Chapter 4

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4.0 CONTAINMENT

4.1 Containment Boundary

The NAC-STC transport containment boundary is designed and analyzed to ensure the containment of the cask contents in accordance with 10 CFR 71.51. The containment boundary is designed, fabricated and inspected in accordance with ASME Code Section III, Subsection NB, with the exception of code stamping.

The components of the containment boundary are described in Table 4.1-1 as a function of the containment condition and the contents. The containment conditions are:

- Containment Condition A: The containment boundary for the transport of directly loaded (i.e., no canister) intact PWR spent fuel assemblies following extended storage of the cask at an ISFSI licensed in accordance with 10 CFR 72.

- Containment Condition B: The containment boundary for the transport of: (1) directly loaded intact PWR spent fuel assemblies loaded immediately prior to transport using either metallic or non-metallic o-rings; or (2) canistered Yankee Class spent fuel assemblies, Reconfigured Fuel Assemblies or GTCC waste loaded into the NAC-STC immediately prior to transport using metallic o-rings.

The transportable storage canister is designed and analyzed to demonstrate that it maintains its structural integrity in accordance with the 10 CFR 71.63(b) requirement for a separate inner container for the Reconfigured Fuel Assembly (i.e., damaged fuel or fuel debris), which may contain more than 20 curies of plutonium.

The canister is leak tested at the time of loading to demonstrate that it satisfies the leaktight criteria of ANSI N14.5-1997 and the release limits of 10 CFR 71.63(b).

The NAC-STC containment boundary is designed to permit leak testing of the cask containment boundary penetrations prior to transport to confirm the containment requirement of the contents. The leak test criteria, minimum test sensitivity and leak test methods and locations for each containment condition are described in Table 4.1-1.

4.1.1 Containment Vessel

The primary containment vessel for the NAC-STC consists of a 71.0-inch inside diameter, 1.5-inch thick inner shell, two 1.5-inch to 2.0-inch thick transition sections, a 6.2-inch thick bottom inner forging, and a 7.85-inch thick top forging. The containment vessel components, except for the transition sections, are fabricated from ASME Boiler and Pressure Vessel Code, Type 304 stainless steel nuclear pressure vessel material. The two transition sections are ASME Boiler and Pressure Vessel Code, Type XM-19 stainless steel nuclear pressure vessel material.

The canister, which satisfies the requirements for a separate inner container, is a right circular cylinder constructed of 5/8-inch thick, Type 304L stainless steel plate. It is closed on the bottom end by a 1-inch thick Type 304L stainless steel plate, and at the top by a 5-inch thick, Type 304 stainless steel plate (shield lid) and by a 3-inch thick Type 304L stainless steel structural lid.

The canister shell welds are full penetration welds, which are radiographed. The bottom plate is joined to the canister shell by a full penetration groove weld and adjacent fillet weld, which are ultrasonically and liquid penetrant examined. The stainless steel material is selected to be compatible with the DOE MPC program guidelines for future disposal and to minimize the potential for any adverse chemical reactions in the spent fuel pool. The design of the shield lid and structural lid provides a redundant confinement boundary at the top of the canister.

The weld examination requirements for both the cask body and the transportable storage canister are defined in Table 4.1-2 and are shown on the License Drawings.

4.1.2 Containment Penetrations

The physical penetrations in the NAC-STC primary containment vessel are the inner lid and the vent and drain ports in the inner lid. The penetrations are designed to ensure sealing of the containment boundary and to ensure that the leakage from the boundary does not exceed 1×10^{-7} ref cm^3/sec using metallic o-rings and 3.1×10^{-5} ref cm^3/sec using non-metallic o-rings. The quick-disconnect fittings installed in the vent and drain openings and in the interseal test port in the inner lid are not considered to be part of the containment boundary.

The separate inner container (i.e., the transportable storage canister) is a completely welded vessel that has no operable penetrations.

