	-6.8	1.2	45.6	135.0	1.96
80	-0.1	-45.3	-0.2	45.3	135.0	1.98
78	-0.1	-45.3	0.3	45.3	135.0	1.98
104	-45.3	-0.1	-0.2	45.3	135.0	1.98
102	-45.3	-0.1	0.3	45.3	135.0	1.98
93	-45.0	-0.1	0.1	45.0	135.0	2.00
95	-44.3	-0.1	-0.2	44.3	135.0	2.05
20	-38.2	-28.4	-0.2	38.2	135.0	2.53
45	-28.3	-37.9	1.2	38.0	135.0	2.55
88	-0.5	-37.7	1.7	37.8	135.0	2.57
89	-0.6	-37.5	-3.1	37.8	135.0	2.57
77	-6.1	-34.3	-9.9	37.4	135.0	2.61
66	-34.3	-6.1	-9.9	37.4	135.0	2.61
87	-0.3	-36.9	1.0	36.9	135.0	2.66
81	0.2	-36.1	-0.5	36.3	135.0	2.72
82	0.3	-36.0	-0.7	36.3	135.0	2.72
106	-35.1	0.3	1.7	35.6	135.0	2.79
105	-35.3	0.2	1.0	35.5	135.0	2.80
96	-35.3	0.2	-0.3	35.5	135.0	2.80
37	8.7	-25.6	3.8	35.1	135.0	2.85
8	-27.5	-35.0	-0.4	35.0	135.0	2.85
97	-34.7	0.3	-0.9	35.0	135.0	2.86
53	-26.0	7.9	-4.2	35.0	135.0	2.86
107	-33.8	0.5	-3.1	34.9	135.0	2.87

Note: See Figure 11.3.2-3 for section locations and definition of coordinate system.

11.3.2.3 Fuel Tube Analysis

Standard Fuel Tube

In the standard fuel tube configuration, BORAL neutron poison plates are supported by the fuel tubes within the canister basket. The fuel tube must preserve the geometry of the BORAL in the 6-inch drop and tip over accident events of the storage cask. The fuel tube has been evaluated for an end drop of 56.1 g and a side drop of 55 g for the hypothetical accident events for transport. That analysis is presented in the Safety Analysis Report for the NAC-STC, Docket 71-9235. That analysis shows that the BORAL neutron poison remains in place in the end and side drop conditions. The fuel tube configuration is shown in Figure 11.3.2.3-1.

Oversized Fuel Tube

The oversized fuel tube configuration is accommodated in the outer four corner positions of the basket where the top and bottom weldment openings for these positions are also enlarged. The oversized fuel tubes, which do not have BORAL and its covering sheath, weigh 20 pounds less than the standard fuel tubes.

Oversized Fuel Tube Side Impact Analysis

By comparing the design parameters of the oversized fuel tube to those of fuel tubes for the NAC-STC system, it is concluded that the design conditions for the directly loaded uncanistered NAC-STC fuel tubes envelope the design conditions for the oversized fuel tubes. Therefore, the stress in the side drop for the oversized fuel tube is bounded by the stress in the side drop for the NAC-STC directly loaded fuel tube. The comparative design parameters are:

Parameter	Oversized Fuel Tube	Directly Loaded Fuel Tube
Fuel Tube Material (stainless steel)	Type 304	Type 304
Fuel Tube Thickness (inch)	0.048	0.048
Fuel Tube Inside Dimension (inch)	8.00	8.78
Fuel Tube Weight (lb)	50	141
Fuel Assembly Weight (lb)	900	1,525
Length of Fuel Tube (inch)	103.5	154.7
Design G-Load (g)	55	55
Pressure (psi)	59.8	61.8

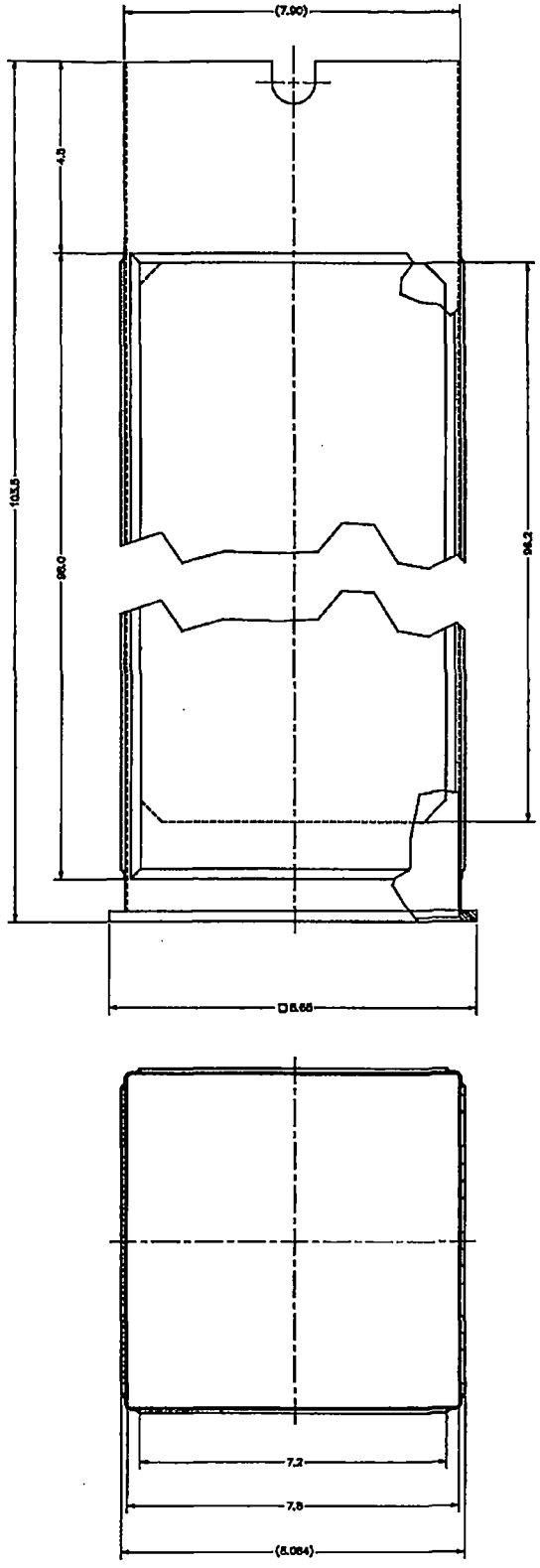
Oversized Fuel Tube End Impact Evaluation

For the oversized fuel tube, the compressive axial stress due to the weight of the fuel tube in the end drop is bounded by the evaluation of the fuel tube for the directly loaded NAC-STC system. The stress in the oversized fuel tube is related to the stress in the directly loaded configuration by:

$$(S_{br})_{\text{directly loaded}} (50/141) \times (8.78/8.0) = 0.39\ (S_{br})_{\text{directly loaded}}$$

Therefore, the stress in the end drop for the oversized fuel tube is bounded by the stress in the end drop for the directly loaded fuel tube.

Figure 11.3.2.3-1 Yankee Class Fuel Basket Tube Configuration with BORAL



11.3.2.4 Fuel Basket Weldment Analysis for End Impact Conditions

The response of the top and the bottom weldment plates of the fuel basket assembly to a 56.1g accident impact load are examined. The top and bottom weldment are 0.5-inch thick plates constructed of ASME SA 240, Type 304 stainless steel. The weldments support their own weight plus the weight of 36 fuel assemblies and standard fuel tubes (fuel tubes with BORAL).

A finite element analysis is performed for both plates, since the support for each weldment is different due to the location of the welded ribs for each. Eight structural ribs, eight tie-rod ends, and a circumferential ring support the top weldment and its loads during a top end drop. These structural components are modeled as zero-translation restraints in the direction of the end drop. The load from the fuel tube (2,108 pounds) is represented as point forces applied to the nodes at the periphery of the fuel assembly slots. An average point force is applied. The application of the nodal loads at the slot periphery is accurate since the tube weight is transmitted to the edge of the slot, which provides support to the fuel tubes in the end drop condition. Both models use the SHELL63 element, which permits out of plane loading. The finite element models represent one-quarter sections of the weldments. Figures 11.3.2.4-1 through 11.3.2.4-4 show the finite element models for the weldments.

For the configurations of the basket in which the enlarged fuel tubes are used, the four corner fuel positions of the top and bottom weldment are enlarged to accommodate four enlarged fuel tubes. Standard slot size in the end weldment is 7.8 inches, but in the enlarged four corner positions, the slot is enlarged to 8.0 inches. The vertical position of the basket allows the weight of the fuel tubes to be transmitted to the bottom end weldment and to the canister bottom plate via the stiffeners attached to the bottom end weldment. The increased slot size is not significant. With the reduction in the weight of the enlarged fuel tube of 20 pounds (due to the absence of the BORAL and sheath), the evaluation of the end weldment using the standard slots bounds the stresses in the end weldment designed for the enlarged fuel tube.

The standard opening size in the bottom and top weldments is 7.8 inches and 6.0 inches, respectively. To accommodate four damaged fuel cans, the openings in the four corner positions of the top and bottom weldments are enlarged to 8.25 inches. In the vertical orientation, the weight of the damaged fuel cans is transmitted to the canister bottom plate. Therefore, the standard configuration bounds the end impact loading condition, since the damaged fuel can configuration does not transmit load to the bottom weldments in the vertical orientation.

Figure 11.3.2.4-1 Top Weldment Finite Element Model with Structural Boundary Conditions

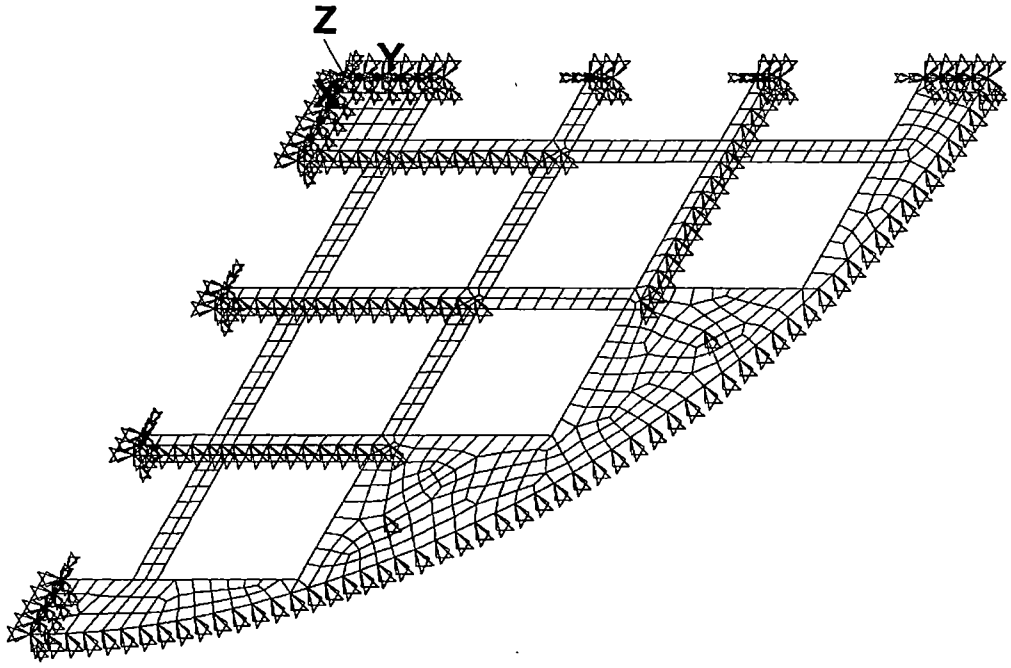
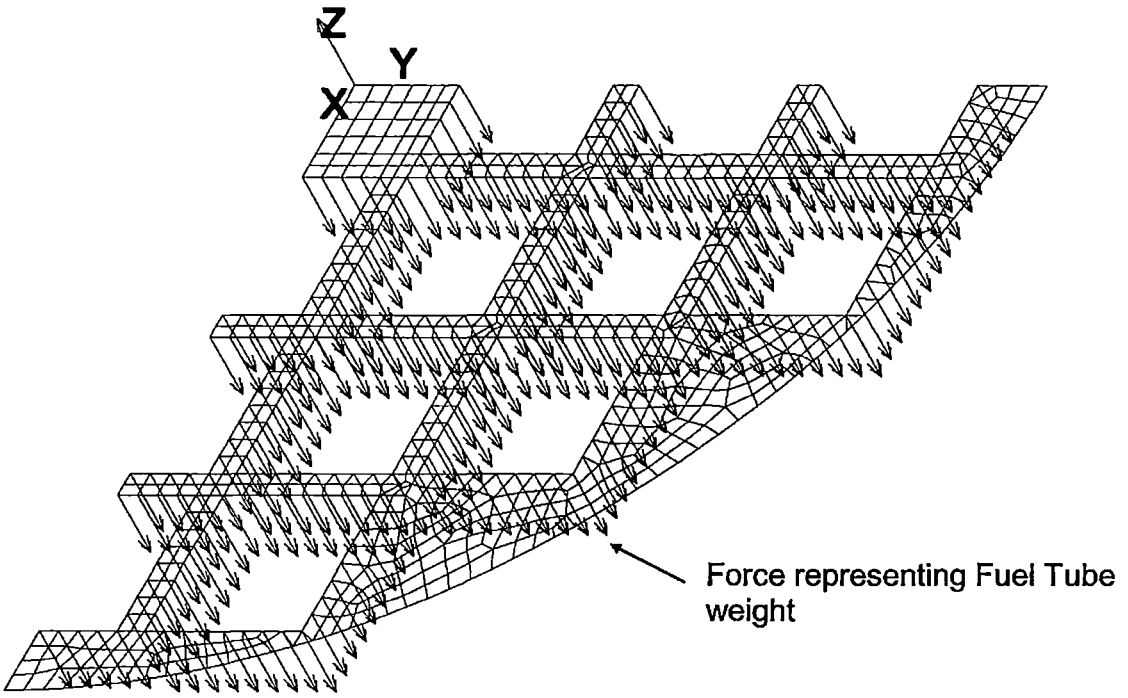


Figure 11.3.2.4-2 Top Weldment Finite Element Model with Structural Applied Loads



Displacement conditions not shown.

Figure 11.3.2.4-3 Bottom Weldment Finite Element Model with Structural Boundary Conditions

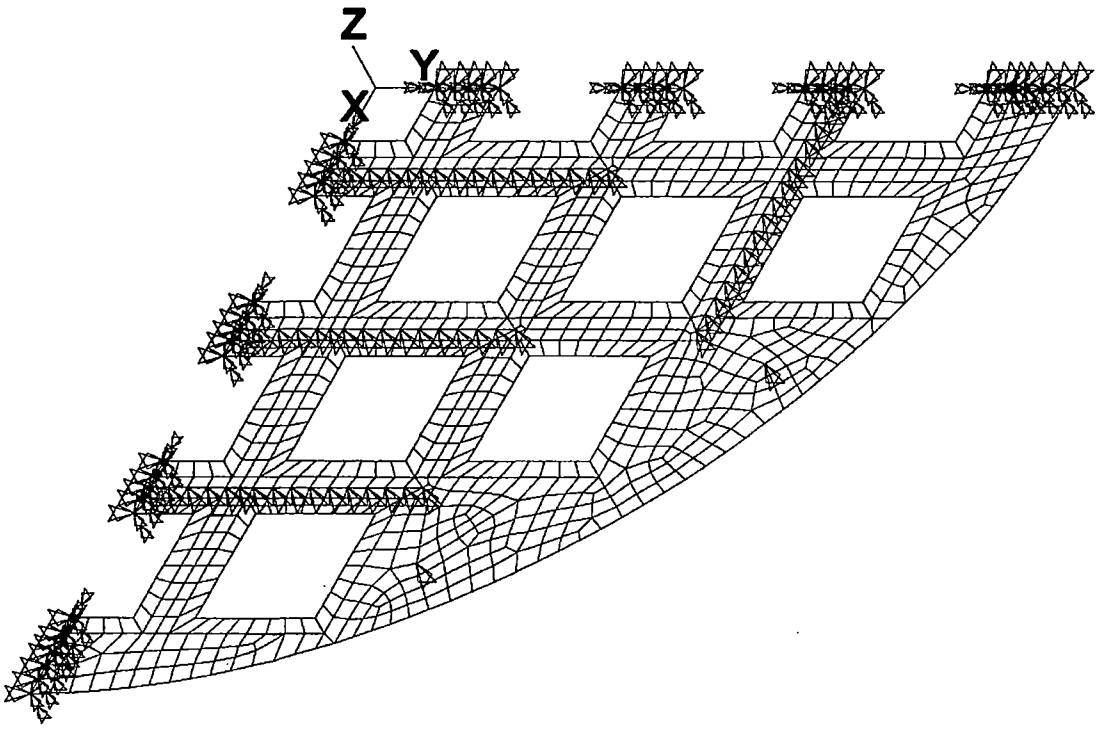
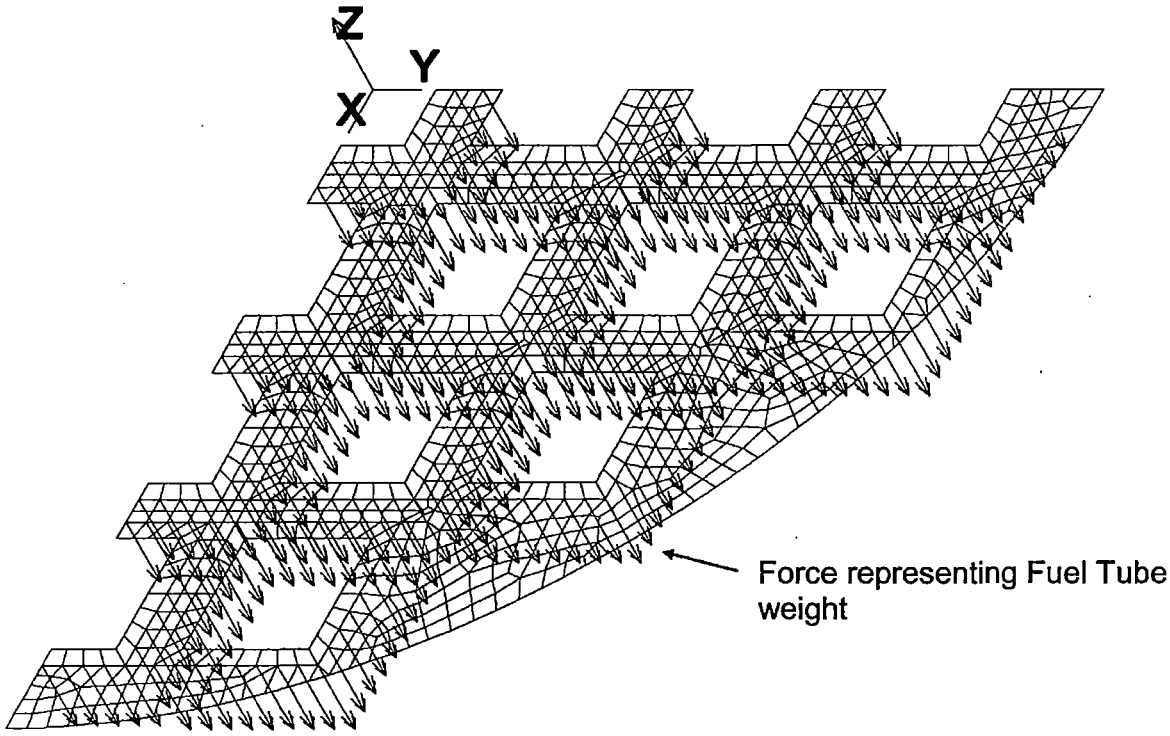


Figure 11.3.2.4-4 Bottom Weldment Finite Element Model with Structural Applied Conditions



Displacement conditions not shown.

11.3.2.4.1 Results of Fuel Basket Weldment Analyses

The analysis using the applied nodal forces demonstrates that the weldment design satisfies the primary membrane (P_m) and the primary membrane plus bending ($P_m + P_b$) stress criteria in ASME Code, Section III Division I, Subsection NG. Conservatively, nodal stresses, in lieu of sectional stresses, are used to compare with the stress allowable. For the end impact conditions, the P_m stresses are essentially zero since the weldments are subjected to bending load only. Hence, the following criteria for the $P_m + P_b$ stresses was used in the evaluation:

$P_m + P_b < 3.6S_m$ or S_u, whichever is less.

(Note: For Type 304 stainless steel in these temperature ranges, S_u is smaller than 3.6 S_m.)

The margin of (MS) was calculated as:

$$\text{M.S.} = \frac{\text{Allowable Stress}}{\text{Nodal Stress Intensity}} - 1$$

The minimum margins of safety for each weldment for the end drop condition are shown in the table below. The allowable stress is determined based on a temperature of 530°F. This temperature is established by using the maximum temperature of the support disk for normal conditions of storage. The minimum Margins of Safety for the top/bottom weldments for the 56.1 g end impact are:

Component	$P_m + P_b$ (ksi)	Allowable (ksi)	M.S.
Top Weldment	58.0	62.2	+0.1
Bottom Weldment	48.1	62.2	+0.3

11.3.2.4.2 Top Weldment Structural Rib Buckling Evaluation

The structural ribs on the top weldment are subjected to axial loads during a top end drop. End constraints on the ribs during a top end drop consist of fixed at the end welded to the top weldment and free at the other end. Because there are no closed solutions readily available for evaluating a plate for buckling loads with end constraints matching those of the top weldment ribs, a closed-form solution for the buckling of a column was used to analyze a 1-inch section of one of the ribs.

For a column under axial loading with one end fixed and the other end free, the critical load (P_{cr}) is determined by:

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

where:

I	= moment of inertia,
E	= modulus of elasticity,
L	= length of the column, and
K	= effective length factor (K = 2 for a column with one end fixed and the other free).

Evaluating a 1-inch section of one of the ribs at the temperature of 540°F yields:

$$P_{cr} = \frac{\pi^2 \left(25.576 \times 10^6 \text{lbf/in}^2\right) \frac{1}{12} (1.0\text{in})(0.38\text{in})^3}{(2 \times 6.80\text{in})^2} = 6{,}241 \text{ lbs}$$

For the 30-foot top end drop, the sum of the forces on the nodes representing the ribs was a maximum of 3,681 pounds. Thus, the maximum load (P) on a 1-inch section of one of the structural ribs is:

$$P = \frac{3{,}681\,\text{lb}}{27.5\,\text{in}/2}(1\,\text{in}) = 268\,\text{lbs}$$

Thus, the margin of safety (MS) for buckling of one of the structural ribs of the top weldment during a 30-foot top end drop is:

$$\text{M.S.} = \frac{6{,}241\ \text{lb}}{268\ \text{lb}} - 1 = 22.3$$

11.3.2.4.3 Evaluation of the Damaged Fuel Can for the End Impact Condition

Six-Inch Drop of the Vertical Concrete Cask

The 6-inch drop of the Vertical Concrete Cask onto an unyielding surface results in accelerations that are bounded by the 60g acceleration used in this structural evaluation of the damaged fuel can. The compressive load (P) on the damaged fuel can is the combined weight of the lid, side plates and tube body.

The compressive load (P) is:

$$P = (11.36 + 6.32 + 50.81) \times 60 = 4{,}110\ \text{lbs; use } 4{,}600\ \text{lbs.}$$

The compressive stress (S_c) in the tube body is:

$$S_c = \frac{P}{A} = \frac{4{,}600}{1.606} = 2{,}864\,\text{psi}$$

The Margin of Safety (MS) is determined based on the accident condition allowable primary membrane stress (0.7 S_u) at a bounding temperature of 600°F for Type 304 stainless steel:

$$MS = \frac{0.7S_u}{S_c} - 1 = \frac{0.7(63{,}300)}{2{,}864} - 1 = +14.5$$

The potential buckling of the tube is evaluated, using the Euler formula, to determine the critical buckling load (P_{cr}):

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2 (25.2\times10^6)(17.26)}{[2(114.35)]^2} = 82{,}075 \text{ lbs}$$

where:

$E = 25.2\times10^6$ psi

$I = \frac{8.08^4 - 7.98^4}{12} = 17.26 \text{ in.}^4$

$L_e = 2L$ (worst case condition)

L = tube body length (114.35 in.)

Because the maximum compressive load (4,600 lbs under the accident condition) is much less than the critical buckling load (82,075 lbs), the damaged fuel can has adequate resistance to buckling.

11.3.3 Yankee-Class Fuel Rod Buckling Assessment

The bounding condition for the evaluation of Yankee-class fuel rod buckling is the end drop orientation since this orientation maximizes the axial force component tending to buckle the fuel rods.

Zircaloy and stainless steel are used for Yankee-class fuel rod cladding. The fuel rods are restrained by the grids and are in contact with the fuel assembly base. In the vertical orientation, the fuel rod weight is transferred to the base of the fuel assembly. Each of the six grids restraining the fuel rods is considered to provide lateral support, but no rotational resistance to buckling. The calculation of the first buckling mode is performed using ANSYS Revision 5.2. Two models are constructed using beam elements. In the first model, the beam elements use effective cross-sectional properties, which combine the cross-sectional properties of the fuel pellet and the fuel rod cladding. The beam elements consider the weight of the fuel pellet and the cladding. The modulus of elasticity (modulus) for the fuel pellet is listed in Rust ("Nuclear Power Plant Engineering") as having a nominal value of 26 x 10^6 psi. Conservatively, only 50% of this value is used. Therefore, the modulus for the fuel pellet is taken to be 13 x 10^6 psi. The modulus for the Zircaloy fuel cladding is also 13 x 10^6 psi. The modulus for the stainless steel cladding is also conservatively taken to be 13 x 10^6 psi, based on a minimum modulus for

stainless steels at 600°F of 25.2 x 10^6 psi. The fuel rod dimensions and physical data used in the evaluation are:

	Stainless Steel Clad	Zircaloy Clad
Outer diameter of cladding (inches)	.340	.365
Cladding thickness (inches)	.042	.048
Cladding density (lb/in^3)	.291	.237
Fuel pellet density (lb/in^3)	.396	.396

The fuel assembly grids are located at 2.86, 20.60, 38.90, 57.20, 75.49 and 93.80 inches as measured from the bottom of the fuel assembly.

The effective cross-sectional properties (EI_{eff}) for the beam element are computed by adding the value of EI for the cladding and for the pellet.

where:

E = modulus of elasticity (lb/in^2)
I = cross-sectional moment of inertia (in^4)

For each material (Zircaloy and stainless steel), two configurations are evaluated:

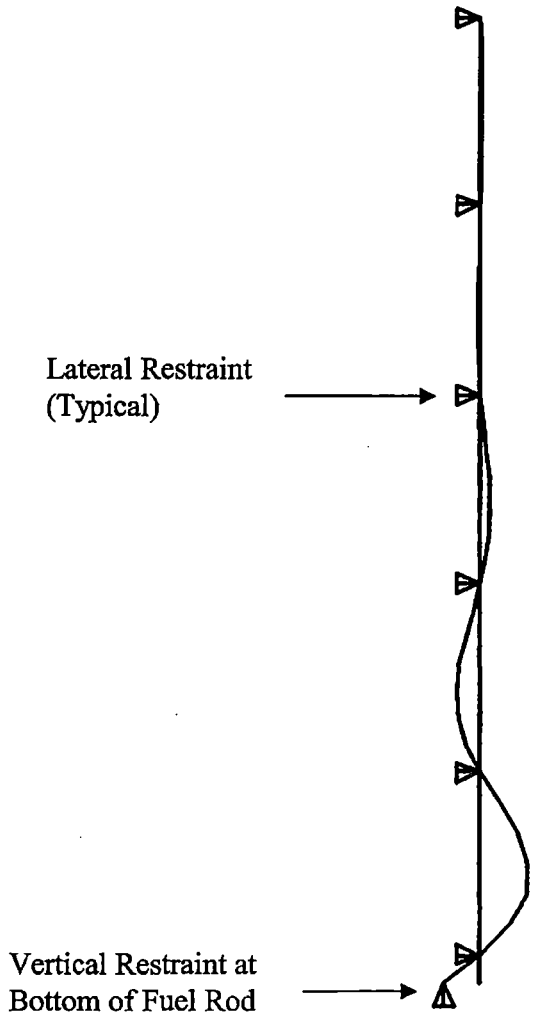
1) with the weight and the contribution of the cross-sectional properties of the fuel pellet and cladding
2) without the contribution of the fuel pellet (fuel rod cladding only)

The buckling shapes for each material using the combined cross-sectional properties of the fuel pellet and the cladding, along with the applied boundary conditions, are shown in Figure 11.3.3-1. The acceleration corresponding to the first buckling mode for the combined cladding and fuel pellet for both materials are:

Cladding Material	With cross-sectional properties and weight of the cladding and fuel pellets	With cross-sectional properties and weight of the cladding only
Zircaloy	94 g	248 g
Stainless Steel	78 g	177 g

For undamaged fuel, the pressure inside the fuel rod actually provides a significant tensile stress in the cladding. Conservatively, this stress is not considered to stiffen the cladding. Additionally, rotational resistance from each grid is not considered, which would increase the acceleration corresponding to the first buckling mode. Since the maximum accelerations in the end drop are less than 60g, the fuel rods do not buckle.

Figure 11.3.3-1 First Buckling Mode for Yankee-Class Fuel



11.4 Evaluation of Site Specific Fuel Components

Site specific fuel components are structures designed to hold fuel assemblies, individual fuel rods, or fuel debris configurations that are not in a standard fuel assembly. The fuel assemblies and the individual fuel rods may be classified as intact, failed or damaged. For fuel rods and fuel debris, the fuel fixture design typically incorporates fuel tubes in a lattice array. The fuel tubes hold the fuel rods or debris in a known geometry during storage normal, off-normal and accident conditions. The design of the fixture is reactor site specific in that the design accommodates the range of fuel conditions, dimensions and handling requirements that exist at the site.

This section presents the evaluation of site-specific fuel components used with the Yankee-MPC and CY-MPC configurations of the NAC-MPC storage system. The evaluation of the site-specific fuel components used with the MPC-LACBWR system is presented in Section 11.A.4 of Appendix 11.A.

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11.4.1 Evaluation of the Yankee-MPC Reconfigured Fuel Assembly

The reconfigured fuel assembly is evaluated at the off-normal (Service Level B) and accident (Service Level D) conditions, which are the bounding conditions. The accelerations for Service Level B are 20 g for both the side impact and the end impact. The accelerations for Service Level D are 55 g for the side impact condition and 57 g for the end impact condition. The results for the off-normal condition are conservatively compared to the allowables for the normal (Service Level A) condition. Material properties are taken at 750°F, which envelops all operating condition temperatures.

11.4.1.1 Shell Casing Weldment Evaluation

The section evaluates the reconfigured fuel assembly shell casing weldment for the side and end impact events.

11.4.1.1.1 Shell Casing Side Impact

The shell weldment is analyzed for bending stress resulting from horizontal-side bending in the longitudinal direction as a simple span with distributed load using material properties at a temperature of 750°F. Because the assembly is supported within the basket tube, the maximum deflection at the weldment center, δ, is limited to 0.107 in. at which time the remaining energy will be transferred into the basket fuel tube assembly.

In accordance with ASME Code Section III, Subsection NF, NF-3322.2(d), members that are subjected to axial compression or compression due to bending are considered to be fully effective if the width-thickness ratio, b/t, meets the following criterion:

$$\frac{b}{t} \leq \frac{238}{\sqrt{S_y}}$$

Since, for the shell casing:

$$\frac{b}{t} = \frac{7.125 - (2)(0.125)}{0.120} = 57 < \frac{238}{\sqrt{S_y}}$$

Where yield stress (S_y) = 17.3 ksi at 750°F and the fuel tube corner radius = 0.125 inch.

The shell casing meets the criteria and no reduction in allowable stress is applied.

The maximum bending stress, f_{bL}, is determined as:

$$\delta = \frac{5wL^4}{384EI} = 0.107\text{in. from which}$$

$$w = \frac{384EI\delta}{5L^4}$$

$$\text{Maximum moment, } M = \frac{wL^2}{8}$$

$$\text{Maximum bending stress, } f_{bL} = \frac{Mc}{I} = \frac{wL^2}{8} \times \frac{c}{I} = \frac{384E\delta\delta}{40L^2} = 9.66 \text{ ksi}$$

where:

E = modulus of elasticity for ASME SA 240, Type 304 stainless steel (24.4×10^3 ksi at 750°F)

c = (7.125 + 2(0.12))/2 = 3.68 in.

L = 97.7 in. distance between supports (top end fitting and bottom end fitting)

The horizontal sides (top and bottom) are evaluated for transverse bending stress, f_{bt}, as follows.

w = 0.120 in. × 0.29 lb/in^3 × 1.0 = 0.035 lb/in for a 1-inch wide strip

w_{20g} = 0.035(20 + 1) = 0.70 lb/in. (Service Level B)

$$S = \frac{1.0\times0.120^2}{6} = 2.40\times10^{-3}\,\text{in}^3$$

$$I = \frac{bt^3}{12} = \frac{1.0(0.120^3)}{12} = 0.144\times10^{-3}\,\text{in}^4$$

$$M = \frac{wL^2}{12} \text{ (conservative)}$$

$$f_{bt} = \frac{M}{S} = \frac{wL^2}{12S} = \frac{0.70(7.25^2)}{12(2.40\times10^{-3})} = 1.28 \text{ ksi}$$

$$f_b = \sqrt{f_{bL}^2 + f_{bt}^2} = \sqrt{9.66^2 + 1.28^2} = 9.74 \text{ ksi}$$

The margin of safety is:

$$M.S. = \frac{S_m}{f_b} - 1 = \frac{15.6\text{ ksi}}{9.74\text{ ksi}} - 1 = +0.60 \text{ (Service Level B)}$$

For Service Level D:

$w_{55g} = 0.035(55) = 1.93$ lb/in. (Service Level D)

$$f_{bt} = \frac{wL^2}{12S} = \frac{1.93\left(7.25^2\right)}{12\left(2.40\times10^{-3}\right)} = 3.52\text{ ksi}$$

$$f_b = \sqrt{f_{bl}^2 + f_{bt}^2} = \sqrt{9.66^2 + 3.52^2} = 10.28\text{ ksi}$$

The margin of safety is:

$$M.S. = \frac{2.4S_m}{f_b} - 1 = \frac{37.4\text{ ksi}}{10.28\text{ ksi}} - 1 = +2.64 \text{ (Service Level D)}$$

<u>Combined Axial Compression and Bending of Vertical Sides</u>

$$\frac{KL}{r} = \frac{1\times7.25}{0.035} = 207 \qquad \text{(NUREG/CR-6322)}$$

where:

K = 1, effective length factor
L = 7.25 in. (conservative)

$$r = \frac{t}{\sqrt{12}} = \frac{0.120}{\sqrt{12}} = 0.035\text{, radius of gyration}$$

$$F_a = S_y\left(0.40 - \frac{KL/r}{600}\right) = 0.952\text{ ksi}$$

For Service Level B:

$$f_a \max = \frac{0.78\left(7.25/2\right)}{0.120} + \frac{0.78(7.25)}{0.120} = 70.7 \text{ psi}$$

$$\frac{f_a}{F_a} = 0.952 = 0.07 < 0.15$$

$$f_{bx} = 1.28 \text{ ksi}; \; f_{by} = 9.66 \text{ ksi}$$

$$F_b = 1.5\ S_m = 1.5 \times 15.6 \text{ ksi} = 23.4 \text{ ksi}$$

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b} = 0.07 + \frac{1.28}{23.4} + \frac{9.66}{23.4} = 0.54$$

Since 0.54 < 1.0, the shell casing meets the NUREG/CR-6322 acceptance criteria.

For Service Level D:

$$f_a = \frac{1.93\left(7.25/2\right)}{0.120} + \frac{1.93(7.25)}{0.120} = 175 \text{ psi}$$

$$\frac{f_a}{F_a} = \frac{0.175}{1.27} = 0.14 < 0.15$$

$$F_B = 1.0 \times S_y = 63.1 \text{ ksi}$$

$$\left(\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b}\right) = \left(0.14 + \frac{3.52}{63.1} + \frac{10.28}{63.1}\right) = 0.36$$

Since 0.36 < 1.0, the shell casing meets the NUREG/CR-6322 acceptance criteria.

Welds, top and bottom fittings to shell casing

The shear force on the top-ring-to-casing and the bottom-fitting-to-casing welds is equal to 1/2 casing weight + 1/2 basket weight + 1/2 fuel weight = 261.3 lb; use 265 lb for evaluation. The top fitting design provides a shear key preventing the bolts from being loaded in shear.

The weld shear area = 7.25 in. × 0.120 in. × 4 = 3.48 in.^{2} and the dead load shear stress, τ_{DL}, is:

$$\tau_{DL} = \frac{265}{3.48} = 76.1 \text{ psi}$$

At Service Level B, the shear stress in the weld in the 20 g acceleration, τ_{20g}, is:

$$\tau_{20g} = 76.1 \times (20g) = 1.5 \text{ ksi}$$

$$F_v = (\text{greater of } 0.6\ S_m \text{ or } 0.6\ S_y) \times \text{weld quality factor}$$

$$= 0.6 \times 17.3 \times 0.50 = 5.19 \text{ ksi}$$

The margin of safety is:

$$\text{M.S.} = \frac{5.19}{1.5} - 1 = +2.46$$

At service level D, the shear stress in the weld in the 55 g acceleration, τ_{55g}, is:

$$\tau_{55g} = 76.1 \times (55g) = 4.2 \text{ ksi}$$

$$F_v = 0.42\ S_u \times \text{weld quality factor}$$

$$= 0.42 \times 63.1 \times 0.50 = 13.25 \text{ ksi}$$

The margin of safety is:

$$\text{M.S.} = \frac{13.25}{4.2} - 1 = +2.15$$

11.4.1.1.2 Shell Casing End Impact

For the bottom end impact, the top fitting and casing act against the bottom fitting assembly. For the top end impact, the bottom fitting and casing act against the top fitting assembly. Because the top fitting is heavier, the bottom end impact is the governing case.

$$K = 1$$
$$L = 97.7 \text{ in.}$$

$$r = \sqrt{\frac{(b+t)^4 - (b-t)^4}{12A}} = 2.73$$

$$\frac{KL}{r} = \frac{1(97.7)}{2.73} = 36 < 120$$

Therefore, use $F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 6.73 \text{ ksi}$

The axial stress in the shell casing wall is:

$$f_a = \frac{P_T}{A} = \frac{124(20g)}{3.48} = 0.71 \text{ ksi (For Service Level B)}$$

$$f_a = \frac{P_T}{A} = \frac{124(57g)}{3.48} = 2.03 \text{ ksi (For Service Level D)}$$

where:

P_T = (total weight of top fitting + shell = 124 lb.)

A = cross-sectional area = $(7.125 + 2(0.120))^2 - 7.125^2 = 3.48 \text{ in}^2$

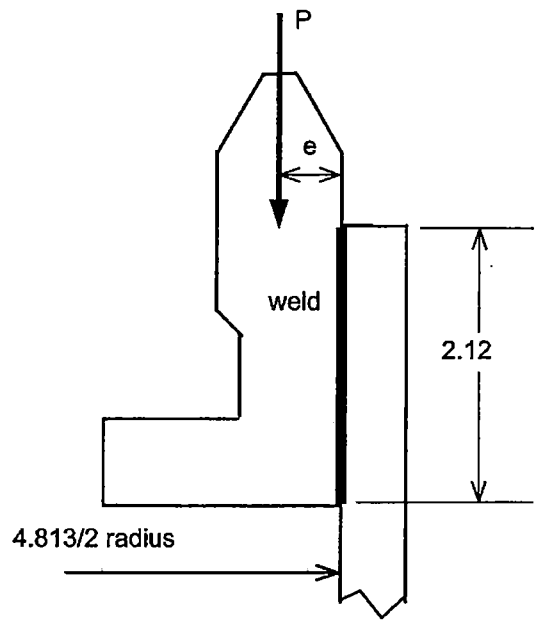
The margin of safety is:

$$MS = \frac{F_a}{f_a} - 1 = \frac{6.72 \text{ ksi}}{0.713 \text{ ksi}} - 1 = +8.42 \text{ (For Service Level B)}$$

$$MS = \frac{F_a}{f_a} - 1 = \frac{6.72 \text{ ksi}}{2.03 \text{ ksi}} - 1 = +2.31 \text{ (For Service Level D)}$$

11.4.1.1.3 Lifting Tab Welds

The lifting tabs will be subjected to bending and shear loads in the end impact condition.



For the Service Level B condition, the bending stress, f_b, on the weld is:

$$f_b = \frac{M}{S} = 6.96 \text{ ksi}$$

where:

$$M = \frac{Pe}{4} = \frac{0.596 \times (20g)(0.53)}{4} = 1.6 \text{ in.-kips}$$

For the Service Level D condition, the bending stress, f_b, on the weld is:

$$f_b = \frac{M}{S} = 19.57 \text{ ksi}$$

where:

$$M = \frac{Pe}{4} = \frac{0.596 \times (57g)(0.53)}{4} = 4.5 \text{ in-kips}$$

$$P = \text{total weight}$$

$$e = \frac{4.813}{2} - \left(\frac{2.0 + 1.75}{2}\right) = 0.53 \text{ in.}$$

$$S = \frac{bd^2}{6} = \frac{\frac{3}{8} \times \left(2.12 - \frac{3}{16}\right)^2}{6} = 0.23 \text{ in.}^3$$

For Service Level B conditions, the shear stress, f_v, on the weld is:

$$f_v = \frac{P/4}{A_w} = \frac{0.596(20g)}{4(0.72)} = 4.14 \text{ ksi}$$

For Service Level D conditions, the shear stress, f_v, on the weld is:

$$f_v = \frac{P/4}{A_w} = \frac{0.596(57g)}{4(0.72)} = 11.80 \text{ ksi}$$

where:

$$A_W = \left(2.12 - 3/16\right)(0.375) = 0.72 \text{ in.}^2\text{, the weld area.}$$

For Service Level B, the total stress, f, on the weld is:

$$f = \sqrt{f_b^2 + f_v^2} = \sqrt{6.96^2 + 4.14^2} = 8.10 \text{ ksi (Service Level B}$$

The allowable stress, F_a, for Service Level B is $1.5 \times S_m \times$ weld quality factor.

$$F_a = 1.5 \times 15.6 \times 0.5 = 11.7 \text{ ksi}$$

The margin of safety is:

$$MS = \frac{F_a}{f} - 1 = \frac{11.7 \text{ ksi}}{8.10 \text{ ksi}} - 1 = +0.44 \quad \text{(Service Level B)}$$

For Service Level D, the total stress, f, on the weld is:

$$f = \sqrt{f_b^2 + f_v^2} = \sqrt{19.57^2 + 11.80^2} = 22.85 \text{ ksi (Service Level D)}$$

The allowable stress, F_a, for Service Level D is $1.0 \times S_u \times$ weld factor.

$$F_a = 1.0 \times 63.1 \times 0.5 = 31.55 \text{ ksi}$$

The margin of safety, M.S., for the Service Level D condition is:

$$MS = \frac{F_A}{f} - 1 = \frac{31.55}{22.85} - 1 = +0.38$$

11.4.1.2 Basket Assembly and Fuel Tube Evaluation

11.4.1.2.1 Corner Angle Side Impact

The side impact load will be shared by two corner leg angles. The maximum deflection, δ, that a corner leg angle can achieve is 0.102 inches.

$$W = \frac{384EI\delta}{5L^3}$$

$$\text{Max moment, } M = \frac{WL}{8}$$

$$\text{The bending stress, } f_b = \frac{Mc}{I} = \frac{384E\delta\delta}{40L^2} = \frac{384(24.4\times10^3)(0.102)(0.077)}{40(97.4^2)(0.091)} = 2.13\text{ksi}$$

where:

$$c = \frac{I}{S} = \frac{0.077}{0.091}$$

The margin of safety is:

$$MS = \frac{1.5\times S_m}{f_b} - 1 = \frac{23.4}{2.13} = \text{large}$$

11.4.1.2.2 Corner Angle End Impact

In the end impact, the load from the tie plates will be shared by four corner leg angles. Because the fuel tubes are not attached to the tie plates, their load will not be transferred to the corner leg angles in the end impact condition.

$$\frac{KL}{r} = \frac{1(15)}{0.369} = 40.6 < 120$$

where:

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.077}{0.563}} = 0.369$$

$$KL/r < 120 \text{ and } \frac{b}{t} = \frac{1.25}{0.25} = 5.0 < \frac{76}{\sqrt{S_y}} = \frac{76}{\sqrt{19.4}} = 17.25$$

Therefore, in accordance with NUREG/CR-6322,

$$F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 6.57 \text{ ksi}$$

The dead load, P_{DL}, on one corner leg angle = (7 × spacer plate weight)/4 +angle weight = 22 lbs

P_{20g} = 22 × (20g) = 0.44 kips at 20g acceleration
P_{57g} = 22 × (57 g) = 1.25 kips at 57g acceleration

For the 20g acceleration:

f_a = 0.44 kips/0.56 in^2 = 0.79 ksi

The margin of safety is:

$$M.S. = \frac{6.57 \text{ ksi}}{0.79 \text{ ksi}} - 1 = +7.31$$

For the 57 g acceleration:

$$f_a = 1.25 \text{ kips}/0.56 \text{ in}^2 = 2.23 \text{ ksi}$$

The margin of safety is:

$$\text{M.S.} = \frac{6.57 \text{ ksi}}{2.23 \text{ ksi}} - 1 = +1.95$$

11.4.1.2.3 Fuel Tube Side Impact

The fuel tube is evaluated for bending as a continuous beam with a uniform load and six equal spans at 15.0-in. on center. The higher stresses in the 5/8-inch diameter tubes bound those in the ¾-inch diameter tubes.

$$M_{max} = -\left(0.106 \times wL^2\right) \qquad \text{(Manual of Steel Construction)}$$

$$f_b = \frac{Mc}{I}$$

For Service Level B:

$$w = 0.019 \text{ lb/in.} \times (20g) = 0.38 \text{ lb/in.}$$

$$f_b = \frac{Mc}{I} = 1.0 \text{ ksi}$$

For Service Level D:

$$w = 0.019 \text{ lb/in.} \times (55g) = 1.05 \text{ lb/in.}$$

$$f_b = \frac{Mc}{I} = 2.8 \text{ ksi}$$

where:

w	= 0.019 lb/in.
L	= 15.0 in.
c	= 0.625/2 = 0.313 in.
I	$= \frac{\pi}{64}\left(D^4 - d^4\right) = 2.83 \times 10^{-3}\,\text{in}^4$
D	= tube outside diameter, 0.625 in.
d	= tube inside diameter, 0.555 in.

The margin of safety at Service Level B is:

The margin of safety at Service Level B is:

$$M.S. = \frac{1.5S_m}{f_b} - 1 = \frac{1.5(15.6)}{1.0} - 1 = +\text{large}$$

The margin of safety at Service Level D is:

$$M.S. = \frac{1.0S_u}{f_b} - 1 = \frac{1.0(63.1)}{2.8} - 1 = +\text{large}$$

11.4.1.2.4 Fuel Tube End Impact

For Service Level B, the fuel tubes are evaluated for axial compression in accordance with NUREG/CR-6322.

For Service Level B, the allowable stress, F_a, is:

$$F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 5.33 \text{ ksi}$$

where:

$$r = \sqrt{\frac{I}{A}} = 0.209 \text{ in.}$$

$$\frac{KL}{r}\frac{(1)(15.0)}{0.209} = 72 < 120$$

$$f_a = \frac{P}{A} = \frac{5.84(20g)}{.065} = 1.8 \text{ ksi}$$

where:

$L = 15.0$ in.

$I = \frac{\pi}{64}(D^4 - d^4) = 0.283\times10^{-3} \text{ in}^4$

$D = 0.625$ in. (fuel tube outside diameter)

$d = 0.555$ in. (fuel tube inside diameter)

$A = \frac{\pi}{4}(D^2 - d^2) = 0.065 \text{ in}^2$

P = (fuel + fuel tube + end cap weight)

The margin of safety for Level B Service is:

$$M.S. = \frac{F_a}{f_a} - 1 = \frac{5.33 \text{ ksi}}{1.8 \text{ ksi}} - 1 = +1.96$$

For Service Level D, the fuel tubes are evaluated for axial compression in accordance with NUREG/CR-6322 and ASME Section III, Appendix F-1334.3.

Because Subparagraph F-1334.3 specifies no criteria for austenitic stainless steel, the following method from NUREG/CR-6322 is used to determine the criteria for the hypothetical accident condition (Service Level D).

The maximum allowable axial load, P_{allow}, is determined using the relation:

$$\frac{P_{allow}}{P_y} = SS_{Level\,D} = \left(\frac{SS}{CS}\right)_{Level\,A} \times CS_{Level\,D} = 0.51$$

(NUREG/CR-6322 Equation 39)

where "SS" and "CS" stand for stainless steel and carbon steel, respectively.

$P_{allow} = P_y \times 0.45 = 0.75 \text{ ksi} \times 0.45 = 0.34 \text{ kips}$

$$SS_{Level\,A} = \left(0.47 - \frac{\frac{KL\lambda}{r}}{444\sqrt{2}}\right) = 0.40 \qquad \text{(NUREG/CR-6322 Equation 45)}$$

$$CS_{Level\,A} = \frac{1 - \frac{\lambda^2}{4}}{\frac{5}{3} + \frac{3}{8}\left(\frac{\lambda}{\sqrt{2}}\right) - \frac{1}{8}\left(\frac{\lambda}{\sqrt{2}}\right)^3} = 0.47 \qquad \text{(NUREG/CR-6322 Equation 43)}$$

$$CS_{Level\,D} = \frac{1 - \frac{\lambda^2}{4}}{1.11 + 0.5\lambda + 0.17\lambda^2 - 0.28\lambda^3} = 0.60 \qquad \text{(NUREG/CR-6322 Equation 33)}$$

$$\lambda = \frac{1}{\pi}\left(\frac{KL}{r}\right)\sqrt{\left(\frac{S_y}{E}\right)}$$

$\lambda_{SS} = 0.61$
$\lambda_{CS} = 0.73$

$P_y = S_y \times A = 17.3 \text{ ksi} \times 0.065 \text{ in}^2 = 1.12 \text{ kips}$

The axial load, P, on the fuel tube is (fuel + fuel tube + end cap weight) × end impact acceleration:

$P = 5.84(57g) = 0.33 \text{ kips}$

The margin of safety for the Service Level D condition is:

$$M.S. = \frac{P_{allow}}{P} - 1 = \frac{0.57 \text{ kips}}{0.33 \text{ kips}} - 1 = +0.73$$

11.4.1.2.5 Tie Plate End Impact

Analysis of the reconfigured fuel assembly tie plate uses a Stardyne finite element model to represent the tie plate during an end impact. The model consists of a square grid of identical stainless steel beams spaced at 0.75 in. The beams are 0.375 in. deep and 0.23 inches wide (clear space between 0.645 in. diameter holes). The tie plate is welded to four corner angles where the plate is assumed fixed. The tie plate is made of Type 304 stainless steel. Loads are applied to the nodes to represent the (weight × g loading) of the plate.

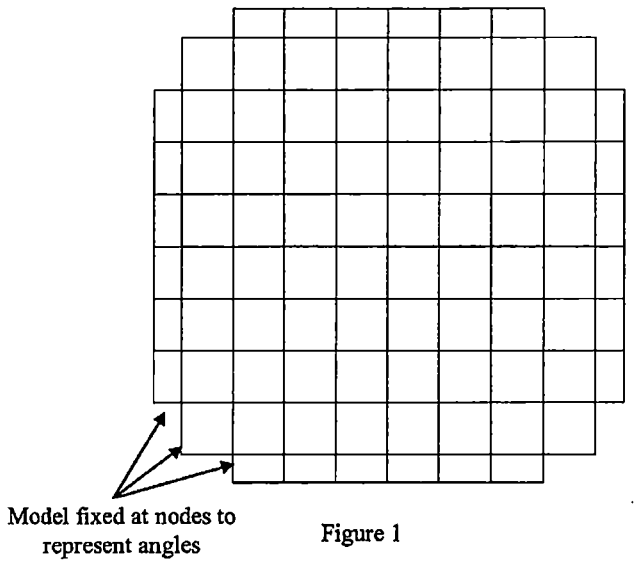


Figure 1

Analysis is done for Service Level B and Service Level D conditions.

Shear and Bending

Stresses from Stardyne output:

	Service Level B: (20 g loading)	Service Level D: (57 g loading)
Maximum Shear Stress:	213 psi	607 psi
Maximum Bending Stress:	1,597 psi	4,554 psi

Service Level B allowable stress at 750°F:

Primary Bending: $1.5 \times S_m = 1.5 \times 15.6$ ksi $= 23.4$ ksi

Shear: greater of: $0.6 \times S_m = 0.6 \times 15.6 = 9.36$ ksi or

$0.6 \times S_y = 0.6 \times 17.3 = 10.4$ ksi

For Service Level D, at the same temperature, the allowable stresses are:

Primary Bending: $1.0 \times S_u = 63.1$ ksi

Shear: $0.42 \times S_u = 0.42 \times 63.1 = 26.5$ ksi

The margins of safety at Service Level B, are:

Primary Bending: $MS = \frac{23.4}{1.597} - 1 = +\text{Large}$

Shear: $MS = \frac{10.4}{0.213} - 1 = +\text{Large}$

At Service Level D, the margins of safety are:

Primary Bending: $MS = \frac{63.1}{4.554} - 1 = +\text{Large}$

Shear: $MS = \frac{26.5}{0.6076} - 1 = +\text{Large}$

Welds at Tie Plates to Corner Angles

Each tie plate is welded to four corner angles with top and bottom 3/16-in. fillet welds. From the Stardyne output, the critical shear, torsion, and bending loads are:

Service Level B:	Service Level D:
Shear = 9.03 lbs.	Shear = 25.72 lbs
Torsion = 1.68 in-lbs	Torsion = 13.28 in-lbs
Bending = 5.91 in-lbs	Bending = 8.36 in-lbs

The stresses for Service Level D are calculated using the beam cross section (0.23 in. wide × 0.375 in. deep) and the weld effective throat.

The weld effective throat is: $0.707 \times 0.1875 = 0.13$ in.

Therefore:

Shear Stress is: $F_s = \frac{9.03}{0.23 \times 0.13} + \frac{1.68}{0.0182 \times 0.13} = 1{,}012$ psi Level B

and,

Bending Stress is: $F_b = \frac{5.91}{0.086 \times 0.13} = 528$ psi Level B

Shear Stress is: $F_s = \frac{25.72}{0.23 \times 0.13} + \frac{13.28}{0.0182 \times 0.13} = 6{,}473$ psi Level D

and,

Bending Stress is: $F_b = \frac{8.36}{0.086 \times 0.13} = 748$ psi Level D

Allowables for the weld are:

ASTM A240 Type 304 Stainless Steel (Section II-D ASME) at 750°F
$S_u = 63.1$ ksi $S_y = 17.3$ ksi $S_m = 15.6$ ksi
Per ASME Section III-NG the minimum quality factor for a Category E Type V weld is $n = 0.4$.

At Service Level B:

Membrane + Bending: $F = 1.5 \times S_m \times n = 1.5 \times 15.6 \times 0.4 = 9.36$ ksi
Shear:(greater of) $F = 0.6 \times S_m \times n = 0.6 \times 15.6 \times 0.4 = 3.74$ ksi
$F = 0.6 \times S_y \times n = 0.6 \times 17.3 \times 0.4 = 4.15$ ksi

At Service Level D:

Membrane + Bending: $F = 1.0 \times S_u \times n = 1.0 \times 63.1 \times 0.4 = 25.24$ ksi
Shear: $F = 0.42 \times S_u \times n = 0.42 \times 63.1 \times 0.4 = 10.60$ ksi

Since the actual weld stress during Service Level D is equal to or less than the allowables during Service Level B, ¼-in. double fillet weld is satisfactory.

The margins of safety are:

<u>Service Level B</u>

$$MS = \frac{9.36 \text{ ksi}}{0.528 \text{ ksi}} - 1 = +\text{Large}$$

$$MS = \frac{3.74 \text{ ksi}}{1.0 \text{ ksi}} - 1 = +2.74$$

Service Level D

$$MS = \frac{25.24 \text{ ksi}}{0.528 \text{ ksi}} - 1 = +\text{Large}$$

$$MS = \frac{10.60 \text{ ksi}}{6.473 \text{ ksi}} - 1 = +0.64$$

A conservative analysis of the RFA Tie Plate shows the plate to be satisfactory for a Service Level B and D end impact.

11.4.1.2.6 Tie Plate Side Impact

The fuel tubes are supported by tie plates at 15 inches on center spacing. During a side impact the weight of the fuel tube, amplified by the g loading, puts the bottom edge of the tie plate in compression. The tie plate is analyzed as compression beam model. The weight of each fuel tube is carried in compression only and does not have the ability to shear to the next row of beams.

For Service Level B:

The weight of each fuel tube at 15 inch spacing is:

$$W_{20g} = \frac{1.84 \text{ lbs/tube}}{97.70 \text{ inches}} \times 15.0 \text{ inch spacing} \times (20g)) = 5.65 \text{ lb/tube}$$

For Service Level D:

The weight of each fuel tube at 15-inch spacing is:

$$W_{55g} = \frac{5.65 \times (55g)}{(20g)} = 15.54 \text{ lb/tube}$$

The compression and shear load at the bottom of the tie plate during a side impact is:

For Service Level B:

$$P = 5.65 \times 8 = 45.2 \text{ lb}$$

$$F = \frac{45.2}{0.375 \times 0.105} = 1{,}148 \text{ psi for both shear and compression}$$

The critical margin of safety is for shear:

$$M.S. = \frac{10{,}400}{1{,}148} - 1 = +8.06$$

For Service Level D:

$$P = 15.54 \times 8 = 124.3 \text{ lb}$$

$$F = \frac{124.3}{0.375 \times 0.105} = 3{,}157 \text{ psi for both shear and compression}$$

The critical margin of safety for shear is:

$$M.S. = \frac{26{,}500}{3{,}157} - 1 = +7.39$$

Because the tie plate and corner angles are of the same material, Type 304 stainless steel, and because the fuel tubes are not connected to the tie plates, thermal stresses can be ignored.

11.4.1.2.7 Tie Plate Thermal Stress Analysis

From Table 4.4.3-4 in Section 4.4.3, the maximum ΔT between the shell casing and the Reconfigured Fuel Assembly tube is 20°F. A ΔT of 25°F is conservatively used for the tie plate analysis.

The thermal stress is calculated using the formula (Roark):

$$S = K_t \text{ x } \frac{\Delta T \alpha E}{1-\nu} = 3 \text{ x} \frac{25(9.76 \text{x} 10^{-6})(24.4 \text{x} 10^{6})}{1-0.275} = 24{,}636 \text{ psi (compression)}$$

where:

Material properties are taken at 750°F.

K_t is the stress concentration for a hole in an infinite plate.

For Service Level B:

S = 1,148 psi + 24,636 psi = 25,784 psi (compression)

The margin of safety is:

$$\text{M.S.} = \frac{3.0 \times 15{,}600}{25{,}784} - 1 = +0.82$$

11.4.2 Evaluation of the CY-MPC Reconfigured Fuel Assembly

The CY-MPC reconfigured fuel assembly is evaluated for hypothetical accident conditions of the concrete cask 6-inch drop (Section 11.2.11) and the tip-over event (Section 11.2.12). The concrete cask 6-inch drop is evaluated considering a 60g end-impact. The tip-over accident is evaluated using a 60g side-impact. Material properties are taken at 750°F, which envelops all operating condition temperatures.

11.4.2.1 CY-MPC Reconfigured Fuel Assembly Weldment Evaluation

11.4.2.1.1 Reconfigured Fuel Assembly Weldment Side Impact

The reconfigured fuel assembly corner angles and tubes are each evaluated as a continuous beam supported at 6 places–the top and bottom housings and 4 intermediate tube support grids. The beam model for the corner angle is analyzed with a uniformly distributed load that is the self-weight of the angle multiplied by an acceleration factor (60g). The beam model for the tube is analyzed with a uniformly distributed load comprising the weight of the fuel rods and the self-weight of the tube multiplied by an acceleration factor (60g).

Corner Angle

The corner angle length between the top and bottom housing is approximately 135.09 inches. The four intermediate tube support grids divide the corner angle into five equal spans approximately 27.02 in. long.

The maximum moment (M_{max}) in the corner angle is:

$$M_{max} = 0.0779wl^2 = 0.0779\ (0.2033)(27.02^2)(60g) = 694\ \text{lb}\cdot\text{in.}$$

The maximum shear force (V) in the corner angle is:

$$V = \frac{23}{38}(wl) = \frac{23}{38}(0.2033)(27.02)(60g) = 200\ \text{lb}$$

The maximum bending stress (f_b) is:

$$f_b = \frac{M_{max} \times c}{I} = \frac{694(1.431)}{0.272} = 3{,}652 \text{ psi}$$

The maximum shear stress (τ) is:

$$\tau = \frac{V}{A} = \frac{200}{0.715} = 280 \text{ psi}$$

The combined stress is:

$$f_{1,2} = \frac{f_b}{2} \pm \sqrt{\left(\frac{f_b}{2}\right)^2 + 4\tau^2} = \frac{3{,}652}{2} \pm \sqrt{\left(\frac{3{,}652}{2}\right)^2 + 4(280)^2} = 1{,}826 \pm 1{,}910 \text{ psi}$$

$f_1 = 3{,}736$ psi

$f_2 = -84$ psi

The maximum combined stress is:

$$f_{max} = |f_1 - f_2| = 3{,}820 \text{ psi}$$

The Margin of Safety (MS) is:

$$MS = \frac{3.6S_m}{f_{max}} - 1 = \frac{3.6(15{,}600)}{3{,}820} - 1 = +13.7$$

Reconfigured Fuel Assembly Tube

The tube length between the top and bottom housing is approximately 135.09 inches. The four intermediate tube support grids divide the tube into five equal spans approximately 27.02 in. long.

The maximum moment (M_{max}) in the tube is:

$$M_{max} = 0.0779wl^2 = 0.0779(0.076)(27.02^2)(60g) = 260 \text{ lb-in.}$$

The maximum shear force (V) in the tube is:

$$V = \frac{23}{38}(wl) = \frac{23}{38}(0.076)(27.02)(60g) = 75 \text{ lb}$$

The maximum bending stress (f_b) is:

$$f_b = \frac{M_{max} \times c}{I} = \frac{260(0.28125)}{.002026} = 35{,}498 \text{ psi}$$

The maximum shear stress (τ) is:

$$\tau = \frac{V}{A} = \frac{75}{0.0580} = 1{,}293 \text{ psi}$$

The combined stress is:

$$f_{1,2} = \frac{f_b}{2} \pm \sqrt{\left(\frac{f_b}{2}\right)^2 + 4\tau^2} = \frac{35{,}498}{2} \pm \sqrt{\left(\frac{35{,}498}{2}\right)^2 + 4(1{,}293)^2} = 17{,}749 \pm 17{,}937 \text{ psi}$$

$f_1 = 35{,}686$ psi

$f_2 = -188$ psi

The maximum combined stress is:

$f_{max} = |f_1 - f_2| = 35{,}874$ psi

The Margin of Safety (MS) is:

$$MS = \frac{3.6S_m}{f_{max}} - 1 = \frac{3.6(15{,}600)}{35{,}874} - 1 = +0.56$$

11.4.2.1.2 Reconfigured Fuel Assembly Weldment End Impact

Corner angle

For the end impact, the corner angles are evaluated to the criteria specified in NUREG/CR-6322, "Buckling Analysis of Spent Fuel Basket," and ASME Code Section III, Appendix F-1334.3.

Because Subsection F-1334.3 specifies no criteria for austenitic stainless steel, the following method from NUREG/CR-6322 is used to determine the criteria for the hypothetical accident condition (Service Level D).

Per NUREG/CR-6322 Equation 39, the criteria for austenitic stainless steel in the hypothetical accident condition can be expressed as:

$$SS_{\text{Level D}} = \left(\frac{SS}{CS}\right)_{\text{Level A}} \times CS_{\text{Level D}}$$

where SS and CS represent stainless steel and carbon steel, respectively.

The maximum allowable stress for stainless steel (F_a = 6,424.4 lb/in.^{2}) at Service Level A is determined as follows:

$$\frac{KL}{r} = \frac{1.0(27.02)}{0.6168} = 43.8$$

where:

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.272}{0.715}} = 0.6168\,\text{in.}$$

K = 1.0, effective length factor

L = 27.02 in., the length between supports

The width-thickness ratio is:

$$\frac{b}{t} = \frac{2.0}{0.1875} = 10.67$$

Applying the NUREG/CR-6322 criteria,

$$\frac{KL}{r} = 43.8 \leq 120, \text{ and } \frac{b}{t} = 10.67 \leq \frac{76}{\sqrt{S_y}} = 18.27$$

Therefore, the allowable stress (F_a) is:

$$F_a = S_y\left(0.47 - \frac{\frac{Kl}{r}}{444}\right) = 17.3\left(0.47 - \frac{43.8}{444}\right) = 6.4244 \text{ ksi}$$

The allowable Service Level A axial load ($P_{SS\text{-Level A}}$) can be determined using the relation:

$$P_{SS-\text{Level A}} = F_a \times A = 6{,}424.4 \text{ lb/in.}^2 \times 0.715 \text{ in.}^2 = 4{,}593.4 \text{ lb}$$

The maximum allowable Service Level A axial load ($P_{CS\text{-Level A}}$) for carbon steel can be determined using NUREG/CR-6322 Equation 22 as follows:

$$F_a = \frac{\left[1 - \frac{1}{2}\left(\frac{Kl}{rC_c}\right)^2\right]S_y}{\frac{5}{3} + \frac{3}{8}\frac{Kl}{rC_c} - \frac{1}{8}\left(\frac{Kl}{rC_c}\right)^3} = \frac{0.9498(25{,}800)}{1.667 + 0.1188 - .0040} = 13{,}752.1 \text{ psi}$$

where:

$$\frac{Kl}{r} = 43.8 < C_c = \sqrt{2\pi^2 \frac{E}{S_y}} = 138.85$$

$$P_{CS-\text{Level A}} = F_a A = 12{,}257.2 \text{ lb/in.}^2 (0.715 \text{ in.}^2) = 9{,}832.8 \text{ lb}$$

The maximum allowable axial compressive load ($P_{CS\text{-Level D}}$) for carbon steel Level D conditions using NUREG/CR-6322 Equation 33 is:

$$P_{CS-Level\ D} = \frac{\left(1-\frac{\lambda^2}{4}\right)P_y}{1.11+0.50\lambda+0.17\lambda^2-0.28\lambda^3} = \frac{0.9502(18{,}447.0)}{1.11+0.224+0.0341-0.025} = 13{,}399.8 \text{ lb}$$

where:

P_y = the average yield load ($S_y \times A$ = 25,800 ksi × 0.715 in.^{2} = 18,447 lb)

$$\lambda = \frac{1}{\pi}\left(\frac{Kl}{r}\right)\sqrt{\frac{S_y}{E}} = \frac{1}{\pi}(43.8)\sqrt{\frac{25.8}{25.2e3}} = 0.4461 \qquad 0 \le 0.4461 \le 1$$

Using NUREG/CR-6322 Equation 39 to determine the allowable load for stainless steel Level D conditions:

$$SS_{Level\ D} = \left(\frac{SS}{CS}\right)_{Level\ A} \times CS_{Level\ D} \qquad \text{(NUREG/CR-6322 Equation 39)}$$

$$P_{SS-Level\ D} = \frac{P_{SS-Level\ A}}{P_{CS-Level\ A}} \times P_{CS-Level\ D} = \frac{4{,}593.4}{9{,}832.8} \times 13{,}399.8 = 6{,}259.7 \text{ lb}$$

The load (P_{60g}) on each corner angle for the hypothetical accident condition is:

$$P_{60g} = \frac{225 \text{ lb}(60g)}{4} = 3{,}375 \text{ lb}$$

The margin of safety (MS) for the corner angle is:

$$MS = \frac{P}{P_{60g}} - 1 = \frac{6{,}259.7}{3{,}375} - 1 = +0.85$$

Tube

The tubes are evaluated for axial compression in accordance with NUREG/CR-6322 and ASME Code Section III, Appendix F-1334.3 the same as are the corner angles in the previous section.

The maximum allowable Service Level A stress for stainless steel (F_a = 2,750 lb/in.^{2}) is determined as follows:

$$\frac{KL}{r} = \frac{1.0(27.02)}{0.1869} = 144.57$$

where:

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.002026}{0.0580}} = 0.1869 \text{ in.}$$

The width-thickness ratio is:

$$\frac{b}{t} = \frac{0.5625}{0.035} = 16.1$$

Applying the NUREG/CR-6322 criteria,

$$\frac{KL}{r} = 144.57 > 120, \text{ and } \frac{b}{t} = 16.1 \leq \frac{76}{\sqrt{S_y}} = 18.27$$

Therefore, the allowable stress (F_a) is:

$$F_a = S_y\left(0.40 - \frac{\frac{Kl}{r}}{600}\right) = 17.3\left(0.40 - \frac{144.57}{600}\right) = 2.75 \text{ ksi}$$

The allowable Service Level A axial load ($P_{SS\text{-Level A}}$) can be determined using the relation:

$$P_{SS\text{-Level A}} = F_a \times A = 2{,}750 \text{ lb/in.}^2 \times 0.0580 \text{ in.}^2 = 159.5 \text{ lb}$$

The maximum allowable Service Level A axial load ($P_{CS\text{-Level A}}$) for carbon steel can be determined as follows:

$$F_a = \frac{12}{23}\frac{\pi^2 E}{\left(Kl/r\right)^2} = \frac{12}{23}\frac{\pi^2(25.2e6)}{\left(144.57^2\right)} = 6{,}208.7 \text{ psi}$$ (NUREG/CR-6322 Equation 23)

where:

$$\frac{Kl}{r} = 144.57 > C_c = \sqrt{2\pi^2\frac{E}{S_y}} = 138.29$$

$$P_{CS-Level\ A} = F_a A = 6208.7 \text{ lb/in.}^2\left(0.0580 \text{ in.}^2\right) = 360.1 \text{ lb}$$

The maximum allowable axial compressive load ($P_{CS\text{-}Level\ D}$) for carbon steel Level D conditions is:

$$P_{CS-Level\ D} = \frac{2P_y}{3\lambda^2} = \frac{2(1496.4)}{3(1.472)} = 460.4 \text{ lb}$$ (NUREG/CR-6322 Equation 35)

where:

P_y = the average yield load ($S_y \times A = 25{,}800$ ksi $\times$ 0.0580 in^2 = 1,496.4 lb)

$$\lambda = \frac{1}{\pi}\left(\frac{Kl}{r}\right)\sqrt{\frac{S_y}{E}} = \frac{1}{\pi}(144.57)\sqrt{\frac{25.8}{25.2e3}} = 1.472 > \sqrt{2}$$

Using NUREG/CR-6322 Equation 39 to determine the allowable load for stainless steel Level D conditions:

$$SS_{Level\ D} = \left(\frac{SS}{CS}\right)_{Level\ A} \times CS_{Level\ D}$$

$$P_{SS-Level\ D} = \frac{P_{SS-Level\ A}}{P_{CS-Level\ A}} \times P_{CS-Level\ D} = \frac{159.5}{355.8} \times 454.9 = 203.9 \text{ lb}$$

The load (P_{60g}) on each tube for the hypothetical accident condition is:

$$P_{60g} = 2.27 \text{ lb}(60g) = 136.2 \text{ lb}$$

The margin of safety (MS) for the hypothetical accident condition is:

$$MS = \frac{P}{P_{60g}} - 1 = \frac{203.9}{136.2} - 1 = +0.50$$

Support Grid End Impact

The support grid is analyzed for accident end drop conditions (VCC 6-inch drop discussed in Section 11.2.11) similarly to that for normal conditions discussed in Section 3.4.4.5. The acceleration applied for the accident condition is 60g. Evaluation of thermal stresses is not required for Service Level D conditions.

The peak nodal stress calculated for the 60g loading is 5,482 psi.

The Margin of Safety (MS) is:

$$MS = \frac{3.6S_m}{\sigma} - 1 = \frac{3.6(15{,}600)}{5{,}482} - 1 = +9.2$$

Support Grid Side Impact

The support grid is analyzed for accident conditions simulating tip-over of the concrete cask (Section 11.2.12) by applying an acceleration representing a side impact. The same model used in Section 3.4.4.5 to address the normal conditions end drop is used for side drop. The acceleration applied for this accident condition is 60g. Thermal stresses are not included.

The peak nodal stress (σ) calculated for the 60g side loading is 43,812 psi.

The margin of safety (MS) is:

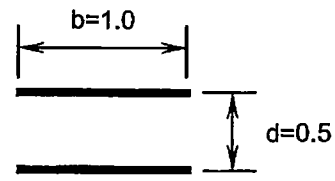
$$MS = \frac{3.6S_m}{\sigma} - 1 = \frac{3.6(15{,}600)}{43{,}812} - 1 = +0.28$$

Tube Support Grid to Corner Angle Welds

Each support grid is welded to four corner angles with 1/8-in. fillet welds one inch in length both

top and bottom. Using Blodgett's method of considering the weld as a line, the bending force (F_b) on the weld per inch of length is determined as follows:

$$F_b = \frac{M}{S_w} = \frac{46.0 \text{ lb} \cdot \text{in.}}{0.5 \text{ in.}^2} = 92.0 \text{ lb/in.}$$



The shear force (F_v) is:

$$F_v = \frac{V}{A_w} = \frac{51.2 \text{ lb}}{2.0 \text{ in.}} = 25.6 \text{ lb/in.}$$

where:

$S_w = b \times d$

$A_w = 2 \times b$

The resultant force (F) on the weld is:

$$F = \sqrt{F_b^2 + F_v^2} = 95.5 \text{ lb}$$

The effective throat thickness of the 1/8-in. fillet weld is 0.707(0.125 in.) = 0.088 in., the effective throat area is 0.088 in.^{2}/in., and the stress (f) in the weld is:

$$f = \frac{F}{nA} = \frac{95.5 \text{ lb/in.}}{0.4(0.088 \text{ in.}^2/\text{in.})} = 2{,}713.1 \text{ psi}$$

where:

n = 0.4 is the minimum quality factor for a Category E Type V weld per ASME Code Section III-NG.

The margin of safety (MS) is determined on the basis of the parent metal yield strength:

$$MS = \frac{3S_m}{f} - 1 = \frac{3.6(15{,}600) \text{ psi}}{(2{,}713.1)} - 1 = +\text{Large}$$

11.4.3 Evaluation of the CY-MPC Damaged Fuel Can

The CY-MPC damaged fuel can is evaluated for hypothetical accident conditions of concrete cask 6-inch drop (Section 11.2.11) and the tip-over event (Section 11.2.12). The concrete cask 6-inch drop is evaluated considering a 60g end-impact and the tip-over accident is evaluated using a 60g side-impact.

A bounding temperature of 600°F is used for accident conditions. Material properties for ASME SA240/SA479 Type 304 Stainless Steel, ASME Code Section III, Subsection NG, are:

S_u	63.3 ksi
S_y	18.6 ksi
S_m	16.7 ksi
E	25.2×10^3 ksi

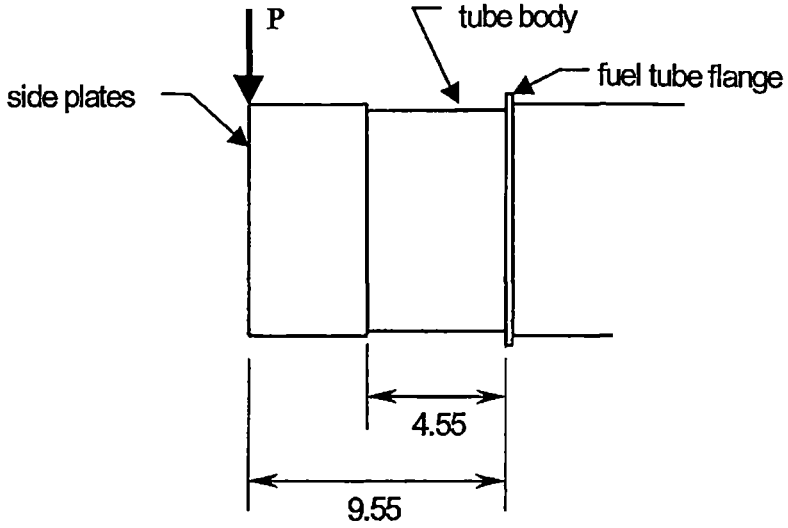
The weight of the damaged fuel can top assembly (lid) is 19.46 lbs, and the weight of the can weldment is 91.6 pounds. Twenty-five lbs and 95 lbs are used in the analysis for the top assembly and can weldment, respectively.

11.4.3.1 Damaged Fuel Can Weldment Stress Analysis

Damaged Fuel Can Tube Body – Side Impact

The majority of the tube body is contained within the fuel tube in the basket assembly. Because both the tube body and the fuel tube have square cross sections, they will be in full contact (for 131.95 in. longitudinally) during the side impact and no significant bending stress will be introduced into the tube body. The last 4.55 in. of the body tube and the 5.0-in. length of the side plates will be unsupported past the fuel tube flange in the side impact configuration.

The tube body will be evaluated as a cantilevered beam with the combined weight (P) of the overhanging tube body, side plates and lid assembly multiplied by a deceleration factor of 60g and, conservatively, concentrated at the top end of the side plates. The 60g conservatively bounds the maximum deceleration of 40g for the cask tip-over accident (Section 11.2.12.5).



The maximum bending stress (f_b) is determined as follows:

$$f_b = \frac{M_{max}c}{I} = \frac{20{,}055(4.44)}{22.95} \cong 3{,}880 \text{ psi}$$

where:

$M_{max} = Pg \times L = 35(60)(9.55) = 20{,}055$ lb·in.

$g = 60$

The shear stress (τ) is:

$$\tau = \frac{Pg}{A} = \frac{35(60)}{1.766} \cong 1{,}189 \text{ psi}$$

$$\sigma_1, \sigma_2 = \frac{1}{2}\left(f_b \pm \sqrt{f_b^2 + 4\tau^2}\right) = \frac{1}{2}\left(3{,}880 \pm \sqrt{3{,}880^2 + 4(1{,}189)^2}\right) \cong 4{,}215 \text{ psi and } -335 \text{ psi}$$

The stress intensity (σ_{max}) = $|\sigma_1 - \sigma_2|$ = 4,550 psi

The Margin of Safety (MS) is:

$$MS = \frac{1.0\ S_u}{\sigma_{max}} - 1 = \frac{1.0(63{,}300)}{4{,}550} - 1 = +12.9$$

For the hypothetical condition of 100% failure of the fuel rods inside the damaged fuel can, the debris will be located in the lower portion of the fuel can. In the cask tip-over accident, this condition has no adverse effect on the structural adequacy of the fuel can or fuel basket, since the deceleration at the lower elevation is not controlling (i.e., deceleration decreases as elevation increases).

Weld Evaluation

The welds joining the tube body to the side plates are full penetration welds (Type III, ASME Code Section III, Subsection NG paragraph NG-3352.3). Per Table NG-3352-1 (ASME Code Section III, Subsection NG), the weld quality factor (n) for a Type III weld with visual surface inspection is 0.5.

The margin of safety (MS) for the weld is:

$$MS = \frac{(1.0)n \cdot S_u}{\sigma_{max}} - 1 = \frac{(1.0)(0.5)(63{,}300\ \text{psi})}{4{,}550\ \text{psi}} - 1 = +5.9$$

Damaged Fuel Can Tube Body – End Impact

For the bottom end impact, the tube body is subjected to the weight of the top assembly (lid), the side plates, and its self-weight. The can contents bear against the bottom assembly through which the loads are transferred to the canister bottom plate.

The compressive load (P) on the tube body is:

P = 5,982.6 lb; use 7,500 lb for evaluation

The compressive stress (S_c) in the tube body is:

$$S_c = \frac{P}{A} = \frac{7{,}500\ \text{lb}}{1.766\ \text{in.}^2} \cong 4{,}247\ \text{psi}$$

The margin of safety (MS) is:

$$MS = \frac{0.7S_u}{S_c} - 1 = \frac{0.7(63{,}300)\text{ psi}}{4{,}247\text{ psi}} - 1 = +9.4$$

Tube Body Buckling

The tube is evaluated, using the Euler formula, to determine the critical buckling load (P_{cr}):

$$P_{cr} = \frac{\pi^2 EI}{L_e^2} = \frac{\pi^2(25.2\times10^6)(22.95)}{2(136.63)} = 20.9\times10^6\text{ lb}$$

where:

$E = 25.2\times10^6$ psi

$$I = \frac{8.88^4 - 8.78^4}{12} = 22.95\text{ in}^4$$

L_e = 2L (worst case condition)

L = tube body length (136.63 in.)

Because the maximum compressive load (7,500 lb under the accident condition) is much less than the critical buckling load (20.9×10^6 psi) the tube has adequate resistance to buckling.

During a bottom end impact, the top lid will be subjected to bending stresses caused by the weight of the top lid. The top lid assembly conservatively weighs 25 lbs. Under a 60g load, the load on the plate is 1,500 lbs or ($1{,}500/8.77^2$) 20 psi. The maximum stress for the lid is calculated by conservatively assuming a unit width simply supported beam 8.77-inches long with a thickness of 0.75-inches.

$$M = \frac{20(8.77^2)}{8} = 192.3\text{ in - lbs}$$

$$S_b = \frac{6(192.3)}{1.0(0.75^2)} = 2{,}051\text{ psi}$$

The Margin of Safety is:

$$MS = \frac{2.4(16{,}700)}{2{,}051} - 1 = +\text{Large}$$

11.4.4 Connecticut Yankee Fuel Rod Buckling Analysis

The bounding condition for the assessment of the evaluation of the fuel rod buckling is the end impact orientation, which corresponds to the concrete cask 6-inch end drop described in Section 11.2.11. The acceleration resulting from the end impact event is 18g. An acceleration of 60g is conservatively used in this evaluation, which bounds the 6-inch impact event acceleration.

In the end impact, the fuel rods are expected to impact the fuel assembly base. The fuel rods will respond similar to an elastic bar under a sudden compression load at its bottom end. The duration of the impact is bounded by the first extentional mode shape of the fuel rods. Contributions of higher frequency extentional modes tend to shorten the duration of impact. The fuel rods, at initiation of impact, correspond to an undeformed state. In the process of the impact, the compression of the fuel rods will increase to a maximum and then return to a near uncompressed state, at which point the time of impact has been completed. This actually represents half of a cycle of the lowest frequency mode shape of the fuel rods. The shape of the time dependence of the deformation is sinusoidal. The single extentional mode shape can also be considered to be a single degree of freedom with a corresponding mass and stiffness.

For dynamic loading, it is assumed that the duration of the loading is sufficiently long to allow the system to experience the complete load, even as the deformation associated with the buckling is initiated. The lateral motion, which would correspond to the buckled shape, will correspond to the lowest mode shape. The mode shapes have the same displacement boundary conditions, the same stiffness matrix, and the same governing finite element equations, i.e.,

$$[K]\{\phi_i\} = \lambda_i\ [A]\{\phi_i\}$$

where:

- $[K]$ = structure stiffness matrix
- $\{\phi_i\}$ = eigenvector
- λ_i = eigenvalue
- $[A]$ = mass matrix for the mode shape calculation or stress stiffening matrix for the buckling evaluation

Based on the time duration of the impact and the inherent inability of the fuel rod to rapidly

displace in the lateral direction, the effect of the actual lateral motion of buckling can be computed with a dynamic load factor (DLF) (Clough). The expression for the DLF for a half-sine loading for a single degree of freedom is given by

$$DLF = \frac{2\beta\cos(\pi/2\beta)}{1-\beta^2}$$

where:

β = ratio of the first extentional mode frequency to the first lateral mode frequency

This calculational methodology is used to determine the acceleration corresponding to the first buckling shape.

Connecticut Yankee fuel uses both Zircaloy and stainless steel clad fuel rods, with fuel rods restrained by grids and in contact with the fuel assembly base. In the vertical orientation, the weight of the fuel rods is transferred to the base of the fuel assembly. Each of the grids restraining the fuel rods is considered to provide lateral support, but no rotational resistance to buckling. The calculation of the first buckling mode is performed using ANSYS Revision 5.5. The beam elements use effective cross-sectional properties, which combined the cross-sectional properties of the fuel pellet and the fuel rod cladding. To be consistent with this approach, the beam element considers the weight of the fuel pellet and the cladding. The fuel rod dimensions and physical data used in the evaluation are:

Case	Fuel Assembly Type	Cladding			Pellet Diameter (inch)	Rod Length (inch)
		Material	Thickness (inch)	Outer Diameter (inch)		
1	Westinghouse	Zircaloy	0.0242	0.422	0.3659	151.85
2	Westinghouse	SS304	0.0165	0.422	0.3895	126.52
3	B&W	Zircaloy	0.0265	0.430	0.3686	153.68
4	B&W	SS304	0.0165	0.422	0.3825	126.68

The modulus of elasticity (EX) for the fuel pellet is listed in Rust as having a nominal value of 26×10^6 psi. Conservatively, only 50% of this value is used. The EX for the fuel pellet is, therefore, taken to be 13×10^6 psi. The EX for Zircaloy fuel cladding used in the evaluation is

also 13 x 10^6 psi. The EX for the stainless steel cladding is conservatively taken to be 13 x 10^6 psi, even though the minimum EX for stainless steels at 600°F is 25.2 x 10^6 psi.

The elevation of grids (lateral constraints) varies for each fuel assembly type. The locations of the grid constraints for each fuel type, as measured from the bottom of the fuel rod, are:

Case	Rod Length (inch)	Lateral (Grid) Constraints (inch)							
1	151.85	2.93	27.14	53.33	79.52	105.71	131.90	150.57	N/A
2	126.52	1.24	20.12	41.20	62.28	83.36	104.44	125.52	N/A
3	153.68	3.45	25.57	46.70	67.79	88.88	109.98	131.07	153.15
4	126.68	1.84	20.21	41.29	62.27	83.45	104.53	125.51	N/A

The effective cross-sectional properties (EI_{eff}) for the beam are computed by adding the value of EI for the cladding and for the pellet, where:

E = modulus of elasticity (lb/in^2)
I = cross-sectional moment of inertia (in^4)

The acceleration corresponding to the first buckling mode for the combined cladding and fuel pellet materials are:

Case	First Extensional Frequency (Hz)	First Lateral Frequency (Hz)	Frequency Ration (β)	Dynamic Load Factor (DLF)	Dynamic Acceleration	First Buckling Mode Acceleration
1	211.5	29.1	7.3	0.279	15.3	41.0
2	231.2	37.1	6.2	0.331	18.2	64.3
3	209.5	41.3	5.1	0.408	22.4	48.2
4	230.4	38.1	6.0	0.343	18.9	60.2

Since the dynamic acceleration is less than the first buckling mode acceleration for all four cases, the fuel rods will not buckle during an end drop.

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11.4.5 CY-MPC Fuel Tube Analysis

The fuel tube provides a foundation to mount BORAL neutron poison plates within the fuel basket structure. The fuel tube does not serve a structural function relative to the support of the fuel assembly. To ensure that the fuel tube remains functional when the cask is subjected to design load conditions, a structural evaluation of the tube is performed for the end and side impact load conditions using the design impact g-load of 55g. This bounds the storage cask 18g end impact load due to the 6-inch vertical drop and the 40g side impact due to the postulated tip-over event. The dimensions used in the fuel tube stress calculations correspond to those of the oversized fuel tube, which provides a bounding weight for the fuel tube and a larger area for the evaluation.

Fuel Tube End-Impact Analysis

During the postulated end impact, the Connecticut Yankee fuel assemblies are supported by the canister bottom plate. The fuel tubes do not carry the fuel assembly load. Therefore, the evaluation of the fuel tube is performed by considering the weight of the fuel tube subjected to the deceleration carried by the minimum tube cross-sectional area. The minimum cross-sectional area is located at the contact point of the tube with the bottom weldment. The minimum cross-sectional area is:

$$A = 0.048 \text{ x } (9.12 + 0.048) \text{ x } 4 = 1.76 \text{ in}^2$$

The total bearing load on the tube during the end impact is 6,820 lbs (55g x 124 lbs). The maximum compressive and bearing stress is (6,820/1.76) = 3,875 psi. Limiting the compressive stress level to the material yield strength ensures that the fuel tube remains in position in the postulated end-drop. Type 304 stainless steel yield strength is 17,300 psi at a conservatively high temperature of 750°F for the axial location on the fuel tube that has the minimum cross-sectional area. The margin of safety is:

$$MS = \frac{17{,}300}{3{,}875} - 1 = +3.46$$

Fuel Tube Side-Impact Analysis

In the side-impact load configuration, the fuel tube is adequately restrained by the basket support disks. The support disks restrain the full length of the fuel tube and are spaced at 4.59 inches (center-to-center), which is about one-half of the fuel tube width. Considering the fuel tube is subjected to a 55g side-impact deceleration at the 28 support locations provided by the basket support disk, the fuel tube shear stress is:

Shear Load = 3,123.2 lbs
Area = 0.048 x 9.12 x 2 = 0.876 in^2
Shear Stress = 3,123.2 / 0.876 = 3,565.3 psi

Using an allowable shear stress equivalent to half the yield strength of the tube (at 750°F), or 8,650 psi (17,300/2), the margin of safety is:

$$MS = \frac{8,650}{3,565.3} - 1 = 1.43$$

The ANSYS finite element program was used to perform the elastic-plastic analysis on the fuel tubes. ANSYS plastic quadrilateral (SHELL43) shell elements were used to model the fuel tube walls, which are 0.048-inch thick. The fuel tube is 131.95 inches long and is supported by 0.5-inch thick support disks at a 4.59-inch pitch. The BORAL plate (0.075 inch) and stainless steel cover plate (0.018 inch) are conservatively not included in the model. The multi-linear kinematic hardening (kinh) option is used for the non-linear material properties. The stress-strain curve for Type 304 stainless steel is used.

Two loading cases were analyzed: pressure loading and grid loading. Note that only a quarter-symmetry periodic section of the fuel tube was modeled (Figures 11.4.5-1 and 11.4.5-2).

For the pressure loading case, surface pressures were applied to the inside bottom surface of the fuel tubes. The distributed load of the fuel assembly on the fuel tube wall was modeled as a surface pressure load (see Figure 11.4.5-1), calculated as:

$$\text{Impact Pressure} = \frac{gW_f}{w_f L_f} = 72.67 \text{ psi}$$

where:

g = acceleration load = 55g
W_f = weight of fuel assembly = 1590 lbs
L_f = length of fuel tube = 131.95 in
w_f = width of fuel tube = 9.12 in

For the grid loading case, it is assumed that the fuel assembly grid is rigid. A constant displacement equal to the thickness of the grid (0.08 inch) is applied in the model at nodes corresponding to grid locations (see Figure 11.4.5-2).

From the elastic-plastic analyses of the fuel tube, the maximum equivalent plastic stress is 24,060 psi for the uniform loading case and 30,970 psi for the grid loading case. Conservatively comparing the plastic stress to the allowable stress of 63,100 psi at 750°F for Type 304 stainless steel (750°F is larger than the maximum fuel clad temperature of 629°F, which would bound the maximum temperature of the fuel tube), and the stress intensity of the displacement loading case to the allowable elastic stress of 17,300 psi at 750°F for Type 304 stainless steel, provides the following margins of safety:

Pressure Loading: $$MS = \frac{63,100}{24,060} - 1 = 1.62$$

Grid Loading: $$MS = \frac{63,100}{30,970} - 1 = 1.04$$

The maximum total strain for the fuel tube is 0.019 for the uniform loading case and 0.047 for the grid loading case, as shown in Figures 11.4.5-3 and 11.4.5-4, respectively. Defining the acceptable elastic-plastic response of the stainless steel as one-half the material failure strain of 0.4 in/in at 750°F, and using this methodology to evaluate total cumulative strain, shows margins of safety of:

Pressure Loading: $$MS = \frac{0.4/2}{0.019} - 1 = 9.53$$

Grid Loading: $$MS = \frac{0.4/2}{0.047} - 1 = 3.26$$

Similarly, the margins of safety for elastic-plastic stress are:

Pressure Loading: $$MS = \frac{63,100 - 17,300}{24,060 - 17,300} - 1 = 5.78$$

Grid Loading: $$MS = \frac{63,100 - 17,300}{30,970 - 17,300} - 1 = 2.35$$

Where the yield strength of Type 304 stainless steel at 750°F is 17,300 psi.

Both the maximum total equivalent strain and the elastic-plastic stress analyses indicate that the tube position is maintained within the basket.

Fuel Tube Deformation Evaluation

The worst case permanent deformation for the fuel tube is required for the criticality analysis. The side impact analysis for the uniform loading case (presented above) is conservative, since it does not consider any stiffness of the fuel assembly. During the tip-over event, the weight of the fuel assembly is transmitted through the 15 peripheral fuel rods to the support disk. The displacement of the fuel tube due to the lateral loading of the fuel rods is dependent on both the stiffness of the fuel tube and the stiffness of the fuel rod.