4.1.3 Seals and Welds

4.1.3.1 Seals

The o-rings of the inner lid, the vent port coverplate, and the drain port coverplate are the seals that provide primary containment, as described in Section 4.1 and as shown in Table 4.1-1. Section 4.5 contains the specifications that describe the PTFE o-rings of the interlid and pressure port covers and the metallic or non-metallic o-rings used in the containment boundary and outer lid. Also included in Section 4.5 are the manufacturer's technical data bulletins for the expansion foam and the Fireblock Protective Coating (FPC) used in the NAC-STC. Leak testing of the cask is performed prior to acceptance from the manufacturer. Leak testing is also performed following fuel loading for either immediate transport or for transport following a storage period. Technical information for Viton o-rings is provided in Section 4.5.5.

4.1.3.1.1 Containment System Fabrication Verification

Upon completion of fabrication, a Containment System Fabrication Verification shall be performed on the cask containment boundary as described in Section 8.1.3. These leak tests verify that the leakage rate of the assembled containment does not exceed the maximum allowable leakage rate of 1×10^{-7} ref cm^3/sec using metallic o-rings or 3.1×10^{-5} ref cm^3/sec using Viton o-rings. The allowable leak test shall conform to the o-ring design, since the inner and outer lids, and the vent and drain port coverplates must be fabricated using the o-ring groove appropriate to the o-ring design. Metallic o-rings and non-metallic o-rings cannot be used interchangeably.

4.1.3.1.2 Containment System Verification

The Containment System Verification shall be performed on the NAC-STC package containment boundary seals and components prior to each shipment, in accordance with the leak test acceptance criteria established for the Containment System Fabrication Verification. For cask transport immediately after loading, the leak test shall be performed in accordance with the procedures and acceptance criteria described in Section 7.4.1. For cask shipments following storage, the verification leak test shall be performed in accordance with the procedures and acceptance criteria described in Section 7.4.2.

Whenever a containment seal or component is replaced, the o-ring or containment component shall be leak tested following replacement using the Containment System Verification (Section 8.2.2.2). This test will verify that the replacement seal or component has been properly installed and that the leakage rate meets acceptance criteria.

8.2.2.2). This test will verify that the replacement seal or component has been properly installed and that the leakage rate meets acceptance criteria.

4.1.3.2 Welds

The NAC-STC containment vessel and the transportable storage canister (separate inner container) are assembled by welding. A list of containment vessel and canister welds, the examinations and tests performed on the welds, and the applicable ASME Code acceptance criteria is provided in Table 4.1-2. The acceptance tests for the NAC-STC and for the transportable storage canister are provided in Section 8.1.

4.1.4 Closure

The primary closure assembly for the NAC-STC for transport consists of the inner lid, bolts, and o-rings. The inner lid is recessed and bolted into the top forging of the cask body. The 9.0-inch thick, 79.00-inch diameter inner lid is made of SA-336, Type 304 stainless steel. The inner lid is retained by 42 inner lid bolts that are 1 1/2 - 8 UN socket head cap screws fabricated from SB-637, Grade N07718 nickel alloy steel bolting material. The initial torque for installation of the inner lid bolts is specified in Table 7-1.

The vent port and the drain port are recessed into the inner lid. The vent and drain port coverplates are secured by four 1/2 - 13 UNC bolts fabricated from SA-193, Grade B6, Type 410 stainless steel. Each coverplate is sealed to the inner lid by a metallic or non-metallic o-ring, with a second, concentric o-ring of the same material, providing an annulus to test the seal.

A secondary closure is provided by the outer lid, which provides puncture protection to the primary closure assembly. The 5.25-inch thick, 86.7-inch diameter outer lid is made of SA-705, Type 630, H1150, 17-4 PH stainless steel. The outer lid is retained by 36 outer lid bolts that are 1 - 8 UNC socket head cap screws fabricated from SA-564, Type 630, H1150, 17-4 PH stainless steel. The initial torque for installation of the outer lid bolts is specified in Table 7-1. The bottom surface of the outer lid is sealed to the top forging of the cask body by a metallic or non-metallic o-ring.