The maximum displacement of the fuel rods between two support disks is calculated using the formula for a four-span continuous beam shown below. However, for a 15 × 15 fuel assembly subjected to a side impact load, all 15 fuel rods (stacked up on top of each other) act together. The weight and inertia of the rods need to be multiplied by 15.

$$\Delta_{max} = 0.0065\frac{wL^4}{EI} = 1.2 \times 10^{-5} \text{ inch}$$

where:

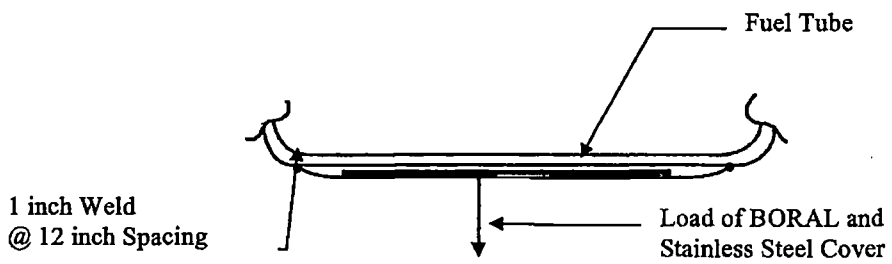
w	= mass/length for 15 rods = $(\rho_{zirc}A_{zirc} + \rho_{UO_2}A_{UO_2}) \times 15 = 0.783$ lb/in
Rod OD	= 0.43 in
Rod ID	= 0.43-2x0.0265 = 0.377 in
Rod Density (Zirc-4)	= $\rho_{zirc} = 0.237$ pci
Rod Area	= $A_{zirc} = \frac{\pi}{4}(0.43^2 - 0.377^2) = 0.03359 \text{ in}^2$
UO_2 Density	= $\rho_{UO_2} = 0.396$ pci
UO_2 Area	= $A_{UO_2} = \frac{\pi}{4}x0.377^2 = 0.11163 \text{ in}^2$
L	= Distance between support disks = 4.09 in
E_{zirc}	= 11.5×10^6 psi
I_{zirc}	= moment of inertia for 15 rods = $\frac{\pi}{64}(0.43^4 - 0.377^4) \times 15$ = 0.0103 in^4

Using the E_{zirc} and I_{zirc} as conservative assumptions, the maximum displacement is estimated as 1.2×10^{-5} inch. For a 55g acceleration, this displacement becomes 6.61×10^{-4} inch.

An analysis is performed using the same model by applying the maximum displacement of the fuel rods as loading on the fuel tube along a line at the center of the fuel tube between the support disks and the fuel tube walls as shown in Figure 11.4.5-5. In conjunction with the displacement boundary condition, the deceleration of 60g is also applied. The analysis is conservative as it considers the displacement of 15 fuel rods in a 15 x 15 fuel assembly applied as uniform displacement loading on the fuel tube. The stress contour for the fuel tube for the analysis is presented in Figure 11.4.5-6. The maximum stress intensity is 11,886 psi, which is actually due to the self-weight of the fuel tube. The maximum stress due to the displacement is 7,291 psi. These stresses are below the yield stress of 17,300 psi at 750°F for Type 304 stainless steel. It is concluded that no plastic deformation occurs in the fuel tube due to the displacement of the fuel rods; therefore, the worst case plastic deformation in the fuel tube will be due to the displacement of the grid spacer, which will not exceed the thickness of the grid spacer (0.08 inch).

Weld Evaluation

Assurance that the BORAL neutron poison remains within the cover is evaluated by considering that loads produced by the BORAL and cover masses, decelerated by 55g, are maintained by the seal weld.



The load exerted by BORAL/stainless steel cover is:

$$F_{b/ss} = g\rho twl$$

where:

g = acceleration due to gravity = 55 g

ρ = density of material
= 0.098 lb/in^3 (BORAL, aluminum density is conservatively used)
= 0.291 lb/in^3 (stainless steel)

t = thickness of material
= 0.075 in (BORAL)
= 0.018 (stainless steel)

w = width of material
= 8.54 in (BORAL) (9.22-0.34x2)
= 9.05 in (stainless steel) (9.22-0.18x2+0.075x2)

l = length of material section = 12.0 in

Loads on a 1-inch weld for a 12-inch section:

F_b = 55 x 0.098 x 0.075 x 8.54 x 12.0 = 41.43 lbs
F_{ss} = 55 x 0.291 x 0.018 x 9.05 x 12.0 = 31.29 lbs

Total load (F_t) on a 1-inch section of fuel tube seal weld:

P = 41.43 + 31.29 = 72.72 lbs

Weld stress, $\sigma = \frac{P}{A} = \frac{72.72/2}{1x0.018} = 2{,}020$ psi

Based on the weld material being Type 304 stainless steel the margin of safety is:

σ_{yield} = 17,300 psi @ 750°F

$MS = \frac{17{,}300}{2{,}020} - 1 = +7.56$

Figure 11.4.5-1 CY-MPC Fuel Tube Finite Element Model for Uniform Loading

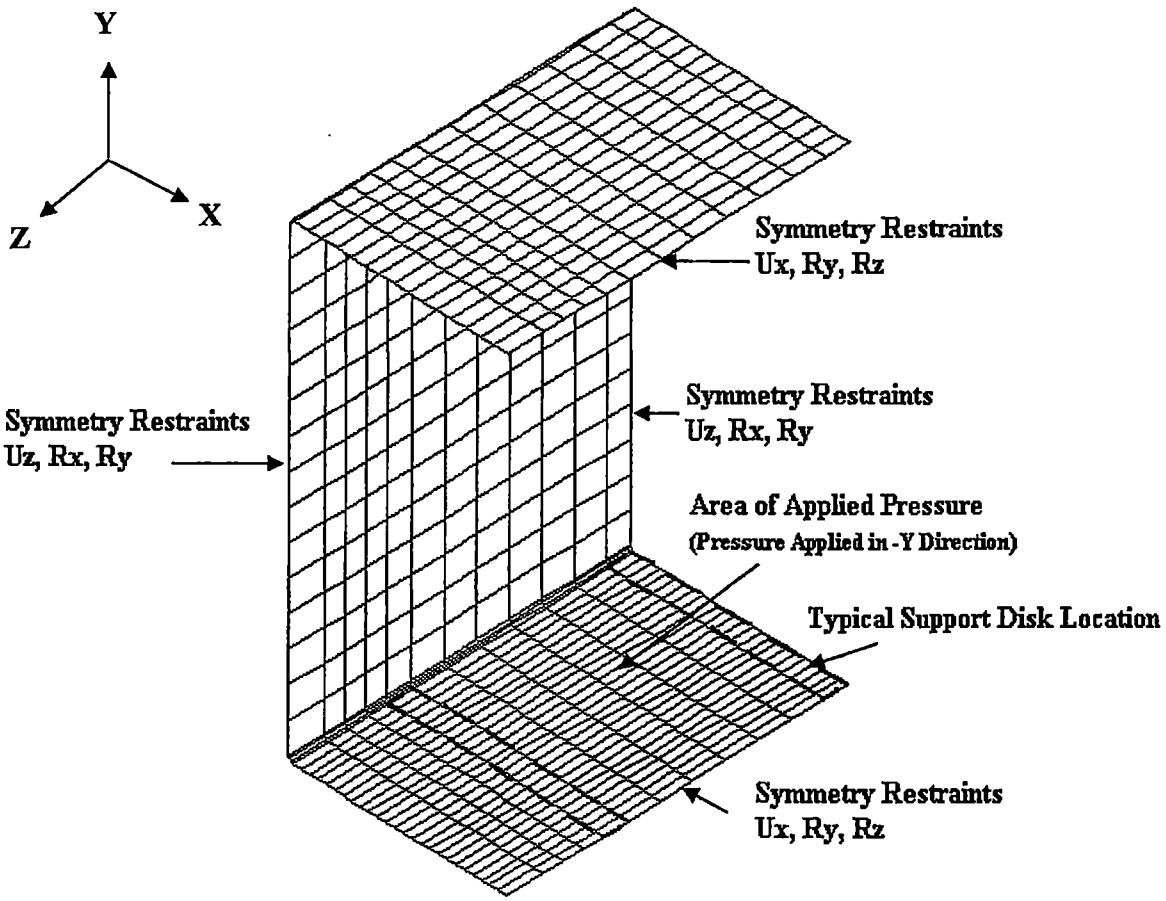


Figure 11.4.5-2 CY-MPC Fuel Tube Finite Element Model for Grid Loading

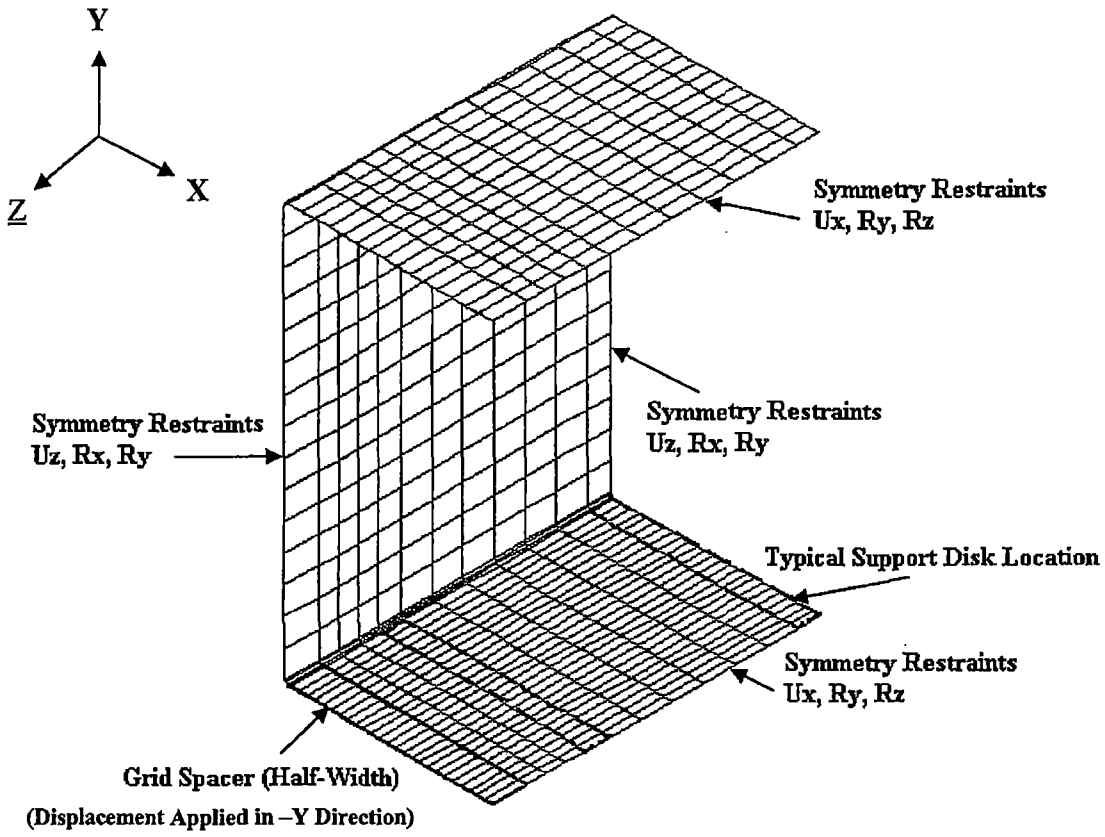
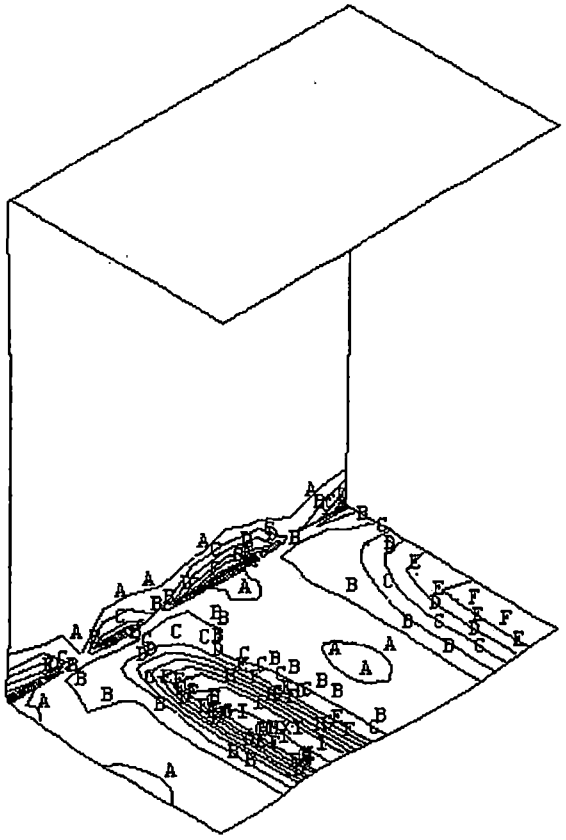


Figure 11.4.5-3 CY-MPC Fuel Tube Total Equivalent Strain – Uniform Loading Analysis



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EffNu=0
TOP
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SMN =.148E-04
SMX =.018568
A =.001046
B =.003107
C =.005168
D =.00723
E =.009291
F =.011353
G =.013414
H =.015476
I =.017537

Figure 11.4.5-4 CY-MPC Fuel Tube Total Equivalent Strain – Grid Loading Analysis

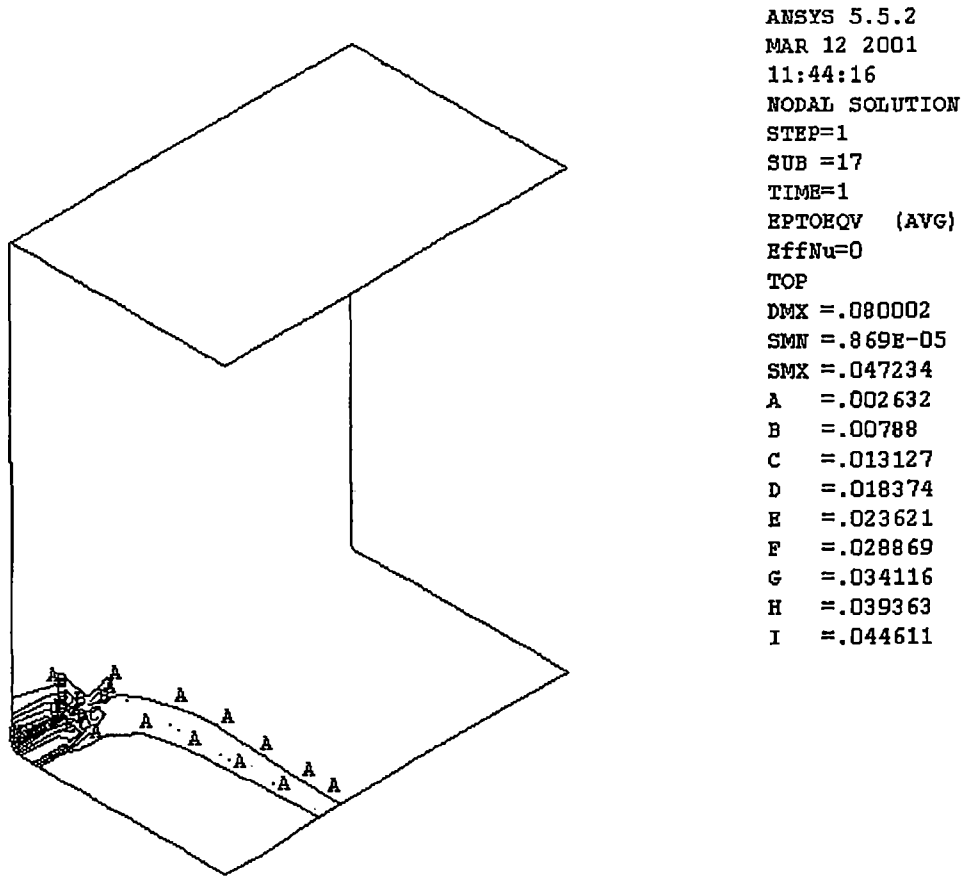


Figure 11.4.5-5 CY-MPC Fuel Tube Finite Element Model for Fuel Rod Displacement Loading

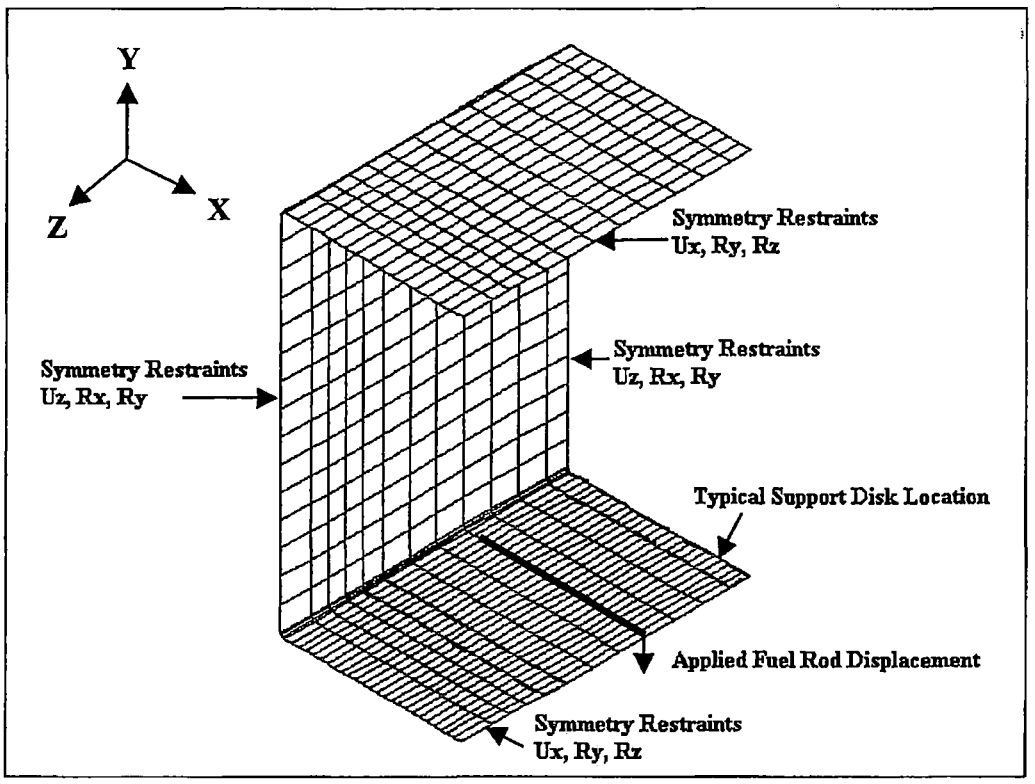
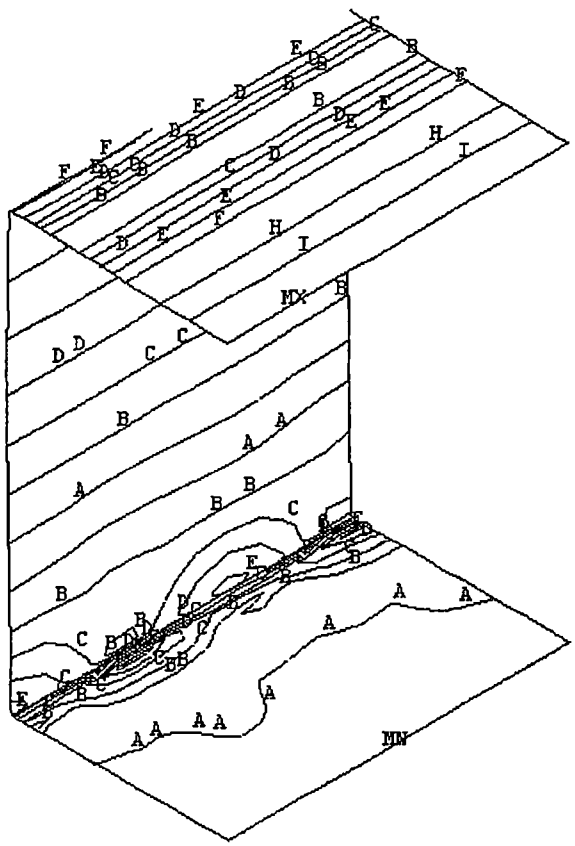


Figure 11.4.5-6 CY-MPC Fuel Tube Stress Intensity – Fuel Rod Displacement Loading Analysis (psi)



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C =3353
D =4665
E =5978
F =7291
G =8604
H =9917
I =11230

11.5 Canister Closure Weld Evaluation – Accident Conditions

11.5.1 Stress Evaluation for the Yankee-MPC Canister Closure Weld

The closure weld for the canister is a partial penetration weld with a thickness of 0.9 inches. The evaluation of this weld, in accordance with NRC guidance, is to incorporate two separate weld stress reduction factors: a 0.8 factor based on weld type and a second 0.8 factor based on NRC ISG-4, Item 5. These two weld stress reduction factors are incorporated by applying a factor of 0.64 (0.8 x 0.8) to the stress allowable for this weld.

The stresses for the canister are evaluated using sectional stresses as permitted by Subsection NB. The canister stress results for the Vertical Concrete Cask tip-over accident evaluation (Section 11.2.12.2.2) are used for evaluation. The location of the section for the canister weld evaluation is shown in Figure 11.2.12.2.2-4 and corresponds to Section 12. The P_m and $P_m + P_b$ stress intensity for Section 12 and the associated allowables are listed in Table 11.2.12.2.2-1 and Table 11.2.12.2.2-2, respectively. The factored allowables, incorporating a 0.64 stress reduction factor, and the resulting controlling Margins of Safety are:

Stress Type	Analysis Stress Intensity (ksi)	0.64 × Allowable Stress (ksi)	Margin of Safety
P_m	24.25	24.65	0.02
$P_m + P_b$	26.66	36.99	0.37

This confirms that the canister closure weld is acceptable for the accident conditions.

11.5.2 Critical Flaw Size for the Yankee-MPC Canister Closure Weld

The closure weld for the canister comprises multiple weld beads using a compatible weld material for Type 304L stainless steel. An allowable (critical) flaw evaluation has been performed to determine the critical flaw size in the weld region. The result of the flaw evaluation is used to define the minimum flaw size, which must be identifiable in the nondestructive examination of the weld. Due to the inherent toughness associated with Type 304L stainless steel, a limit load analysis is used in conjunction with a J-integral/tearing modulus approach. The safety margins used in this evaluation correspond to the stress limits contained in Section XI of the ASME Code.

The stress component used in the evaluation for the critical flaw size is the radial stress component in the weld region of the structural lid. For an accident (Level D) event, in accordance with ASME Code Section XI, a safety factor of $\sqrt{2}$ is required. For the purpose of identifying the stress for the flaw evaluation, the weld region corresponds to Section 12 in Figure 11.2.12.2.2-4 is considered. From additional post processing of the tipover analysis, the maximum tensile radial stress is 3.8 ksi. To perform the flaw evaluation, a 10 ksi stress is conservatively used, resulting in a significantly larger safety factor than the required safety factor of $\sqrt{2}$. Using 10 ksi as the basis for the evaluation, the minimum detectable flaw size is 0.52 inch for a flaw that extends 360 degrees around the circumference of the canister. Stress components for the circumferential and axial directions are also determined, which would be associated with flaws oriented in the radial or horizontal directions, respectively. The maximum stress for these components is 1.7 ksi, which is enveloped by the stress value of ksi used for the critical flaw evaluation for radial directions. The 360-degree flaw employed for the circumferential direction is considered to be bounding with respect to any partial flaw in the weld, which could occur in the radial and horizontal directions. Therefore, using a minimum detectable flaw size of 0.375 inch is acceptable, since it is less than the very conservatively determined 0.52-inch critical flaw size.

11.5.3 Stress Evaluation for the CY-MPC Canister Closure Weld

The closure weld for the canister is a partial penetration weld with a minimum thickness of 0.75 inch. The evaluation of this weld incorporates a weld stress reduction factors of 0.8 factor based on NRC ISG-4, R1, Item 6(c). This weld stress reduction factor is incorporated by applying a factor of 0.8 to the stress allowable for this weld.

The stresses for the canister are evaluated using sectional stresses as permitted by Subsection NB. The canister stress results for the Vertical Concrete Cask tip-over accident evaluation (Section 11.2.12.5.2) are used for evaluation. The location of the section for the canister weld evaluation is shown in Figure 11.2.12.5.2-4 and corresponds to Section 11. The P_m and $P_m + P_b$ stress intensity for Section 12 and the associated allowables are listed in Table 11.2.12.5.2-1 through Table 11.2.12.5.2-8, respectively. The factored allowables, incorporating a 0.8 stress reduction factor, and the resulting controlling Margins of Safety are:

Stress Type	Analysis Stress Intensity (ksi)	0.8 × Allowable Stress (ksi)	Margin of Safety
P_m	30.22	31.20	0.03
$P_m + P_b$	30.55	46.80	0.53

This confirms that the CY-MPC canister closure weld is acceptable for the accident conditions.

11.5.4 Critical Flaw Size for the CY-MPC Canister Closure Weld

The closure weld for the canister comprises multiple weld beads using a compatible weld material for Type 304L stainless steel. An allowable (critical) flaw evaluation has been performed to determine the critical flaw size in the weld region. The result of the flaw evaluation is used to define the minimum flaw size, which must be identifiable in the nondestructive examination of the weld. Due to the inherent toughness associated with Type 304L stainless steel, a limit load analysis is used in conjunction with a J-integral/tearing modulus approach. The safety margins used in this evaluation correspond to the stress limits contained in Section XI of the ASME Code.

The stress component used in the evaluation for the critical flaw size is the radial stress component in the weld region of the structural lid. For an accident (Level D) event, in accordance with ASME Code Section XI, a safety factor of $\sqrt{2}$ is required. For the purpose of identifying the stress for the flaw evaluation, the weld region corresponding to Section 11 in Figure 11.2.12.5.2-4 is considered. From additional post processing of the tipover analysis, the maximum tensile radial stress is 5.7 ksi. To perform the flaw evaluation, a 10 ksi stress is conservatively used, resulting in a significantly larger safety factor than the required safety factor of $\sqrt{2}$. Using 10 ksi as the basis for the evaluation, the minimum detectable flaw size is 0.44 inch for a flaw that extends 360 degrees around the circumference of the canister. Stress components for the circumferential and axial directions are also determined, which would be associated with flaws oriented in the radial or horizontal directions, respectively. The maximum stress for these components is 1.6 ksi, which is enveloped by the stress value of 10 ksi used for the critical flaw evaluation for radial directions. The 360-degree flaw employed for the circumferential direction is considered to be bounding with respect to any partial flaw in the weld, which could occur in the radial and horizontal directions. Therefore, using a minimum detectable flaw size of 0.375 inch is acceptable, since it is less than the very conservatively determined 0.44-inch critical flaw size.

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Appendix 11.A ACCIDENT ANALYSIS – MPC-LACBWR MPC STORAGE SYSTEM FOR DAIRYLAND POWER COOPERATIVE LA CROSSE BOILING WATER REACTOR

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11.A ACCIDENT ANALYSIS FOR THE MPC-LACBWR STORAGE SYSTEM

The analyses of the MPC-LACBWR storage system for off-normal and accident design events, including those identified by ANSI/ANS 57.9-1992 [A1], are presented in this appendix. The analyses of off-normal events, which could occur during the use of the MPC-LACBWR storage system as often as once per calendar year, are described in Section 11.A.1. The analyses of accident conditions, which are postulated events that have a very low probability of occurrence (e.g., may occur once during the lifetime of the ISFSI) or have consequences that may result in maximum potential impact on the surrounding environment, are described in Section 11.A.2. The analyses of the MPC-LACBWR transportable storage canister for design basis transportation accident conditions are described in Section 11.A.3.

This appendix demonstrates that the MPC-LACBWR storage system satisfies the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident conditions. The analyses are based on conservative assumptions to ensure that the consequences of off-normal conditions and accident events are bounded by the reported results. In many cases, the accident analyses of the Yankee-MPC storage system are shown to bound those of the MPC-LACBWR storage system, and are conservatively used for the evaluation of the MPC-LACBWR storage system.

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11.A.1 Off-Normal Events for the MPC-LACBWR Storage System

This section presents the evaluation of the MPC-LACBWR storage system for off-normal events that, although unlikely to occur, are postulated to occur on the order of one time per calendar year of operation.

11.A.1.1 Blockage of Half of the Air Inlets

This section evaluates the MPC-LACBWR storage cask for the steady state effects of a blockage of one-half of the air inlets at the normal ambient temperature (75°F).

11.A.1.1.1 Cause of Event

The most likely causes of a partial blockage of the concrete cask air inlets is the accumulation of snow or debris at the base of the concrete cask or an obstruction caused by intrusion of a burrowing animal. It is expected that screens over the inlets would preclude such animals and would exclude debris from the inlet channels.

Blockage of the concrete cask air inlets would be detected by the daily visual inspection of the concrete cask inlet screens. However, it is not necessary to detect this event since it will not cause the maximum component temperatures to exceed those reported in Section 4.A (Table 4.A.3-3) for normal condition. The analysis for normal condition documented in Section 4.A is based on the conservative assumption of the no air follow in the inlets, outlets, and the concrete cask annulus region.

11.A.1.1.2 Analysis of the Blockage Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.A.3.1.1 for the MPC-LACBWR. Since air flow is neglected in the thermal model, the analysis results for the normal storage condition bound the analysis results for the condition due to one-half of the air inlets being blocked. The analysis results are listed in Table 4.A.3-3.

The evaluations show that the component temperatures are within the allowable temperature range for the one-half of the inlets blocked condition.

11.A.1.1.3 Radiological Consequences

There are no radiological consequences for this event.

11.A.1.1.4 NAC-MPC Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are less than the allowable temperatures. The MPC-LACBWR concrete cask continues to perform its thermal function with one-half of the air inlets blocked.

11.A.1.1.5 Recovery and/or Corrective Actions

The debris blocking the inlets does not have to be removed.

11.A.1.2 Canister Off-Normal Handling Load

The MPC-LACBWR canister is evaluated for off-normal handling loads that are postulated to occur during the canister transfer operations. For this condition, the MPC-LACBWR canister, suspended by the shield lid lift points, is subjected to simultaneous acceleration loads of 0.5*g* in the vertical direction and 0.7071*g* in the horizontal direction (i.e., 0.5*g* acting along two orthogonal horizontal axes.) These off-normal handling loads are evaluated in combination with dead weight and normal internal pressure loads.

11.A.1.2.1 Cause of Event

Off-normal canister handling is postulated to result from canister misalignment, faulty crane operation, or inattention of the operators during canister transfer operations. An off-normal canister handling event would most likely be detected by the crew performing the canister transfer operation due to banging and/or scraping noise.

11.A.1.2.2 Analysis of Canister Off-Normal Handling Event

The stresses in the MPC-LACBWR canister due to the combined loading of dead weight, off-normal handling, and internal pressure loads are calculated using the finite element model shown in Figure 11.A.1.2.2-1. This is the same model used for the MPC-LACBWR canister normal condition stress analysis, as described in Section 3.A.4.4.1.1, but includes the basket support disks in order to properly simulate the interaction between the basket and shell under transverse loading conditions. Gap elements are used to simulate the contact between the basket support disks and canister shell and between the canister shell and transfer cask cavity. The initial gap sizes are determined using the nominal dimensions of the contacting components.

Vertical and horizontal acceleration loads of 1.5*g* and 0.7071*g*, respectively, are applied to the model to account for the combined effects of dead weight and off-normal handling. The vertical

load from the canister contents is applied as a uniform pressure load acting on the inside surface of the cansiter bottom plate. The horizontal loading from the canister contents includes an acceleration load of 0.7071*g* to account for the support disks that are included in the model and applied forces to account for the remainder of the canister contents. The horizontal load from the basket components that are not modeled (i.e., fuel assemblies, fuel tubes, and heat transfer disks) is assumed to be evenly distributed between the support disks that are included in the model.

A design off-normal internal pressure is calculated based on the condition of 10 percent fuel rod failure with 30 percent fission gas release at a conservative gas temperature of 475°K. The calculated off-normal internal pressure is 11.4 psig. A bounding design internal pressure load of 12 psig is applied to the inside surfaces of canister shell, bottom plate, and lid elements in combination with dead weight and off-normal handling loads.

The linearized membrane and membrane plus bending stress components and stress intensities at each canister stress section identified in Figure 3.A.4.4.1-2 due to the combined dead weight, off-normal handling, and normal internal pressure loads are summarized in Tables 11.A.1.2.2-1 and 11.A.1.2.2-2, respectively. The allowable stresses and the corresponding margins of safety are also summarized in Tables 11.A.1.2.2-1 and 11.A.1.2.2-2. The results of the analysis show that the MPC-LACBWR canister satisfies the applicable allowable stress design criteria for the off-normal handing event.

As noted in Table 11.A.1.2.2-2, the bending stress at the bottom plate-to-shell junction is classified as secondary stress in accordance with Table NB-3217-1 if the edge moment is not required to maintain the bending stress at the center of the bottom plate to within acceptable limits. To demonstrate this, the bending stress at the center of the bottom plate is determined using hand calculations (Roark), treating it as a simply-supported circular plate subjected to a uniform pressure load. For a combined pressure load of 28.2 psi from the 1.5*g* dead weight plus off-normal handling load (i.e., 16.2 psi pressure load) and design internal pressure (12 psig), the membrane plus bending stress at the center of the bottom plate is calculated to be 28.28 ksi. The allowable primary membrane plus bending stress intensity, based on Type 304 stainless steel properties at a bounding design temperature of 400°F, is 33.48 ksi. Therefore, the edge moment is not required to maintain the bending stress at the center of the bottom plate to within acceptable limits, and the design margin for primary membrane plus bending stress intensity at the center of the bottom plate is 0.18 (= 33.48/28.28 – 1).

The maximum stresses in the MPC-LACBWR basket support disks due to the off-normal handling loads are calculated using the finite element model described in Section 3.A.4.4.2.1.

The off-normal handling horizontal acceleration is assumed to act along the +X direction. The support disk model nodes located at the centerline of each tie-rod are restrained in the vertical direction (i.e., UY=0).

The inertial loading due to the support disk self weight is accounted for by applying a horizontal acceleration loads of 0.7071*g* and a vertical acceleration load of 1.5*g* to the model. The horizontal load from the basket components that are not modeled (i.e., fuel assemblies, fuel tubes, heat transfer disks, and tie-rods) is applied as line loads on the supporting disk ligaments.

The linearized membrane and membrane plus bending stress intensities are evaluated at all critical sections of the support disk. All membrane and membrane plus bending stress intensities are conservatively classified as primary stresses and compared to the off-normal condition (i.e., Service Level C) allowable primary membrane (P_m) and membrane plus bending (P_m+P_b) stress intensity limits. The maximum calculated P_m and P_m+P_b stress intensities in the MPC-LACBWR basket assembly support disk due to the combined off-normal handling plus dead weight loading are summarized in Table 11.A.1.2.2-3 along with the corresponding accident condition allowable stresses and margins of safety. The result of the analysis show that MPC-LACBWR basket support disks satisfy the applicable allowable stress design criteria for the off-normal handing event.

11.A.1.2.3 Radiological Consequences

There are no radiological consequences for the canister off-normal handling event.

11.A.1.2.4 NAC-MPC Performance

This evaluation of the MPC-LACBWR canister for the off-normal handling event shows that the maximum stresses in the canister and fuel basket satisfy the applicable allowable stress design criteria. This event does not cause any damage to the MPC-LACBWR canister that would affect its ability to perform its design functions.

11.A.1.2.5 Recovery and/or Corrective Actions

Operations should be halted until the cause of the misalignment, interference or faulty operation is identified and corrected. Since the radiation level of the canister sides and bottom is high, extreme caution should be exercised if inspection of these surfaces is required.

Figure 11.A.1.2.2-1 MPC-LACBWR Canister Off-Normal Handling Finite Element Model

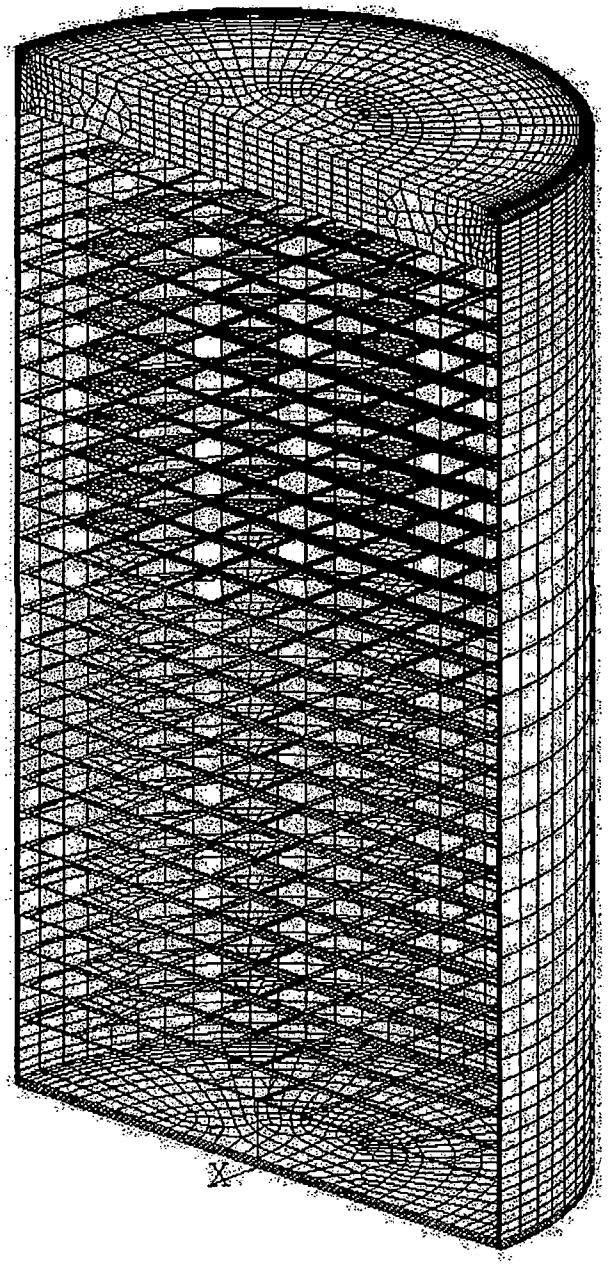

Table 11.A.1.2.2-1 Summary of MPC-LACBWR Primary Membrane (P_m) Stresses, Dead Weight + Off-Normal Handling + Internal Pressure

Section No.[1]	Component Stresses (ksi)						Stress Intensity (ksi)	Allowable Stress Intensity (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	-1.8	1.2	6.0	0.0	0.0	-0.7	7.96	23.13	1.91
2	4.7	-4.4	-2.3	0.0	0.0	-1.5	9.45	23.13	1.45
3	-0.8	-8.6	1.5	0.0	0.0	1.4	10.71	23.11	1.16
4	-0.2	0.9	1.3	0.0	0.0	0.0	1.49	22.77	14.24
5	-0.2	0.8	1.2	0.0	0.1	0.0	1.40	22.46	15.05
6	0.0	0.9	1.5	0.0	0.0	0.0	1.49	22.67	14.21
7	0.0	0.9	1.6	0.0	0.0	0.0	1.66	23.26	13.05
8	0.0	0.6	2.0	0.0	0.1	0.0	2.05	23.80	10.59
9	-1.1	0.0	0.9	0.0	0.0	-0.2	2.07	23.95	10.55
10	-1.8	-0.3	0.1	0.0	0.0	-0.6	2.26	23.96	9.60
11	-1.7	-0.2	0.0	0.0	0.0	0.1	1.77	23.97	12.52
12	0.0	0.3	-0.8	0.0	0.0	-1.0	2.08	19.16[2]	8.20
13	-2.9	0.0	0.2	0.0	0.0	-0.1	3.13	23.97	6.66
14	0.6	0.5	0.0	0.0	0.0	0.0	0.63	22.32	34.41
15	0.0	0.0	0.0	0.0	0.0	0.0	0.01	24.00	>100

1. Canister section locations are shown in Figure 3.A.4.4.1-2.
2. The closure weld allowable stress intensity includes a weld strength reduction factor of 0.8.

Table 11.A.1.2.2-2 Summary of MPC-LACBWR Primary Membrane + Bending (P_m+P_b) Stresses, Dead Weight + Off-Normal Handling + Internal Pressure

Section No.[1]	Component Stresses (ksi)						Stress Intensity (ksi)	Allowable Stress Intensity (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	4.9	1.7	16.3	-0.3	-0.2	0.4	14.68	34.69	1.36
2	4.7	-4.4	-2.3	0.0	0.0	-1.5	9.45[2]	34.69	2.67
3	-0.8	-8.6	1.5	0.0	0.0	1.4	10.71[2]	34.67	2.24
4	-0.4	1.5	1.5	0.0	0.0	0.0	1.90	34.15	16.95
5	-0.3	1.5	1.4	0.0	0.1	0.0	1.75	33.69	18.27
6	-0.3	1.8	1.5	0.0	0.1	0.0	2.07	34.01	15.45
7	-0.3	1.9	1.4	0.0	0.1	0.0	2.16	34.89	15.12
8	0.0	0.7	2.1	0.0	0.0	0.0	2.14	35.71	15.65
9	-0.7	0.6	1.4	0.0	0.0	-0.9	2.80	35.92	11.82
10	-1.3	0.0	1.2	0.0	0.0	-0.1	2.52	35.94	13.26
11	-2.3	0.0	0.1	0.0	0.0	0.1	2.41	35.96	13.93
12	-0.5	0.2	-0.3	0.0	0.0	-1.4	2.72	28.74[3]	9.56
13	-3.0	-0.1	0.2	0.0	0.0	-0.3	3.18	35.96	10.30
14	18.7	19.0	-0.1	0.0	0.0	0.0	19.02	33.48	0.76
15	-0.5	-0.5	0.0	0.0	0.0	0.0	0.53	36.00	66.98

1. Canister section locations are shown in Figure 3.A.4.4.1-2.
2. The bending stress at a gross structural discontinuity (flat head at junction to shell) is classified as a secondary stress per Table NB-3217-1 since the edge moment is not required to maintain the bending stress at the center of the plate to within acceptable limits. Therefore, the maximum membrane stress is reported.
3. The closure weld allowable stress intensity includes a weld strength reduction factor of 0.8.

Table 11.A.1.2.2-3 Summary of Maximum Stresses for the MPC-LACBWR Fuel Basket Support Disks, Off-Normal Handling + Dead Weight

Canister Basket Component	Calculated Stress		Allowable Stress		Margin of Safety
	Stress Type	Maximum Value (ksi)	Criteria	Allowable Value (ksi)	
Support Disks	P_m	9.57	$1.5S_m$	64.2	5.71
	P_m+P_b	12.63	$2.25S_m$	96.3	6.62

11.A.1.3 Failure of Instrumentation

The MPC-LACBWR storage system may use a temperature-sensing system to take daily measurements of the outlet air temperature at each of the four outlets of the concrete cask in lieu of performing daily visual inspection of the concrete cask air inlet and outlet screens for obstructions. This section presents the evaluation of the MPC-LACBWR storage system for a potential failure of the temperature-sensing system. The cause, radiological consequences, and recovery actions for the event are the same as those described in MPC FSAR Sections 11.1.3.1, 11.1.3.3, and 11.1.3.5, respectively.

The analysis of the MPC-LACBWR storage system temperature-sensing system failure event is essentially the same as that of the Yankee-MPC storage system. Failure of the temperature-sensing system does not have any adverse effects on the storage system. When the concrete cask air inlets are clear, no significant changes in the MPC-LACBWR storage system temperatures will occur during the time that it takes to indentify and correct the condition causing the failure of the temperature-sensing system. Furthermore, even under the worst-case fully blocked inlets and outlets accident condition evaluated in Section 11.A.2.8, the temperatures of the MPC-LACBWR storage system components do not reach or exceed their allowable temperature limits in 24 hours. Therefore, the 24-hour inspection interval provides sufficient time to identify and correct the condition causing the temperature-sensing system failure.

11.A.1.4 Severe Environmental Conditions (100°F and -40°F)

This section evaluates the MPC-LACBWR storage system for the steady-state effects of high and low ambient temperature conditions.

11.A.1.4.1 Cause of Event

To bound the expected steady state temperatures of the canister and storage cask during severe ambient conditions, analyses were performed to calculate the steady state storage cask, canister, and fuel cladding temperatures for a 105°F ambient temperature and 24-hour average solar loads. Similarly, winter weather analyses were performed for a -40°F ambient temperature with no solar load. A bounding heat load of 4.5 kW is conservatively used for the MPC-LACBWR storage system thermal analyses.

11.A.1.4.2 Analysis of the Off-Normal Ambient Temperature Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.A.3.1.1. This evaluation shows that the component temperatures are within the allowable values for the off-normal ambient conditions. The principal component temperatures for each of these ambient temperature conditions are summarized as follows:

MPC-LACBWR Component	Maximum Temperature (°F)		Allowable Temperature (°F)
	105°F Ambient	-40°F Ambient	
Fuel Cladding	459	377	806
Support Disks	454	370	800
Heat Transfer Disks	452	368	700
Canister Shell	365	280	800
Concrete[1]	196	5	350

1. Concrete temperature is from Table 4.1-4 for NAC-MPC with a heat load of 12.5 kW.

The thermal stress evaluation for the MPC-LACBWR concrete cask for these off-normal conditions is bounded by that for the accident condition with 125°F ambient temperature (Section 11.2.10), since the heat load for MPC-LACBWR is much lower than the heat load for NAC-MPC and the accident condition has the maximum temperature gradient through the storage cask concrete wall.

The thermal stresses for the MPC-LACBWR canister, the support disks and weldments are classified as secondary stress in accordance with the ASME Code, which need not be evaluated for off-normal and accident conditions.

11.A.1.4.3 Radiological Consequences

There are no radiological consequences for this off-normal event.

11.A.1.4.4 MPC-LACBWR Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are within the allowable temperature values. The materials used are not subject to low temperature brittle fracture.

11.A.1.4.5 Corrective Actions

No corrective actions are required for this off-normal condition.

11.A.1.5 Small Release of Radioactive Particulate from the Canister Exterior

The procedures for loading the canister provide for steps to ensure that the canister exterior surface does not come into contact with contaminated spent fuel pool water. The exterior surface of the canister is surveyed by smear to verify canister surface conditions. No particulate release from the canister exterior surface is expected to occur in normal use.

11.A.1.5.1 Cause of Event

Irrespective of precautions taken to preclude contamination to the external surface of the canister, it is possible that a portion of the canister surface may become slightly contaminated and that the contamination will go undetected. Surface contamination could become airborne and be released as a result of the air flow over the canister surface.

Detection of the release of small amounts of radioactive particles over time would be difficult to ascertain. The release would likely not be at a level that would result in detection by any of the long-term radiation dose monitoring methods (such as TLDs) normally employed. It is possible that a suspected release could be verified by a smear survey of the air outlets.

11.A.1.5.2 Analysis

The small release analysis is performed using the plume dispersion method of Regulatory Guides 1.109 and 1.145.

A calculation was made to determine dose rate as a function of distance based on residual contamination limits of 20,000 dpm/100 cm^2 β-γ activity and 200 dpm/100 cm^2 α activity, simultaneously released from the surface of 5 MPC-LACBWR canisters, using the plume dispersion method of Regulatory Guides 1.109 and 1.145.

The factor χ/Q is determined according to the formula from Regulatory Guide 1.145:

$$\frac{\chi}{Q} = \frac{1}{U_{10} \cdot \pi \cdot \Sigma_y \cdot \sigma_z}$$

where:

U_{10} = the wind speed at ten meters above plant grade [m/sec]

Σ_y = the lateral plume spread with meander and building wake effects [m]

σ_z = the vertical plume spread [m]

For distances less than 800 meters, Σ_y is the product of the horizontal plume spread, σ_y, and the plume meander and building wake correction factor, M.

From Regulatory Guide 1.145, the values for these parameters are as follows, with σ values taken at 100 meters:

U_{10} = 1 m/sec

M = 4

σ_y = 4.0

σ_z = 2.4

Σ_y = 16.0

χ/Q = 8.29×10^{-3} sec/m^3

The releasable activity is determined using:

$$Q[Ci] = \frac{(C)(A)(N)}{(2.22E+12)(100)}$$

where 2.22E+12 is the conversion from curies (Ci) to disintegrations per minute [dpm], and;

C = the contamination limits [20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α]

Q = the activity released [Ci]

A = the surface area of the canister [217,000 cm^2]

N = the number of canisters placed in service [5]

Therefore, the releasable activities are:

$Q(\beta\text{-}\gamma)$ = 9.77E-05 Ci

$Q(\alpha)$ = 9.77E-07 Ci

Regulatory Guide 1.109 defines the annual dose due to submersion and inhalation. These equations are solved for the annual dose, D [rem].