Port covers protect the interlid and pressure ports, which are located in the top forging and access the region between the inner and outer lids. For transport operations, solid port covers with no penetrations are installed in the interlid and pressure ports. These port covers are secured by three 3/8 - 16 UNC bolts, fabricated from SA-193, Grade B6, Type 410 stainless steel material. Each cover is sealed to the cask body by two "piston-type" (bore seal) PTFE o-rings, with a test port located between the o-rings.

Table 4.1-1 NAC-STC Containment Boundaries

Containment Condition	Content Condition	Containment Components	Allowable Test Leakage Rate/Sensitivity	Test Location/Method	Remarks
A (Primary) Using metallic o-rings.	Up to 26 directly loaded intact PWR spent fuel assemblies following storage operations per 10 CFR 72.	• Inner shell • Upper and lower shell rings (transition sections) • Bottom inner forging • Top forging • Inner lid • Inner lid outer metallic o-ring • Inner lid interseal test port threaded plug with metallic o-ring • Vent port coverplate • Vent port outer metallic o-ring • Vent port interseal port threaded plug with metallic o-ring • Drain port coverplate • Drain port coverplate outer metallic o-ring • Drain port coverplate interseal test port plug with metallic o-ring	• Allowable leakage rate is $\leq 2 \times 10^{-7}$ cm^3/sec (helium) (i.e., leaktight) • Minimum test sensitivity is $\leq 1 \times 10^{-7}$ cm^3/s (helium)	• Vent port outer o-ring using helium sniffer probe method with helium in interseal region • Drain port outer o-ring using helium sniffer probe method with helium in interseal region • Inner lid outer o-ring using evacuated envelope method (envelope provided by outer lid with test performed through the interlid port) with helium in interseal region	These series of leak tests are performed on the NAC-STC containment boundary following directly loaded fuel storage operations. The outer o-rings are the designated boundary as access to the cask cavity to verify helium backfill conditions is not planned. Testing is performed in accordance with ANSI N14.5 requirements immediately prior to transport.

Table 4.1-1 NAC-STC Containment Boundaries (Continued)

Containment Condition	Content Condition	Containment Components	Allowable Test Leakage Rate/Sensitivity	Test Location/Method	Remarks
B (Primary) Using Viton o-rings.	Up to 26 directly loaded intact PWR spent fuel assemblies for immediate transport.	• Inner shell • Upper and lower shell rings transitional sections • Bottom inner forging • Top forging • Inner lid • Inner lid inner Viton o-ring • Vent port coverplate • Vent port coverplate inner Viton o-ring • Drain port coverplate • Drain port coverplate inner Viton o-ring	• Allowable leakage rate is $\leq 4.1\times10^{-5}$ cm^3/s (helium) • Minimum test sensitivity is $\leq 2.0\times10^{-5}$ cm^3/s (helium)	• Inner lid inner o-ring using helium mass spectrometer leak detector (MSLD) connected to the interseal test port with pressurized helium in cask. • Vent port inner o-ring using the MSLD at the interseal test port with helium in the cask. • Drain port inner o-ring using the MSLD at the interseal test port with helium in the cask.	Testing is performed in accordance with ANSI N14.5 requirements immediately prior to transport.

4.2 Containment Requirements for Normal Conditions of Transport

The NAC-STC has been designed to safely transport spent fuel assemblies in either of two configurations. The spent fuel assemblies may be sealed in a transportable storage canister (canistered), or loaded directly into a fuel basket installed in the cask cavity. In the canistered configuration, the NAC-STC can transport up to 36 fuel assemblies, depending on the mix of fuel assembly types within the canister, or up to 24 containers of GTCC waste. The NAC-STC is designed and tested to meet the requirements of 10 CFR 71.51 for containment of radioactive materials.