Submersion: $D_{submersion} = Q \cdot \frac{\chi}{Q} \cdot DCF_S$

Inhalation: $D_{inhalation} = Q \cdot \frac{\chi}{Q} \cdot BR \cdot DCF_I$

where:

Q = activity released [Ci]

DCF_S = submersion dose conversion factor [rem-m^3/Ci-yr]

DCF_I = inhalation dose conversion factor [rem/Ci]

BR = amount of air breathed annually [8,000 m^3]

The selected dose conversion factors are based on using the highest conversion factor for each group of nuclides, with ^{60}Co assumed to comprise all of the β-γ activity and ^{241}Am assumed to comprise all of the α activity. Dose conversion factors are taken from EPA Federal Guidance Report No. 11, Table 2.1 and Federal Guidance Report No. 12, Table III.1. Both Class Y (oxide) and W compound dose conversion factors were extracted. Class Y (oxide) conversion factors are bounding for the β-γ cobalt release. Only class W conversion factors are available for the ^{241}Am release. The dose conversion factors employed after conversion for unit consistency are:

Activity	Submersion Skin (Rem-m^3/Ci-yr)	Inhalation -Lung (Rem/Ci)	Inhalation-Whole Body (Rem/Ci)	Inhalation -bone (Rem/Ci)
β-γ (^{60}Co)	1.70×10^7	1.28×10^6	2.19×10^5	--
α (^{241}Am)	--	6.81×10^7	4.44×10^8	8.03×10^9

The inventory available for release is calculated assuming that 100% of the surface area of each canister is covered with the contamination levels listed above, and applies a conservative release fraction of 1% using the methodology presented in Section 1.2.1 of NUREG-1400, which references the values presented in 10 CFR 30.72. The resulting inventory available for release is conservative, as the release fractions presented in 10 CFR 30.72 are a factor of 10 lower for ^{241}Am (0.001) and ^{60}Co (0.001). This inventory is conservatively assumed to be simultaneously

released from every canister for the purposes of calculating the worst-case dose contributions at the site boundary.

Employing the submersion and inhalation equations from Regulatory Guide 1.109, doses were calculated over a range of distances from 100 to 1000 meters. A dose summary for a distance of 100 meters is shown below for 1 and 5 cask arrays. Included in the listing is the skin dose, followed by the β–γ and α dose contributors to the significant organs and whole body. Also shown is the total exposure from α and β–γ for lungs, bone and whole body.

Dose	Exposures at 100 meters	Unit	1 Cask	5 Casks
β–γ	Skin Dose (β–γ)	[mrem]	8.69E-07	4.34E-06
	Lung Dose (β–γ)	[mrem]	5.24E-04	2.62E-03
	Whole Body Dose (β–γ)	[mrem]	8.97E-05	4.49E-04
α	Bone Surface Dose (α)	[mrem]	3.29E-02	1.65E-01
	Lung Dose (α)	[mrem]	4.90E-03	2.45E-02
	Whole Body Dose (α)	[mrem]	1.82E-03	9.11E-03
Total	Skin Dose (β–γ)	[mrem]	8.69E-07	4.34E-06
	Bone Surface Dose (α)	[mrem]	3.29E-02	1.65E-01
	Whole Body Dose (α + β–γ)	[mrem]	1.91E-03	9.56E-03
	Lung Dose (α + β–γ)	[mrem]	5.43E-03	2.71E-02

11.A.1.5.3 Radiological Consequences

The projected dose at a boundary located 100 meters from the MPC-LACBWR 5-cask array ISFSI is estimated to be less than one (1) mrem due to the postulated release of surface contamination. This dose is based on a postulated surface contamination of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α, for each of 5 storage casks being simultaneously released to the environment. These analyses are highly conservative and demonstrate that the potential off-site radiological consequences from the release of canister surface contamination are negligible.

11.A.1.5.4 NAC-LACBWR Performance

Procedural steps are employed to ensure that the canister surface is generally free of surface contamination prior to its installation in the storage cask. The surface of the canister is free of traps that could hold contamination. The presence of external surface contamination on the canister is unlikely.

11.A.1.5.5 Corrective Actions

No corrective action is required, since the radiological consequence is negligible.

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11.A.2 Accident Conditions for the MPC-LACBWR Storage System

This section presents the evaluation of the MPC-LACBWR storage system for postulated accident events whose consequences could have the maximum potential impact on the immediate environment, and very low probability natural phenomena events that might occur once during the lifetime of an ISFSI. The analyses of the MPC-LACBWR storage system for accident conditions show that the owner-controlled area boundary dose limits of 10 CFR 72.106 are satisfied. In addition, the accident evaluation of the MPC-LACBWR storage system demonstrates that occupational exposure can be adequately controlled.

11.A.2.1 Accident Pressurization

This section describes the evaluation of the MPC-LACBWR storage system for an accident pressurization event in which all fuel rods in the canister are postulated to fail and release their fission and fill gases into the canister. The evaluations of the canister internal pressure load resulting from this condition and the stresses in the canister due to that internal pressure load are presented in this section. There are no radiological consequences for the accident pressurization event and no corrective actions are required for recovery from the event.

11.A.2.1.1 MPC-LACBWR Canister Maximum Internal Pressure

The analysis requires the calculation of the free volume of the canister, calculation of the quantity of fill and fission gas in the 68 fuel assemblies, and the subsequent calculation of the pressure in the canister if these gases are added to the helium pressure (initially at 1 atm) already present in the canister (Section 4.A.3.5). The quantity of fission gases was conservatively estimated assuming that 70% of the total gases present are released from the fuel. The bulk temperature of the fill gas is conservatively taken to be 400°F. This temperature bounds the calculated bulk temperature of fill gas for any of the evaluated normal, off-normal, or accident conditions. The internal pressure is a function of rod-fill, fission and canister backfill gases. All of the gases, except the fission gases, are helium. The total pressure for each volume are found by calculating the molar quantity of each gas and summing those directly. The design basis fuel assembly for the internal pressure calculation is the Allis Chalmers 10×10 fuel assembly. This assembly has the highest fuel mass (0.1201 MTU) and received the highest burnup (22,000 MWd/MTU).

The number of moles of the backfill gases is calculated using the Ideal Gas Law, PV = NRT. Backfill gases for the canister and cavity are assumed to be initially at 1 atmosphere. The

quantity of fission gas is derived from the SAS2H source term evaluation of the Allis Chalmers fuel assembly. The number of moles of gas in the canister is:

$$N = N_{\text{TSC Back-Fill}} + N_{\text{Rod Back-Fill}} + 0.70(N_{\text{Fission Gas}})$$

The number of moles of helium contained in the canister as backfill and the number of moles of gas in the fuel rods (as helium backfill and fission products) are calculated in Section 4.A.3.5.

Based on an assumed bounding temperature of 400°F, the maximum pressure in the canister is 3.18 atm ≈ 46.8 psia ≈ 32.1 psig.

11.A.2.1.2 MPC-LACBWR Canister Maximum Stress Due to Internal Pressure

The stresses in the MPC-LACBWR canister due to the combined loading of dead weight, normal handling, and accident pressurization are calculated using the finite element model described in Section 3.A.4.4.1.1 and shown in Figure 3.A.4.4.1-1. A bounding uniform pressure load of 32.1 psig is conservatively applied to the inside surfaces of canister shell, bottom plate, and shield lid elements. In addition, the 1.1*g* vertical acceleration loading for combined effects of dead weight and normal handling are applied to the model as described in Section 3.A.4.4.1.4.

The membrane and membrane plus bending stresses in the MPC-LACBWR canister due to the combined dead weight, normal handling, and 32.1 psig internal pressure loads are evaluated at the stress sections shown in Figure 3.A.4.4.1-2. The results show that the maximum primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stress intensities in the canister due to the 32.1 psig internal pressure load, which both occur at the bottom plate-to-shell junction, are 15.19 ksi and 61.88 ksi, respectively. The corresponding allowable P_m and P_m+P_b stress intensities for accident conditions are 45.65 ksi and 65.2 ksi, respectively. Therefore, the minimum margin of safety in the MPC-LACBWR canister for the accident pressurization event is +0.05.

11.A.2.1.3 Radiological Consequences

There are no radiological consequences for this accident.

11.A.2.1.4 MPC-LACBWR Performance

This analysis demonstrates that the canister performance is not significantly affected by the increase in internal pressure that results from the hypothetical rupture of all of the fuel rods contained in the canister. There is a positive margin of safety throughout the canister.

11.A.2.1.5 Recovery and/or Corrective Actions

There are no recovery or corrective actions required for this hypothetical accident event. The rupture of fuel rods within the canister is unlikely to be detected by any measurements or inspections that could be undertaken from the exterior of the canister or storage cask.

11.A.2.2 Earthquake Event

This section describes the evaluation of the MPC-LACBWR storage system for the design basis earthquake event. The design basis earthquake load for the MPC-LACBWR storage system is defined as a horizontal acceleration load of 0.45*g* at the top surface of the ISFSI pad. The design basis vertical acceleration is equal to two-thirds of the horizontal acceleration in accordance with ASCE 4-86. The earthquake evaluation of the MPC-LACBWR storage system demonstrates that the design basis earthquake loading will not cause the loaded concrete cask to overturn or slide to an extent that it could impact any adjacent casks or slide off the edge of the ISFSI pad. The evaluation also shows that the maximum stresses in the MPC-LACBWR concrete cask shell due to the design basis earthquake load satisfy the applicable allowable stress design criteria.

Overturning stability of the MPC-LACBWR concrete cask is evaluated for the 0.45*g* design basis horizontal base acceleration using the same moment-equilibrium methods used for the evaluation of the Yankee-MPC concrete cask, as described in MPC FSAR Section 11.2.2.2.1. Although the design basis earthquake loads for the MPC-LACBWR storage system are higher than those of the Yankee-MPC system, they are proportionally identical. Therefore, the general overturning stability equations developed in MPC FSAR Section 11.2.2.2.1 for the Yankee-MPC storage system are applicable to the MPC-LACBWR storage system. These equations relate the horizontal acceleration required to overturn the cask to the horizontal and vertical distances from the concrete cask bottom edge to its center of gravity (i.e., moment arms b and d, respectively). The general overturning stability equations, which are developed considering the possible combinations of horizontal and vertical acceleration using the 100-40-40 rule of ASCE 4-86, are:

Case 1: $$a \leq \frac{(b/d)}{[0.566 + 0.667(b/d)]} = 0.68g$$

Case 2: $$a \leq \frac{(b/d)}{[1.077 + 0.267(b/d)]} = 0.56g$$

Where the horizontal moment arm, b, of the MPC-LACBWR storage system is 58.83 inches (calculated based on the maximum possible off-center position of the canister, as described in

MPC FSAR Section 11.2.2.2.1) and the vertical moment arm, d, of the MPC-LACBWR storage system is 83.0 inches.

Therefore, the minimum horizontal acceleration load that is required to overturn the loaded MPC-LACBWR concrete cask is 0.56*g*. Since this is higher than the 0.45*g*, the MPC-LACBWR concrete cask will not overturn due to the design basis earthquake. The minimum factor of safety provided by the MPC-LACBWR concrete cask against overturning is 1.24 (= 0.56/0.45), which is greater than the factor of safety of 1.10 required by ANSI/ANS-57.9.

The maximum horizontal sliding displacement of the concrete cask due to a horizontal peak base acceleration of 0.45*g* is determined based on the following curve fit equation and parameters provided in Appendix VII of NUREG/CR-6865 [A2]:

$$y = Ax^B = (0.837)(0.45)^{2.52} = 0.112 \text{ m } (4.4 \text{ in.})$$

Where parameters A and B are conservatively taken from Table VII.2 of NUREG/CR-6865, based on a lower bound sliding coefficient of friction between the cask and ISFSI pad of 0.2. This coefficient value is conservative when compared to the results of steel-on-concrete friction tests performed under both dry and wet conditions [A3]. The test results show that the coefficient of sliding friction between clean steel (i.e., blasted to remove mill scale) and concrete is in the range of 0.51 to 0.68.

At the minimum concrete cask center-to-center spacing of 15 feet, a 52-inch clear space is provided between adjacent casks. Thus, sliding of the MPC-LACBWR concrete cask due to design basis earthquake loading will not cause adjacent concrete casks to impact one another, nor will it cause a concrete cask to slide off the edge of the ISFSI pad. The minimum factor or safety for sliding, conservatively assuming that adjacent cask slides toward one another by the calculated maximum sliding distance of 4.4 inches, is 5.91 (= 52/8.8).

The stresses in the MPC-LACBWR concrete cask shell due to the design basis earthquake load are determined using the same approach described in MPC FSAR Section 11.2.2.2.1 for the Yankee-MPC concrete cask evaluation. The design basis horizontal base acceleration of 0.45*g* is conservatively applied simultaneously in two orthogonal horizontal directions (i.e., $a_x = 0.64g$), and the vertical acceleration is taken as two-thirds of the horizontal acceleration (i.e., $a_y = 0.30g$). The maximum vertical stress due to combined axial and bending loads in the concrete shell due to the seismic acceleration loads is calculated based on simple beam theory equations, treating it as a cantilever beam (fixed at the bottom end), as follows:

$$\sigma_y = \frac{Mr}{I} + \frac{P}{A}$$

= 65.4 psi at outer diameter of concrete shell base

= 44.9 psi at inside diameter of concrete shell base

where:

M = 9.96×10^6 in-lb, Maximum bending moment at the base of the concrete shell.
= $wL^2/2$

r = Radial distance to stress location.
= 64.0 inches (to outside of concrete shell)
= 42.0 inches (to inside of concrete shell)

I = 10.7×10^6 in^4, Section modulus of the concrete shell.
= $\pi(D_O^4 - D_I^4)/64$

P = 42,360 lbs, Vertical force at base of concrete shell due to vertical acceleration.
= $(0.30g \times W_E)$

A = 7,326 in^2, Area of concrete shell.
= $\pi(D_O^2 - D_I^2)/4$

w = 779 lb/inch, Uniform line load on concrete shell beam due to horizontal acceleration.
= $\sqrt{(0.45g)^2 + (0.45g)^2} \times (W_L)/L$

L = 159.9 in., Concrete shell length.

D_O = 128.0 in., Concrete shell outside diameter.

D_I = 84.0 in., Concrete shell inside diameter.

W_E = 141,200 lbs, Weight of empty MPC-LACBWR concrete cask.

W_L = 195,800 lbs, Weight of loaded MPC-LACBWR concrete cask.

The average shear stress at the base of the MPC-LACBWR concrete cask shell is calculated as follows:

$$\sigma_v = \frac{V}{A} = \frac{wL}{A} = 17.0 \text{ psi}$$

where w, L, and A are defined previously in this section.

The maximum stresses in the LACBWR concrete cask shell due to the earthquake loading are evaluated in combination with the stresses due to dead load, live load, and normal thermal loads, and are shown to satisfy the applicable allowable stress criteria in Section 3.A.4.4.3.

The cause, radiological consequences, and corrective actions for recovery from the earthquake event are the same as those described in MPC FSAR Sections 11.2.2.1, 11.2.2.3, and 11.2.2.5, respectively.

11.A.2.3 Explosion

The evaluation of the MPC-LACBWR storage system for explosive overpressure shows that it will not be adversely affected by explosion events that are bounded by the design basis flood event. The cause, radiological consequences, and recovery actions for the explosion event are discussed in MPC FSAR Sections 11.2.3.1, 11.2.3.3, and 11.2.3.5, respectively.

The analysis of the MPC-LACBWR storage system for explosive overpressure is based on the bounding effects of the design basis flood event. As discussed in Section 11.A.2.6, the loaded MPC-LACBWR concrete cask will not overturn or slide due to the bounding lateral forces associated with the design basis flood. In addition, the stresses in the MPC-LACBWR concrete cask shell resulting from the bounding flood loads, which are evaluated in combination with stresses due to dead load, live load, and normal thermal load, are shown to satisfy the applicable allowable stress design criteria. The stresses in the MPC-LACBWR canister shell due to a flood hydrostatic pressure load of 22 psig are also evaluated and shown to meet the applicable structural design criteria.

11.A.2.4 Failure of all Fuel Rods with a Subsequent Ground Level Breach of the Canister

This section addresses the potential mechanistic failure of the MPC-LACBWR canister and subsequent release of radioactive gas, volatile and particulate material from the canister.

As described in Appendices 3.A, 4.A and 11.A, the NAC-MPC is evaluated for normal conditions and for a series of off-normal and accident events that include cask tip over, cask drop, flooding, fire and explosion, lightning, earthquake, loss of shielding, adiabatic heat up, and tornado generated missiles. The evaluations show that for these design basis events, there is no

mechanistic failure of the confinement boundary of the canister, i.e., the canister maintains its structural integrity. As described in Appendix 7.A and in Section 8.A.1.1, the canister is tested to demonstrate that it is leaktight as defined by ANSI N14.5-1997.

Therefore, no further evaluation of this potential accident condition is required.

11.A.2.5 Fire Accident

Two fire accident conditions are considered in this section, one which could occur as the VCC is being moved to the ISFSI and one which could occur when the VCC is on the ISFSI for long term storage.

11.A.2.5.1 Fire condition during the VCC movement to the ISFSI pad

The VCC is to be moved to the ISFSI pad using a heavy haul trailer pulled by a truck. During the movement, an accident condition could occur which would result in the ignition of the following materials.

1) 60 gallon of diesel fuel for the truck
2) 32 quarts of motor oil for the truck
3) 48 tires

The resulting ignition of the above materials can only result in a maximum flame temperature of 1475°F as defined in NUREG-1536 [A5]. While this is required for the transport condition, it is acceptable for the fire condition at any point during the movement of the VCC to the ISFSI pad.

To evaluate the fire condition for the VCC during movement to the ISFSI pad, the two dimensional axisymmetric VCC model shown in Figure 11.A.2.5-1 is used. This model is comprised of the concrete shell, the inner liner of the VCC, the canistered fuel and intermediate air gaps. The fuel heat applied to the model is 4.5 kW with a power profile. As for the model described in Section 4.A.3.1.1, the air gap in the two dimensional model in Figure 11.A.2.5-1 incorporates the radiation across the air gap, while any convection up through the annulus is neglected. While the detailed three dimensional model in Section 4.A.3.1.1 contains a detailed model of the fuel, fuel tubes and basket, the two dimensional model in Figure 11.A.2.5-1 uses effective properties which allow the steady temperature of the fuel to be 443°F as determined by the detailed model in Section 4.A.3.1.1. The basket region uses an effective density corresponding to the weight of a loaded canister. To determine a bounding temperature rise of

the fuel, the specific heat of the basket region corresponds to the lowest value of the materials internal to the canister which is the specific heat for the fuel pellets.

The fire condition of a 1475°F ambient is applied as a convection boundary condition which incorporates radiation as defined in Section 4.4.1.1.2. This condition is conservatively applied to the entire outer surface of the VCC, except to the top and bottom of the VCC. The emissivity of the surface during the fire is 0.9 which is consistent with [A5]. The duration for the tire to burn is 30 minutes as identified in [A6], which is shown in Figure 11.A.2.5-2. The fire accident analysis is comprised of three distinct phases:

1. Initial conditions (steady-state): Maximum decay heat of the fuel; ambient temperature = 75°F; solar insolance.
2. 30-min fire (transient): Maximum decay heat of the fuel; fire temperature of 1475°F; no solar insolance.
3. Post-fire cool-down (transient): Maximum decay heat of the fuel; ambient temperature = 75°F; solar insolance.

After the fire, the same boundary conditions as described in Section 4.A.3.1.1 are applied to the model.

The post-fire cool-down transient analysis is solved for an additional 80 hours to ensure fuel clad temperature reaches the peak temperature. The maximum fuel temperature of 454°F occurs at 53 hours, which is an increase of 11°F. This confirms that the VCC will maintain the fuel clad and canister below the normal operational temperature limits.

11.A.2.5.2 Fire condition for the VCC at the ISFSI pad

The bounding hypothetical fire accident condition occurring at the ISFSI pad is assumed to be an 8-minute fire in which the conditions applied are listed in MPC FSAR Section 11.2.5.2 for the Yankee-MPC system.

The fire transient analyses performed in MPC FSAR Section 11.2.5.2 for the Yankee-MPC system utilize the heat load of 12.5 kW, which bounds the heat load of 4.5 kW for the MPC-LACBWR fuels. Convection is considered in the analysis documented in MPC FSAR Section 11.2.5.2. The maximum steady-state temperatures for the NAC-MPC components (MPC FSAR Table 4.4.3-1) for normal storage condition, which are used as the initial temperature for the fire accident analysis, are higher than the corresponding maximum component temperatures for the MPC-LACBWR system. Also, the similar design of the Yankee-MPC system and the MPC-

LACBWR system results in an insignificant difference in thermal mass, therefore, the analysis results of the fire accident condition for the NAC-MPC bound the analysis results of the fire accident condition for the MPC-LACBWR.

Figure 11.A.2.5-1 Two Dimensional Model of VCC with Canister

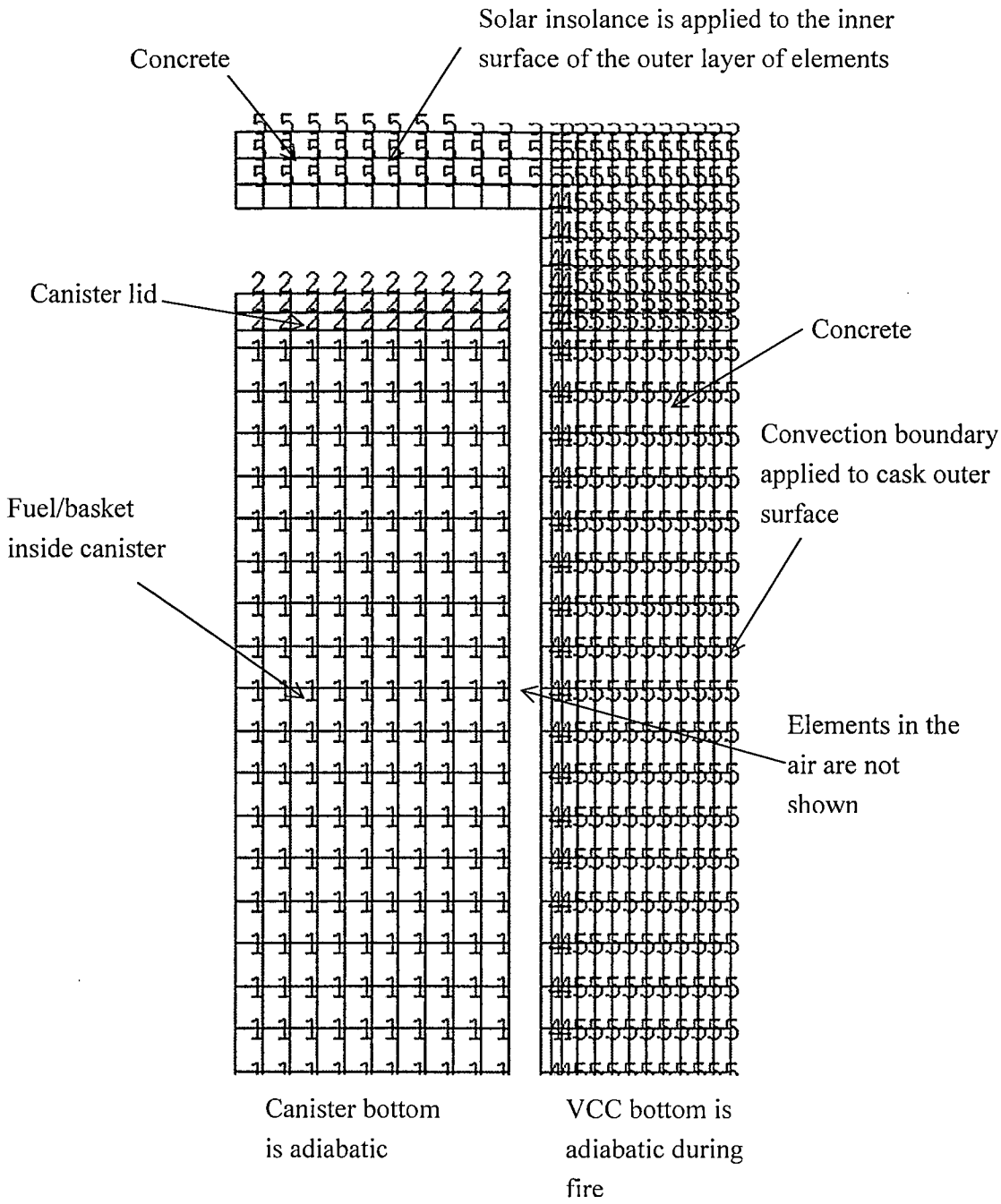


Figure 11.A.2.5-2 Definition of the Time for a Tire to Burn

Table 8-1
Fire-fighting Tactics According to Stage of Fire

Stages of Tire Combustion	Typical Time (minutes)	Whole Tires	Shredded Tires / Crumb Rubber	Possible Action
Ignition and Propagation Stage	0 – 30	Active tire burning of individual tires. Fire has not spread to the entire pile. Once spreading begins, the fire continues at rate of approximately 2 square feet every five minutes.	Tire shreds are readily ignited. Fire spreads along surface of pile quickly involved entire pile in fire.	In first 5 minutes, extinguishment may be possible using water, foams or wetting agents. Otherwise, focus efforts on separating remaining tires/products from the fire. Focus on down wind direction first.
Compression Stage	30 – 60	Top layer of tires collapse. Flaming is reduced as fire becomes deep-seated.	Burns like coal - hot center with clay-like ash crust .	Continue separation efforts; build containment berms and collection ponds for oil and run-off.
Equilibrium / Pyrolysis Stage and Smoldering Stage	60+	Fuel consumption = available heat, fuel and oxygen efficiently consuming most products. Downward pressures push pyrolytic oil from the burn; increasing run-off. As fire moves into smoldering stage, products not consumed in combustion are released.	Clay-like crust prevents water from penetrating to hot core.	Focus on Containing Fire Spread and Oily/Run-Off. Most favorable means of suppression involves separation of a small portion of burning debris; which is then extinguished by fog stream or submersion (roll-off bin filled with water or shallow pond). Another method involves allowing tire pile to burn to a manageable size. Oily run-off may be ignited - Class B Foam is effective in suppressing oily-run-off fires (used after containment is in place)

Sources: (USFA, 1993 and Scrap Tire Management Council, 1992)

11.A.2.6 Flood

The MPC-LACBWR storage system is evaluated for a fully-immersing design basis flood with a 50-foot water depth and a steady-state flow velocity of 15-feet/second. Under design basis flood conditions, the concrete cask is subjected to the same horizontal drag force calculated for the Yankee-MPC storage system (21.72 kips per MPC FSAR Section 11.2.6.2.) The horizontal drag force is resisted by shear and bending loads developed in the concrete cask shell, which are considered in the stress analysis. The water displaced by the MPC-LACBWR storage system produces buoyancy forces that are considered in the overturning and sliding analyses. In addition, stresses in the canister shell resulting from hydrostatic pressure due to the 50-foot flood depth are evaluated.

The overturning stability analysis of the MPC-LACBWR concrete cask is evaluated using the moment balance approach developed in MPC FSAR Section 11.2.6.2 for the Yankee-MPC concrete cask flood evaluation. The flood drag force ($F_{D,OT}$) required for overturning the MPC-LACBWR concrete cask is calculated using the following equation, assuming the concrete cask pivots about its outer edge and that the lateral drag force acts at the mid-height of the concrete cask:

$$F_{D,OT} = \frac{(W_{VCC} - F_B)(r)}{(h/2)} = 98.7 \text{ kips}$$

where:

W_{VCC} = 195.8 kips, weight of the loaded LACBWR concrete cask.

F_B = 64.3 kips, buoyancy force from water displaced by LACBWR concrete cask system.
= $(\rho)(V_D)$

r = 5.0 ft (60.0 in.), radial distance from the concrete cask bottom edge to the system center of gravity (accounting for 4-inch chamfer at bottom end.)

h = 13.33 ft (159.9 in.), height of concrete cask.

ρ = 62.4 lb/ft^3 (1.94 slugs/ft^3), density of water.

V_D = 1,030 ft^3, total volume of water displaced by MPC-LACBWR concrete cask and canister.

The drag force required to overturn the MPC-LACBWR concrete cask is greater than the drag force resulting from the design basis flood. Therefore, the MPC-LACBWR concrete cask will not overturn under design basis flood loading. The factor of safety provided by the MPC-LACBWR concrete cask against overturning due to the design basis flood is 4.54 (= 98.7/21.72), which is higher than the required factor of safety of 1.1.

The corresponding flood velocity required to overturn the MPC-LACBWR concrete cask is calculated as follows:

$$V = \sqrt{\frac{2F_{D,OT}}{C_D \rho A}} = 32 \text{ ft/second}$$

Where ρ is the density of water (1.94 slugs/ft^3), C_D is 0.7, and A is the horizontally projected area of the concrete cask (142 ft^2).

The minimum coefficient of friction between the bottom end of the MPC-LACBWR concrete cask and the ISFSI pad that is required to prevent sliding under the design basis flood condition is calculated as follows:

$$\mu_{min} = \frac{1.1(F_D)}{F_y} = \frac{1.1(F_D)}{W_{VCC} - F_B} = 0.18$$

Where F_D is the drag force resulting from the design basis flood (21.72 kips), and W_{VCC} and F_B are defined above. Since the minimum required coefficient of static friction is less than the lower bound coefficient of static friction for steel-on-concrete (0.35), the design basis flood will not cause the MPC-LACBWR concrete cask to slide. Therefore, the LACBWR concrete cask system provides a minimum factor of safety against sliding of 1.94 (= 0.35/0.18) due to the design basis flood load.

The stresses in the MPC-LACBWR concrete cask shell due to the design basis flood are lower than those calculated in MPC FSAR Section 11.2.6.2.2 for the Yankee-MPC concrete cask shell since the MPC-LACBWR cask concrete shell is thicker and has higher section properties than the Yankee-MPC cask shell. Conservatively, the bounding flood stresses calculated for the Yankee-MPC cask concrete shell are conservatively used for the structural evaluation of the MPC-LACBWR cask shell. These stresses, when evaluated in combination with the maximum stresses resulting from dead load, live load, and normal thermal loads, as discussed in Section 3.A.4.4.3, are shown to satisfy the applicable allowable stress criteria.

The stresses in the MPC-LACBWR canister due to the flood hydrostatic pressure load are determined using the finite element model shown in Figure 3.A.4.4.1-1. A uniform pressure load of 22 psig is applied to the exterior surfaces of the canister model. For this analysis, the canister internal pressure is conservatively assumed to be 0 psig. The membrane and membrane plus bending stresses in the canister due to the flood hydrostatic pressure loading are evaluated at the stress sections shown in Figure 3.A.4.4.1-2. The results show that the maximum primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stress intensities, which both occur at the bottom plate-to-shell junction in the canister due to the 22 psig flood hydrostatic pressure load, are 7.28 ksi and 30.14 ksi, respectively. The corresponding allowable P_m and P_m+P_b stress intensities for accident conditions are 46.23 ksi and 66.04 ksi, respectively. Therefore, the minimum margin of safety in the MPC-LACBWR canister for the flood accident is 1.19.

The cause, radiological consequences, and corrective actions for recovery from the flood event are the same as those described in MPC FSAR Sections 11.2.6.1, 11.2.6.3, and 11.2.6.5, respectively.

11.A.2.7 Fresh Fuel Loading in Canister

This section presents the results of the evaluation of the effects of the inadvertent loading of fresh, unburned fuel assemblies in the canister. While, this event is not considered to be credible, the MPC-LACBWR criticality analysis presented in Appendix 6.A is based on fresh fuel loading.

11.A.2.7.1 Cause of Accident

The cause of this event would be operator and/or procedural error. The design basis criticality condition demonstrates that the canister is designed to accommodate fresh fuel without a resulting criticality event.

This accident is expected to be identified immediately by observation of the condition of the fuel installed in the canister or by a review of the fuel handling records.

11.A.2.7.2 Analysis of Fresh Fuel Loading in the MPC-LACBWR Canister

The criticality analysis presented in Appendix 6.A assumes the loading of up to 68 LACBWR Class fuel assemblies in the MPC-LACBWR having no burn up. The design of the NAC-MPC is adequate to preclude any effects due to this accident condition.

The analysis presented in Section 6.A.4 shows that the maximum k_{eff} for the MPC canister in the dry normal condition is < 0.4. The maximum k_{eff} in the accident condition is 0.930. The accident condition assumes the most reactive configuration of the fuel and full moderator intrusion.

11.A.2.7.3 Radiological Consequences

There are no radiological consequences for this event.

11.A.2.7.4 MPC-LACBWR Performance

The criticality control features of the MPC-LACBWR canister and basket ensure that the k_{eff} of the fuel is less than 0.95 for all loading conditions of fresh fuel. There is no adverse impact on the MPC-LACBWR due to this event.

11.A.2.7.5 Recovery and Corrective Actions

This event requires that the canister be unloaded when the incorrect loading is identified. Compliance with the controls placed on the movement of fuel assemblies will preclude this accident event from occurring.

11.A.2.8 Full Blockage of Air Inlets and Outlets

This section evaluates the MPC-LACBWR storage system for the effects of full blockage of the air inlets and outlets at the normal ambient temperature (75°F). It determines the duration of the event that would result in the concrete reaching its design basis limiting temperature of 350°F.

11.A.2.8.1 Cause of Event

The likely cause of complete air inlet and outlet blockage is the covering of the cask with earth in a catastrophic event such as a greater than design basis earthquake or a landslide. This event is a bounding condition accident that is not credible.

This event would be detected by inspection of general conditions at the site following such an event. It would be detected visually by the persons inspecting the ISFSI site.

11.A.2.8.2 Analysis of the Blockage Event

Accident temperature conditions are evaluated using the thermal models described in Section 4.A.3.1.1 for the MPC-LACBWR storage system. Since no air flow is modeled in the model, the analysis results for the normal storage condition bound the analysis results for the accident conditions due to all air inlets and outlets being blocked. The analysis results are listed in Table 4.A.3-3.

11.A.2.8.3 Radiological Consequences

There are no significant radiological consequences for this event, as the MPC-LACBWR storage system retains its shielding performance. Dose is incurred as a consequence of uncovering the storage cask. Since the dose rates at the air inlets and outlets are higher than the maximum dose rate at the cask wall, personnel will be subject to an estimated maximum dose rate of 75 mrem/hr when clearing the inlets and outlets. For the MPC-LACBWR storage system, if it is assumed that a worker kneeling with his hands on the inlets or outlets would require 15 minutes to clear each inlet or outlet, the estimated extremity dose is 150 mrem for the 8 openings. The whole body dose would be slightly less. In addition, some dose is incurred clearing debris away from the cask body. Based on an average dose rate at 1 foot from the cask of 30 mrem/hr, this dose is estimated at 60 mrem, assuming 2 hours is spent near the cask exterior surface.

11.A.2.8.4 MPC-LACBWR Performance

There are no adverse consequences for this accident condition, even if the debris is not cleared. The maximum component temperatures are less than the allowable temperatures. The MPC-LACBWR storage system continues to satisfactorily perform the cooling function with all the inlets and outlets blocked.

11.A.2.8.5 Recovery and/or Corrective Actions

The debris blocking the vents can be manually removed. In addition, a considerable effort may be involved in clearing the area around the storage casks. No actions are required with regard to the casks proper, provided that the inlets and outlets are cleared within certain days (as many as needed).

11.A.2.9 Lightning

The MPC-LACBWR storage system is evaluated for the same design basis lightning accident event as the Yankee-MPC storage system. The cause of the lightning accident event is discussed in MPC FSAR Section 11.2.9.1. The lightning accident analysis of the Yankee-MPC concrete cask presented in Section 11.2.9.2 of the MPC FSAR is applicable to the MPC-LACBWR concrete cask since the concrete cask design parameters considered in the lightning accident analysis are the same. The analysis shows that the maximum increase in the temperatures of the concrete cask steel liner and concrete shell caused by the lightning strike are small. As discussed in MPC FSAR Sections 11.2.9.3 and 11.2.9.5, there are no radiological consequences or required recovery actions for the lightning accident event.

11.A.2.10 Maximum Anticipated Heat Load (125°F Ambient Temperature)

The MPC-LACBWR storage system is evaluated for steady-state operation with an ambient air temperature of 125°F. The evaluation demonstrates that the maximum temperatures of the MPC-LACBWR storage system components for this thermal condition are all within the corresponding allowable material temperatures. Thermal stresses in the MPC-LACBWR canister are not calculated for this thermal condition since thermal stress is classified as secondary stress, which does not require evaluation for accident conditions. However, thermal stresses in the MPC-LACBWR concrete cask shell are evaluated for this condition. The evaluation demonstrates that the maximum stresses in the MPC-LACBWR concrete cask shell resulting from this thermal condition, which are evaluated in combination with the stresses due to dead load, live load, and wind load, as discussed in Section 3.A.4.4.1.5, satisfy the applicable requirements of ACI 349-85.

11.A.2.10.1 Cause of Accident

The cause of this condition is a weather event that subjects the MPC-LACBWR storage system to a 125°F ambient temperature with full solar insolance. Detection of the high ambient temperature condition would occur during the daily measurement of ambient temperature and storage cask outlet air temperature.

11.A.2.10.2 Analysis of the 125°F Ambient Temperature Event

The severe high temperature condition is evaluated using the thermal models described in Section 4.A.3.1.1. A contents heat load of 4.5 kW is assumed. The principal component temperatures for this ambient condition are:

Component	Maximum Temperature (°F)	Allowable Temperature (°F)
Fuel Cladding	470	806
Support Disks	465	800
Heat Transfer Disks	463	700
Canister Shell	377	800
Concrete[1]	228	350

1. Concrete temperature is from Table 4.1-4 for NAC-MPC with a heat load of 12.5 kW.

This evaluation shows that the component temperatures are within the allowable temperature for the severe high ambient temperature conditions.

For this thermal condition, the decay heat load from the canister inside the concrete cask is transferred to the environment primarily by passive convective air flow through the concrete cask ventilation ducts. However, some portion of the decay heat is transferred to the environment by conduction through the concrete cask. The thermal resistance of the concrete cask steel and concrete shells produces axial and radial temperature gradients that generate stress within the concrete cask shell. Given that the MPC-LACBWR concrete cask and Yankee-MPC concrete cask designs are very similar; their heat transfer characteristics are also very similar. Therefore, since the design basis canister heat load for the MPC-LACBWR canister is much lower than that of the Yankee-MPC canister (i.e., 4.5 kW vs. 12.5 kW) the temperature gradients and the thermal stresses in the MPC-LACBWR concrete cask resulting from the 125°F ambient air temperature will be much lower than those calculated for the Yankee-MPC concrete cask in MPC FSAR Section 11.2.10.2.1. However, the bounding thermal stresses calculated for the Yankee-MPC concrete cask are conservatively used for evaluation of the MPC-LACBWR concrete cask.

11.A.2.10.3 Radiological Consequences

There are no radiological consequences for this event.

11.A.2.10.4 MPC-LACBWR Performance

There are no adverse consequences for this accident condition. The maximum component temperatures are less than the allowable temperatures for accident conditions and are also less than the temperature limits for normal conditions of storage.

11.A.2.10.5 Corrective Actions

No corrective actions are required for this accident condition.

11.A.2.11 Storage Cask 6-Inch Drop

The loaded MPC-LACBWR concrete cask is evaluated for a 6-inch free drop onto a concrete storage pad. The evaluation shows that the event does not cause any significant structural damage to the MPC-LACBWR concrete cask or canister.

11.A.2.11.1 Cause of Accident

As discussed in MPC FSAR Section 11.2.11.1, the concrete storage cask, containing the loaded canister, must be raised approximately 4 inches using hydraulic jacks in order to install the inflatable air pads beneath it. A 6-inch cask drop is conservatively evaluated in this section based on the assumption of the failure of one or more of the jacks or of the air pad system.

11.A.2.11.2 Analysis of the 6-Inch Drop Event

The analyses of the MPC-LACBWR concrete cask and canister for the concrete cask 6-inch drop event are described in this section.

11.A.2.11.2.1 MPC-LACBWR Concrete Cask Analysis

The MPC-LACBWR concrete cask is analyzed for the 6-inch drop using the same approach described in MPC FSAR Section 11.2.11.2.1 for the Yankee-MPC concrete cask. The analysis considers the concrete cask dropping onto an infinitely rigid target, conservatively neglecting any deflection of the ISFSI concrete pad and underlying soil. The kinetic energy of the loaded concrete cask at impact is assumed to be absorbed entirely through crushing of the cask concrete shell and plastic deformation of the concrete cask steel pedestal stand. The analyses provide a conservative estimate of the concrete cask damage resulting from the 6-inch drop event. In addition, the analyses provide an estimate of the average canister deceleration resulting from the 6-inch drop.

The crush depth of the concrete at the bottom end of the MPC-LACBWR concrete cask shell required to absorb the kinetic energy due to the 6-inch drop is shown to be 0.044 inch, based on the energy balance approach described in MPC FSAR Section 11.2.11.2.1. The area of concrete at the bottom end of the cask concrete shell, between the air inlets, is assumed to crush when it reaches its compressive strength. The concrete crush depth is calculated based on the empty

weight of the MPC-LACBWR concrete cask, considering that the canister weight is supported by the concrete cask pedestal stand and does not load the concrete shell. The average deceleration of the concrete cask due to the 6-inch drop is calculated to be 137g.

The maximum plastic deformation of the concrete cask pedestal stand, which supports the canister during the 6-inch drop event, is shown to be 0.31 inch, based on the energy balance approach described in MPC FSAR Section 11.2.11.2.1. Under bottom end drop loads, the area of the steel ligaments in the concrete cask pedestal stand between the cutouts for the air inlet (i.e., 24 in^2 total area) experiences the highest stress. These steel ligaments are assumed to deform plastically and absorb the kinetic energy due to the weight of the MPC-LACBWR canister. The plastic deformation of the steel ligaments is calculated based on a flow stress that is equal to the average of the steel yield and ultimate strengths. Using the approach described in MPC FSAR Section 11.2.11.2.1, the average deceleration of the canister due to the 6-inch drop event is shown to be 21*g* based on the plastic flow force developed in the concrete cask pedestal ligaments.

11.A.2.11.2.2 MPC-LACBWR Canister and Basket Analysis

Canister Stress Analysis

The MPC-LACBWR canister is evaluated for the concrete cask 6-inch end drop conditions using finite element analysis. The maximum stresses in the canister are conservatively calculated using a 60*g* bottom end drop load, which bounds the 21*g* canister load determined in the concrete cask drop analysis. The results of the concrete cask 6-inch drop analyses demonstrate that the maximum stresses in the MPC-LACBWR canister shell and basket assembly resulting from a 60*g* bottom end drop satisfy the applicable accident condition allowable stress design criteria.

The maximum stresses in the MPC-LACBWR canister due to a 60*g* bottom end drop load are calculated using the finite element model described in Section 3.A.4.4.1.2. Analyses are performed for a 60*g* bottom end drop load both with and without internal pressure loading (12.0 psig.) The inertial load from the weight of the canister contents (i.e., basket assembly and spent fuel) is applied as a uniform pressure load on the inside surface of the canister bottom plate. The linearized membrane and membrane plus bending stress components and stress intensities at each canister stress section identified in Figure 3.A.4.4.1-2 are summarized in Table 11.A.2.11-1 through Table 11.A.2.11-4. The results of the analysis show that the canister maintains positive margins of safety for the concrete cask 6-inch drop condition.

Basket Support Disk and Weldment Stress Analysis

The basket support disks and weldments are also conservatively evaluated for a 60g bottom end drop condition. The maximum stresses in the support disks and top and bottom weldments are calculated using the finite element models described in Sections 3.A.4.4.2.1 and 3.A.4.4.2.2. The 60*g* bottom end drop loads are applied in the same manner as the loading due to dead weight plus handling load for normal conditions. The linearized membrane and membrane plus bending stress intensities are evaluated at all critical sections of the support disk, top weldment, and bottom weldment. The maximum calculated primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stress intensities in the MPC-LACBWR basket support disk, top weldment, and bottom weldment due to a 60*g* bottom end drop are summarized in Table 11.A.2.11-5 along with the corresponding accident condition allowable stresses and margins of safety.

Basket Tie-Rod Analysis

For the concrete cask 6-inch drop, the tie-rod spacers located at the bottom end of the basket assembly must support the entire weight of the basket assembly, not including the weight of the fuel assemblies or damaged fuel cans. The cross-section dimensions of the MPC-LACBWR basket tie-rod spacers are the same as those of the Yankee-MPC basket. Furthermore, the MPC-LACBWR basket weighs less than the Yankee-MPC basket. Therefore, the maximum axial compressive stress in the MPC-LACBWR basket tie-rod spacers due to the 21*g* bottom end drop are bounded by those calculated for the Yankee-MPC basket tie-rod spacers for a 56.1*g* bottom end drop load in MPC FSAR Section 11.3.2.2.

Basket Fuel Tube Analysis

For the concrete cask 6-inch drop, the fuel tubes in the MPC-LACBWR canister basket are supported at their bottom ends by the basket bottom weldment and are loaded only by their own weight. Thus, the fuel tube loading and support conditions for the concrete cask 6-inch drop are the same as those for normal handling, only different in the magnitude of the load.

As shown in Section 3.A.4.4.2.3, the maximum compressive stresses at the bottom end of the standard and oversized fuel tubes due to a 1.1*g* vertical acceleration load are 45 psi and 59 psi, respectively. For the 21*g* bottom end drop load, the maximum compressive stresses at the bottom end of the standard and oversized fuel tubes are 859 psi and 1,126 psi, respectively. The maximum stresses in the fuel tubes are much lower than the yield strength of Type 304 stainless steel material (e.g., S_y = 17,300 psi at 750°F) from which they are made. Therefore, it is

concluded that the fuel tubes will remain in position and maintain the position of the neutron absorbers for the concrete cask 6-inch drop event.

Damaged Fuel Can Analysis

The stresses in the Damaged Fuel Can (DFC) are calculated for a 20*g* vertical acceleration load in Section 3.A.4.4.2.4. The results of that analysis show that the maximum compressive stress at the bottom end of the DFC tube is 862 psi and the maximum bending stress for the DFC lid is 1,717 psi. For the 21*g* bottom end drop load, these stresses will be only 5% higher (i.e., 905 psi and 1,803 psi). The maximum stresses in the DFC are much lower than the yield strength of Type 304 stainless steel material (e.g., S_y = 17,300 psi at 750°F) from which they are made. Therefore, it is concluded that the DFC will remain in position and retain its contents for the concrete cask 6-inch drop event.

11.A.2.11.3 Radiological Consequences

There are no radiological consequences for this accident.

11.A.2.11.4 NAC-MPC Performance

Evaluations of the Yankee-MPC concrete storage cask for a 6-inch bottom end drop accident results in a maximum deceleration of 137 g for the storage cask, which does not reduce the shielding effectiveness of the cask. The base support, which contains the air inlets, is crushed approximately 0.31 inch. The effect of the reduction of the inlet area by the 6-inch drop is to reduce cooling air flow. The consequence of the loss of one-half of the air inlets is evaluated in Section 11.A.1.1, which bounds this condition.

The maximum deceleration of 21g for the MPC-LACBWR canister and basket, as a result of the 6-inch storage cask drop, is conservatively evaluated using a bounding deceleration of 60g. The analysis results indicate that the canister and basket remain structurally adequate.

11.A.2.11.5 Recovery and/or Corrective Actions

Even though the storage cask system remains functional and no immediate recovery steps are required, the canister should be moved to a new concrete storage cask as soon as one is available. The damaged storage cask should be inspected for stability, and repaired as required prior to continued use.

Table 11.A.2.11-1 MPC-LACBWR Canister Membrane (P_m) Stresses, Concrete Cask 6-inch Drop without Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	0.0	-0.6	-2.7	0.0	0.0	-0.2	2.76	46.26	15.74
2	0.4	-1.4	-6.1	0.0	0.0	-0.1	6.54	46.25	6.07
3	-0.1	-1.5	-6.5	0.0	0.0	0.1	6.41	46.23	6.21
4	0.0	0.0	-6.1	0.0	0.0	0.0	6.10	45.53	6.46
5	0.0	0.0	-5.8	0.0	0.0	0.0	5.76	44.92	6.80
6	0.0	0.0	-5.4	0.0	0.0	0.0	5.37	45.35	7.45
7	0.0	0.0	-5.0	0.0	0.0	0.0	4.98	46.51	8.34
8	0.0	0.2	-4.6	0.0	0.0	0.0	4.79	47.61	8.95
9	0.8	-1.7	-3.2	0.0	0.0	0.5	4.15	47.90	10.54
10	0.6	-1.4	-0.8	0.0	0.0	0.7	2.29	47.92	19.94
11	-1.7	-2.2	-0.2	0.0	0.0	0.5	2.19	47.94	20.92
12	0.2	-0.4	2.3	0.0	0.0	2.0	4.50	38.32[2]	7.52
13	-0.9	-2.3	-1.0	0.0	0.0	0.2	1.54	47.94	30.05
14	0.1	0.1	-0.7	0.0	0.1	0.0	0.79	44.64	55.73
15	0.0	0.0	0.0	0.0	0.0	0.0	0.01	48.00	>100

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.11-2 MPC-LACBWR Canister Membrane + Bending (P_m+P_b) Stresses, Concrete Cask 6-inch Drop without Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	0.4	-0.6	-3.1	0.0	0.0	-0.4	3.53	66.08	17.71
2	-0.1	-2.3	-8.4	0.0	0.0	0.1	8.29	66.08	6.97
3	0.0	-1.7	-7.3	0.0	0.0	0.1	7.30	66.04	8.04
4	0.0	0.0	-6.1	0.0	0.0	0.0	6.10	65.04	9.66
5	0.0	0.0	-5.8	0.0	0.0	0.0	5.76	64.17	10.15
6	0.0	0.0	-5.4	0.0	0.0	0.0	5.37	64.78	11.07
7	0.0	0.0	-5.0	0.0	0.0	0.0	4.98	66.45	12.34
8	0.0	-0.1	-5.4	0.0	0.0	0.0	5.39	68.01	11.63
9	-0.5	-2.7	-5.4	0.0	0.0	-0.8	5.07	68.43	12.49
10	0.2	-3.0	-5.8	0.0	0.0	0.1	6.06	68.45	10.29
11	-3.9	-3.0	-0.3	0.0	0.0	0.7	3.86	68.49	16.75
12	1.6	0.1	1.7	0.0	0.0	2.6	5.28	54.75[2]	9.37
13	3.1	-0.9	-0.2	0.0	0.0	-0.4	4.07	68.49	15.83
14	0.8	0.6	-0.7	0.0	0.1	0.0	1.54	63.77	40.36
15	4.1	4.1	0.0	0.0	0.0	0.0	4.07	68.57	15.84

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.11-3 MPC-LACBWR Canister Membrane (P_m) Stresses, Concrete Cask 6-inch Drop with 12 psig Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	0.0	-0.5	-2.5	0.0	0.0	-0.2	2.46	46.26	17.78
2	0.5	-1.3	-5.8	0.0	0.0	-0.1	6.37	46.25	6.26
3	-0.1	-1.4	-6.1	0.0	0.0	0.1	5.97	46.23	6.74
4	0.0	0.8	-5.7	0.0	0.0	0.0	6.52	45.53	5.98
5	0.0	0.8	-5.3	0.0	0.0	0.0	6.18	44.92	6.27
6	0.0	0.8	-5.0	0.0	0.0	0.0	5.79	45.35	6.83
7	0.0	0.8	-4.6	0.0	0.0	0.0	5.40	46.51	7.61
8	0.0	0.9	-4.2	0.0	0.0	0.0	5.09	47.61	8.36
9	0.9	-1.5	-3.0	0.0	0.0	0.5	4.03	47.90	10.87
10	0.5	-1.3	-0.8	0.0	0.0	0.7	2.11	47.92	21.75
11	-1.6	-2.1	-0.2	0.0	0.0	0.5	2.02	47.94	22.75
12	0.2	-0.2	2.4	0.0	0.0	1.8	4.27	38.32[2]	7.98
13	-0.9	-2.1	-0.9	0.0	0.0	0.2	1.39	47.94	33.52
14	0.1	0.1	-0.7	0.0	0.1	0.0	0.82	44.64	53.18
15	0.0	0.0	0.0	0.0	0.0	0.0	0.01	48.00	>100

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.11-4 MPC-LACBWR Canister Membrane + Bending (P_m+P_b) Stresses, Concrete Cask 6-inch Drop with 12 psig Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	0.4	-0.3	-2.5	0.0	0.0	-0.4	3.01	66.08	20.98
2	0.0	-2.4	-8.8	0.0	0.0	0.0	8.75	66.08	6.56
3	0.0	-1.8	-7.7	0.0	0.0	0.2	7.68	66.04	7.60
4	0.0	0.8	-5.7	0.0	0.0	0.0	6.53	65.04	8.97
5	0.0	0.8	-5.3	0.0	0.0	0.0	6.18	64.17	9.38
6	0.0	0.8	-5.0	0.0	0.0	0.0	5.80	64.78	10.18
7	0.0	0.8	-4.6	0.0	0.0	0.0	5.41	66.45	11.29
8	0.0	0.6	-5.2	0.0	0.0	0.0	5.78	68.01	10.77
9	-0.5	-2.7	-5.8	0.0	0.0	-0.7	5.47	68.43	11.51
10	0.2	-2.9	-5.7	0.0	0.0	0.1	5.93	68.45	10.55
11	-3.7	-2.8	-0.3	0.0	0.0	0.7	3.71	68.49	17.46
12	-1.4	-0.7	2.9	0.0	0.0	1.2	4.90	54.75[2]	10.17
13	2.9	-0.8	-0.2	0.0	0.0	-0.3	3.75	68.49	17.26
14	0.9	0.6	-0.7	0.0	0.1	0.0	1.59	63.77	39.03
15	3.7	3.7	0.0	0.0	0.0	0.0	3.70	68.57	17.55

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.11-5 MPC-LACBWR Basket Maximum Stress Summary, Concrete Cask 6-inch Drop

Canister Component	Calculated Stress		Allowable Stress		Margin of Safety
	Stress Type	Maximum Value (ksi)	Criteria	Allowable Value (ksi)	
Support Disk	P_m	3.4	$2.4S_m$	90.0	25.5
	P_m+P_b	36.3	$3.6S_m$	128.5	2.53
Top Weldment	P_m	3.0	$2.4S_m$	44.9	14.0
	P_m+P_b	26.2	$1.0S_u$	64.4	1.46
Bottom Weldment	P_m	0.4	$2.4S_m$	43.4	107.5
	P_m+P_b	39.2	$1.0S_u$	64.0	0.63

11.A.2.12 Tip-Over of the Concrete Cask

This section discusses the evaluation of the MPC-LACBWR concrete cask for a non-mechanistic tip-over onto the ISFSI concrete pad. For a concrete cask tip over event to occur, the center of gravity of the loaded cask must be rotated beyond the cask bottom edge, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the loaded concrete cask will be converted to kinetic energy as it rotates toward a horizontal orientation on the ISFSI pad. The subsequent motion of the concrete cask is governed by the structural characteristics of the concrete cask, ISFSI pad, and underlying soil.

11.A.2.12.1 Cause of Concrete Cask Tip-Over Event

The structural analysis of the concrete cask demonstrates that no design-basis accident events will cause the concrete cask to tip-over. An earthquake magnitude that greatly exceeds the design-basis earthquake described in Section 11.A.2.2 would be required to tip-over the concrete cask.

A tip-over of the concrete cask would be observed during a survey of the site following the earthquake or other catastrophic event. The tipped-over orientation of the concrete cask would be obvious by inspection.

11.A.2.12.2 Analysis of the MPC-LACBWR Concrete Cask Tip-Over Event

11.A.2.12.2.1 Analysis of the MPC-LACBWR Concrete Cask

The concrete cask tip-over evaluation is performed to determine the response of the concrete cask to the tip-over event and the maximum accelerations experienced by canister and basket structural. The methodology used to determine the concrete cask response is based on NUREG/CR-6608. The dynamic response of the concrete cask for the tip-over event is evaluated using the LS-DYNA program. The MPC-LACBWR concrete cask tip-over analysis is performed using the Yankee-MPC concrete cask tip-over finite element model described in MPC FSAR Section 11.2.12. The soil depth for the MPC model in MPC FSAR Section 11.2.12 is 6 feet. At the MPC-LACBWR site, the soil depth is 40 feet, thereby confirming that the 6-foot soil thickness used in the model is conservative. Modifications to the concrete strength, density and elastic modulus of the soil underneath the concrete pad are as follows:

Soil Property	Concrete Cask Tip-Over Model	
	Yankee - MPC	LACBWR - MPC
Soil Density	100 pcf	120 pcf
Soil Elastic Modulus	70,000 psi	10,000 psi
Concrete Pad Compressive Strength	4,000 psi	6,000 psi

The results of the MPC-LACBWR concrete cask tip-over analysis show that the peak accelerations at key locations of the concrete cask liner, which are used in the evaluation of the loaded canister/basket model (Section 11.A.2.12.2 and Section 11.A.2.12.3) are:

Axial Position (Distance from Cask Bottom End)	Canister/Basket Component at Location	Peak Acceleration
122.8 in.	Top Support Disk	21.9g
139.4 in.	Canister Top End	24.6g

11.A.2.12.2.2 Analysis of the MPC-LACBWR Canister and Basket

Canister Stress Analysis

The MPC-LACBWR canister is evaluated for the concrete cask tip-over condition using a plastic analysis in accordance with Appendix F of the ASME Code. The analysis is performed using the half-symmetry finite element model shown in Figure 11.A.2.12-1. This model is similar to the model used for the MPC-LACBWR canister normal condition stress analysis, as described in Section 3.A.4.4.1.1, but has a refined mesh, gap elements that are sized based on the concrete cask annulus, and plastic material properties.

A bi-linear kinematic hardening material model, defined by a yield strength and a tangent modulus, is used to perform a plastic analysis. The material model is based on the properties of the canister Type 304 stainless steel material at a temperature of 300°F, corresponding to the temperature of the lid weld region where the highest stresses are expected to occur. The yield strength is modeled as 21.4 ksi. The tangent modulus is taken as $(S_u - S_y)/\varepsilon_p = 10.95\times10^4$ psi, where S_u is the ultimate tensile strength (66.2 ksi) and ε_p is the ultimate strain (40%).

The canister tip-over stress analysis is conservatively performed using a transverse acceleration of 25*g* over the full length of the canister. Note that this corresponds to a DLF of 1.02 (25/24.6)

at the top of the canister, which is conservative since the canister lid (7 inches thick) region is stiff due to its monolithic structure. The inertial load of the basket assembly is modeled as a pressure load on the inside surface of the canister shell. The basket pressure load distribution is assumed to be uniform over the length of the canister shell that is in contact with the support disks and is assumed to vary linearly in the circumferential direction, from a maximum value at the symmetry plane to zero at an angle of 22° from the symmetry plane. In addition, a uniform internal pressure load of 12 psig is applied to the model.

The maximum primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stress components and stress intensities in the MPC-LACBWR canister due to the storage cask tip-over load are summarized in Tables 11.A.2.12-1 and 11.A.2.12-2, respectively. In accordance with Appendix F of the ASME Code, the membrane stress is limited to $0.7S_u$ and the membrane plus bending stress is limited to $0.9S_u$. An additional factor of 0.8 is applied to the allowable stresses for the lid closure weld (Section 12). The results of the analysis show that the lowest margins of safety in the cansiter shell for P_m and P_m+P_b stress intensities both occur in the lid closure weld (Section 12 in Figure 3.A.4.4.1-2) and result from the storage cask tip-over load with internal pressure loading. The lowest margins of safety for P_m and P_m+P_b stress intensity are 0.40 and 0.63, respectively.

Support Disk and Weldment Stress Analysis

The MPC-LACBWR canister fuel basket is evaluated for the concrete cask tip-over conditions using the finite element model shown in Figure 11.A.2.12-2. This finite element model is similar to the model used for the MPC-LACBWR canister normal condition stress analysis, as described in Section 3.A.4.4.1.1, but uses a coarse mesh for the canister and includes the basket support disks in order to properly model the interaction between the basket and shell under transverse loading conditions. Modeling the interaction of the basket and canister shell does not require a detail element discretization of the weld region or the lid. It is only necessary for the model to represent the stiffness that the lid applies to the canister shell at the lid-canister shell junction.

Each of the basket support disks and the top weldment are modeled using elastic shell elements (SHELL63) with thickness input as real constants. The 15 support disks that are located in the bottom-end region of the canister, where tip-over loads are lowest, are modeled using the coarse mesh shown in Figure 11.A.2.12-3. The 11 support disks located in the canister top-end region, where the tip-over loads are highest, are modeled using the fine mesh shown in Figure 11.A.2.12-4. The top weldment disk is also modeled using a fine mesh, similar to that shown in Figure 11.A.2.12-4 for the support disk. Rather than modeling the basket tie-rods, each support disk is restrained in the axial direction (i.e., UY=0) at the nodes located at the centerline of each tie-rod. The interface between the basket and canister is modeled by CONTAC52

elements. Contact between the canister shell and the concrete cask steel liner is modeled by CONTAC52 elements that are attached at one end to the canister shell and constrained in all degrees-of-freedom on the other end. The gap elements on the canister shell are positioned to model the shift in the position of the canister shell as it comes into contact with the concrete cask inner liner.

As presented in Section 11.A.2.12.2.1, the maximum acceleration of the steel liner at the location of the top support disk is determined to be 21.9g. Using the acceleration time history developed in Section 11.A.2.12.2.1 and the methodology described in Section 11.2.12.2.2 for the Yankee-MPC basket support disk DLF calculation, the maximum DLF and corresponding frequencies for the MPC-LACBWR support disks are:

Mode Number	Frequency (Hz)	DLF
1	87	1.02
2	256	1.02
3	347	1.02
4	421	1.01

Applying the maximum DLF of 1.02 to the 21.9g results in a peak acceleration of 22.3g. The applied inertial load to the finite element model described in this section corresponds to a bounding transverse load of 25*g* at the basket top support disk. The inertial load of the canister and basket support disks due to the 25*g* tip-over load is accounted from by applying a rotational acceleration load of 76.4 rad/s^2 about the global origin of the model, which corresponds to the location of the concrete cask bottom edge about which the concrete cask tips over. In addition, horizontal line loads are applied to the edges of the fuel tube holes in each support disk to account for the weight of the basket components that are not modeled (i.e., fuel, fuel tubes, damaged fuel cans, heat transfer disks, and tie-rods.) The magnitudes of horizontal line loads applied to the ligaments of the standard and damaged fuel tube openings are calculated based on the weight of the contents of each opening and the transverse acceleration corresponding to the tip-over rotational acceleration. The analysis is performed for five (5) basket impact orientations as shown in Figure 11.A.2.12-5.

The highest stresses occur in the top two support disks (disk no. 25 and 26). The maximum primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stresses for the sections defined in Figure 11.A.2.12-6 for support disks 25 and 26 due to each of the concrete cask tip-over impact orientations evaluated are summarized in Table 11.A.2.12-3. The allowable P_m and P_m+P_b stress intensities for the support disks are based on 17-4 PH material properties at a

bounding temperature of 500°F. The results of the basket tip-over stress analysis show that the lowest design margins for P_m and P_m+P_b are 0.20 and 0.55, respectively.

Basket Support Disk Buckling Analysis

Buckling of the MPC-LACBWR support disk is evaluated for the tip-over condition in accordance with the methods and acceptance criteria of NUREG/CR-6322. The support disks are fabricated from 17-4 PH ferritic steel. Therefore, the formulas for non-austenitic steel presented in MPC FSAR Section 11.2.12.2.2 are used for the support disk buckling analysis.

The support disk buckling analysis considers the highest ligament stresses in the two support disks located nearest the top end of the basket (i.e., 25th and 26th support disks) resulting from each of the impact orientations shown in Figure 11.A.2.12-5. The support disk buckling analysis is conservatively performed using the smallest ligament cross-section dimensions and the largest ligament length for all disk ligaments. Table 11.A.2.12-4 summarizes the calculated and allowable forces and moments at the stress sections in support disks 25 and 26 with the lowest margins of safety against buckling for each concrete cask tip-over impact orientation evaluated. The results show that the lowest margin of safety against buckling of 0.16 occurs at section 111 of support disk number 25 for the 15.2° impact orientation. Therefore, the MPC-LACBWR support disks satisfy the buckling design criteria of NUREG/CR-6322 for the tip-over condition.

Basket Fuel Tube Analysis

The MPC-LACBWR fuel tube stresses and deformation resulting from the concrete cask tip-over load are bounded by those calculated for the MPC-CY fuel tubes in MPC FSAR Section 11.4.5 for a 55*g* side impact load. This conclusion is based on a comparison of the MPC-LACBWR and MPC-CY fuel tube loads and boundary conditions considered in the concrete cask tip-over stress analysis.

The MPC-LACBWR fuel tubes are similar to the MPC-CY fuel tubes, having the same 0.048-inch tube thickness, but are shorter, have smaller openings, and contain much lighter payloads than the MPC-CY fuel tubes. The MPC-LACBWR fuel tubes are 98.25 inches long compared to 131.95 inches for the MPC-CY fuel tubes. The MPC-LACBWR standard and oversized fuel tubes have square 5.75-inch and 6.00-inch openings, whereas the MPC-CY fuel tube has a square 9.12-inch opening. The lateral pressure loading on the MPC-LACBWR standard and oversized fuel tubes due to the 25*g* tip-over are 17.7 psi (i.e., 25*g* × 400 lb/(98.25×5.75)) and 19.0 psi (i.e., 25*g* × 449 lb/(98.25×6.00), respectively, whereas the MPC-CY fuel tubes are designed for lateral pressure load of 72.67 psi, as discussed in MPC

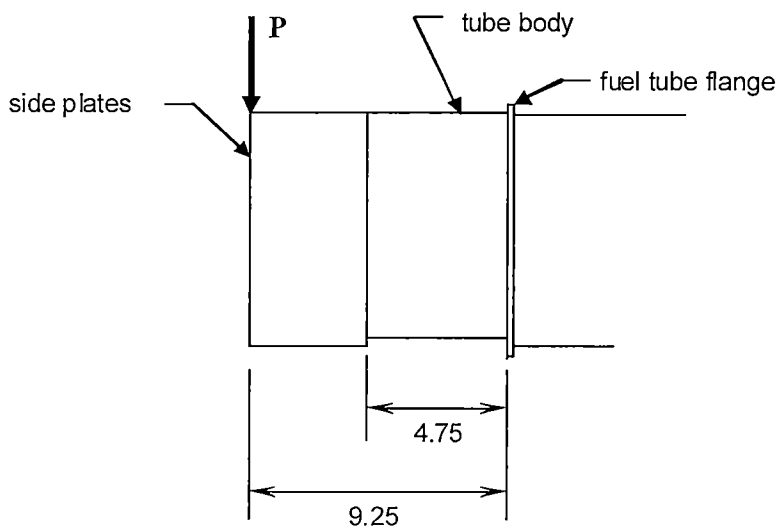
FSAR Section 11.4.5. Furthermore, the axial spacing (or pitch) of the support disks, and therefore the unsupported span length of the MPC-LACBWR fuel tubes, is smaller than that of the MPC-CY basket (i.e., 3.83-inch vs. 4.59-inch).

Therefore, the maximum stresses and deformation of the MPC-LACBWR fuel tubes due to the concrete cask tip-over are much lower than those calculated for the MPC-CY fuel tubes due to the 55*g* side impact load in MPC FSAR Section 11.4.5.

Damaged Fuel Can Analysis

The majority of the damaged fuel can body is contained within the fuel tube in the basket assembly. Because both the can tube body and the fuel tube have square cross-sections, they will be in full contact (for 95.24 inches longitudinally) during the cask tip-over condition, and no significant bending stress will be introduced into the can body. However, the top 4.75 inches of the can tube body and the 4.5-inch-long side plates are unsupported past the fuel tube flange.

The unsupported can tube body is evaluated as a cantilevered beam with the combined weight (P) of the overhanging can tube body, lid and side plates using a conservative deceleration of 60g. The combined loading is conservatively applied at the top end of the side plates.



The maximum bending stress (f_b) is determined as follows.

$$f_b = \frac{M_{max}c}{I} = \frac{33{,}300(2.93)}{6.5} = 15{,}011 \text{ psi}$$

where:

$M_{max} = Pg \times L = 60(60)(9.25) = 33{,}300$ lb-inch

$g = 60$

The shear stress (τ) is

$$\tau = \frac{Pg}{A} = \frac{60(60)}{1.16} = 3{,}103 \text{ psi}$$

$$\sigma_1, \sigma_2 = \frac{1}{2}\left(f_b \pm \sqrt{f_b^2 + 4\tau^2}\right) = \frac{1}{2}\left(15{,}011 \pm \sqrt{15{,}011^2 + 4(3{,}103)^2}\right) = 15{,}627 \text{ psi and } -616 \text{ psi}$$

The stress intensity (σ_{max}) = $|\sigma_1 - \sigma_2|$ = 16,243 psi

The margin of safety (MS) is

$$MS = \frac{1.0\ (3.6S_m)}{\sigma_{max}} - 1 = \frac{1.0(3.6)(16{,}700)}{16{,}243} - 1 = 2.70$$

The welds joining the can tube body to the side plates are full-penetration welds. The weld quality factor (n) for a Type III weld with visual surface inspection is 0.5. The margin of safety (MS) for the welds is

$$MS = \frac{(1.0)n \cdot 3.6S_m}{\sigma_{max}} - 1 = \frac{(1.0)(0.5)(3.6)(16{,}700 \text{ psi})}{16{,}243 \text{ psi}} - 1 = 0.85$$

11.A.2.12.3 Radiological Consequences

There is an adverse radiological consequence in the hypothetical tip-over event, since the bottom end of the storage cask and the canister have significantly less shielding than the sides and tops of these same components. In previous calculations for the Yankee-MPC, the dose rate at 1 meter is calculated to be approximately 156 rem/hour, and the dose rate at 5 meters is calculated to be approximately 32 rem/hour. These does rates are bounding for the MPC-LACBWR system due to the smaller source in the LACBWR payload. Regardless of the MPC system configuration, high dose rates expected at the cask bottom following the tip-over event would dictate the use of supplemental shielding until the concrete cask can be uprighted. Stringent access controls must be applied to ensure that personnel do not enter the area of radiation shine from the exposed bottom of the tipped over concrete cask. As previously noted in the tip-over analysis, tip-over is not a credible event.

11.A.2.12.4 NAC-MPC Performance

Following a tip-over event, the MPC-LACBWR canister will maintain confinement of radioactive material and continue to provide criticality control. Minor damage to the exterior surface of the concrete cask, such as cracking or spalling of cover concrete, may result from the tip-over event. The damage to the concrete cask exterior may result in local increases to the concrete cask exterior dose rates. The radiological consequences of the MPC-LACBWR concrete cask tip-over are evaluated in Section 11.A.2.12.3.

11.A.2.12.5 Recovery and/or Corrective Actions

The actions required for recovery from the concrete cask tip-over event are discussed in MPC FSAR Section 11.2.12.8.

Figure 11.A.2.12-1 MPC-LACBWR Canister Tip-Over Finite Element Model

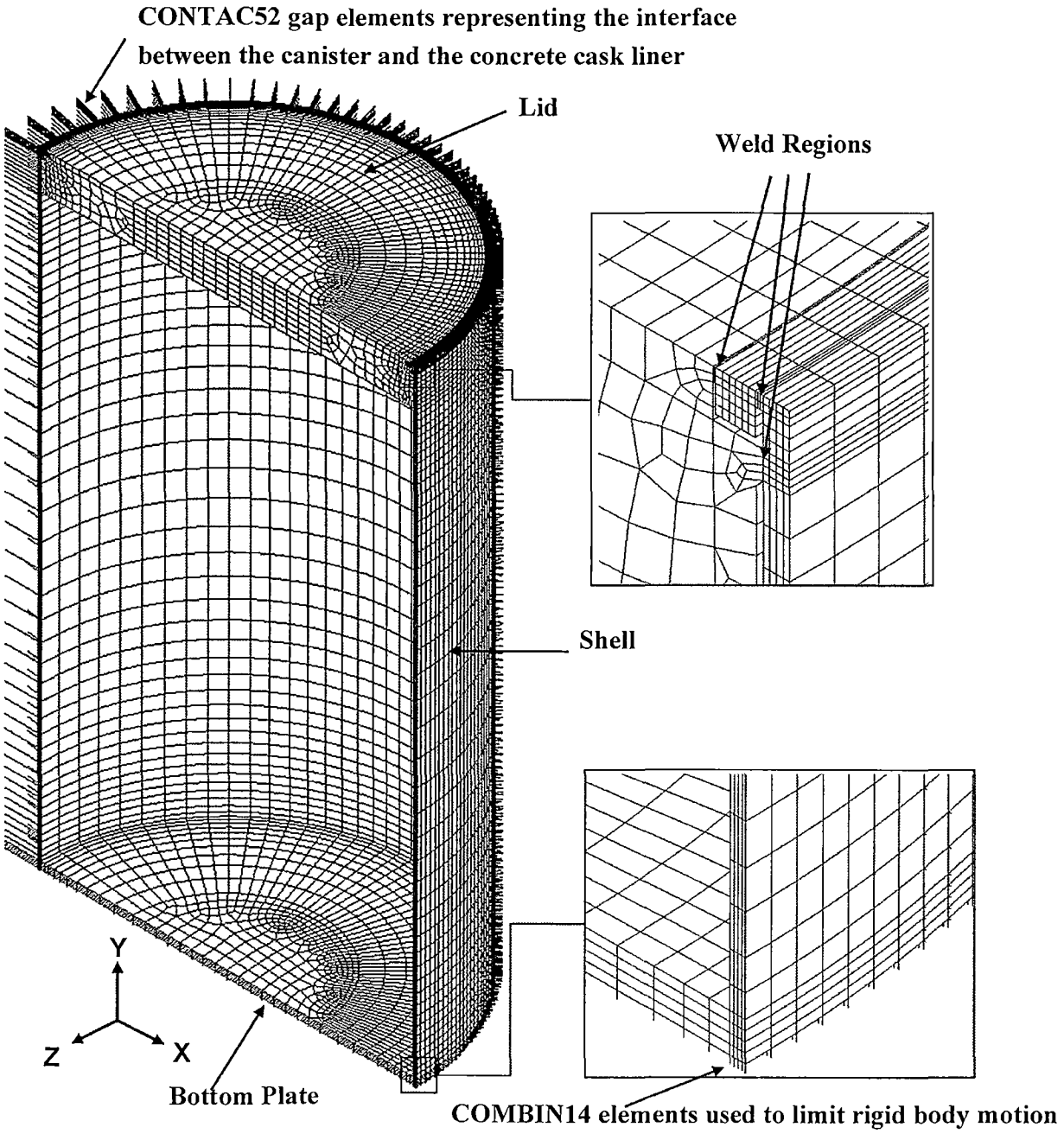


Figure 11.A.2.12-2 MPC-LACBWR Basket Tip-Over Finite Element Model

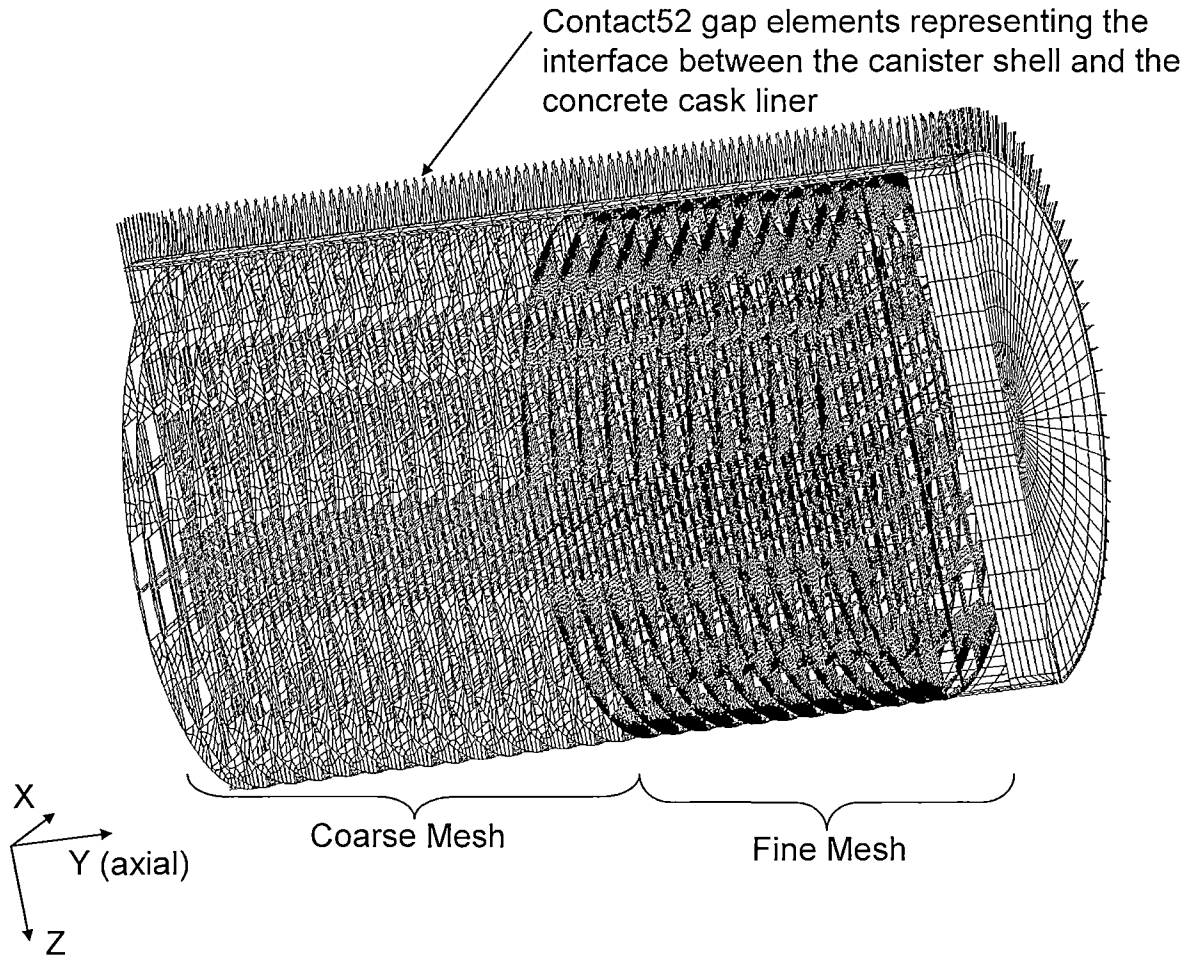


Figure 11.A.2.12-3 MPC-LACBWR Basket Tip-Over Finite Element Model – Coarse Disk Mesh

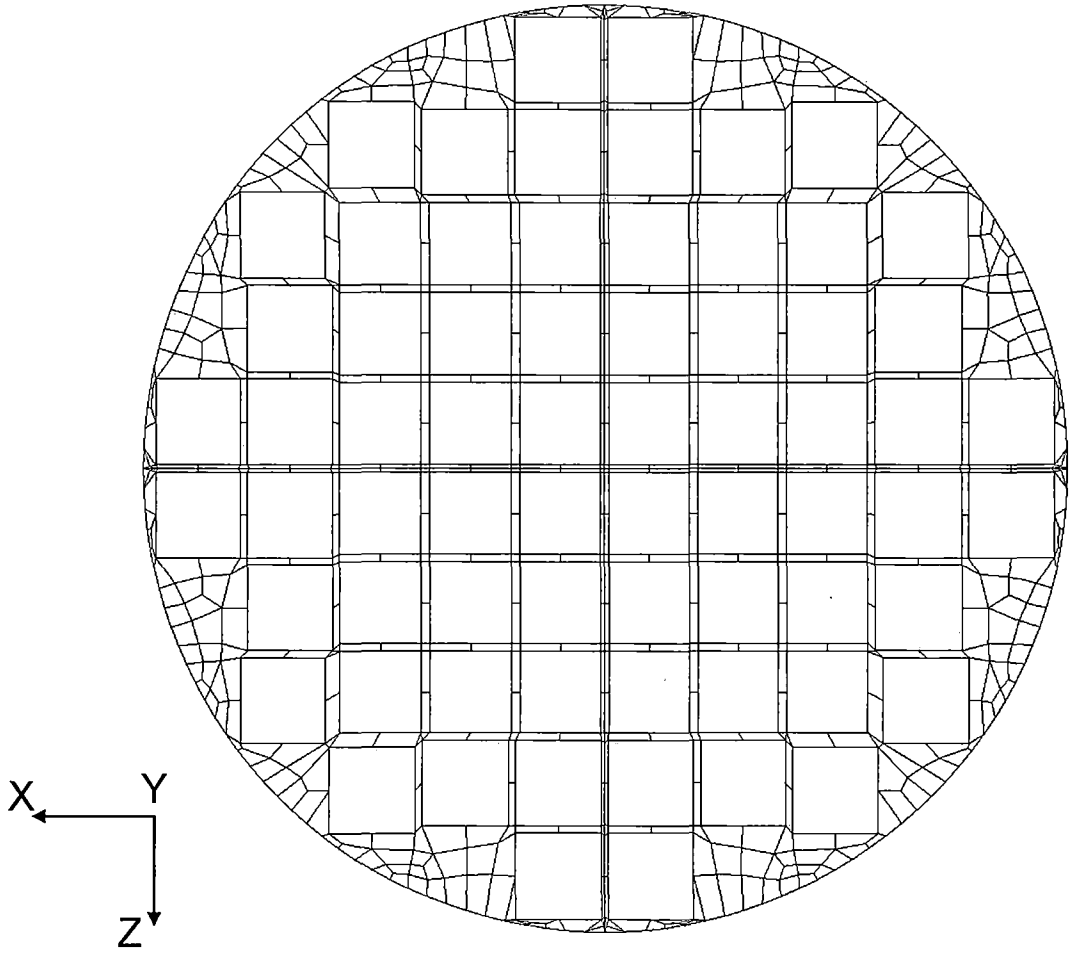


Figure 11.A.2.12-4 MPC-LACBWR Basket Tip-Over Finite Element Model – Fine Disk Mesh

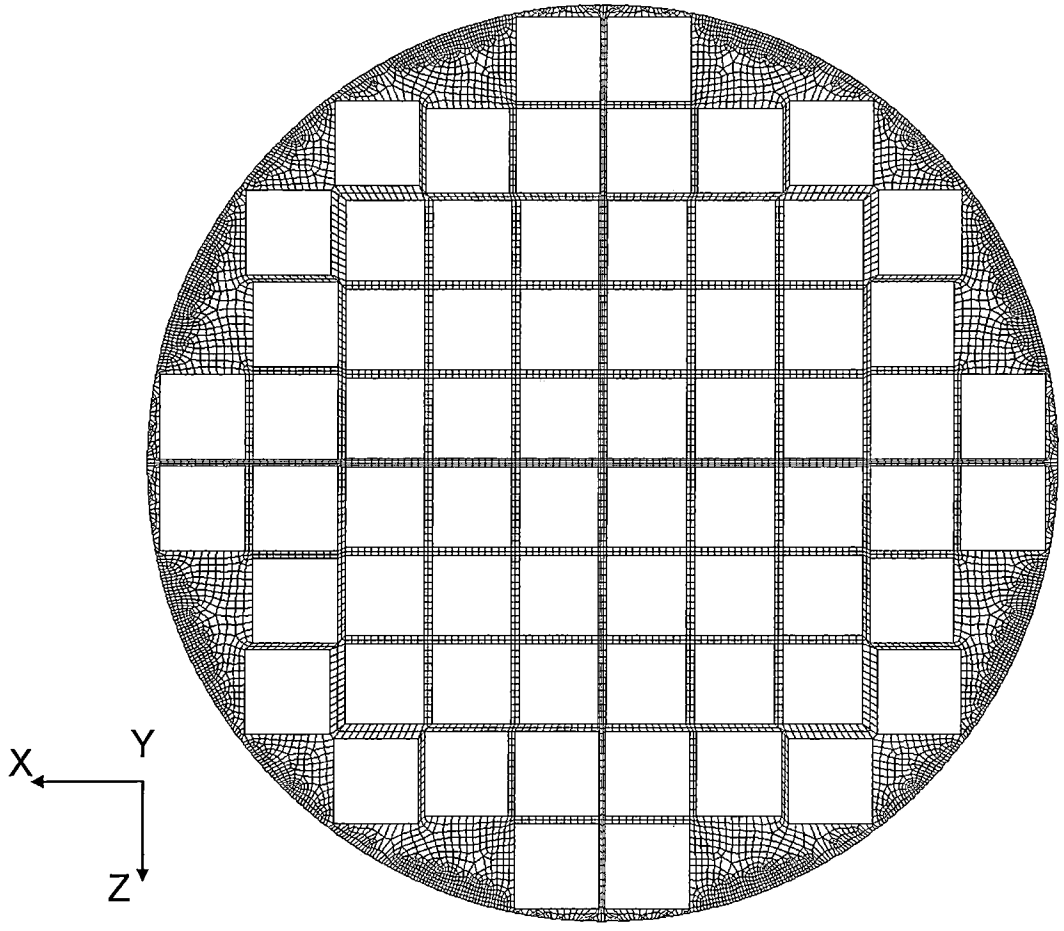


Figure 11.A.2.12-5 MPC-LACBWR Basket Tip-Over Impact Orientations Evaluated

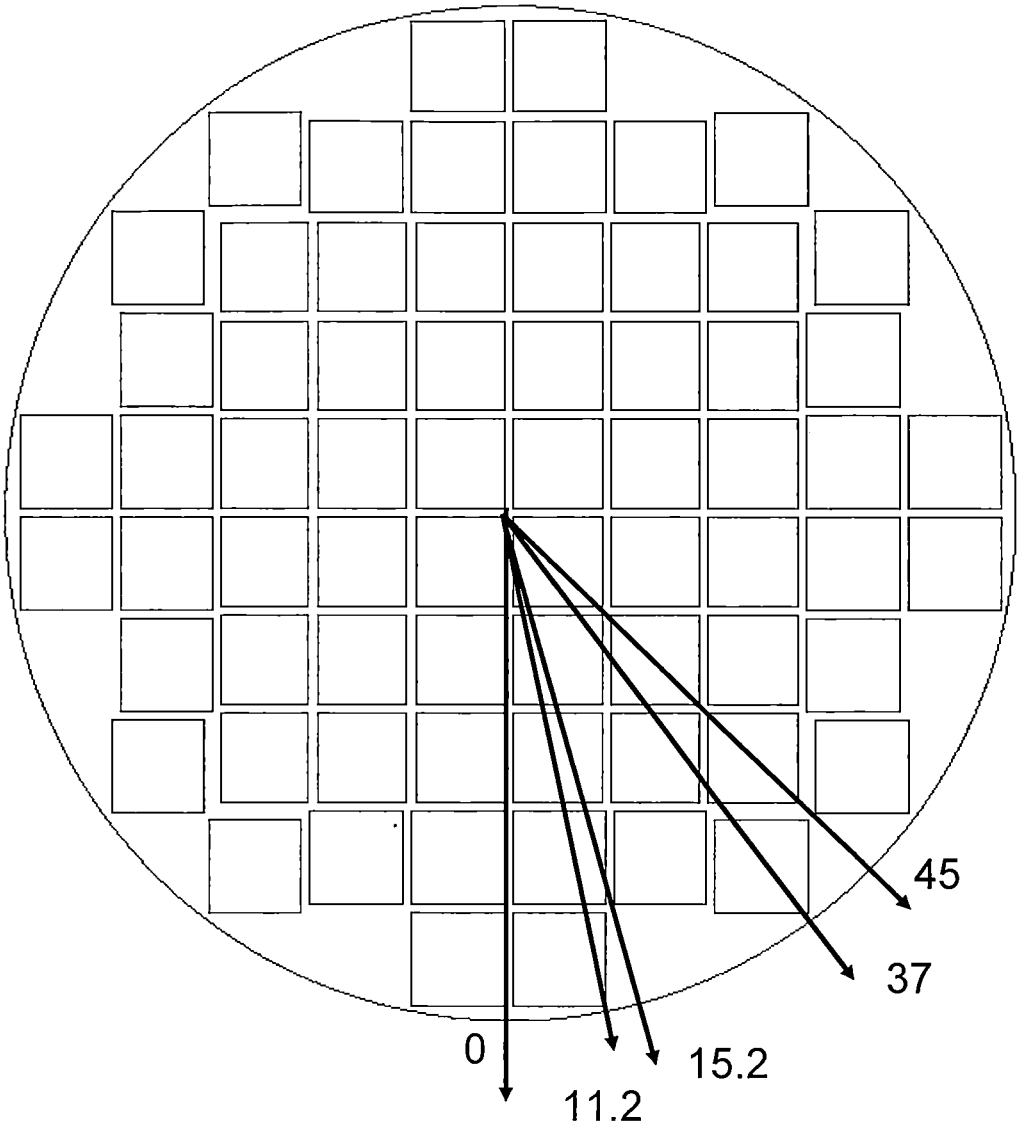


Figure 11.A.2.12-6 MPC-LACBWR Support Disk Stress Sections

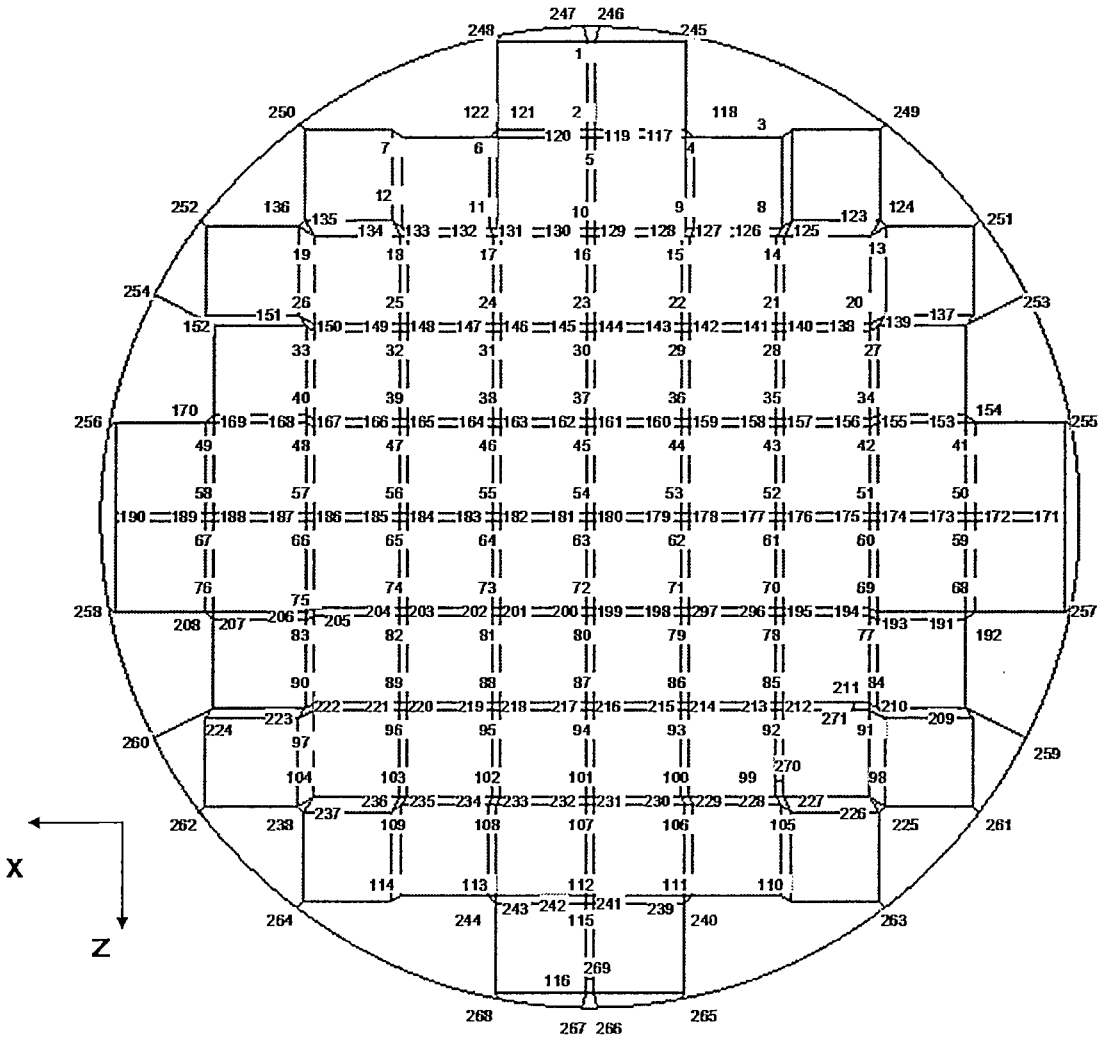


Table 11.A.2.12-1 Summary of MPC-LACBWR Canister Primary Membrane (P_m) Stresses, Concrete Cask Tip-Over + Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	-26.13	-16.39	-1.00	0.74	0.75	-1.30	25.35	45.64	0.80
2	-14.36	-24.53	-4.68	0.46	0.23	-3.51	21.02	45.64	1.17
3	0.02	-10.47	3.16	-0.46	1.15	-0.20	13.87	45.64	2.29
4	-0.55	3.47	5.19	1.43	-0.61	-0.06	6.44	45.08	6.00
5	-0.63	2.04	5.46	1.20	0.01	-0.01	6.55	45.08	5.88
6	-0.62	1.97	5.17	1.15	0.16	0.00	6.24	45.08	6.23
7	-0.64	3.07	4.29	1.41	0.61	0.04	5.74	45.08	6.86
8	0.00	1.32	-0.13	-0.01	5.28	0.06	10.66	46.20	3.34
9	-21.77	-8.88	4.66	-0.09	0.02	2.71	26.98	46.20	0.71
10	-20.01	-10.04	1.05	-0.08	-0.08	-7.79	26.20	46.20	0.76
11	-21.40	-10.38	-0.79	0.12	0.00	3.17	21.57	46.20	1.14
12	-31.19	-18.76	-6.27	-0.04	0.01	-4.26	26.34	36.96[2]	0.40
13	-30.31	-16.18	-1.76	0.01	-0.06	0.61	28.58	46.20	0.62
14	-1.31	0.73	-0.01	0.07	-0.01	0.01	2.04	45.08	21.05
15	-0.56	0.18	-0.01	0.02	0.00	-0.04	0.74	46.20	61.58

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.12-2 Summary of MPC-LACBWR Canister Primary Membrane + Bending (P_m+P_b) Stresses, Concrete Cask Tip-Over + Internal Pressure

Section No.[1]	Stress Components (ksi)						Stress Intensity (ksi)	Stress Allowable (ksi)	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ			
1	-27.68	-16.02	-0.79	0.85	0.63	0.46	27.00	58.68	1.17
2	0.81	-15.94	-32.59	-0.07	-2.00	-2.91	34.14	58.68	0.72
3	0.12	6.56	30.86	0.48	-6.89	2.26	33.04	58.68	0.78
4	-0.11	31.04	14.77	-0.23	-1.97	-0.01	31.39	57.96	0.85
5	-0.14	31.85	15.17	-0.20	-0.49	0.00	32.01	57.96	0.81
6	-0.15	31.63	14.85	-0.18	0.43	0.00	31.79	57.96	0.82
7	-0.14	31.18	14.00	-0.23	1.76	0.01	31.50	57.96	0.84
8	0.13	-27.47	-6.59	0.28	-0.18	0.08	27.61	59.40	1.15
9	-15.80	-2.21	12.44	-0.13	-0.04	1.67	28.44	59.40	1.09
10	-22.25	-14.41	-6.61	0.01	-0.06	-12.49	29.48	59.40	1.02
11	-28.42	-8.56	1.90	-0.35	0.04	5.13	32.02	59.40	0.86
12	-27.34	-16.68	-5.94	-0.02	-0.02	-9.83	29.07	47.52[2]	0.63
13	-36.42	-21.37	-6.32	-0.05	-0.04	5.73	32.20	59.40	0.84
14	-8.80	-6.71	-0.01	0.08	-0.01	0.01	8.80	57.96	5.59
15	-0.92	0.46	0.00	0.04	0.00	-0.04	1.38	59.40	41.97

1. Refer to Figure 3.A.4.4.1-2 for canister section locations.
2. Section 12 allowable multiplied by a weld strength reduction factor of 0.8.