For directly loaded fuel, a reference 17×17 fuel assembly having a burnup of 60,000 MWD/MTU, an enrichment of 3.5 wt % ^{235}U and a cool time of 5 years is used to establish the source term for the containment analysis. The reference fuel assembly is also used in the shielding analysis and is described in Section 5.1.2. The source term of the reference fuel assembly bounds the licensed inventory as described in Chapter 5. For direct loading for immediate transport using metallic o-rings in the containment boundary, the containment boundary is tested to a leaktight condition as defined in ANSI N14.5-1997. For direct loading for immediate transport using Viton o-rings, the containment boundary is tested to 3.1×10^{-5} ref cm^3/sec, or 4.1×10^{-5} cm^3/sec (helium).

For canistered fuel, the Combustion Engineering Type A fuel assembly has the highest burnup and, therefore, represents the limiting assembly for the design basis Yankee Class fuels. The source term for Reconfigured Fuel Assemblies is also bounded by the source term for the Combustion Engineering Type A fuel assemblies. While the releasable curie content of the 32,000 MWD/MTU CE (7.0-year cooled) fuel assemblies is higher than that of the design basis 8.1-year cooled and 36,000 MWD/MTU burned CE Type A fuel assembly, the A_2 value of the nuclide mixture is higher for the 32,000 MWD/MTU fuel assemblies. The higher A_2 value offsets the higher volumetric activity, so the CE 36,000 MWD/MTU burned (8.1-year cooled) fuel assembly has the bounding allowable release rate. While the 32,000 MWD/MTU Westinghouse fuel assembly at 19.0-years cooled has an A_2 value lower than that of the 36,000 MWD/MTU burned (8.1-year cooled) CE Type A fuel assembly, it also has a significantly lower releasable activity inventory, and is thus, bounded by the higher burned assembly.

The canistered GTCC waste consists primarily of irradiated and surface contaminated, stainless steel hardware and core components. The waste is separately enclosed in containers having the

same external dimensions as the Yankee Class fuel. There are no radioactive gases associated with the GTCC waste.

The structural and thermal evaluations provided in Chapters 2 and 3 demonstrate that cask containment is maintained during normal conditions of transport. Therefore, the package satisfies the containment requirement of 10 CFR 71.51.

4.2.1 Containment of Radioactive Material

The NAC-STC uses one of two o-ring configurations based on the loading condition. For directly loading of fuel for transport without interim storage, the o-rings may be either metallic or non-metallic. For direct fuel loading for storage, the o-rings must be metallic. For loading of canistered fuel or GTCC waste for transport without interim storage, the o-rings must also be metallic. For configurations using metallic o-rings, the containment boundary is designed and tested to leaktight conditions as defined by ANSI N14.5-1997. For direct fuel loading for transport without interim storage using non-metallic o-rings, the allowable leak rate is calculated using the methodology of NUREG/CR-6487. Consequently, the cask meets the requirements of 10 CFR 71.51 and IAEA Safety Standard Series TS-R-1 (Paragraph 656) for directly loaded and for canistered fuel or GTCC waste. During final assembly, the canister closure is tested to leaktight conditions. Consequently, the canister provides the separate inner container (double containment) for the transport of Reconfigured Fuel Assemblies containing damaged fuel or fuel debris as required by 10 CFR 71.63.

4.2.2 Pressurization of Containment Vessel

The maximum normal operating pressure (MNOP) in the cask during normal transport conditions is calculated, based on 100 percent failure of the fuel rods, using the methodology presented in Section 3.4.4. The cask cavity under normal transport conditions is backfilled to one atmosphere with 99.9 percent pure helium gas. To determine the limiting temperature conditions, it has been assumed that the helium gas could possibly be replaced by air. Therefore, the normal operating pressure is determined for both gas conditions. From Section 3.4.4, the free gas volume, fuel fill gas volume, and fuel fission gas volumes for the two spent fuel configurations are presented below. The GTCC waste does not release any gas. The Reconfigured Fuel Assemblies contain failed fuel. The initial charge gas and any significant fission product gases have already been released from the Reconfigured Fuel Assemblies.