Table 11.A.2.12-3 Summary of MPC-LACBWR Support Disk Stresses, Concrete Cask Tip-Over

Support Disk	Impact Angle(3)	Stress Type	Section Number(4)	Stress Intensity	Allowable S.I. (ksi)	Margin of Safety
25(1)	0°	P_m	112	57.92	90.0	0.55
		P_m+P_b	265	105.67	128.6	0.22
	11.2°	P_m	111	55.25	90.0	0.63
		P_m+P_b	269	102.4	128.6	0.26
	15.2°	P_m	111	56.25	90.0	0.60
		P_m+P_b	179	101.75	128.6	0.26
	37°	P_m	72	39.49	90.0	1.28
		P_m+P_b	99	90.91	128.6	0.41
	45°	P_m	72	39.34	90.0	1.29
		P_m+P_b	99	95.95	128.6	0.34
26(2)	0°	P_m	112	57.62	90.0	0.56
		P_m+P_b	265	107.19	128.6	0.20
	11.2°	P_m	111	51.34	90.0	0.75
		P_m+P_b	269	95.43	128.6	0.35
	15.2°	P_m	111	52.05	90.0	0.73
		P_m+P_b	179	97.88	128.6	0.31
	37°	P_m	72	37.9	90.0	1.37
		P_m+P_b	99	86.78	128.6	0.48
	45°	P_m	72	37.82	90.0	1.38
		P_m+P_b	99	91.56	128.6	0.40

1. Support disk 25 is the 5/8-inch thick support disk located nearest the top end of the basket.
2. Support disk 26 is the 1 ¼-inch thick support disk located at the top end of the basket.
3. Tip-over impact orientations are shown in Figure 11.A.2.12-5.
4. Support disk section locations are shown in Figure 11.A.2.12-6.

Table 11.A.2.12-4 Summary of MPC-LACBWR Support Disk Ligament Buckling Analysis Results, Concrete Cask Tip-Over

Support Disk	Impact Angle[3]	Section Number[4]	Calculated Forces and Moments			Allowable Forces and Moments[5]			Margin of Safety[5]	
			P (kip)	P_y (kip)	M (in-kip)	P_{cr} (kip)	M_p (in-kip)	M_m (in-kip)	MS1	MS2
25[1]	0°	241	9.95	28.11	1.87	42.64	4.39	4.68	0.75	0.40
	11.2°	269	10.21	28.11	2.40	42.64	4.39	4.68	0.48	0.21
	15.2°	111	14.88	28.11	1.71	42.64	4.39	4.68	0.52	0.16
	37°	72	5.60	28.11	3.13	42.64	4.39	4.68	0.43	0.24
	45°	72	6.13	28.11	2.92	42.64	4.39	4.68	0.48	0.28
26[2]	0°	269	30.27	56.22	1.46	84.93	17.57	18.69	1.36	0.64
	11.2°	111	26.05	56.22	2.30	84.93	17.57	18.69	1.43	0.74
	15.2°	111	26.46	56.22	3.22	84.93	17.57	18.69	1.18	0.60
	37°	72	10.89	56.22	6.23	84.93	17.57	18.69	1.43	1.02
	45°	72	12.08	56.22	5.80	84.93	17.57	18.69	1.46	1.02

1. Support disk 25 is the 5/8-inch thick support disk located nearest the top end of the basket.
2. Support disk 26 is the 1 ¼-inch thick support disk located at the top end of the basket.
3. Tip-over impact orientations are shown in Figure 11.A.2.12-5.
4. Support disk section locations are shown in Figure 11.A.2.12-6.
5. Allowable forces and moments and margins of safety are calculated as described in Section 11.2.12.2.2.

11.A.2.13 Tornado and Tornado-Driven Missiles

The MPC-LACBWR Concrete Cask is evaluated for tornado wind and tornado-generated missile impact loads that are based on the design basis tornado wind and tornado-generated missiles characteristics described in Section 2.2.1. The evaluation, which is performed using the same classical techniques used for the evaluation of the Yankee-MPC concrete cask, demonstrates that the MPC-LACBWR concrete cask remains structurally intact and upright when subjected to the design basis tornado wind and tornado-generated missile loads. The extent of local damage of the MPC-LACBWR storage system caused by the design basis tornado-generated missile impacts is identical to that of the Yankee-MPC storage system (i.e., local dislodge of concrete on the concrete cask exterior to a depth of 5.68 inches.) Furthermore, since the MPC-LACBWR canister is adequately protected by the concrete cask from the effects of tornado loading, the tornado event has no significant effect on the canister.

The cause and detection of the tornado event and the corrective actions for recovery from the tornado event are essentially the same as those described in MPC FSAR Sections 11.2.13.1 and 11.2.13.5, respectively. The radiological consequences of the tornado event for the MPC-LACBWR storage system are addressed in Section 11.A.2.13.3.

11.A.2.13.2 Analysis of the Tornado Event

The analyses of the MPC-LACBWR storage system for tornado wind and tornado-generated missile impact loads are described in the following sections. Section 11.A.2.13.2.1 describes the stress analysis of the MPC-LACBWR concrete cask reinforced concrete shell for tornado wind loading. Section 11.A.2.13.2.2 describes the local damage analysis of the MPC-LACBWR concrete cask for tornado-generated missile impact loads and the overall damage analysis of the MPC-LACBWR concrete cask for the combined effects of tornado wind and tornado-generated missile impact loads.

11.A.2.13.2.1 Tornado Wind Loading

This section describes the evaluation of the maximum stresses in the MPC-LACBWR concrete cask resulting from the design basis tornado wind load. The evaluation of the overturning stability of the MPC-LACBWR concrete cask under the combined effects of tornado wind and tornado-generated missile impact loading is described in Section 11.A.2.13.2.2.

Tornado wind loading for the MPC-LACBWR concrete cask is identical to that of the Yankee-MPC concrete cask because the two cask designs have the same outside diameter and height.

Therefore, the MPC-LACBWR concrete cask is subjected to the same lateral tornado wind force as the Yankee-MPC concrete cask. As shown in MPC FSAR Section 11.2.13.2.1.1, the 23.59 kip lateral wind force results in an overturning moment of 157.3 kip-feet on the concrete cask. The stresses in the Yankee-MPC concrete cask resulting from the tornado wind load are calculated in MPC FSAR Section 11.2.13.2.1.1 using classical small-deformation beam theory, conservatively assuming that the concrete cask steel liner does not provide any structural support of the concrete shell.

The stresses in the MPC-LACBWR concrete cask, calculated using the same analysis approach as that used for the Yankee-MPC concrete cask, are lower since the MPC-LACBWR cask concrete shell is thicker and has higher section properties than the Yankee-MPC cask concrete shell. However, the bounding stresses calculated for the Yankee-MPC concrete cask are conservatively used for the evaluation of the MPC-LACBWR concrete cask. These stresses, when evaluated in combination with the maximum stresses resulting from dead load, live load, and normal thermal load, as discussed in Section 3.A.4.4.1.5, are shown to satisfy the applicable allowable stress criteria.

11.A.2.13.2.2 Tornado Missile Loading

The MPC-LACBWR concrete cask is designed to withstand the effects of impacts from the design basis tornado-generated missiles described in MPC FSAR Section 2.2.1.3, consisting of: (1) a high-kinetic energy missile (i.e., 4,000-pound automobile with a frontal area of 20 ft^2); (2) a 275-pound, 8-inch-diameter armor piercing artillery shell; and (3) a 1-inch-diameter solid steel sphere. All missiles have an impact velocity of 126 mph and are assumed to impact the cask in a manner that produces maximum damage.

The evaluation of the MPC-LACBWR concrete cask for tornado-generated missile impacts includes analyses of local damage and overall damage (i.e., overturning stability). The evaluation demonstrates that the MPC-LACBWR concrete cask will not overturn and satisfies the applicable allowable stress design criteria.

Local Damage Prediction

Local damage to the MPC-LACBWR concrete cask is predicted to be the same as the damage calculated for the Yankee-MPC MPC in MPC FSAR Section 11.2.13.2.1.2 since the exterior members of the MPC-LACBWR concrete cask are either the same as, or stronger (i.e., thicker) than those of the Yankee-MPC. Furthermore, the MPC-LACBWR concrete cask, which has

essentially the same inlet and outlet structure as the Yankee-MPC MPC, prevents the 1-inch diameter solid steel sphere missile from directly impacting the MPC-LACBWR canister.

The 1.5-inch-thick steel lid of the MPC-LACBWR concrete cask is greater than the plate thickness recommended to prevent perforation by the 8-inch-diameter armor piercing artillery shell. The thickness of the MPC-LACBWR concrete cask reinforced concrete shell is over three times greater than the predicted 5.68-inch penetration depth of the 8-inch-diameter armor piercing artillery shell missile. Therefore, the thickness of the MPC-LACBWR concrete cask reinforced concrete shell, even without structural credit for backing support provided by the concrete cask steel liner, is sufficient to prevent scabbing.

Overall Damage Prediction

The MPC-LACBWR storage system is evaluated for potential overturning due to the combined effects of tornado wind and tornado-generated missile loading using the same approach used for the Yankee-MPC storage system, as described in MPC FSAR Section 11.2.13.2.1.2. The design basis tornado-generated missile with the highest kinetic energy (i.e., 4,000-pound automobile) is conservatively assumed to impact the top edge of the concrete cask, causing the concrete cask to rotate about its bottom edge, as illustrated in the figure at the end of this section. The evaluation demonstrates that the MPC-LACBWR concrete cask will not tip over under the most severe combination of tornado wind and tornado-generated missile impact loads.

As discussed in MPC FSAR Section 11.2.13.2.1.2, the following equation, which is based on principle of conservation of momentum, is used to determine the angular velocity of the missile following impact:

$$M_m(v_2 - v_1) = \frac{I_m(\varpi_1 - \varpi_2)}{H}$$

where (with reference to the figure at the end of this section):

M_M = 10.35 lb-s^2/in (4,000 lbf), Mass of missile

v_2 = 0, Velocity of missile at time t_2

v_1 = 2,220 in/sec (185 ft/sec = 126 mph), Velocity of missile time of impact, t_1

I_m = 6.917×10^6 lb-in-s^2, mass moment of inertia of the concrete cask about the point of rotation
= $I_{mx} + (M_{VCC})(d_{cg})^2$

ϖ_1 = 0, angular velocity of the concrete cask at time of impact, t_1

ϖ_2 = angular velocity of the concrete cask at time t_2

H = 160 in., height of concrete cask

I_{mx} = 1.601×10^6 lb-in-s^2, mass moment of inertia of loaded concrete cask about the horizontal axis through the center of gravity
= $(M_{VCC})(3r^2 + H^2)/12$

M_{VCC} = 507 lb-s^2/in (195,800 lbf), mass of loaded concrete cask

d_{CG} = 102.4 in., Radial distance from point of rotation to concrete cask center of gravity

$$= \sqrt{(h_{CG})^2 + (r - c)^2}$$

$$= \sqrt{(83.0)^2 + (64 - 4)^2}$$

r = 64 in., Radius of concrete cask

During the restitution phase the final velocity of the missile will depend upon the coefficient of restitution of the missile, the geometry of the missile and target, the angle of incidence, and the amount of energy dissipated in deforming the missile and target. It is conservatively assumed that the final velocity of the missile following the impact, v_f, is zero and that all of the missile's kinetic energy is transferred to the concrete cask. Thus, the angular velocity of the concrete cask at time t_2 is determined by setting $v_2 = 0$ in the previous equation, as follows:

$$(10.35)(0 - 2{,}220) = \frac{(6.917 \times 10^6)(0 - \varpi_2)}{160}$$

Rearranging terms and solving for ϖ_2 yields:

ϖ_2 = 0.531 rad/sec

thus,

$$v_2 = (\varpi_2)\sqrt{H^2 + (2r - c)^2} = 107.5 \text{ in/sec}$$

where ϖ_2, H, and r are defined previously, and c is the chamfer size at the bottom end of the concrete cask (i.e., c = 4 in.).

Setting the impulse of the force on the missile during restitution equal to the impulse of the force on the cask, as follows, yields the angular velocity of the concrete cask following the impact (ϖ_f).

$$-M_m(v_f - v_2) = \frac{I_m(\varpi_f - \varpi_2)}{H}$$

Substituting the values of M_m, I_m, and H from above and setting $v_f = 0$, $v_2 = 107.5$ in/second, and $\varpi_2 = 0.531$ rad/second gives:

$$-(10.35)(0 - 107.5) = \frac{(6.917\text{x}10^6)(\varpi_f - 0.531)}{160}$$

Solving the equation yields the angular velocity of the concrete cask following the impact:

$$\varpi_f = 0.557 \text{ rad/sec}$$

Thus, the final kinetic energy of the concrete cask following the impact, E_k, is:

$$E_k = (I_m)(\varpi_f)^2/2 = 1.073\text{x}10^6 \text{ lb-in}$$

Based on the conservation of energy, the kinetic energy of the concrete cask following impact will cause the center of gravity to increase by:

$$h_{KE} = E_k/W_{VCC} = 5.5 \text{ in.}$$

Thus, the maximum angle of rotation of the cask due to the high-energy tornado-generated missile impact is (with reference to the figure at the end of this section):

$$\theta = \alpha - \beta = 5.7°$$

where:

$\alpha = \cos^{-1}(h_{CG}/d_{CG}) = 35.9°$

$\beta = \cos^{-1}[(h_{CG} + h_{KE})/d_{CG}] = 30.2°$

The total energy required to overturn the concrete cask, E_p, is:

$E_p = (W_{VCC})(h_{PE}) = 3.80 \times 10^6$ lb-in.

where:

h_{PE} = 19.4 in., Increase in height of the concrete cask system center of gravity required to overturn the cask.
= $d_{CG} - h_{CG}$

Therefore, the high-energy tornado-generated missile impact will not cause the MPC-LACBWR concrete cask to overturn.

As a result of the rotation due to the missile impact, the restoring moment of the MPC-LACBWR concrete cask available to counteract the overturning moment due to tornado wind loading is reduced slightly. The reduced horizontal moment arm caused by the concrete cask rotation is calculated as follows:

$e = (d_{CG}) \times \sin(\beta) = 51.5$ in (4.29 ft)

Thus, the available gravity restoration moment after missile impact is:

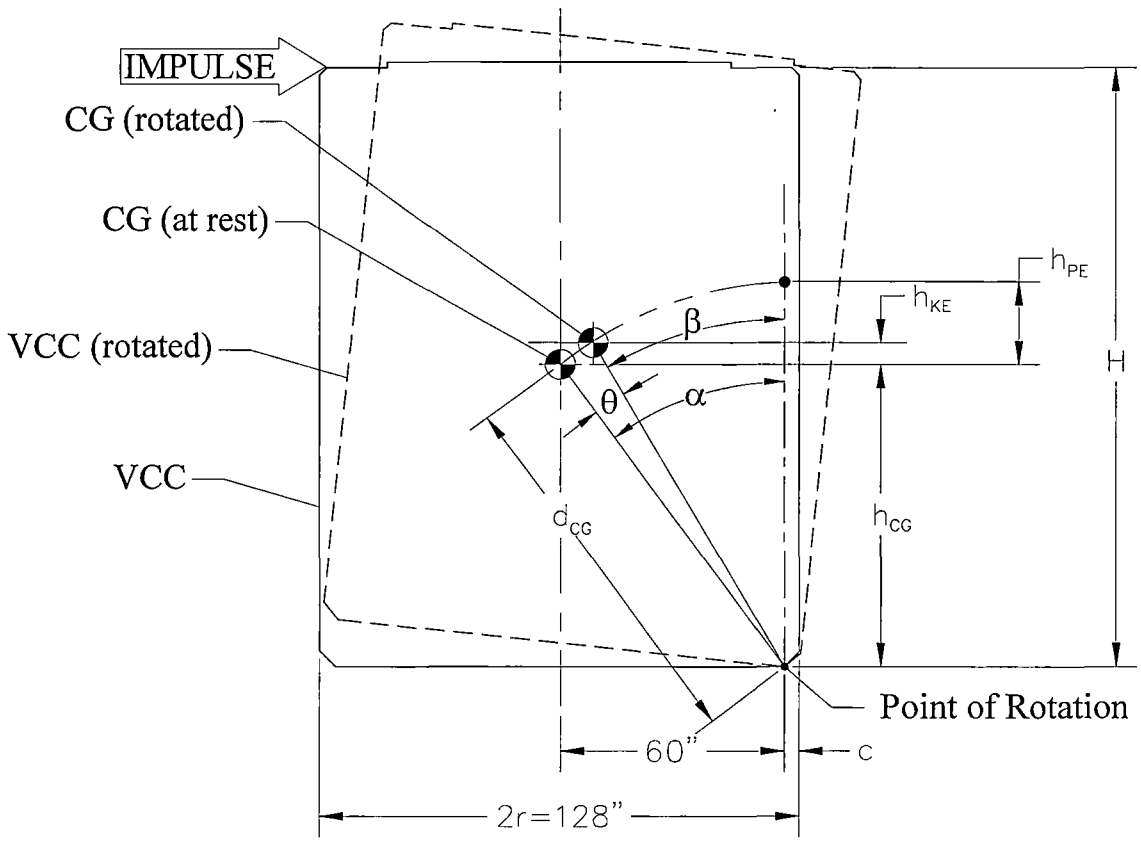
$M_R = (W_{VCC})(e) = 840.0$ kip-ft

Since the restoring moment is much greater than the overturning moment due to the tornado wind force of 157.3 kip-feet, the MPC-LACBWR concrete cask will not tip over under the combined effects of tornado wind loading and tornado-generated missile impact loading. The factor of safety provided by the MPC-LACBWR concrete cask against overturning due to the combined effects of tornado wind and missile loading is 5.34 (= 840.0/157.3).

11.A.2.13.3 Radiological Consequences

This evaluation shows that there is little potential for significant damage to the concrete cask, which provides radiation shielding.

Under the most severe tornado missile impact for the MPC-LACBWR, a penetration of 5.68 inches into the concrete shield is possible. A conservative dose rate calculation was performed assuming a 6 inch penetration into the shield. This would result in a local surface radiation dose rate at the point of penetration of approximately 278 mrem/hr. Since the area of reduced shielding is very small, there would not be a noticeable increase in the dose rate at the site boundary. Repair of the damage would likely require two persons to set up forms in the damaged area and apply grout. This is estimated to require 30 minutes. The estimated extremity dose is 278 mrem. The whole body dose would be less. The extremity dose rate of clearing inlets and outlets has been estimated in Section 11.A.2.8.3 at a total of 150 mrem.



11.A.2.14 Transfer Cask Seismic Accident Condition

The MPC-LACBWR transfer cask is evaluated for lateral loading applied to its outer surface as a result of the use of a seismic restraint system during an accident level seismic event. During loading operations the transfer cask may be restrained using straps and/or compression struts/pads to provide additional assurance that the stability of the loaded transfer cask is maintained under all postulated conditions. The following analysis provides a bounding evaluation of the transfer cask subject to such loading from a typical seismic restraint configuration consisting of 6×6 inch square compression pads and 6 inch wide straps.

To evaluate this loading, the half symmetry transfer cask finite element model shown in Figure 11.A.2.14-1 is used. The model represents the shells of the cask (i.e., inner shell, lead, NS4FR and the outer shell). A detailed view of the shells is shown in Figure 11.A.2.14-2. The effect of the transfer cask base is incorporated by coupling the displacements of the nodes in the X and Y direction for the nodes at the bottom of the model (Z=0 in Figure 11.A.2.14-1). The constraints for the symmetry plane are applied to the model (Y displacement is zero at Y=0), which are not shown in Figure 11.A.2.14-1. The relative axial displacement along the transfer cask base is negligible due to its rigidity, therefore the Z displacements were set to zero at Z=0, removing rigid body motion from the model. The adjacent shells are connected to each other using compression only elements (CONTAC52) and the friction between the surfaces was specified to be zero (the CONTAC52 elements are shown in Figure 11.A.2.14-2). Therefore, the shells can only transmit compression to the adjacent shell. Linear elastic properties at 300°F for the A588 carbon steel is used in the model (see Section 3.3). Since the lead shell is comprised of lead bricks, the elastic properties for the lead were specified to be orthotropic such that the radial direction (to support radial loading) used the nominal value for lead modulus, while the axial direction and circumferential direction used a value one-tenth of the nominal values. The nominal value for the lead modulus of 1,940 ksi at 300°F is obtained from NUREG/CR-0481. Limiting the lower value for the lead modulus to one-tenth in the axial and circumferential directions assures that the lead material properties will remain positive definite.

The pressure loading shown in the model plot corresponds to two six inch wide straps subtending an angle of 76° (one-half of this is used for the half symmetry model). The pressure applied to the transfer cask conservatively corresponds to a lateral load of 160,000 pounds. The lower edge of the lower strap is 44 inches from the model base and the straps are 24 inches apart. To resist the loading in the opposite direction a compression pad is positioned at the mid axial position between the two opposite straps (see Figure 11.A.2.14-1). The 6×6 inch square compression pad is located 25° from the model symmetry plane. The loading did not include dead weight since

stresses associate with the dead weight loading are negligible compared to the stresses resulting from the 160,000 pound lateral loading. Thermal expansion was also not considered since it is a secondary stress which is not included in primary loads in an accident condition evaluation.

The shear stress due to the edge of the 6×6 compression pad is 160,000/24 or 6.7 ksi. The Margin of Safety (MS) against the allowable shear stress for accident conditions is

$$\mathrm{MS} = \frac{0.42 \times S_u}{6.7} - 1 = \frac{0.42 \times 70.0}{6.7} - 1 = +3.4$$

The maximum stress intensity in the model due to the 160,000 pound loading occurs at the edge of the compression pad. The cross sectional stress intensities at this location are 14.55 ksi for the membrane stress and 41.47 ksi for the bending plus membrane stress. These result in the following margins of safety (at 300°F).

For membrane stress:

$$\mathrm{MS} = \frac{0.7 \times S_u}{14.55} - 1 = \frac{0.7 \times 70.0}{14.55} - 1 = +2.37$$

For membrane plus bending stress:

$$\mathrm{MS} = \frac{S_u}{14.55} - 1 = \frac{70.0}{41.47} - 1 = +0.69$$

This confirms that the transfer cask integrity will be maintained during an accident level seismic event.

As a result of this loading, the diameter across the inner shell of the transfer cask will be decreased. The analysis using the 160,000 loading will decrease the diameter at the top where the radial displacements are maximum by 0.30 inches. The diametrical clearance between the canister (outer diameter of 70.64 inches) and the transfer cask inner shell (inner diameter of 71.50 inches) is 0.86 inches. The reduction in the transfer cask inner shell diameter by 0.30 inches is insufficient to result in the transfer cask providing a diametrical load on the canister.

Figure 11.A.2.14-1 Transfer Cask Model with Seismic Restraint Loading Conditions

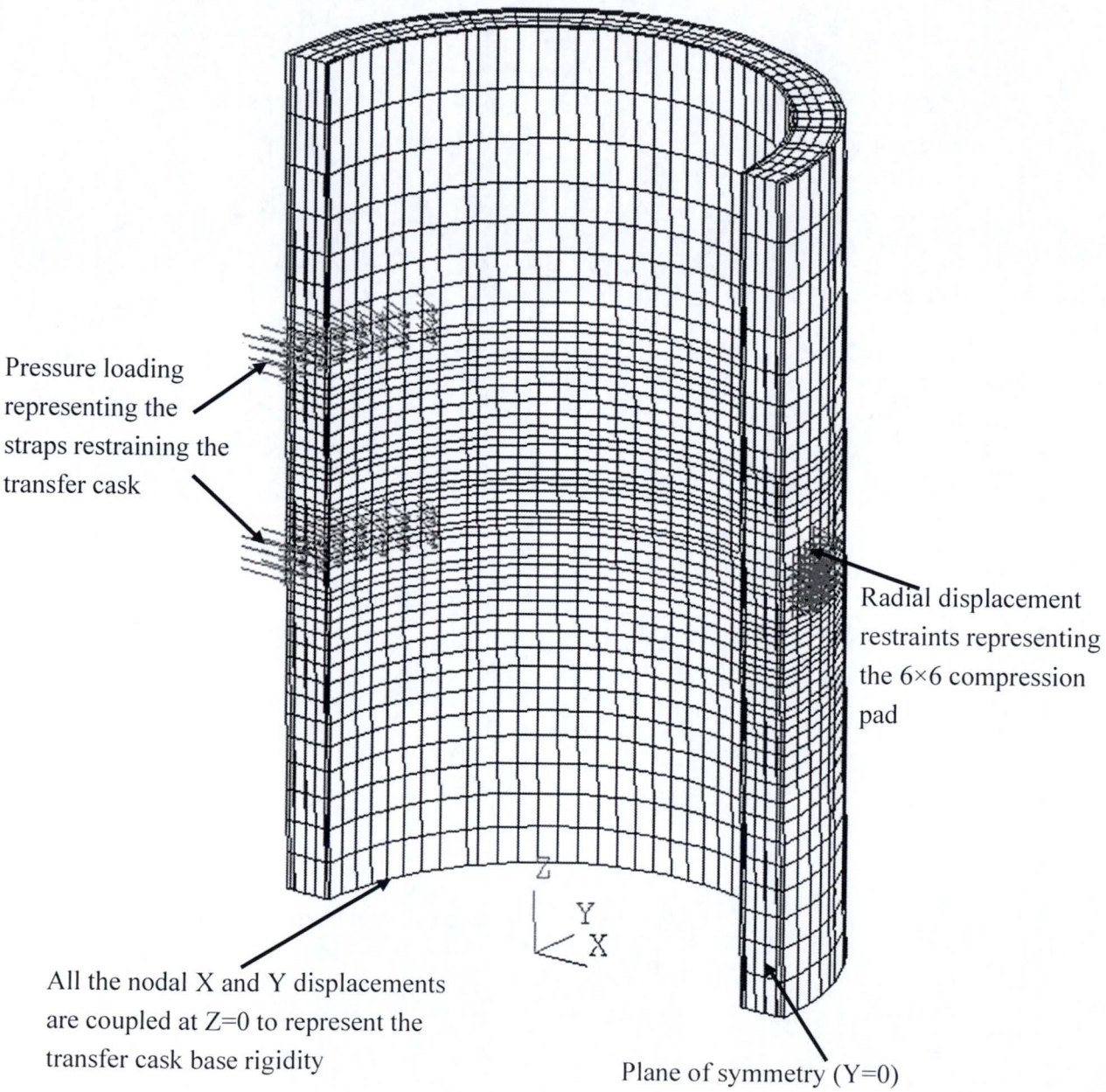
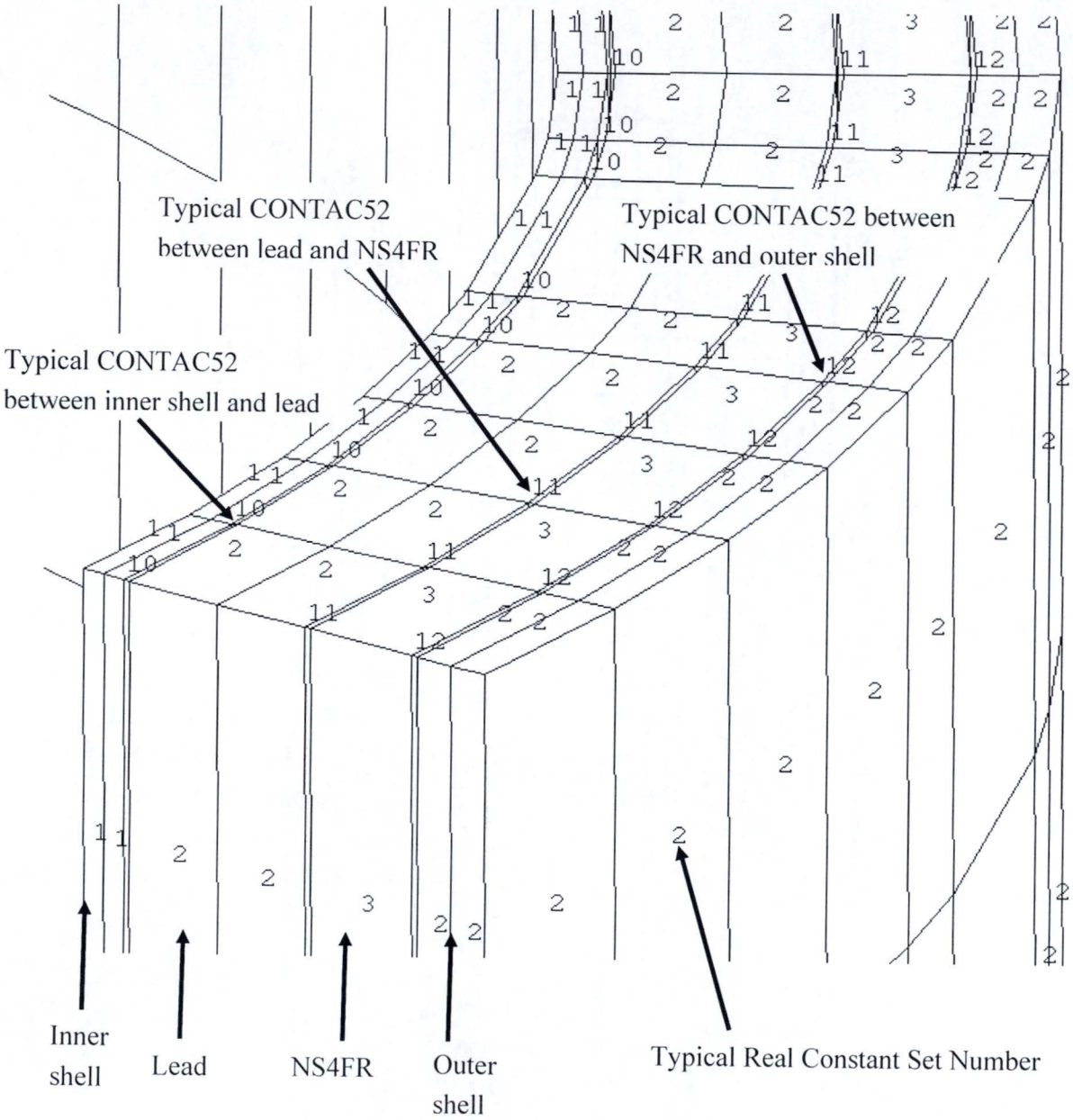


Figure 11.A.2.14.-2 Detailed View of the Transfer Cask Shells and CONTAC52 Elements



11.A.3 Design Basis Loading of the MPC-LACBWR Transportable Storage Canister

NAC has completed analyses to verify that the MPC-LACBWR canister design satisfies 10 CFR 71 loading conditions in response to 10 CFR 72.236 (m) requirements.

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11.A.4 Evaluation of Site-Specific Fuel Components

Site-specific fuel components are structures designed to hold fuel assemblies, individual fuel rods or fuel debris configurations that are not in a standard fuel assembly. The LACBWR spent fuel assemblies are classified as LACBWR undamaged fuel assemblies and LACBWR damaged fuel assemblies that may contain fuel debris.

This section presents the evaluation of the LACBWR site-specific components used with the MPC-LACBWR storage system.

End Drop Evaluation

This section presents the buckling evaluation for the LACBWR fuel rods. The analysis shows that the maximum stresses in the fuel remain below the yield strength in the design basis event and confirm that the fuel rods will return to their original configuration. An end drop orientation is considered with an acceleration of 21g, which subjects the fuel rods to axial loading. This 21g acceleration bounds the maximum end drop acceleration calculated for the 6-inch concrete cask end drop.

In the end drop orientation, the fuel rods are laterally restrained by the grids and come into contact with the fuel assembly base. The only vertical constraint for the fuel rod is the base of the assembly.

Fuel Assembly	Cladding Diameter (in)	Cladding Thickness (in)	Fuel Rod Pitch (in)	Maximum Gap Between Fuel Assembly and Fuel Tube Wall (in)
ENC 10 × 10	0.394	0.022	0.557	0.136

Review of the design basis fuel indicates that the largest bow between a straight fuel assembly and the basket fuel tube inner wall could be 0.136 inch. A bow of 0.25 inch is conservatively used in the model. The fuel is not explicitly modeled, but the fuel pellet weight is included with the clad by increasing the density of the clad elements as required. Properties are used for the fuel pellet and the stainless steel 348H clad as shown in the following table. The mechanical properties for the clad were obtained from the PIE examination and the associated comprehensive report of the results published in 1976 [A4].

	Modulus of Elasticity (10^6 psi)	Density (lb/in^3)
Rod Clad	25.3	0.291
Fuel Pellet	-	0.396

To implement a bow of 0.25 inch into the fuel assembly, a half-symmetry ANSYS model is used in which lateral forces are applied at the 3rd grid at the approximate mid-length of the fuel to develop a 0.25-inch lateral displacement. The fuel rod is simply supported at each end. The purpose of the ANSYS model and solution is to provide the coordinates of the clad for the LS-DYNA model. This is accomplished by obtaining a static solution with the ANSYS model, and then using the option to update the coordinates of the nodes with the displacements from the solution.

Figures 11.A.4-1 and 11.A.4-2 show the LS-DYNA model. Each grid is modeled using spring elements (with a stiffness of 1.0E6 lb/in) to maintain the spacing between the fuel rods at the grid locations. No restriction in axial movement or rotation at the attachment to the fuel rods is provided by the spring elements. The LS-DYNA model employs the same nodes and elements as the ANSYS model (with the incorporation of the 0.25-inch bow). The shell elements in LS-DYNA use additional integration points to ensure that the maximum shear stress at the surface of the shell elements is accurately computed. Elastic properties used in the LS-DYNA model are the same as those used in the ANSYS model. An initial downward velocity of 68.1 in/sec (corresponding to a 6-inch drop) is assigned to all nodes in the model. The deceleration applied to the base of the model has a duration of 0.0087 second and a 21g maximum value, which provide bounding acceleration for the 6-inch end drop of the concrete cask.

The LS-DYNA analysis was performed for a duration of 0.015 second to capture the response of the fuel after the 0.0087-second loading duration. Post-processing identifies the maximum shear stress occurring at the shell surface. The maximum shear stress result from LS-DYNA is factored by two to determine the maximum stress intensity. The maximum stress intensity in the fuel cladding is shown to be 7.83 ksi, which gives a factor of safety against yield of 4.73.

The temperature of the fuel at the bottom end of the basket is bounded by 662°F (350°C) and the static yield strength for irradiated stainless at 662°F is 37.0 ksi. This conservatively neglects any strengthening effect due to the dynamic loading.

The analysis results confirm that the LACBWR fuel will remain undamaged for design basis cask end drop load condition.

Tip-Over Evaluation

The tip-over condition is considered as a uniform side drop in the LS-DYNA analysis. The LS-DYNA model used for the tip over analysis of the fuel rod assembly is similar to that used for the end drop analysis. No fuel rod bow is considered. A uniform gap is used along the length of the fuel rod and fuel tube, with a small gap of 0.005-inch between the rod and tube in the loading direction. Model details are shown in Figure 11.A.4-3.

The deceleration time history is applied in the lateral direction. This time history, which is shown in Figure 11.A.4-4, was computed at the top of the cask and is conservatively applied uniformly along the length of the fuel tube. An initial lateral velocity of 243.6 in/sec is assigned to the model, and is calculated from integrating the acceleration time history curve.

The maximum stress intensity in the fuel cladding is shown to be 29.6 ksi, which gives a factor of safety against yield of 1.25. This confirms that the LACBWR fuel rod will remain intact for a tip-over condition.

Figure 11.A.4-1 LS-DYNA End Drop Model for the LACBWR Fuel Rod

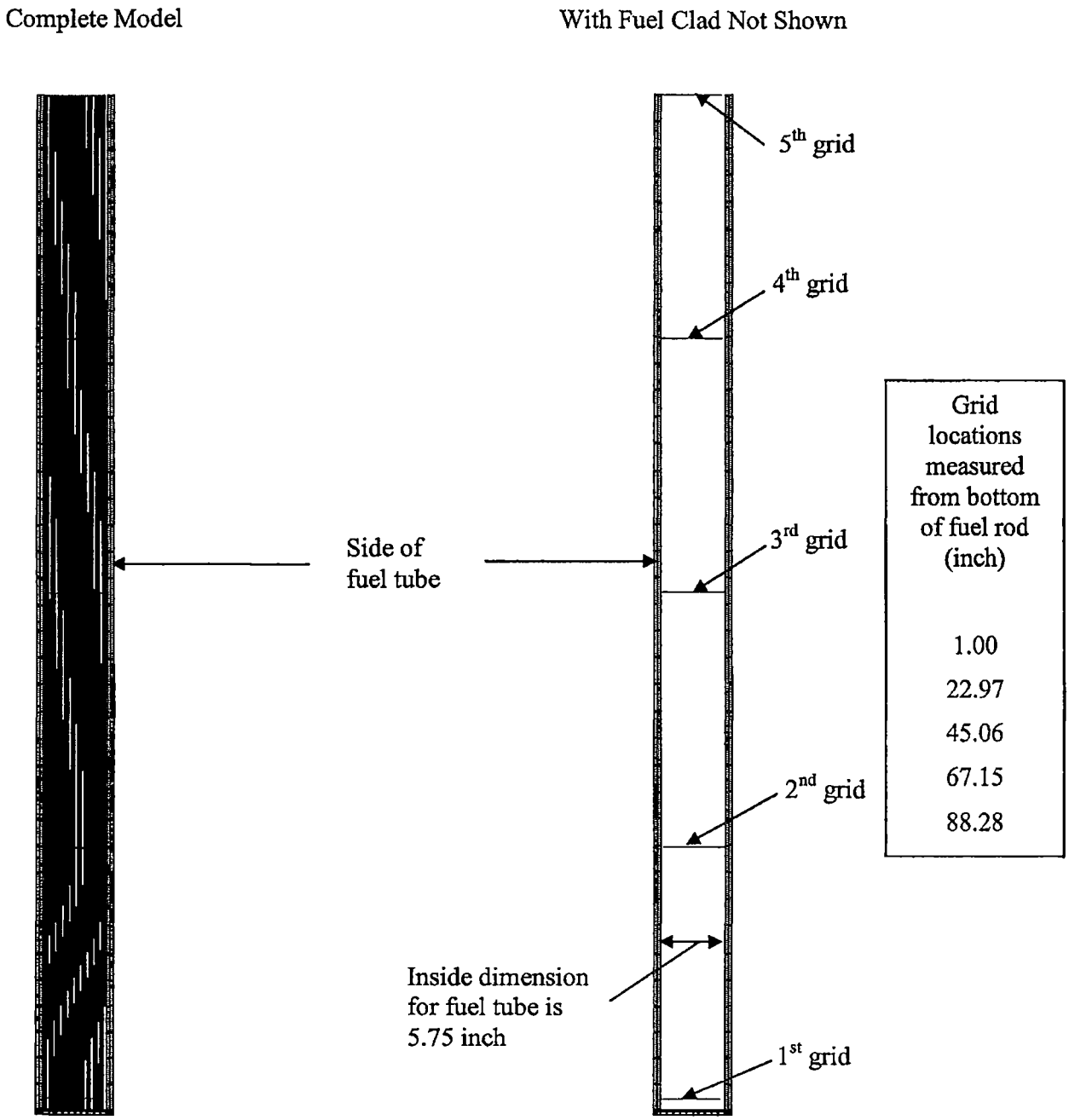


Figure 11.A.4-2 Detail of LS-DYNA End Drop Model for the LACBWR Fuel Rod

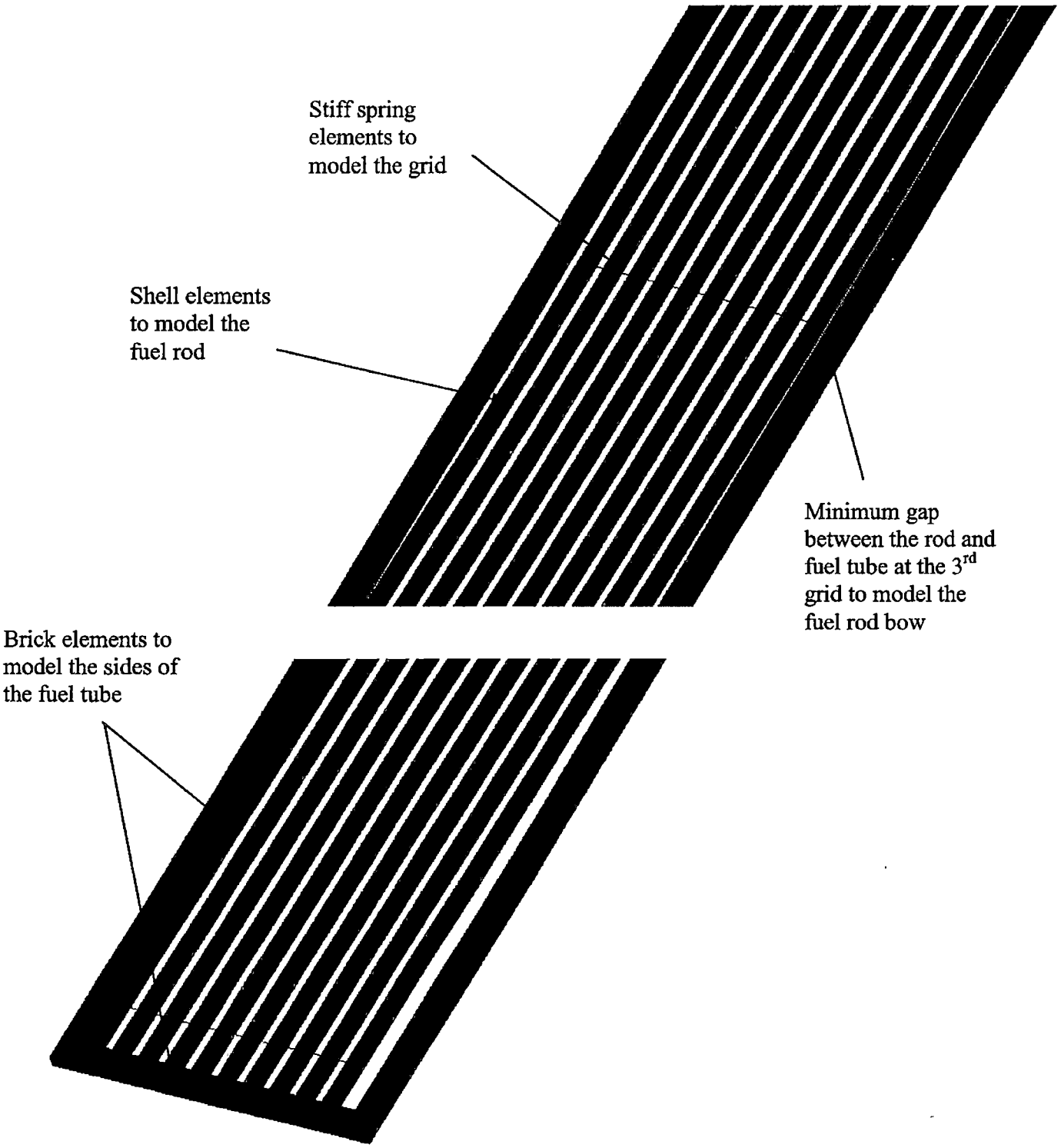


Figure 11.A.4-3 LS-DYNA Tip-Over Model for the LACBWR Fuel Rod

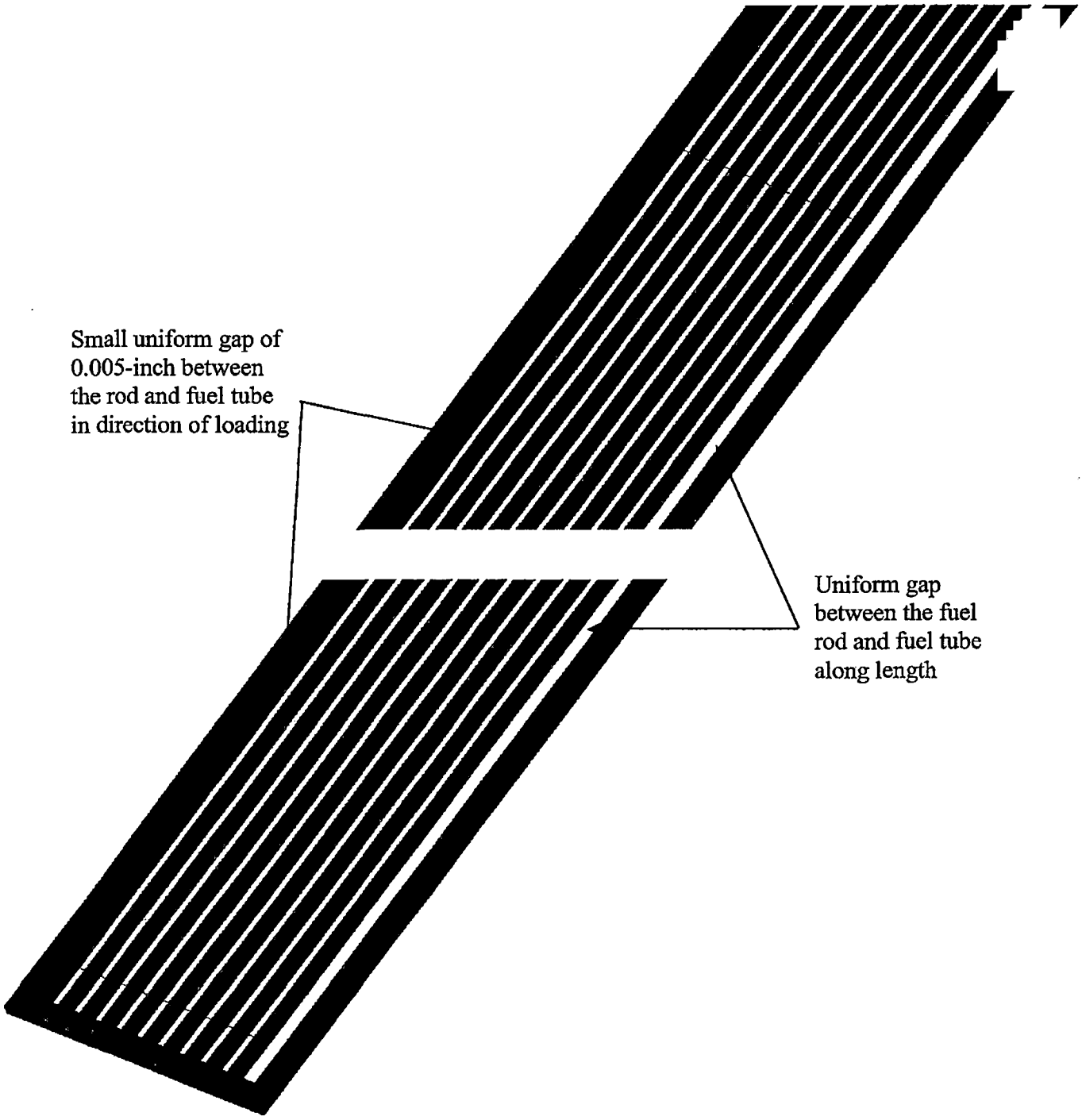
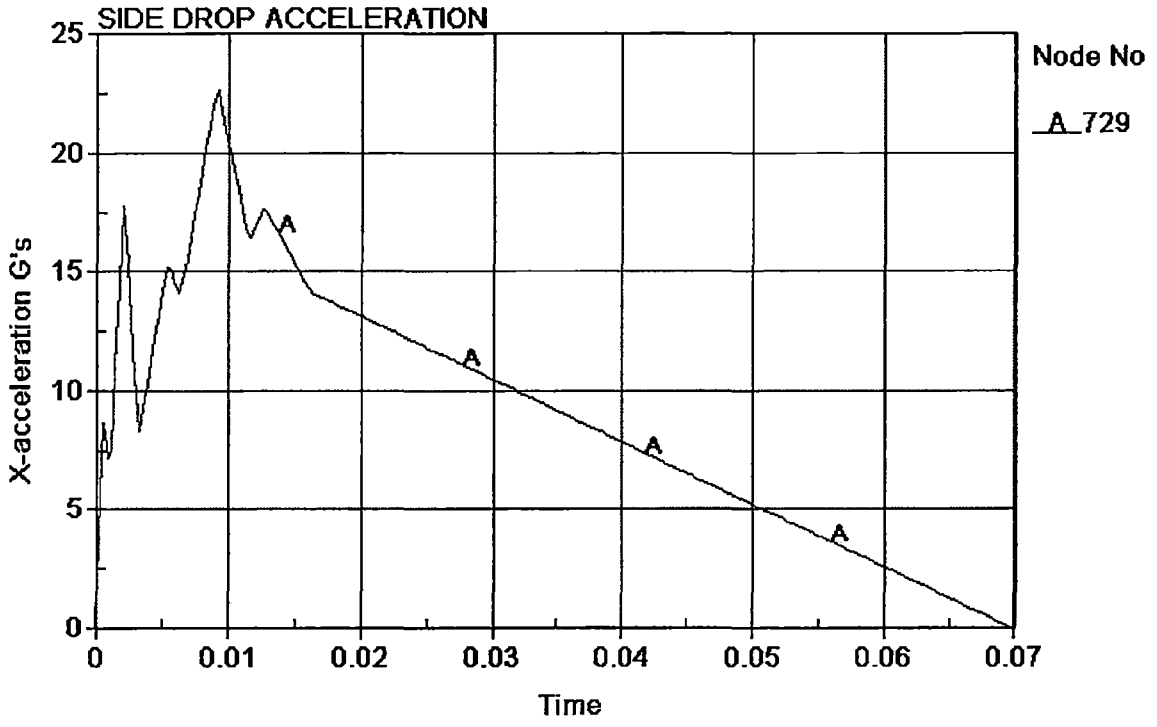


Figure 11.A.4-4 Applied Acceleration Time History for Tip-Over Analysis



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11.A.5 Canister Closure Weld Evaluation – Accident Conditions

This section discusses the results of the MPC-LACBWR canister closure weld stress analysis for accident conditions of storage. In addition, this section discusses the closure weld critical flaw size evaluation. The corresponding evaluation for normal conditions is presented in Section 3.A.6. This evaluation confirms that the canister closure weld is acceptable accident conditions of storage and that the NDE of the canister closure weld is sufficient to detect a critical flaw.

Closure Weld Stress Evaluation:

The MPC-LACBWR canister closure weld is a ½-inch thick partial penetration groove weld that is designed using a weld stress reduction factor of 0.8 per ISG-4. This stress reduction factor is incorporated by applying a factor of 0.8 to the allowable stesses for the closure weld. The results of the MPC-LACBWR canister stress analyses for accident conditions demonstrate that the maximum stresses in the closure weld satsify the applicable allowable stress design criteria, which includes the 0.8 stress reduction factor.

The stress evaluation of the MPC-LACBWR canister for accident conditions considers a range of off-normal and accident conditions for analysis. The results of the MPC-LACBWR canister accident analyses show that the maximum stresses in the closure weld are much lower than the corresponding allowable stresses for most off-normal and accident conditions and load combinations. The highest primary membrane (P_m) and primary membrane plus bending (P_m+P_b) stress intensities in the canister closure weld result from the postulated concrete cask tip-over accident, which is evaluated with a bounding internal pressure load of 12 psig, are 26.34 psi and 29.07 psi, respectively. The corresponding accident condition allowable stress intensities for the closure weld, which are based on Type 304 stainless steel material properties at an upper bound temperature of 300°F and include the 0.8 stress reduction factor, are 36.96 ksi and 47.52 ksi, respectively. Therefore, the maximum stresses in the MPC-LACBWR canister closure weld due to accident conditions satisfy the allowable stress design criteria.

Closure Weld Critical Flaw Size Evaluation:

The MPC-LACBWR canister closure weld is comprised of multiple weld beads using a compatible weld material for Type 304 stainless steel base metal. The ½-inch thick closure weld is PT-examined on the root, mid-plane, and final passes. An allowable (critical) flaw evaluation has been performed to determine the critical flaw size in the weld region. The results of the flaw evaluation are used to define the minimum flaw size that must be identifiable in the

nondestructive examination (NDE) of the weld. Due to the inherent toughness associated with Type 304 stainless steel, a limit load analysis is conservatively used in conjunction with a J-integral/tearing modulus approach. The maximum radial tensile stress in the closure weld (i.e., SX at Section 12 in Figure 3.A.4.4.1-2) is used for the critical flaw size evaluation. The safety margins used in this evaluation correspond to the stress limits contained in Section XI of the ASME Code. In accordance with ASME Code Section XI, the required safety factor for accident condition is 1.414 ($\sqrt{2}$).

The maximum radial tensile stress for accident conditions is 1.61 ksi due to the combined concrete cask 6-inch drop and internal pressure loads. To perform the flaw evaluation, a bounding 4.17 ksi tensile stress is conservatively used, resulting in a significantly larger safety factor than the required safety factor of 1.414. The results of the analysis show that the critical flaw size is 0.34 inch for a flaw that extends 360° around the circumference of the canister. The 360° flaw employed for the circumferential direction is considered to be bounding with respect to any partial flaw in the weld, which could occur in the radial and horizontal directions. Therefore, using a minimum detectable flaw size of 0.30 inches is acceptable, since it is less than the conservatively determined 0.34-inch critical flaw size.

11.A.6 References

The references for the MPC-LACBWR storage system accident analysis are the same as those listed in MPC FSAR Section 11.6, and supplemented as follows:

[A1] ANSI/ANS-57.9-1992, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type)," American Nuclear Society, May 1992.

[A2] NUREG/CR-6865, "Parametric Evaluation of Seismic Behavior of Freestanding Spent Fuel Drop Cask Storage Systems," Sandia National Laboratories, February 2005.

[A3] Tennessee Valley Authority, Division of Engineering Design, Thermal Power Project, Report No. CEB 77-46, "All Projects Steel to Concrete Coefficient of Friction Preliminary Tests," December 1977.

[A4] General Electric Report No. NEDC-12633, "Post-Irradiation Evaluation of Fuel Rods from the La Crosse Boiling Water Reactor," June 1976.

[A5] NUREG-1536, Standard Review Plan for Dry Cask Storage Systems, Final Report, January 1997.

[A6] Environmental Engineering & Contracting, Tire Pile Fires: Prevention, Response, Remediation, June 7, 2012.

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12.0 OPERATING CONTROLS AND LIMITS

This chapter identifies operating controls and limits, technical parameters and surveillance requirements imposed to ensure the safe operation of the NAC-MPC SYSTEM.

Controls used by NAC International (NAC) as part of the NAC-MPC design and fabrication are provided in the NAC Quality Assurance Manual and Quality Procedures. The NAC Quality Assurance Program is discussed in Chapter 13.0. If procurement and fabrication of the NAC-MPC SYSTEM is performed by others, a Quality Assurance Program prepared in accordance with 10 CFR 72 Subpart G shall be implemented. Site specific controls for the organization, administrative system, procedures, record keeping, review, audit and reporting necessary to ensure that the NAC-MPC storage system installation is operated in a safe manner, are the responsibility of the User.

The NAC-MPC is provided in three configurations. The first is designed to store up to 36 intact Yankee Class spent fuel and reconfigured fuel assemblies and is referred to as the Yankee-MPC. The second configuration, referred to as the CY-MPC, is designed to store up to 26 Connecticut Yankee fuel assemblies, CY-MPC reconfigured fuel assemblies or CY-MPC damaged fuel cans. The CY-MPC is provided with a 24-assembly or 26-assembly basket. The third configuration, referred to as the MPC-LACBWR system, is designed to store up to 68 Dairyland Power Cooperative (DPC) La Crosse Boiling Water Reactor (LACBWR) spent fuel assemblies with up to 32 damaged fuel cans. Certain Connecticut Yankee spent fuel, including fuel assemblies with non-fuel hardware and CY-MPC damaged fuel cans, require preferential loading as described in Appendix B of the Certificate of Compliance.

The NAC-MPC storage system operating controls and limits are summarized in Table 12-1. Appendix A of the Certificate of Compliance provides the Limiting Conditions for Operations (LCO) for the Yankee-MPC and the CY-MPC configurations of the NAC-MPC storage system. Appendix 12.A provides the combined LCOs for all three configurations of the NAC-MPC SYSTEM. The Approved Contents and Design Features for the NAC-MPC SYSTEM are presented in Technical Specification format in Appendix 12.B. The Bases for the specified controls and limits are presented in Appendix 12.C. Separate controls or limits are specified for each NAC-MPC configuration as appropriate.

Table 12-1 NAC-MPC SYSTEM Controls and Limits

Control or Limit	Applicable Technical Specification	Condition or Item Controlled
1. Fuel Characteristics	Table B.2-1	Yankee Class Fuel Assembly Limits
	Table B.2-2	Yankee Class INTACT FUEL ASSEMBLY Characteristics
	Table B.2-3	Connecticut Yankee Fuel Assembly Limits
	Table B.2-4	Connecticut Yankee INTACT FUEL ASSEMBLY Characteristics
	Table B.2-5	Connecticut Yankee Fuel and CANISTER Heat LOADING CATEGORY Limits
	Table B.2-6	Heat Load Matrix Used to Determine LOADING CATEGORY Limits
	Table B.2-7	MPC-LACBWR Fuel Assembly Limits
	Table B.2-8	MPC-LACBWR Fuel Assembly Characteristics
2. Canister	LCO 3.1.4	Maximum Time in TRANSFER CASK
Drying	LCO 3.1.2	Vacuum Drying Pressure
Backfilling	LCO 3.1.3	Helium Backfill Pressure
Sealing	LCO 3.1.5	Helium Leak Rate
Vacuum	LCO 3.1.1	Maximum Time in Vacuum Drying
External Surface	LCO 3.2.1	Surface Contamination
Unloading	LCO 3.1.7	Fuel Cooldown Requirements
3. Concrete Cask	LCO 3.2.2	Average Surface Dose Rates
	Note 1	Cask Spacing
	Note 2	Cask Handling Height
	LCO 3.1.6	Heat Removal System
4. Transfer Cask	B 3.4(8)	Minimum Temperature
5. ISFSI Concrete Pad	Note 3	Pad Concrete Thickness
	Note 3	Pad Subsoil Thickness
	Note 3	Pad Concrete Compressive Strength

1. Limits are presented in the Operating Procedures of Chapter 8.
2. Lifting height and handling restrictions are provided in Section A5.5 of Appendix 12.A of the Technical Specifications.
3. Limits are verified at the time of construction of the ISFSI in accordance with Section B3.4(6) of Appendix 12.B of the Technical Specifications.

APPENDIX 12.A

TECHNICAL SPECIFICATIONS FOR THE NAC-MPC SYSTEM

The Technical Specifications for the Yankee-MPC and the CY-MPC configurations of the NAC-MPC storage system, including the Limiting Conditions for Operations (LCOs), Surveillance Requirements (SRs), and the Administrative Controls and Programs, are incorporated in Appendix A of Certificate of Compliance No. 1025, Amendment 5.

The Technical Specifications included herein have been expanded to include the LCOs, SRs and Administrative Controls and Programs for the MPC-LACBWR storage system.

APPENDIX 12.B

APPROVED CONTENTS AND DESIGN FEATURES FOR THE NAC-MPC SYSTEM

The Approved Contents and Design Features for the Yankee-MPC and the CY-MPC configurations of the NAC-MPC storage system are incorporated in Appendix B of Certificate of Compliance No. 1025, Amendment 5.

The Technical Specifications presented in this Appendix have been expanded to include the Approved Contents and Design Features for the MPC-LACBWR storage system.

APPENDIX 12.C

TECHNICAL SPECIFICATION BASES FOR THE NAC-MPC SYSTEM

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C 1.0 Introduction

The design or operational condition, or regulatory requirement, which establishes the Bases for the Technical Specifications provided in Appendix A of the Certificate of Compliance for the Yankee-MPC and the CY-MPC configurations of the NAC-MPC storage system are presented in this Appendix. Different conditions or requirements may exist for the MPC-LACBWR system. Those differences are noted as appropriate and the Bases have been expanded to include the LCOs, SRs and Administrative Controls and Programs for the MPC-LACBWR storage system.

The section and paragraph numbering used in this Appendix is consistent with the numbering used in Appendix 12.A, Technical Specifications for the NAC-MPC SYSTEM, and Appendix 12.B, Approved Contents and Design Features for the NAC-MPC SYSTEM.

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C 2.0 APPROVED CONTENTS

C 2.1 Fuel to be Stored in the NAC-MPC SYSTEM

BASES

BACKGROUND

The NAC-MPC SYSTEM design requires specifications for the spent fuel to be stored, such as the type of spent fuel, minimum and maximum allowable enrichment prior to irradiation, maximum burnup, minimum acceptable post-irradiation cooling time prior to storage, maximum decay heat, and condition of the spent fuel (e.g., INTACT FUEL ASSEMBLY). Other important limitations are the dimensions and weight of the fuel assemblies.

The approved contents, which can be loaded into the NAC-MPC SYSTEM for the Yankee-MPC and the CY-MPC storage systems, are specified in Appendix B of Amendment No. 5 of Certificate of Compliance No. 1025. The proposed contents, which can be loaded into the MPC-LACBWR storage system, are specified in Appendix 12.B.

Actions required to respond to violations of any Approved Contents limits are provided in Section B2.2 of Appendix B of Amendment No. 5 of Certificate of Compliance No. 1025 for the Yankee-MPC and the CY-MPC storage systems and in Section B2.2 of Appendix 12.B for the MPC-LACBWR storage system.

Specific limitations for the NAC-MPC SYSTEM are specified in Section B3.0 of Appendix B of the Certificate of Compliance for the Yankee-MPC and the CY-MPC storage systems. Specific limitations for the MPC-LACBWR storage system are specified in Section B3.0 of Appendix 12.B. These limitations support the assumptions and inputs used in the thermal, structural, shielding and criticality evaluations performed for the NAC-MPC SYSTEMs.

APPLICABLE SAFETY ANALYSES

To ensure that the shield lid or closure lid is not placed on a CANISTER containing an unauthorized fuel assembly, facility procedures require verification of the loaded fuel assemblies to ensure that the correct fuel assemblies have been loaded in the allowed locations in the canister.

APPROVED CONTENTS

C 2.1.1

Approved Contents, Section B2.0 of Appendix B of the Technical Specifications refers to Tables B2-1 through B2-6 for the specific fuel assembly characteristics for Yankee Class fuel and the Connecticut Yankee fuel authorized for loading into the NAC-MPC SYSTEM.

(continued)

APPROVED CONTENTS (continued)

Contents, Section B2.0 of Appendix 12.B, refers to Tables B.2.7 and B.2.8 for the specific fuel assembly characteristics for MPC-LACBWR fuel assemblies authorized for loading into the MPC-LACBWR storage system. These fuel assembly characteristics include parameters such as cladding material, minimum and maximum enrichment, decay heat generation, post-irradiation cooling time, burnup, and fuel assembly length, width and weight. Tables B2-2, B2-4 and B.2-8 are referenced from Tables B2-1, B2-3 and B.2-7, respectively, and provide additional specific fuel characteristic limits for the fuel assemblies based on the fuel assembly type, enrichment, burnup and cooling time, for the NAC-MPC configurations.

The fuel assembly characteristic limits of Tables B2-1 through B2-6 of the Certificate of Compliance and Tables B.2-7 and B.2-8 in Appendix 12.B must be met, as appropriate, to ensure that the thermal, structural, shielding and criticality analyses supporting the NAC-MPC SYSTEM Safety Analysis Report are bounding.

C 2.1.2

Approved Contents Section B2.0 in Appendix B requires CY-MPC preferential loading of fuel assemblies with significantly different post-irradiation cooling times. This preferential loading is required to prevent a cooler assembly from heating up due to being surrounded by hotter fuel assemblies. For the purposes of complying with this Approved Contents limit, only fuel assemblies with heat loads greater than 808 watts need to be loaded preferentially. This is based on the fact that the heat-up phenomenon can only occur with significant differences in decay heat generation characteristics between adjacent fuel assemblies.

C 2.1.3

Approved Contents Section B2.0 in Appendix 12.B requires MPC-LACBWR preferential loading of fuel assemblies with different enrichment values to assure control of criticality in LACBWR DAMAGED FUEL CAN positions.

(continued)

APPROVED CONTENT LIMITS AND VIOLATIONS	C 2.2.1 If any Approved Contents limit of B2.1.1 or B2.1.2 in Appendix B or of B2.1.3 in Appendix 12.B is violated, the limitations on fuel assemblies to be loaded are not met. Action must be taken to place the affected fuel assembly(s) in a safe condition. This safe condition may be established by returning the affected fuel assembly(s) to the spent fuel pool. However, it is acceptable for the affected fuel assemblies to temporarily remain in the NAC-MPC SYSTEM, in a wet or dry condition, if that is determined to be a safe condition.
	C 2.2.2 and C 2.2.3 NRC notification of the Approved Contents limit violation is required within 24 hours. A written report on the violation must be submitted to the NRC within 30 days. This notification and written report is required by 10 CFR 72.75 and is independent of any reports and notifications that may be required by 10 CFR 72.242.
REFERENCES	1. FSAR Sections 2.1, 2.A.1,4.4, 4.A.4, 4.5, 4.A.5, Chapters 5 and 6, and Appendices 5.A and 6.A.

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C 3.0 LIMITING CONDITION FOR OPERATION (LCO) APPLICABILITY

BASES

LCOs	LCO 3.0.1, 3.0.2, 3.0.4, and 3.0.5, presented in Section 3.0 of Appendix A of the Certificate of Compliance and Section 3.0 in Appendix 12.A establish the general requirements applicable to all Specifications and apply at all times, unless otherwise stated.
LCO 3.0.1	LCO 3.0.1 establishes the Applicability statement within each individual Specification as the requirement for when the LCO is required to be met (i.e., when the NAC-MPC SYSTEM is in the specified conditions of the Applicability statement of each Specification).
LCO 3.0.2	LCO 3.0.2 establishes that upon discovery of a failure to meet an LCO, the associated ACTIONS shall be met. The Completion Time of each Required Action for an ACTIONS Condition is applicable from the point in time that an ACTIONS Condition is entered. The Required Actions establish those remedial measures that must be taken within the specified Completion Times when the requirements of an LCO are not met. This Specification establishes that: a. Completion of the Required Actions within the specified Completion Times constitutes compliance with a Specification; and, b. Completion of the Required Actions is not required when an LCO is met within the specified Completion Time, unless otherwise specified. There are two basic Required Action types. The first Required Action type specifies a time limit, the Completion Time to restore a system or component or to restore variables to within specified limits, in which the LCO must be met. Whether stated as a Required Action or not, correction of the entered Condition is an action that may always be considered upon entering ACTIONS. The second Required Action type specifies the remedial measures that permit continued activities that are not further restricted by the Completion Time. In this case, compliance with the Required Actions provides an acceptable level of safety for continued operation.

(continued)

LCO 3.0.2 (continued)	Completing the Required Actions is not required when an LCO is met or is no longer applicable, unless otherwise stated in the individual Specifications. The Completion Times of the Required Actions are also applicable when a system or component is removed from service intentionally. The reasons for intentionally relying on the ACTIONS include, but are not limited to, performance of Surveillance, preventive maintenance, corrective maintenance, or investigation of operational problems. Entering ACTIONS for these reasons must be done in a manner that does not compromise safety. Intentional entry into ACTIONS should not be made for operational convenience.
LCO 3.0.3	This specification is not applicable to the NAC-MPC SYSTEM because it describes conditions under which a power reactor must be shut down when an LCO is not met and an associated ACTION is not met or provided. The placeholder is retained for consistency with the power reactor technical specifications.
LCO 3.0.4	LCO 3.0.4 establishes limitations on changes in specified conditions in the Applicability when an LCO is not met. It precludes placing the facility in a specified condition stated in that Applicability (e.g., Applicability desired to be entered) when the following exist: a. NAC-MPC SYSTEM conditions are such that the requirements of the LCO would not be met in the Applicability desired to be entered; and b. Continued noncompliance with the LCO requirements, if the Applicability were entered, would result in NAC-MPC SYSTEM activities being required to exit the Applicability desired to be entered to comply with the Required Actions. Compliance with Required Actions that permit continued operation for an unlimited period of time in a specified condition provides an acceptable level of safety for continued operation. This is without regard to the status of the NAC-MPC SYSTEM. Therefore, in such cases, entry into a specified condition in the Applicability may be made in accordance with the provisions of the Required Actions.

(continued)

LCO 3.0.4 (continued)

The provisions of this Specification should not be interpreted as endorsing the failure to exercise the good practice of restoring systems or components before entering an associated specified condition in the Applicability.

The provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS. In addition, the provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are related to the unloading of the NAC-MPC SYSTEM.

Exceptions to LCO 3.0.4 are stated in the individual Specifications. Exceptions may apply to all the ACTIONS or to a specific Required Action of a Specification.

LCO 3.0.5

LCO 3.0.5 establishes the allowance for restoring equipment to service under administrative controls when it has been removed from service or determined to not meet the LCO to comply with the ACTIONS. The sole purpose of the Specification is to provide an exception to LCO 3.0.2 (e.g., to not comply with the applicable Required Action[s]) to allow the performance of testing to demonstrate:

a. The equipment being returned to service meets the LCO; or

b. Other equipment meets the applicable LCOs.

The administrative controls ensure the time the equipment is returned to service in conflict with the requirements of the ACTIONS is limited to the time absolutely necessary to perform the allowed testing. This Specification does not provide time to perform any other preventive or corrective maintenance.

C 3.0 SURVEILLANCE REQUIREMENT (SR) APPLICABILITY

BASES

Surveillance Requirements (SRs)	SR 3.0.1 through SR 3.0.4 in Section 3.0 of Appendix A of the Certificate of Compliance and Section 3.0 in Appendix 12.A establish the general requirements applicable to all Specifications and apply at all times, unless otherwise stated.
SR 3.0.1	SR 3.0.1 establishes the requirement that SRs must be met during the specified conditions in the Applicability for which the requirements of the LCO apply, unless otherwise specified in the individual SRs. This Specification is to ensure that Surveillance is performed to verify that systems and components meet the LCO and variables are within specified limits. Failure to meet Surveillance within the specified Frequency, in accordance with SR 3.0.2, constitutes a failure to meet an LCO. Systems and components are assumed to meet the LCO when the associated SRs have been met. Nothing in this Specification, however, is to be construed as implying that systems or components meet the associated LCO when: a. The systems or components are known to not meet the LCO, although still meeting the SRs; or, b. The requirements of the Surveillance(s) are known to be not met between required Surveillance performances. Surveillances do not have to be performed when the NAC-MPC SYSTEM is in a specified condition for which the requirements of the associated LCO are not applicable, unless otherwise specified. Surveillances, including those invoked by Required Actions, do not have to be performed on equipment that has been determined to not meet the LCO because the ACTIONS define the remedial measures that apply. Surveillances have to be met and performed in accordance with SR 3.0.2, prior to returning equipment to service. Upon completion of maintenance, appropriate post maintenance testing is required. This includes ensuring applicable Surveillances are not failed and their most recent performance is in accordance with SR 3.0.2. Post-maintenance

(continued)

SR 3.0.1 (continued)	testing may not be possible in the current specified conditions in the Applicability, due to the necessary NAC-MPC SYSTEM parameters not having been established. In these situations, the equipment may be considered to meet the LCO provided testing has been satisfactorily completed to the extent possible and the equipment is not otherwise believed to be incapable of performing its function. This will allow operation to proceed to a specified condition where other necessary post maintenance tests can be completed.
SR 3.0.2	SR 3.0.2 establishes the requirements for meeting the specified Frequency for Surveillances and any Required Action with a Completion Time that requires the periodic performance of the Required Action on a "once per..." interval. This extension facilitates Surveillance scheduling and considers facility conditions that may not be suitable for conducting the Surveillance (e.g., transient conditions or other ongoing Surveillance or maintenance activities). The 25% extension does not significantly degrade the reliability that results from performing the Surveillance at its specified Frequency. This is based on the recognition that the most probable result of any particular Surveillance being performed is the verification of conformance with the SRs. The exceptions to SR 3.0.2 are those Surveillances for which the 25% extension of the interval specified in the Frequency does not apply. These exceptions are stated in the individual Specifications as a Note in the Frequency stating, "SR 3.0.2 is not applicable." As stated in SR 3.0.2, the 25% extension also does not apply to the initial portion of a periodic Completion Time that requires performance on a "once per..." basis. The 25% extension applies to each performance after the initial performance. The initial performance of the Required Action, whether it is a particular Surveillance or some other remedial action, is considered a single action with a single Completion time. One reason for not allowing the 25% extension to this Completion Time is that such an action usually verifies that no loss of function has occurred by checking the status of redundant or diverse components or accomplishes the function of the affected equipment in an alternative manner.

(continued)

SR 3.0.2 (continued)

The provisions of SR 3.0.2 are not intended to be used repeatedly, merely as an operational convenience to extend Surveillance intervals or periodic Completion Time intervals beyond those specified.

SR 3.0.3

SR 3.0.3 establishes the flexibility to defer declaring affected equipment as not meeting the LCO or an affected variable outside the specified limits when a Surveillance has not been completed within the specified Frequency. A delay period of up to 24 hours or up to the limit of the specified Frequency, whichever is less, applies from the point in time that it is discovered that the Surveillance has not been performed in accordance with SR 3.0.2, and not at the time that the specified Frequency was not met.

This delay period provides adequate time to complete Surveillances that have been missed. This delay period permits the completion of a Surveillance before complying with Required Actions or other remedial measures that might preclude completion of the Surveillance.

The basis for this delay period includes: consideration of facility conditions, adequate planning, availability of personnel, the time required to perform the Surveillance, the safety significance of the delay in completing the required Surveillance, and the recognition that the most probable result of any particular Surveillance being performed is the verification of conformance with the requirements. When a Surveillance with a Frequency, based not on time intervals, but upon specified NAC-MPC SYSTEM conditions, is discovered not to have been performed when specified, SR 3.0.3 allows the full delay period of 24 hours to perform the Surveillance.

SR 3.0.3 also provides a time limit for completion of Surveillances that become applicable as a consequence of changes in the specified conditions in the Applicability imposed by the Required Actions.

Failure to comply with specified Frequencies for SRs is expected to be an infrequent occurrence. Use of the delay period established by SR 3.0.3 is a flexibility, which is not intended to be used as an operational convenience to extend Surveillance intervals.

(continued)

SR 3.0.3 (continued)

If a Surveillance is not completed within the allowed delay period, then the equipment is considered to not meet the LCO or the variable is considered outside the specified limits and the Completion Times of the Required Actions for the applicable LCO Conditions begin immediately upon expiration of the delay period. If a Surveillance is failed within the delay period, then the equipment does not meet the LCO, or the variable is outside the specified limits and the Completion Times of the Required Actions for the applicable LCO Conditions begin immediately upon the failure of the Surveillance.

Completion of the Surveillance within the delay period allowed by this Specification, or within the Completion Time of the ACTIONS, restores compliance with SR 3.0.1.

SR 3.0.4

SR 3.0.4 establishes the requirement that all applicable SRs must be met before entry into a specified condition in the Applicability.

This Specification ensures that system and component requirements and variable limits are met before entry into specified conditions in the Applicability for which these systems and components ensure safe operation of NAC-MPC SYSTEM activities.

The provisions of this Specification should not be interpreted as endorsing the failure to exercise the good practice of restoring systems or components before entering an associated specified condition in the Applicability.

However, in certain circumstances, failing to meet an SR will not result in SR 3.0.4 restricting a change in specified condition. When a system, subsystem, division, component, device, or variable is outside its specified limits, the associated SR(s) are not required to be performed per SR 3.0.1, which states that Surveillances do not have to be performed on equipment that has been determined to not meet the LCO.

(continued)

SR 3.0.4 (continued)

When equipment does not meet the LCO, SR 3.0.4 does not apply to the associated SR(s), since the requirement for the SR(s) to be performed is removed. Therefore, failing to perform the Surveillance(s) within the specified Frequency does not result in a SR 3.0.4 restriction to changing specified conditions of the Applicability. However, since the LCO is not in this situation, LCO 3.0.4 will govern any restrictions that may be (or may not) apply to specified condition changes.

The provisions of SR 3.0.4 shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS. In addition, the provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are related to the unloading of the NAC-MPC SYSTEM.

The precise requirements for performance of SRs are specified such that exceptions to SR 3.0.4 are not necessary. The specific time frames and conditions necessary for meeting the SRs are specified in the Frequency, in the Surveillance, or both. This allows performance of Surveillances, when the prerequisite condition(s) specified in a Surveillance procedure require entry into the specified condition in the Applicability of the associated LCO, prior to the performance or completion of a Surveillance. A Surveillance that could not be performed until after entering LCO Applicability, would have its Frequency specified such that is not "due" until the specific conditions needed are met.

Alternately, the Surveillance may be stated in the form of a Note as not required (to be met or to be performed) until a particular event, condition, or time has been reached. Further discussion of the specific formats of SRs' annotation is found in Section 1.4, Frequency.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.1 CANISTER Maximum Time in Vacuum Drying

BASES

BACKGROUND

A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Approved Contents limits. A shield lid or closure lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area and the CANISTER shield lid or closure lid is welded to the CANISTER shell and the lid weld is examined, pressure tested and leak tested (Yankee-MPC and CY-MPC only). For the MPC-LACBWR storage system, the closure ring is installed and welded. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is then backfilled with helium. In the MPC-LACBWR system, a helium cover gas is maintained in the CANISTER during draining. The CANISTER vent port and drain port covers are installed and welded. For the Yankee-MPC and the CY-MPC storage systems, the structural lid is installed and welded. Nondestructive examinations are performed on the welds and leak testing is performed for the inner port cover welds. The TRANSFER CASK and CANISTER are moved into position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, the CONCRETE CASK top lid is installed and the cask is then moved to the ISFSI.

Limiting the elapsed time for the Yankee-MPC and CY-MPC systems from the end of CANISTER draining operations through dryness verification testing and subsequent backfilling of the CANISTER with helium ensures that the short-term temperature limits established in the Safety Analysis Report for the spent fuel cladding and CANISTER materials are not exceeded.

For the MPC-LACBWR, the maximum time in vacuum drying is unlimited. The thermal analysis shows that for the low heat load of ≤4.5 kW, the maximum fuel cladding temperature does not exceed the temperature limits for stainless steel clad fuel in EPRI TR-106440.

(continued)

APPLICABLE SAFETY ANALYSIS

Limiting the total time for the Yankee-MPC and CY-MPC loaded CANISTER vacuum drying operations ensures that the short-term temperature limits for the fuel cladding and CANISTER materials are not exceeded. If vacuum drying operations are not completed in the required time period, per LCO 3.1.1.1.a or 3.1.1.1.b, the CANISTER is backfilled with helium and either WATER COOLING or FORCED AIR COOLING is initiated. The WATER COOLING or FORCED AIR COOLING of the loaded CANISTER is maintained for a minimum of 24 hours.

Thermal analysis for the MPC-LACBWR design with heat load limited to 4.5 kW validates system temperature limits are not exceeded with no time limits imposed.

FORCED AIR COOLING

The basis for FORCED AIR COOLING is the application of forced convection cooling of the CANISTER with cool air at flow rates exceeding the CONCRETE CASK natural convection cooling flow rate. Because of the small annulus between the TRANSFER CASK and CANISTER, this results in a high flow velocity. The high flow velocity results in improved heat transfer from the CANISTER compared to normal storage conditions in the CONCRETE CASK. For the Yankee-MPC the time limits for FORCED AIR COOLING are conservatively applied to the WATER COOLING condition, as the FORCED AIR COOLING evaluation bounds that for WATER COOLING.

YANKEE-MPC

Analyses reported in the Final Safety Analysis Report conclude that spent fuel cladding and CANISTER material short-term temperature limits will not be exceeded for total elapsed times less than 40 hours in vacuum drying and for an unlimited time with the CANISTER filled with helium in the TRANSFER CASK. Since the rate of heat-up is lower for lower total heat loads, the time required to reach component temperature limits is longer than for the design basis heat load. Consequently, longer time limits are specified for heat loads below the design basis heat load, as shown in LCO 3.1.1.1.a. The times specified in the LCO are reduced by 2 hours to allow commencement of the REQUIRED ACTIONS should the LCO time limits not be met.

(continued)

APPLICABLE SAFETY ANALYSIS (continued)

After a minimum of 24 hours of WATER COOLING or FORCED AIR COOLING operations, the spent fuel cladding temperature will be below 552°F. Analyses in the Final Safety Analysis Report show that short-term limits will not be reached for a minimum of 10 hours under vacuum drying conditions for the design basis heat load. For reduced heat loads, the time duration is longer, as shown in LCO 3.1.1.2.a.

CY-MPC

Analyses reported in the Final Safety Analysis Report conclude that spent fuel cladding and CANISTER material short-term temperature limits will not be exceeded for total elapsed time less than 21 hours in vacuum drying and for 25 days (600 hrs) with the CANISTER filled with helium in the TRANSFER CASK. Since the rate of heat-up is lower for the lower total heat loads (LOADING CATEGORIES B through D), the time required to reach component limits is longer. Consequently, longer time limits are specified for these categories as shown in LCO 3.1.1.1.b. The times specified in the LCO are reduced by 2 hours from the calculated times to allow for commencement of the REQUIRED ACTIONS should the LCO time limits not be met.

After 24 hours of WATER COOLING or FORCED AIR COOLING, the time limits for additional vacuum drying of the CY-MPC are 12 hours following WATER COOLING and 8 hours following FORCED AIR COOLING for the design basis heat load of LOADING CATEGORY A. Since the rate of heat-up is lower for the lower total heat loads (LOADING CATEGORIES B through D), the time required to reach component limits is longer than for the design basis heat load. Consequently, longer time limits are specified for these categories for the CY-MPC configuration as shown in LCO 3.1.1.2.b.

In the event of a FORCED AIR COOLING interruption(s) during LCO 3.1.1, ACTIONS, remedial action to extend the FORCED AIR COOLING time to account for the interruption in air cooling is required. The extension of FORCED AIR COOLING assures that the temperatures of the fuel cladding and critical fuel basket components evaluated in the thermal analysis for the restart of the vacuum drying are achieved. The period of additional FORCED AIR COOLING required is based on the duration of the interruption as shown in the following table.

(continued)

APPLICABLE SAFETY ANALYSIS (continued)

Duration of Interruption(s) T (hr)	Additional FORCED AIR COOLING Time (hr)
$T \leq 0.5$	0
$0.5 < T \leq 1$	2
$1 < T \leq 2$	4
$2 < T \leq 3$	6
$3 < T \leq 4$	8

Note that the preceding table is established for short periods (up to 4 hours) of interruption. The "Duration of Interruption(s)" corresponds to the cumulative time of interruption events. The "Additional FORCED AIR COOLING Time" is to be added to the time remaining in the LCO action prior to the first interruption (i.e., the original 24 hours of cooling must be completed plus the additional cooling time corresponding to the duration of the interruption). Additional FORCED AIR COOLING time is not required if the duration of interruption(s) is 30 minutes or less. The additional FORCED AIR COOLING time determinations are based on the design heat load for the CY-MPC system and, consequently, all other heat loads are bounded.

For an interruption(s) with a duration greater than 4 hours, a minimum duration of 30 hours of FORCED AIR COOLING is required following the end of the last interruption event. (Note: the original 24 hours of FORCED AIR COOLING does not need to be completed.) The minimum duration of 30 hours of FORCED AIR COOLING is conservatively determined based on the required cooling time to ensure that the fuel clad and component temperatures are acceptable for the restart of the vacuum drying for the durations listed in the LCO for all heat load cases following FORCED AIR COOLING.

MPC-LACBWR
Analyses reported in the FSAR conclude that the spent fuel cladding and CANISTER material long-term temperature limits will not be exceeded for operational boundary conditions with no time limits imposed. Based on system draining with helium backfill and limited heat load at 4.5 kW, LCO time limits are not required.

LCO

Limiting the length of time for the Yankee-MPC and CY-MPC vacuum drying operations for the CANISTER ensures that the spent fuel cladding and CANISTER material temperatures remain below the short-term temperature limits in the FSAR for the NAC-MPC SYSTEM.

(continued)

APPLICABILITY	The restrictions for Yankee-MPC and CY-MPC vacuum drying operations on a loaded CANISTER apply during LOADING OPERATIONS from the completion point of CANISTER draining operations through the completion point of the CANISTER dryness verification testing and the backfilling of the CANISTER with helium for long-term STORAGE OPERATIONS. The LCO is not applicable to TRANSPORT OPERATIONS or STORAGE OPERATIONS.
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC SYSTEMS that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1 Commence filling CANISTER with helium to a pressure of 0 (+1, -0) psig.

AND Commence WATER COOLING.

A.2.1 AND

Maintain WATER COOLING for a minimum of 24 hours.

A.2.2

OR

A.2.3 Commence FORCED AIR COOLING.

AND

A.2.4 Maintain FORCED AIR COOLING for a minimum of 24 hours.

(continued)

SURVEILLANCE REQUIREMENTS	SR 3.1.1.1 The elapsed time shall be monitored from completion of CANISTER draining through completion of the CANISTER vacuum dryness verification testing. Monitoring the elapsed time ensures that helium backfill and cooling operations can be initiated in a timely manner during LOADING OPERATIONS to prevent fuel cladding and CANISTER materials from exceeding short-term temperature limits. The times specified in the LCO are reduced by 2 hours from the calculated times to allow commencement of the REQUIRED ACTIONS should the LCO time limits not be met. SR 3.1.1.2 The elapsed time shall be monitored from the end of WATER COOLING or FORCED AIR COOLING through completion of the CANISTER vacuum dryness verification testing. Monitoring the elapsed time ensures that helium backfill and cooling operations can be initiated in a timely manner during LOADING OPERATIONS to prevent fuel cladding and CANISTER materials from exceeding short-term temperature limits. The times specified in the LCO are reduced by 2 hours from the calculated times to allow commencement of the REQUIRED ACTIONS should the LCO time limits not be met.
REFERENCES	1. FSAR Sections 4.4, 4.5, 4.A.3, 8.1 and 8.A.1.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.2 CANISTER Vacuum Drying Pressure

BASES

BACKGROUND

A TRANSFER CASK with a CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Approved Contents limits. A shield lid or closure lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area. The CANISTER shield lid or closure lid is welded to the CANISTER shell and the lid weld is examined, pressure tested and leak tested (Yankee-MPC and CY-MPC only). For the MPC-LACBWR storage system, the closure ring is installed and welded. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is then backfilled with helium. In the MPC-LACBWR system, a helium cover gas is maintained in the CANISTER during draining. The CANISTER vent port and drain port covers are installed and welded. For the Yankee-MPC and the CY-MPC storage systems, the structural lid is installed and welded. Nondestructive examinations are performed on the welds and leak testing is performed for the inner port cover welds. The TRANSFER CASK and CANISTER are moved into position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, the CONCRETE CASK top lid is installed and the cask is then moved to the ISFSI.

CANISTER cavity vacuum drying is utilized to remove residual moisture from the CANISTER cavity after the water is drained from the CANISTER. Any water not drained from the CANISTER cavity evaporates due to the vacuum. This is aided by the temperature increase, due to the heat generation of the fuel.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of design basis spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix, the metallic fuel cladding tubes where the fuel pellets are contained, and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel cladding depends on removal of oxidizing gases and on storage in an inert atmosphere. This is accomplished by removing water from the CANISTER, evacuating the CANISTER to a pressure of ≤ 3 torr and backfilling the cavity with helium. The thermal analysis assumes that the CANISTER cavity is dry and filled with helium.

(continued)

APPLICABLE SAFETY ANALYSIS (continued)	The heat-up of the CANISTER and contents will occur during CANISTER vacuum drying, but is controlled by LCO 3.1.1. Dryness of the CANISTER (e.g., no free water) is verified by holding a vacuum of ≤ 10 torr for a period of not less than 10 minutes. The vapor pressure of water at 70°F is approximately 30 mm Hg. Selecting a maximum pressure (10 torr) that is 1/3 of the vapor pressure at 70°F ensures that all of the free water in the CANISTER is removed. The actual temperatures in the loaded CANISTER are expected to be above 70°F, which would result in a higher vapor pressure. Consequently, the maximum vacuum pressure of 10 torr is conservatively selected. Holding the vacuum pressure for 10 minutes demonstrates that there is no free water since the presence of any free water will result in a pressure exceeding 10 torr within the CANISTER. The removal of oxidizing gases that could lead to fuel cladding deterioration is assured by evacuation to ≤ 3 torr (minimum). After this vacuum condition is achieved, the CANISTER is backfilled with helium to approximately one atmosphere. After the first backfill, the CANISTER is evacuated again to a ≤ 3 torr and backfilled with helium to approximate atmospheric pressure and sealed. The removal of oxidizing gases and the establishment of an inert helium atmosphere in the CANISTER is controlled by LCO 3.1.3. These vacuum and helium backfill cycles ensure that the CANISTER contents are dry and that the atmosphere in the canister is essentially free (< one mole) of any oxidizing gases that could affect the fuel cladding, as recommended by PNL-6365.
LCO	A vacuum pressure of ≤ 10 torr indicates that liquid water has evaporated and been removed from the CANISTER cavity. Removing water from the CANISTER cavity helps to ensure the long-term maintenance of fuel cladding integrity.
APPLICABILITY	Cavity vacuum drying is performed during LOADING OPERATIONS before the TRANSFER CASK holding the CANISTER is moved to transfer the CANISTER into the CONCRETE CASK. Therefore, the vacuum requirements do not apply after the CANISTER is backfilled with helium and leak tested prior to TRANSPORT OPERATIONS and STORAGE OPERATIONS.

(continued)

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the CANISTER cavity vacuum drying pressure limit cannot be met, actions must be taken to meet the LCO. Failure to successfully complete cavity vacuum drying could have many causes, such as failure of the vacuum drying system, inadequate draining, ice clogging of the drain lines, or leaking CANISTER welds. The Completion Time is sufficient to determine and correct most failure mechanisms. Excessive heat-up of the CANISTER and contents is precluded by LCO 3.1.1.

B.1

If the CANISTER cannot be successfully vacuum dried, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met. A.1 may be repeated as necessary prior to performing B.1. The time frame for completing B.1 can not be extended by re-performing A.1. The Completion Time is reasonable, based on the time required to reflood the CANISTER, perform fuel cooldown operations, cut the shield lid weld, move the TRANSFER CASK into the spent fuel pool, and remove the CANISTER shield lid in an orderly manner and without challenging personnel.

Corrective action leading to system reflood and return to the spent fuel pool is not applicable to MPC-LACBWR since the system temperature limits are maintained by helium cavity gas and TRANSFER CASK boundary conditions.

(continued)

SURVEILLANCE REQUIREMENTS	SR 3.1.2.1 The long-term integrity of the stored fuel is dependent on storage in a dry, inert environment. Cavity dryness is demonstrated by evacuating the cavity to a very low absolute pressure and verifying that the pressure is held over a specified period of time. The maintenance of low vacuum pressure for the specified time indicates that the cavity is dry. The surveillance must be performed prior to TRANSPORT OPERATIONS, as the vacuum drying pressure must be achieved before the CANISTER is sealed. This allows sufficient time to backfill the CANISTER cavity with helium, while minimizing the time the fuel is in the CANISTER without water or an inert atmosphere in the cavity. In addition, the CANISTER can be maintained in a safe condition based on the use of FORCED AIR COOLING or WATER COOLING.
REFERENCES	1. FSAR Sections 4.4, 4.5, 4.A.3, 7.1, 7.A.1, 8.1 and 8.A.1 and PNL-6365.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.3 CANISTER Helium Backfill Pressure

BASES

BACKGROUND

A TRANSFER CASK with a CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Approved Contents limits. A shield lid or closure lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area. The CANISTER shield lid or closure lid is welded to the CANISTER shell and the lid weld is examined, pressure tested and leak tested (Yankee-MPC and CY-MPC only). For the MPC-LACBWR storage system, the closure ring is installed and welded. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is then backfilled with helium. In the MPC-LACBWR system, a helium cover gas is maintained in the CANISTER during draining. The CANISTER vent port and drain port covers are installed and welded. For the Yankee-MPC and the CY-MPC storage systems, the structural lid is installed and welded. Nondestructive examinations are performed on the welds and leak testing is performed for the inner port cover welds. The TRANSFER CASK and CANISTER are moved into position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, the CONCRETE CASK top lid is installed and the cask is then moved to the ISFSI.