For normal transport conditions, 100 percent of the fuel rods are assumed to fail over a period of one year in transport in accordance with Regulatory Guide 7.8. Regulatory Guide 1.25 suggests that 10 percent of the tritium and 30 percent of the krypton-85 should be assumed to be available to escape each failed fuel rod. It is conservatively assumed that 30 percent of both tritium and krypton-85 escape each failed fuel rod. Other radiologically important gaseous nuclides are present only in negligible amounts after the 8.1-year minimum cooling period for the design basis canistered Yankee Class fuel and the 5-year minimum cooling period for directly loaded fuel. The postulated release of other radionuclides, including volatiles, fines, particulates and crud, does not contribute to an increase in internal pressure.

The calculated curie content of the fission gases in the design basis directly loaded PWR and Yankee Class canistered fuel for both normal and hypothetical accident conditions are:

Fission Gas	Inventory - Directly Loaded Fuel		Inventory - Canistered Fuel	
	Curies/Assembly	Curies/ Cask	Curies/Assembly	Curies/ Cask
Tritium	302	7,852	80.3	2,890
Krypton-85	4,540	118,040	1,390	50,000
Iodine-129	0.03	0.71	0.0	0.0

The directly loaded fuel inventory is based on fuel having a 3.5 wt % ^{235}U initial enrichment, 60,000 MWD/MTU burnup, and 5-year cool time, and the canistered fuel inventory is based on fuel having a 3.7 wt % ^{235}U initial enrichment, 36,000 MWD/MTU burnup and 8-year cool time.

4.2.2.1 Containment Pressurization Due to Directly Loaded Fuel

An increase in pressure within the containment boundary results from an increase in the cask cavity temperature and the postulated failure of 100 percent of the fuel rods in normal conditions of transport (MNOP).

The pressure with air in the cask cavity, based on a conservative bulk air temperature of 450°F (Section 3.4.4), is 4.3 atm (63.2 psia = 48.5 psig). Based on a bulk average gas temperature of 401°F when helium is the cover gas, the pressure in the cask cavity is:

$$P_2 = (4.3)\left(\frac{478}{505}\right) = 4.07\,\text{atm} = 59.8\,\text{psia} = 45.1\,\text{psig}$$

This is less than the containment boundary design pressure of 75 psig.

4.2.2.2 Pressurization of Containment Due to Canistered Fuel

The MNOP during transport conditions in the transportable storage canister is calculated in Section 3.4.4, and found to be 3.23 atmospheres, or 32.8 psig. This pressure is conservatively calculated at 450°F, compared to the calculated maximum normal conditions of transport bulk gas temperature of 442°F. This pressure assumes the rupture of 100 percent of the fuel rods. The MNOP for the transportable storage canister is below the design pressure of 55 psig. As described above, the GTCC waste and Reconfigured Fuel Assemblies do not release gases to the canister cavity due to failures. Consequently, there is no increase in canister internal pressure due to these contents.

Since the canister does not fail in any of the evaluated normal transport or accident conditions, this pressure increase occurs within the canister. There is no increase in pressure in the cask cavity except that due to the increase in cavity temperature.

4.2.3 Containment Criterion for Normal Conditions of Transport

The NAC-STC is designed and tested to meet the containment criteria of 10 CFR 71.51 and IAEA Safety Standard Series Ts-R-1. The 10 CFR 71 limit for the release of radioactive material under normal conditions of transport is 10^{-6} A_2 per hour. This condition is met for the metallic o-ring configuration by testing the NAC-STC to leak tight conditions, 1×10^{-7} ref cm^3/ sec (air), which is equivalent to 2×10^{-7} cm^3/sec (helium) as defined by ANSI N14.5-1997. The leak test sensitivity is 1×10^{-7} cm^3/sec (helium), or less. This condition is met for the Viton o-ring configuration by testing the NAC-STC to 3.1×10^{-5} ref cm^3/ sec (air), which is equivalent to 4.1×10^{-5} cm^3/sec (helium). The calculation of the allowable leak rate for the Viton o-ring configuration is provided in Section 4.2.3.3. The leak test sensitivity is one-half of the allowable leak rate, or less, as recommended by ANSI N14.5-1997.