Backfilling of the CANISTER cavity with helium provides for heat transfer from the spent fuel to the CANISTER structure and the inert atmosphere protects the fuel cladding. Providing a helium pressure equal to atmospheric pressure ensures that there will be no in-leakage of air over the life of the CANISTER, which might be harmful to the heat transfer features of the NAC-MPC SYSTEM and to the stored spent fuel.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix, the metallic fuel cladding tubes where the fuel pellets are contained, and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel and cladding depends on the ability of the NAC-MPC SYSTEM to remove heat from the CANISTER and reject it to the environment. This is

(continued)

APPLICABLE SAFETY ANALYSIS (continued)	accomplished by removing water from the CANISTER cavity and backfilling the cavity with an inert gas. Removal of free water from the CANISTER is verified by LCO 3.1.2. The removal of oxidizing gases that could lead to fuel cladding deterioration is by evacuation of the CANISTER to a pressure of ≤3 torr. After this vacuum condition is achieved, the CANISTER is backfilled with helium to one atmosphere. After the backfill, the CANISTER is evacuated again to ≤3 torr and the CANISTER is then backfilled with helium to approximately one atmosphere (0 [+1, -0] psig) and sealed. These vacuum cycles ensure that the canister contents are dry and that the atmosphere in the canister is essentially free (< one mole) of any oxidizing gases, as recommended by PNL-6365. The duration that the CANISTER and contents may remain in the TRANSFER CASK following backfilling with helium is controlled by LCO 3.1.4. The thermal analyses of the CANISTER assume that the CANISTER cavity is dry and filled with dry helium.
LCO	Backfilling the CANISTER cavity with helium at a pressure equal to atmospheric pressure ensures that there is no air in-leakage into the CANISTER, which could decrease the heat transfer properties and result in increased cladding temperatures and damage to the fuel cladding over the storage period. The helium backfill pressure of one atmosphere (0 [+2, -0] psig) was selected based on a minimum helium purity of 99.9% for the Yankee-MPC and the CY-MPC systems and 99.995% for the MPC-LACBWR system to ensure that the CANISTER internal pressure and heat transfer from the CANISTER to the environment are maintained consistent with the design and analysis basis of the CANISTER.
APPLICABILITY	Helium backfill is performed during LOADING OPERATIONS, before the TRANSFER CASK and CANISTER are moved to the CONCRETE CASK for transfer of the CANISTER.

(continued)

ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent condition entry and application of associated Required Actions. A.1 If the backfill pressure cannot be established within limits, actions must be taken to meet the LCO. The Completion Time is sufficient to determine and correct most failures, which would prevent backfilling of the CANISTER cavity with helium. These actions include identification and repair of helium leak paths or replacement of the helium backfill equipment. B.1 If the CANISTER cavity cannot be backfilled with helium to the specified pressure, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met. A.1 may be repeated as necessary prior to performing B.1. The time frame for completing B.1 can not be extended by reperforming A.1. The Completion Time is reasonable based on the time required to re-flood the CANISTER, perform cooldown operations, cut the CANISTER shield lid weld, move the TRANSFER CASK and CANISTER into the spent fuel pool, remove the CANISTER shield lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.
SURVEILLANCE REQUIREMENTS	SR 3.1.3.1 The long-term integrity of the stored fuel is dependent on storage in a dry, inert atmosphere and maintenance of adequate heat transfer mechanisms. Filling the CANISTER cavity with helium at a pressure of one atmosphere will ensure that there will be no air in-leakage, which could potentially damage the fuel. This pressure of helium gas is sufficient to maintain fuel cladding temperatures within acceptable levels.

(continued)

SURVEILLANCE REQUIREMENTS (continued)	Backfilling of the CANISTER cavity with helium must be performed successfully on each CANISTER before placing it in storage. The surveillance must be performed prior to TRANSPORT OPERATIONS, as the helium atmosphere must be established before the CANISTER can be moved to storage.
REFERENCES	1. FSAR Sections 4.5, 4.A.3, 7.1, 7.A.1, 8.1 and 8.A.1.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.4 CANISTER Maximum Time in the TRANSFER CASK

BASES

BACKGROUND

During LOADING OPERATIONS, a TRANSFER CASK with a CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Approved Contents limits. A shield lid or closure lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area. The CANISTER shield lid or closure lid is welded to the CANISTER shell and the lid weld is examined, pressure tested and leak tested (Yankee-MPC and CY-MPC only). For the MPC-LACBWR storage system, the closure ring is installed and welded. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is then backfilled with helium. In the MPC-LACBWR system, a helium cover gas is maintained in the CANISTER during draining. The CANISTER vent port and drain port covers are installed and welded. For the Yankee-MPC and the CY-MPC storage systems, the structural lid is installed and welded. Nondestructive examinations are performed on the welds and leak testing is performed for the inner port cover welds. The TRANSFER CASK and CANISTER are moved into position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, the CONCRETE CASK top lid is installed and the cask is then moved to the ISFSI.

During TRANSFER OPERATIONS, a loaded CANISTER is transferred from one CONCRETE CASK to another CONCRETE CASK (or a TRANSPORT CASK) using the TRANSFER CASK. The TRANSFER CASK is placed on the CONCRETE CASK, the bottom doors are opened, the loaded CANISTER is lifted into the TRANSFER CASK cavity, the bottom shield doors are closed and the CANISTER is lowered until it rests on the bottom doors. Subsequently, the loaded TRANSFER CASK is placed on another CONCRETE CASK (or TRANSPORT CASK) and the procedure is reversed, lowering the loaded CANISTER into another CONCRETE CASK (or TRANSPORT CASK).

During UNLOADING OPERATIONS, a loaded CANISTER is removed from a CONCRETE CASK (or TRANSPORT CASK) using the same procedure used during TRANSFER OPERATONS. After removal from the CONCRETE CASK, the loaded CANISTER is moved to a cask handling area, unsealed, cooled and unloaded.

(continued)

BACKGROUND (continued)	Backfilling the CANISTER cavity with helium provides sufficient heat transfer from the fuel and ensures that the short-term temperature limits for the fuel cladding and CANIISTER components are not exceeded. The LCO limits the total time a CANISTER can be maintained in the TRANSFER CASK to 25 days (600 hrs).
APPLICABLE SAFETY ANALYSIS	Limiting the total time that a loaded CANISTER backfilled with helium may be in the TRANSFER CASK, prior to placement in a CONCRETE CASK, TRANSPORT CASK, or returned for UNLOADING OPERATIONS, precludes the inappropriate use of the TRANSFER CASK as a storage component. The thermal analyses in the Final Safety Analysis Report show that the short-term temperature limits for the spent fuel cladding are not exceeded for an unlimited period of time (steady state analysis). The duration of 25 days (600 hrs) is defined based on a test time of 30 days for abnormal regimes as described in PNL-4835.
LCO	Limiting the length of time that the loaded CANISTER backfilled with helium is allowed to remain in the TRANSFER CASK ensures that the TRANSFER CASK is not inappropriately used as a storage component.
APPLICABILITY	The elapsed time restrictions on a loaded CANISTER in the TRANSFER CASK apply during: LOADING OPERATIONS (beginning with backfilling of the CANISTER with helium per LCO 3.1.3); TRANSFER OPERATIONS (beginning with closure of the bottom doors of the TRANSFER CASK containing a loaded CANISTER); and UNLOADING OPERATIONS (beginning with closure of the bottom doors of the TRANSFER CASK containing a loaded CANISTER).

(continued)

ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC SYSTEMS that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. The CANISTER is backfilled with helium to 0 (+2, -0) psig in accordance with the conditions and requirements of LCO 3.1.3. The ACTIONS and SURVEILLANCES of LCO 3.1.3 apply until the helium backfill activity is complete. A.1 Complete CANISTER transfer. B.1 Remove all fuel assemblies from the CANISTER.
SURVEILLANCE REQUIREMENTS	SR 3.1.4.1 Verify CANISTER transfer complete.
REFERENCES	1. FSAR Sections 4.4, 4.5, 4.A.3, 8.1, 8.2, 8.3, 8.A.1, 8.A.2 and 8.A.3.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.5 CANISTER Helium Leak Rate

BASES

BACKGROUND

A TRANSFER CASK with a CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Approved Contents limits. A shield lid or closure lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area. The CANISTER shield lid or closure lid is welded to the CANISTER shell and the lid weld is examined, pressure tested and leak tested (Yankee-MPC and CY-MPC only). For the MPC-LACBWR storage system, the closure ring is installed and welded. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is then backfilled with helium. In the MPC-LACBWR system, a helium cover gas is maintained in the CANISTER during draining. The CANISTER vent port and drain port covers are installed and welded. For the Yankee-MPC and the CY-MPC storage systems, the structural lid is installed and welded. Nondestructive examinations are performed on the welds and leak testing is performed for the inner port cover welds. The TRANSFER CASK and CANISTER are moved into position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, the CONCRETE CASK top lid is installed and the cask is then moved to the ISFSI.

Backfilling the CANISTER cavity with helium promotes heat transfer from the fuel to the CANISTER shell. The inert atmosphere protects the fuel cladding. Prior to transferring the CANISTER to the CONCRETE CASK, the CANISTER shield lid closure welds and port cover weld are helium leakage rate tested to verify the closure meets leaktight requirements. Successful test performance ensures that the fuel and helium backfill gas are confined during STORAGE OPERATIONS.

(continued)

APPLICABLE SAFETY ANALYSIS	The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix, the metallic fuel cladding tubes where the fuel pellets are contained, and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel and cladding depends on maintaining an inert atmosphere, and maintaining the cladding temperatures below established long-term limits. This is accomplished by removing water from the CANISTER, backfilling the CANISTER cavity with helium, leakage rate testing the CANISTER shield lid closure welds for the CY-MPC and Yankee-MPC systems, and leakage rate testing of the inner port cover of the MPC-LACBWR systems. Verification of the leaktight condition is achieved for the CY-MPC system based on demonstrating a helium leak rate less than 2×10^{-7} cm^3/sec (helium) using a leak test sensitivity of 1×10^{-7} cm^3/sec (helium). Verification of the leaktight condition is achieved for the Yankee-MPC system based on demonstrating a helium leak rate less than 8×10^{-8} cm^3/sec (helium) using a leak test sensitivity of 4×10^{-8} cm^3/sec (helium). Both test conditions result in a leaktight configuration of the CANISTER.
LCO	Verifying that the CANISTER cavity helium leak rate is below the leaktight limit ensures that the CANISTER shield lid is sealed. Verifying that the helium leak rate is below leaktight levels will also ensure that the assumptions in the accident analyses and radiological evaluations are maintained.
APPLICABILITY	The helium leakage rate test is performed during LOADING OPERATIONS before the TRANSFER CASK and integral CANISTER are moved for transfer operations to the CONCRETE CASK. TRANSPORT OPERATIONS would not commence if the CANISTER helium leak rate was not below the test sensitivity. Therefore, CANISTER leak rate testing is not required during TRANSPORT OPERATIONS or STORAGE OPERATIONS.
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

(continued)

ACTIONS	A.1 If the helium leak rate limit is not met, actions must be taken to meet the LCO. The Completion Time is sufficient to determine and correct most failures, which could cause a helium leak rate in excess of the limit. Actions to correct a failure to meet the helium leak rate limit would include, in ascending order of performance, 1) verification of helium leak test system performance; 2) inspection of weld surfaces to locate helium leakage paths using a helium sniffer probe; and 3) weld repairs, as required, to eliminate the helium leakage. Following corrective actions, the helium leakage rate test shall be reperformed. B.1 If the CANISTER leak rate cannot be brought within the limit, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met. A.1 may be repeated as necessary prior to performing B.1. The time frame for completing B.1 cannot be extended by re-performing A.1. The Completion Time is reasonable based on the time required to re-flood the CANISTER, perform fuel cooldown operations, cut the CANISTER shield lid weld, move the TRANSFER CASK into the spent fuel pool, remove the CANISTER shield lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.
SURVEILLANCE REQUIREMENTS	SR 3.1.5.1 The primary design consideration of the CANISTER is that it is leaktight to ensure that off-site dose limits are not exceeded and to ensure that the helium remains in the CANISTER during long-term storage. Long-term integrity of the stored fuel is dependent on storage in a dry, inert environment. Verifying that the helium leakage rate meets leaktight requirements must be performed successfully on each CANISTER during LOADING OPERATIONS and prior to TRANSPORT OPERATIONS. The Surveillance Frequency allows sufficient time to backfill the CANISTER cavity with helium and perform the leakage rate test, while minimizing the time the fuel is in the CANISTER and loaded in the TRANSFER CASK.
REFERENCES	1. FSAR Sections 7.1, 7.A.1, 8.1 and 8.A.1.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.6 CONCRETE CASK Heat Removal System

BASES

BACKGROUND	The CONCRETE CASK Heat Removal System is a passive, air-cooled convective heat transfer system, which ensures that heat from the CANISTER is transferred to the environment by the upward flow of air through the CONCRETE CASK. Relatively cool air is drawn into the annulus between the CONCRETE CASK and the CANISTER through the four air inlets at the bottom of the CONCRETE CASK. The CANISTER transfers its heat from the CANISTER surface to the air via natural convection. The buoyancy created by the heating of the air creates a chimney effect and the air flows back into the environment through the four air outlets at the top of the CONCRETE CASK.
APPLICABLE SAFETY ANALYSIS	The thermal analyses of the CONCRETE CASK take credit for the decay heat from the spent fuel assemblies being ultimately transferred to the ambient environment surrounding the CONCRETE CASK. Transfer of heat away from the fuel assemblies ensures that the fuel cladding and CANISTER component temperatures do not exceed applicable limits. Under normal storage conditions, the four air inlets and four air outlets are unobstructed and full air flow (i.e., maximum heat transfer for the given ambient temperature) occurs. Analyses have been performed for the complete obstruction of all of the air inlets and outlets. The complete blockage of all air inlets and outlets stops air cooling of the CANISTER. The CANISTER will continue to radiate heat to the relatively cooler inner shell of the CONCRETE CASK. With the loss of air cooling, the CANISTER component temperatures will increase toward their respective short-term temperature limits. The limiting component is the CANISTER basket support and heat transfer disks, which, by analysis, approach their temperature limits in 24 hours for Yankee-MPC and CY-MPC systems, if no action is taken to restore air flow to the heat removal system. The MPC-LACBWR analysis for all inlets and outlets blocked shows system temperatures remain below long-term limits for the 4.5 kW total heat load. Thermal performance of the MPC-LACBWR system is provided by radiation between the CANISTER and CONCRETE CASK, and air cooling convection heat transfer is not required to maintain system safety limits.

(continued)

LCO	The CONCRETE CASK Heat Removal System must be verified to be OPERABLE for Yankee-MPC and CY-MPC systems to preserve the assumptions of the thermal analyses. Operability of the heat removal system ensures that the decay heat generated by the stored fuel assemblies is transferred to the environment at a sufficient rate to maintain fuel cladding and CANISTER component temperatures within design limits for the Yankee-MPC and CY-MPC systems.
APPLICABILITY	The LCO is applicable during STORAGE OPERATIONS. Once a CONCRETE CASK containing a CANISTER loaded with spent fuel has been placed in storage, the heat removal system must be OPERABLE to ensure adequate heat transfer of the decay heat away from the fuel assemblies for the Yankee-MPC and CY-MPC systems.
ACTIONS	A note has been added to ACTIONS that states for this LCO, separate Condition entry is allowed for each CONCRETE CASK. This is acceptable since the Required Actions for each Condition provide appropriate compensatory measures for each CONCRETE CASK not meeting the LCO. Subsequent CONCRETE CASKs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. <u>A.1</u> If the CONCRETE CASK heat removal system has been determined to be not OPERABLE, it must be restored to OPERABLE status within 8 hours. Eight hours is reasonable based on the accident analysis that shows that the limiting CONCRETE CASK component temperatures will not reach their temperature limits for 24 hours after a complete blockage of all inlets and outlets. This time frame allows for the 4-hour Response Surveillance required following an off-normal, accident or natural phenomena event established in Section A 5.3 of the Technical Specifications, plus 8 hours (typically, one operating shift) to take action to remove the obstructions in the air flow path. <u>B.1</u> Until the completion of Required Action A.1, performance of SR 3.1.6.1 shall be performed on an increased Completion Time Frequency of 6 hours to document the OPERABLE status of the CONCRETE CASK heat removal system. <u>AND</u>

(continued)

ACTIONS (continued)

B.2.1

If Required Action A.1 cannot be met, an engineering evaluation is performed to verify that the CONCRETE CASK heat removal system is OPERABLE. The Completion Time for this Required Action of 12 hours will ensure that the CANISTER remains in a safe, analyzed condition.

OR

B.2.2

Place the affected NAC-MPC SYSTEM in a safe condition. The Completion Time for this Required Action of 12 hours will ensure that the NAC-MPC SYSTEM is maintained in a safe condition.

SURVEILLANCE REQUIREMENTS

SR 3.1.6.1

The long-term integrity of the stored fuel is dependent on the ability of the CONCRETE CASK to reject heat from the CANISTER to the environment. Visual observation that all four air inlet and outlet screens are unobstructed and intact ensures that air flow past the CANISTER is occurring and heat transfer is taking place. Complete blockage of more than two air inlet or outlet screens or the equivalent effective screen area renders the heat removal system not OPERABLE and this LCO is not met. Partial blockage of less than two air inlet or outlet screens or the equivalent effective screen area does not result in the heat removal system being not OPERABLE. However, corrective actions should be taken promptly to remove the obstruction and restore full flow through the affected air inlet and outlet screens. Alternatively, based on the thermal analyses, if the air temperature rise is less than the limits stated in the SR, adequate air flow and, therefore, adequate heat transfer is occurring to provide assurance of long-term fuel cladding integrity. The reference ambient temperature used to perform this Surveillance shall be measured at the ISFSI facility.

The Frequency of 24 hours is reasonable based on the time necessary for CONCRETE CASK and CANISTER components to heat up to unacceptable temperatures assuming design basis heat loads, and allowing for corrective actions to take place upon discovery of the blockage of the air inlet and outlet screens.

(continued)

REFERENCES	1.	FSAR Chapter 4, Appendix 4.A and Chapter 11, Section 11.1.1, Section 11.2.8 and Appendix 11.A.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.7 Fuel Cooldown Requirements

BASES

BACKGROUND

In the event that a CANISTER must be unloaded, the CONCRETE CASK with its enclosed CANISTER is returned to the fuel building or similar facility, the CANISTER is removed from the CONCRETE CASK using the TRANSFER CASK, and the TRANSFER CASK and CANISTER are placed in the cask preparation area to begin the process of fuel unloading. The Yankee-MPC and the CY-MPC structural lids and vent and drain port cover welds on all NAC-MPC systems are removed. The CANISTER cavity gas is sampled to determine the level of radioactive gases in the cavity. A flow of nitrogen gas is established to flush radioactive gases from the cavity. A cooldown system is attached to the drain connection (inlet) and vent connection (outlet). A controlled water flow rate with a specified minimum water temperature is established to the drain connection with the steam and water being discharged from the vent to the spent fuel pool or radioactive water treatment system. Cooling water flow is maintained until the CANISTER is filled and the contents sufficiently cooled down to allow placement of the TRANSFER CASK and CANISTER in the spent fuel pool, or similar water filled space.

Following cooldown, the Yankee-MPC and the CY-MPC shield lid welds and the MPC-LACBWR closure ring and closure lid welds are removed and the TRANSFER CASK and CANISTER are placed in the fuel pool. The shield lid or closure lid is removed and the fuel assemblies are removed and placed in storage rack locations. The TRANSFER CASK and CANISTER are removed from the spent fuel pool and decontaminated.

During the time that the CANISTER is in the TRANSFER CASK prior to the start of internal cooldown of the CANISTER cavity, the CANISTER begins to heat up due to the decay heat of the contents and the reduced heat transfer provided by the TRANSFER CASK compared to the CONCRETE CASK. Note that the conditions of LCO 3.1.4 also apply.

(continued)

APPLICABLE SAFETY ANALYSIS	The use of a controlled cooldown process allows the reflooding of the CANISTER and cooling of the stored fuel assemblies in a manner which precludes the creation of excessive thermal stresses in the fuel cladding, which could result in cladding rupture and steam pressures in the cavity that could exceed the CANISTER's design pressure.
LCO	Controlling the inlet water flow rate and temperature ensures that there is no excessive thermally induced stress in the fuel cladding leading to failure, and that the steam pressure will be maintained below analyzed design values. The exit water temperature is monitored to ensure that the CANISTER contents are sufficiently cooled down to allow return of the CANISTER to the spent fuel pool for fuel assembly unloading.
APPLICABILITY	The elapsed time restrictions on the sealed, loaded CANISTER in the TRANSFER CASK apply during UNLOADING OPERATIONS from the completion point of the closing of the TRANSFER CASK shield doors through the initiation of internal cooling of the CANISTER per LCO 3.1.4. The inlet water flow rate and temperature and water/steam outlet temperatures are controlled and measured during UNLOADING OPERATIONS after the CANISTER has been transferred to the TRANSFER CASK from the CONCRETE CASK. Therefore, the CANISTER fuel cooldown LCO does not apply during TRANSPORT OPERATIONS and STORAGE OPERATIONS. A note has been added to the Applicability for LCO 3.1.7, which states that the APPLICABILITY is only applicable to wet UNLOADING OPERATIONS. This is acceptable, since the intent of the LCO is to avoid uncontrolled CANISTER pressurization due to steam creation during CANISTER reflooding, which is not a concern for dry UNLOADING OPERATIONS.

(continued)

ACTIONS	A note has been added to the ACTIONS that states that separate Condition entry is allowed for each NAC-MPC SYSTEM. Separate condition entry is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. A.1 If the inlet water flow rate and minimum temperature requirements are not met, actions must be taken to restore the parameters to within the limits. If any of the required cooldown parameters are not met (e.g., minimum water temperature, flow rate, or maximum pressure), appropriate actions, including changing of water supply source, and repositioning of inlet and outlet flow valves on the cooldown system, shall be taken to restore the cooldown parameters to be within the limits. The Completion Time for verification of water temperature and flow rate is short to ensure actions are taken to correct the LCO before fuel cladding damage or overpressurization of the CANISTER has occurred. No additional actions are appropriate, since this LCO applies during UNLOADING OPERATIONS, which cannot proceed until the LCO is met.
SURVEILLANCE REQUIREMENTS	SR 3.1.7.1 These SURVEILLANCE REQUIREMENTS apply to Condition A.1. This SR ensures that short-term temperature limits of the spent fuel cladding and CANISTER components are not exceeded by limiting sudden changes in temperature in the CANISTER and fuel components and by limiting the pressure excursion within the CANISTER that may occur due to the formation of steam.

(continued)

SURVEILLANCE REQUIREMENTS (continued)	The time duration for the flow of nitrogen is specified as a minimum of 10 minutes, but longer flow is allowed since it provides for heat removal and is not reactive with the spent fuel or CANISTER components. Cooling water temperature is determined prior to the start of flow. Flow rate is determined soon after water flow starts to limit the thermal shock and pressure excursion that could occur as a result of higher than evaluated water flow. CANISTER pressure is monitored continuously until water flows out of the CANISTER to ensure that the evaluated conditions of pressure are not exceeded. Water discharge temperature is monitored to determine when adequate cooling of the spent fuel has been achieved so that opening of the CANISTER for fuel removal can continue.
REFERENCES	1. FSAR Sections 4.4, 4.5, 4.A.3, 8.2, 8.3, 8.A.2 and 8.A.3 and Chapter 3.

C 3.1 NAC-MPC SYSTEM Integrity

C 3.1.8 CANISTER Removal from the CONCRETE CASK

BASES

[Deleted]

C 3.2 NAC-MPC SYSTEM Radiation Protection

C 3.2.1 CANISTER Surface Contamination

BASES

BACKGROUND	A TRANSFER CASK containing a CANISTER is immersed in the spent fuel pool in order to load the spent fuel assemblies. The external surfaces of the CANISTER are maintained clean by the application of clean water to the annulus of the TRANSFER CASK. However, there is potential for the surface of the CANISTER to become contaminated with the radioactive material in the spent fuel pool water. This contamination is reduced to acceptable levels on exterior surfaces of the CANISTER prior to moving the CONCRETE CASK containing the CANISTER to the ISFSI in order to minimize the radioactive contamination to personnel or the environment. This allows the ISFSI to be entered without additional radiological controls to prevent the spread of contamination and reduces personnel dose due to the spread of loose contamination or airborne contamination. This is consistent with ALARA practices.
APPLICABLE SAFETY ANALYSIS	The radiation protection measures implemented at the ISFSI are based on the assumption that the exterior surfaces of the CANISTER are within acceptable contamination levels on accessible surfaces. Failure to decontaminate the surfaces of the CANISTER could lead to higher-than-projected occupational dose and potential site contamination.
LCO	Removable surface contamination on exterior surfaces of the CANISTER is limited to 10,000 dpm/100 cm^2 from beta and gamma sources and 100 dpm/100 cm^2 from alpha sources. These limits are one-half of the values shown in Section 11.1.5 (Section 11.A.1.5 for MPC-LABWR) to produce a minimum site boundary dose of less than 1 mrem annually. Only removable contamination is controlled, as fixed contamination will not result from the CANISTER loading process. Experience has shown that these limits are low enough to prevent the spread of contamination to clean areas and are significantly less than the levels, which would cause significant personnel skin dose.

(continued)

LCO (continued)	LCO 3.2.1 requires removable contamination to be within the specified limits for the exterior surfaces of the CANISTER. The location and number of CANISTER surface swipes used to determine compliance with this LCO are determined based on standard industry practice and the user's plant-specific contamination measurement program for objects of this size. The objective is to determine a removable contamination value representative of the entire upper circumference of the CANISTER and the structural or closure lid, while implementing sound ALARA practices.
APPLICABILITY	Verification that the exterior surface contamination of the CANISTER is less than the LCO limits is performed during LOADING OPERATIONS. This occurs before TRANSPORT OPERATIONS and STORAGE OPERATIONS. Measurement of the CANISTER surface contamination is unnecessary during UNLOADING OPERATIONS as surface contamination would have been measured prior to moving the subject CANISTER to the ISFSI.
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER LOADING OPERATION. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. <u>A.1</u> If the removable surface contamination of the CANISTER that has been loaded with spent fuel is not within the LCO limits, action must be initiated to decontaminate the CANISTER and bring the removable surface contamination to within limits. The Completion Time of 25 days (600 hours) is appropriate, given that the time needed to complete the decontamination varies with the extent of the contamination and surface contamination does not affect temperatures or otherwise affect the spent fuel assemblies.

(continued)

SURVEILLANCE REQUIREMENTS	SR 3.2.1.1 This SR verifies that the removable surface contamination on the exterior surfaces of the CANISTER is less than the limits in the LCO. The Surveillance is performed using smear surveys to detect removable surface contamination. The Frequency requires performing the verification prior to initiating TRANSPORT OPERATIONS in order to confirm that the CANISTER can be moved to the ISFSI without spreading loose contamination.
REFERENCES	1. FSAR Sections 8.1 and 8.A.1. 2. FSAR Sections 11.1.5 and 11.A.1.5.

C 3.2 NAC-MPC SYSTEM Radiation Protection

C 3.2.2 CONCRETE CASK Average Surface Dose Rates

BASES

BACKGROUND	The regulations governing the operation of an ISFSI set limits on the control of occupational radiation exposure and radiation doses to the general public (Ref. 1). Occupational radiation exposure should be kept as low as reasonably achievable (ALARA) and within the limits of 10 CFR Part 20. Radiation doses to the public are limited for both normal and accident conditions in accordance with 10 CFR 72.
APPLICABLE SAFETY ANALYSIS	The CONCRETE CASK average surface dose rates are not an assumption in any accident analysis, but are used to ensure compliance with regulatory limits on occupational dose and dose to the public.
LCO	The limits on CONCRETE CASK average surface dose rates are based on the Safety Analysis Report shielding analysis of the NAC-MPC SYSTEM (Ref. 2). The limits are selected to minimize radiation exposure to the public and to maintain occupational dose ALARA to personnel working in the vicinity of the NAC-MPC SYSTEM. The LCO specifies sufficient locations for taking dose rate measurements to ensure the dose rates measured are indicative of the effectiveness of the shielding materials.
APPLICABILITY	The CONCRETE CASK average surface dose rates apply during STORAGE OPERATIONS. These limits ensure that the CONCRETE CASK average surface dose rates during STORAGE OPERATIONS are bounded by the shielding safety analyses. Radiation doses during STORAGE OPERATIONS are monitored by the NAC-MPC SYSTEM user in accordance with the plant-specific radiation protection program as required by 10 CFR 72.212(b)(6) and 10 CFR 20 (Reference 1).
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each loaded CONCRETE CASK. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CONCRETE CASK not meeting the LCO. Subsequent NAC-MPC

(continued)

ACTIONS (continued) SYSTEMs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the CONCRETE CASK average surface dose rates are not within limits, it could be an indication that a fuel assembly that did not meet the Approved Contents Limits in Section B2.0 of Appendix B of the Certificate of Compliance, or in Section B2.0 of Appendix 12.B for the MPC-LACBWR, was inadvertently loaded into the CANISTER. Administrative verification of the CANISTER fuel loading, by means such as review of video recordings and records of the loaded fuel assembly serial numbers, can establish whether a misloaded fuel assembly is the cause of the out-of-limit condition. The Completion time is based on the time required to perform such a verification.

A.2

If the CONCRETE CASK average surface dose rates are not within limits and it is determined that the CONCRETE CASK was loaded with the correct fuel assemblies, an analysis may be performed. This analysis will determine if the CONCRETE CASK would result in the ISFSI offsite or occupational calculated doses exceeding regulatory limits in 10 CFR Part 72 or 10 CFR Part 20, respectively. If it is determined that the measured average surface dose rates do not result in the regulatory limits being exceeded, STORAGE OPERATIONS may continue.

B.1

If it is verified that the fuel was misloaded, or that the ISFSI offsite radiation protection requirements of 10 CFR Part 20 or 10 CFR Part 72 will not be met with the CONCRETE CASK average surface dose rates above the LCO limit, the fuel assemblies must be placed in a safe condition in the spent fuel pool. The Completion Time is reasonable, based on the time required to transport the CONCRETE CASK, transfer the CANISTER to the TRANSFER CASK, remove the structural lid (MPC-Yankee and CY-MPC) and vent and drain port cover welds (all NAC-MPC systems), perform fuel cooldown operations, cut the shield lid weld (closure lid for the MPC-LACBWR), move the TRANSFER CASK and CANISTER into the spent fuel pool, remove the shield or closure lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

(continued)

SURVEILLANCE REQUIREMENTS

SR 3.2.2.1

This SR ensures that the CONCRETE CASK average surface dose rates are within the LCO limits prior to the beginning of STORAGE OPERATIONS. This Frequency is acceptable as corrective actions can be taken before off-site dose limits are compromised. The surface dose rates are measured approximately at the locations indicated on Figure A.3-1, following standard industry practices for determining average surface dose rates for large containers.

REFERENCES

1. 10 CFR Parts 20 and 72.
2. FSAR Sections 5.1, 5.A.1, 8.2 and 8.A.2.

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13.0 QUALITY ASSURANCE

13.1 Introduction

The NAC International (NAC) Quality Assurance (QA) Program is designed and administered to meet all Quality Assurance criteria of 10 CFR 72, Subpart G [1], 10 CFR 50, Appendix B [2], 10 CFR 71, Subpart H [3], and NQA-1 (Basic and Supplemental Requirements) [4]. The Nuclear Regulatory Commission (NRC) has reviewed and approved (Approval No. 0018) NAC's QA Program description.

The NAC QA Manual (as approved by the company's President) describes the policy NAC follows to comply with the applicable regulatory quality assurance criteria. The policy described in the NAC QA Manual is implemented by detailed procedures presented in the Quality Procedures Manual.

Employing a graded methodology, as described in U.S. NRC Regulatory Guide 7.10 [5], NAC applies quality controls to items and activities consistent with their safety significance. Table 13.1-1 identifies the NAC QA Manual sections that address the applicable quality criteria.

Table 13.1-1 Correlation of Regulatory Quality Assurance Criteria to the NAC Quality Assurance Program

Regulatory Quality Assurance Criteria[a]	Corresponding NAC QA Manual Section Number
Organization	1.0
Quality Assurance Program	2.0
Design Control	3.0
Procurement Document Control	4.0
Procedures, Instructions, and Drawings	5.0
Document Control	6.0
Control of Purchased Items and Services	7.0
Identification and Control of Material, Parts and Components	8.0
Control of Special Processes	9.0
Inspection	10.0
Test Control	11.0
Control of Measuring and Test Equipment	12.0
Handling, Storage and Shipping	13.0
Inspection, Test and Operating Status	14.0
Control of Nonconforming Items	15.0
Corrective Action	16.0
Records	17.0
Audits	18.0

[a] The criteria are obtained from 10 CFR 50, Appendix B; 10 CFR 71, Subpart H; and 10 CFR 72, Subpart G

13.2 NAC Quality Assurance Program Synopsis

Eighteen applicable Quality Assurance criteria are identified in 10 CFR 72, Subpart G; 10 CFR 50, Appendix B; 10 CFR 71, Subpart H; and ASME NQA-1 (Basic and Supplemental Requirements). Refer to the following sections for NAC's compliance with each of these criteria.

13.2.1 Organization

The President of NAC has the ultimate authority and responsibility over all organizations and their functions within the corporation. However, the President delegates and empowers qualified personnel with the authority and responsibility over selected key areas, as identified in the NAC Organization Chart (see Figure 13.2-1).

The Vice President, Quality, is responsible for definition, development, implementation, and administration of the NAC QA Program. The QA organization is independent from other organizations within NAC and has complete authority to assure adequate and effective program execution, including problem identification, satisfactory corrective action implementation and the authority to stop work, if necessary. The Vice President, Quality, reports directly to the President of NAC. The Vice President, Quality, has sufficient expertise in the field of quality to direct the quality function and qualifies as a lead auditor.

Strategic Business Unit (SBU) Vice Presidents direct operations and use project teams as appropriate for a particular work scope. SBU Vice Presidents are responsible to the President for the proper implementation of the NAC QA Program.

13.2.2 Quality Assurance Program

Employing a grading methodology consistent with U.S. NRC Regulatory Guide 7.10, the QA Program provides control over activities affecting quality from the design to fabrication, operation, and maintenance of nuclear products and services for nuclear applications. The QA Program is documented in the QA Manual and implemented via Quality Procedures. These documents are approved by the Vice President, Quality and the applicable Vice President from each SBU performing activities within the scope of the NAC QA Manual.

Personnel assigned responsibilities by the QA Program may delegate performance of activities associated with that responsibility to other personnel in their group when those individuals are qualified to perform those activities by virtue of their education, experience, and training. Such delegations need not be in writing. The person assigned responsibility by the QA Program retains full accountability for the activities.

13.2.3 Design Control

The established Quality Procedures covering design control ensure that the design activity is planned, controlled, verified, and documented so that applicable regulatory and design basis requirements are correctly translated into specifications, drawings, and procedures with appropriate acceptance criteria for inspection and test delineated.

All software used to perform engineering calculations is verified for computational accuracy and error tracking, and is controlled in accordance with approved Quality Procedures.

Design interface control is established and adequate to ensure that the review, approval, release, distribution, and revision of design documents involving interfaces are performed by appropriately trained and cognizant design personnel, using approved procedures.

Design verification is performed by individuals other than those who performed the original design. These verifications may include design reviews, alternate calculations, or qualification tests. Selection of the design verification method is based on regulatory, contractual, or design complexity requirements. When qualification testing is selected, the "worst case" scenario will be used. The verification may be performed by the originator's supervisor, provided the supervisor did not specify a singular design approach, rule out certain design considerations, or establish the design inputs used in the design, or unless the supervisor is the only individual in the organization competent to perform the verification. When verification is provided by the supervisor, the need and basis shall be so documented in advance and evaluated after performance by internal audit.

Design changes are controlled and require the same review and approvals as the original design.

13.2.4 Procurement Document Control

Procurement documents and their authorized changes are generated, reviewed, and approved in accordance with the Quality Procedures. These procedures ensure that all purchased material, components, equipment, and services adhere to design specification, regulatory, and contractual requirements including QA Program and documentation requirements.

NAC QA personnel review and approve all procurement actions invoking compliance with the QA Program for inclusion of quality-related requirements in the procurement documents.

13.2.5 Procedures, Instructions and Drawings

All activities affecting quality are delineated in the Quality Procedures, Specifications, Inspection/Verification Plans, or on appropriate drawings. These documents are developed via approved Quality Procedures and include appropriate quantitative and qualitative acceptance criteria. These documents are reviewed and approved by QA personnel prior to use.

13.2.6 Document Control

All documents affecting quality, including revisions, are reviewed and approved by authorized personnel, and are issued and controlled in accordance with Quality Procedures by those responsible persons or groups. Transmittal forms, with provisions for receipt acknowledgment, are used and controlled document distribution logs are maintained.

All required support documentation for prescribed activities is available at the work location prior to initiation of the work effort.

13.2.7 Control of Purchased Items and Services

Items and services affecting quality are procured from qualified suppliers. These suppliers have been evaluated and selected in accordance with the Quality Procedures based on their capability to comply with applicable regulatory and contractual requirements.

Objective evidence attesting to the quality of items and services furnished by NAC suppliers is provided with the delivered item or service, and is based on contract requirements and item or service complexity. This vendor documentation requirement is delineated in the procurement documents.

Source inspection, receipt inspection, vendor audits, and vendor surveillance are performed as required to assure product quality, documentation integrity, and supplier compliance to the procurement, regulatory and contractual requirements.

13.2.8 Identification and Control of Material, Parts and Components

Identification is maintained either on the item or in quality records traceable to the item throughout fabrication and construction to prevent the use of incorrect or defective items.

Identification, in accordance with drawings and inspection plans, is verified by QA personnel prior to releasing the item for further processing or delivery.

13.2.9 Control of Special Processes

Special processes, such as welding, heat treating, and nondestructive testing, are performed in accordance with applicable codes, standards, specifications, and contract requirements by qualified personnel. NAC and NAC suppliers' special process procedures and personnel certifications are reviewed and approved by NAC QA prior to their use.

13.2.10 Inspection

NAC has an established and documented inspection program that identifies activities affecting quality and verifies their conformance with documented instructions, plans, procedures, and drawings.

Inspections are performed by individuals other than those who performed the activity being inspected. Inspection personnel report directly to the Vice President, Quality.

Process monitoring may also be used in conjunction with identified inspections, if beneficial to achieve required quality.

Mandatory inspection hold points ensure verification of critical characteristics. Such hold points are delineated in appropriate process control documents.

13.2.11 Test Control

NAC testing requirements are developed and applied in order to demonstrate satisfactory performance of the tested items to design/contract requirements.

The NAC test program is established to ensure that preoperational or operational tests are performed in accordance with written test procedures. Test procedures developed in accordance with approved Quality Procedures identify test prerequisites, test equipment and instrumentation, and suitable environmental test conditions. Test procedures are reviewed and approved by NAC QA personnel.

Test results are documented, evaluated, and accepted by qualified personnel as required by the QA inspection instructions prepared for the test, as approved by cognizant quality personnel.

13.2.12 Control of Measuring and Testing Equipment

Control of measuring and testing equipment/instrumentation is established to assure that devices used in activities affecting quality are calibrated and properly adjusted at specified time intervals to maintain their accuracy.

Calibrated equipment is identified and traceable to calibration records, which are maintained as quality records. Calibration accuracy is traceable to national standards when such standards exist. The basis of calibration shall always be documented.

Whenever measuring and testing equipment is found to be out of calibration, an evaluation shall be made and documented of the validity of inspection or test results performed and of the acceptability of items inspected or tested since the previous calibration.

13.2.13 Handling, Storage and Shipping

Requirements for handling, storage and shipping are documented in specifications and applicable procedures or instructions. These requirements are designed to prevent damage or deterioration to items and materials.

Information pertaining to shelf life, environment, packaging, temperature, cleaning and preservation are also delineated as required.

QA Surveillance/Inspection personnel are responsible for verifying that approved handling, storage and shipping requirements are met.

13.2.14 Inspection, Test and Operating Status

Procedures are established to indicate the means of identifying inspection and test status on the item and/or on records traceable to the item. These procedures assure identification of items that have satisfactorily passed required inspections and/or tests to preclude inadvertent bypassing of the inspection/test.

Inspection, test and operating status indicators may only be applied or modified by Quality Assurance personnel or with formal Quality Assurance concurrence.

13.2.15 Control of Nonconforming Items

NAC has established and implemented procedures that assure appropriate identification, segregation, documentation, notification and disposition of items that do not conform to specified requirements. These measures prevent inadvertent usage of the item and assure appropriate authorization or approval of the item's disposition.

All nonconformances are reviewed and accepted, rejected, repaired or reworked in accordance with documented approved procedures. If necessary, a Review Board is convened, consisting of engineering, licensing, quality, operations and testing personnel, as applicable, to provide disposition of nonconforming conditions.

NAC procurement documents provide for control, review and approval of nonconformances noted on NAC items, including associated dispositions.

13.2.16 Corrective Action

Conditions adverse to quality, such as failures, malfunctions, deficiencies, defective material/ equipment and nonconformances, are promptly identified, documented and corrected.

Significant conditions adverse to quality will have their cause determined and sufficient corrective action taken to preclude recurrence. These conditions are documented and reported to the Vice President, Quality, who assures awareness by the President.

13.2.17 Records

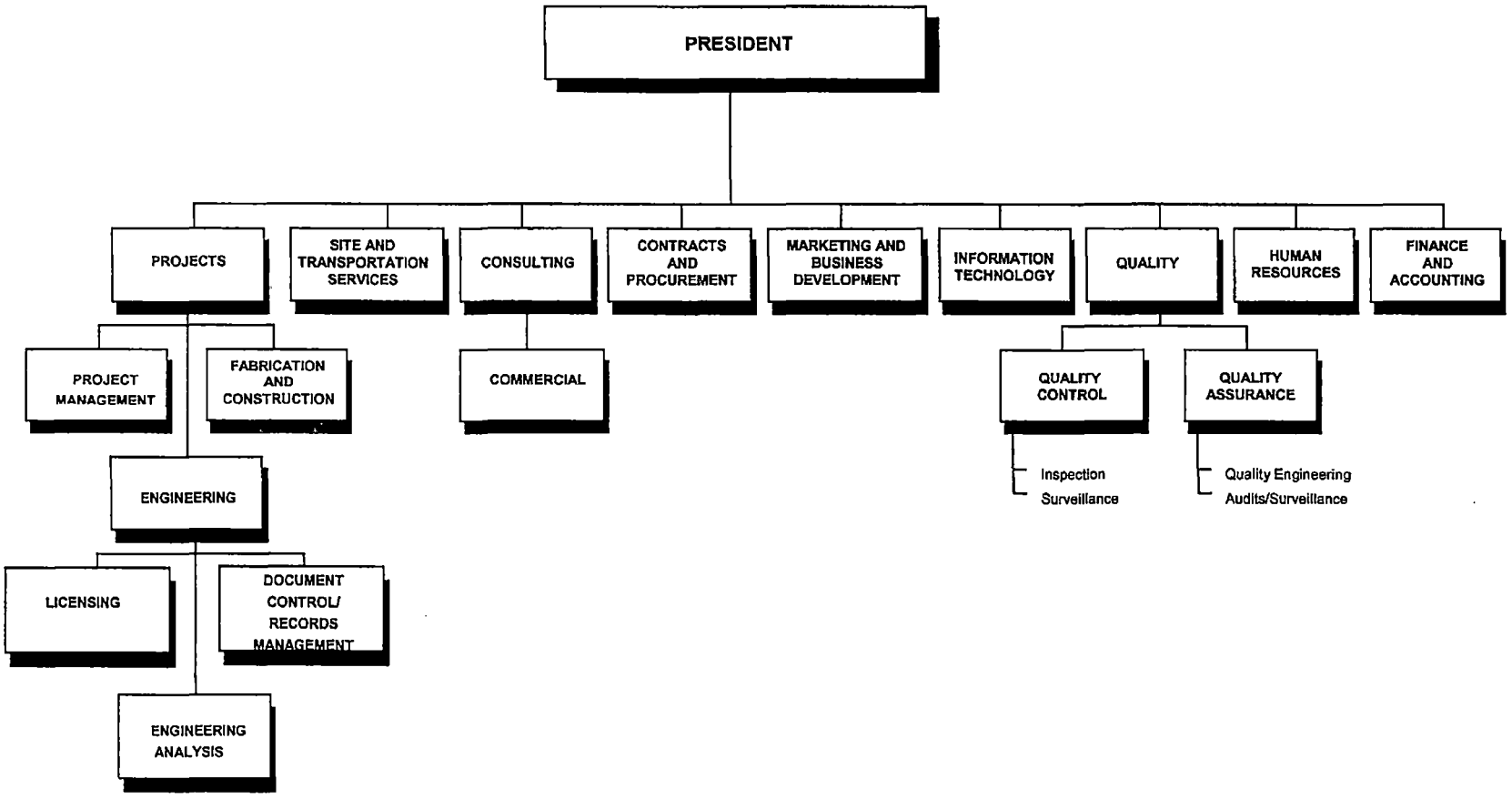
NAC maintains a records system in accordance with approved procedures to ensure that documented objective evidence pertaining to quality-related activities is identifiable, retrievable and retained to meet regulatory and contract requirements, including retention duration, location and responsibility.

Quality records include, but are not limited to, inspection and test reports, audit reports, quality personnel qualifications, design documents, purchase orders, supplier evaluations, fabrication documents, nonconformance reports, drawings, specifications and related documents. QA maintains a complete list of records and provides for record storage and disposition to meet regulatory and contractual requirements.

13.2.18 Audits

Approved Quality Procedures provide for a comprehensive system of planned and periodic audits performed by qualified personnel, independent of activities being audited. These audits are performed in accordance with written procedures and are intended to verify program adequacy and its effective implementation and compliance, both internally and at approved-supplier locations. Internal audits are conducted annually, and approved suppliers are audited on a triennial basis, as a minimum.

Figure 13.2-1 NAC Functional Organization Chart



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13.3 References

1. 10 CFR 72, Code of Federal Regulations, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste and Reactor-Related Greater than Class C Waste," Subpart G, "Quality Assurance Requirements," US Government, Washington, DC.
2. 10 CFR 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," Code of Federal Regulations, US Government, Washington, DC.
3. 10 CFR 71, Code of Federal Regulations, "Packaging and Transportation of Radioactive Material," Subpart H, "Quality Assurance," US Government, Washington, DC.
4. ASME NQA-1, Part 1, Basic and Supplemental Requirements (as referenced by the ASME Code, including latest accepted addenda), Quality Assurance Requirements for Nuclear Facility Applications.
5. Regulatory Guide 7.10, "Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material," US Nuclear Regulatory Commission, Washington, DC.