Correlation to Air Standard Conditions

The air standard leak rate is 1×10^{-7} ref cm^3/ sec, the leaktight condition as defined by Section 2.1 of ANSI N14.5-1997. Leak testing of the NAC-STC cask and the transportable storage canister is performed using helium gas. The NAC-STC cask leak test is performed using an allowable leak rate of 2×10^{-7} cm^3/sec (helium) with a detection sensitivity of 1×10^{-7} cm^3/sec (helium). The canister leak test is performed using an allowable leak rate of 8×10^{-8} cm^3/sec (helium) with a detection sensitivity of 4×10^{-8} cm^3/sec (helium).

4.2.3.1 Permissible Release Rate for the NAC-STC with Metallic O-Rings

Metallic o-rings must be used in the containment boundary when the cask is directly loaded for long-term storage and when the cask is loaded with a transportable storage canister for transport without interim storage. Metallic o-rings may also be used in the containment boundary when the cask is directly loaded for transport without interim storage. For the metallic o-ring configuration, the containment boundary is tested to leaktight conditions as defined by ANSI N14.5-1997 and, therefore, meets the requirements of 10 CFR 71.51 for containment of the radioactive contents.

Since the cask containment boundary is tested to demonstrate a leaktight condition, an allowable release rate, based on gases, fines, volatiles and particulates that are available for release from the directly loaded spent fuel or GTCC waste in the transportable storage canister, is not calculated.

4.2.3.2 Permissible Release Rate for the Transportable Storage Canister

The transportable storage canister welded closure is leak tested at final assembly to leak tight conditions, 1×10^{-7} ref cm^3/ sec, as defined by ANSI N14.5-1997. To meet this requirement, the allowable leak rate is 8×10^{-8} cm^3/sec (helium). The leak test sensitivity applied in testing the canister at the time it is closed is 4×10^{-8} cm^3/sec (helium), or less, to account for a test pressure difference of less than 1 atmosphere. Consequently, the canister provides adequate containment for the fuel or GTCC waste.

As shown in Section 2.6.13, the canister does not fail in any of the evaluated normal conditions of transport. Consequently, the canister and cask provide leak tight containment for Reconfigured Fuel Assemblies containing damaged fuel or fuel debris. This configuration meets the requirement of 10 CFR 71.63(b) for a separate inner container (double containment) for radioactive material containing more than 20 curies of plutonium.

4.2.3.3 Permissible Release Rate for the NAC-STC with Viton O-Rings

Viton o-rings may be used in the containment boundary when the cask is directly loaded for transport without interim storage. For the Viton o-ring configurations, the containment boundary is tested to 3.1×10^{-5} ref cm^3/sec. As described in this section, this leak rate meets the requirements of 10 CFR 71.51 for containment of the radioactive contents.

The 10 CFR 71.51 limit for the release of radioactive material under normal conditions of transport is 10^{-6} A_2/hr. In this analysis, A_2 for a mixed gas is determined by using the method described in 10 CFR 71, Appendix A. The release fractions for the various radionuclides transported in the NAC-STC are obtained from NUREG/CR-6487 and summarized in Table 4.2-1. The curie content for gases, volatiles, fines and particulates for the directly loaded 5-year cooled PWR reference fuel assembly is provided in Tables 4.2-6 through 4.2-8.

In addition to the radionuclides produced by the fuel material, fuel assemblies develop a coating of impurities deposited by cooling water during power generation. This coating is known as crud. Crud contains mostly non-radioactive elements but also contains a significant amount of ^{60}Co. NUREG/CR-6487 lists the maximum ^{60}Co concentrations on spent fuel assemblies to be 140 μCi/cm^2 for PWR assemblies at initial discharge. The surface area of the reference 17×17 PWR assembly is calculated to be 3.54×10^5 cm^2, based on the assembly characteristics provided in Table 5.2-2.

The maximum permissible leak rate from the cask under normal conditions of transport is determined from the 10 CFR 71 limit of 10^{-6} A_2/hr.

$$R_N = L_N C_N \leq A_2 \text{ x } \cdot 1 \text{x} 10^{-6} \text{hr}^{-1} \text{ or}$$
$$R_N = L_N C_N \leq A_2 \text{ x } \cdot 2.78 \text{x} 10^{-10} \text{sec}^{-1}$$

where:

L_N = Volumetric gas leakage rate [cm^3/s]
C_N = Curies per unit volume (termed "activity density") of the radioactive material that passes through the leak path [Ci/cm^3]
R_N = Release rate for normal transport conditions [Ci/sec]

Activity Density of Radioactive Material (C_N)

The total inventories of fission product gases, volatiles and fines are shown in Table 4.2-6 through Table 4.2-8. These inventories are calculated by using the source terms produced by the SAS2H sequence, the release fractions and the postulated crud (^{60}Co). The ^{60}Co content is decayed 5 years from discharge.

$$C_n = C_{Crud} + C_{Volaties} + C_{FissionGas} + C_{Fines}$$

$$C_{Crud} = \frac{f_C M_T}{V} = \frac{f_C S_C N_A (N_R S_{AR})}{V}$$

where:

C_{crud}	=	Activity density inside containment vessel resulting from crud spallation [Ci/cm^3]
M_T	=	Total crud activity inventory [Ci]
f_c	=	Crud spallation factor
V	=	Free volume inside containment vessel [cm$_3$]
S_C	=	Crud surface activity [Ci/cm^2]
N_R	=	Number of fuel rods per assembly
N_A	=	Number of assemblies
S_{AR}	=	Surface area per rod [cm^2]

and,

$$C_{fines} = \frac{f_F W_R A_R N_R N_A f_B}{V}$$

where:

C_{fine}	=	Activity concentration inside containment vessel resulting from fines released from cladding breaches [Ci/cm^3]
f_F	=	Fraction of fuel rod mass released as fines resulting from cladding breach
f_B	=	Fraction of fuel rods that develop cladding breach
W_R	=	Mass of the fuel in fuel rod [g]
N_R	=	Number of fuel rods per assembly
N_A	=	Number of assemblies
A_R	=	Specific activity of fines emitted from cladding breach in fuel rod [Ci/g]
V	=	Containment vessel void volume [cm^3]

and,

$$C_{vg} = C_{vol} + C_{gas} = \frac{N_R N_A f_B W_R (A_V f_V + A_G f_G)}{V}$$

where:

C_{vg}	=	Releasable activity concentration inside the containment vessel resulting from gases and volatiles released from cladding breaches [Ci/cm^3]
C_{vol}	=	Releasable activity concentration inside the containment vessel resulting from volatiles released from cladding breaches [Ci/cm^3]
C_{gas}	=	Releasable activity concentration inside the containment vessel resulting from gases released from cladding breaches [Ci/cm^3]
W_R	=	Mass of the fuel in a fuel rod [g]

N_R	=	Number fuel rods per assembly
N_A	=	Number of assemblies
f_B	=	Fraction of rods that develop cladding breaches
A_V	=	Specific activity of volatiles in fuel rod [Ci/g]
f_V	=	Fraction of volatiles in fuel rod released if rod develops cladding breach
A_G	=	Specific activity of gas in fuel rod [Ci/g]
f_G	=	Fraction of gas that would escape from fuel rod that develops cladding breach
V	=	Void volume inside containment vessel [cm^3]

Activity Values for Radionuclides

A_2 values used in this analysis (based on 10 CFR 71 Appendix A) are listed in Tables 4.2-6 through 4.2-8 for all radionuclides produced by the SAS2H analysis (plus ^{60}Co). The mixture A_2 value is shown in Table 4.2-2. For those isotopes for which no specific A_2 values are given in 10 CFR 71 Appendix A, the generic values listed in Table A.2 of Appendix A are applied. A_2 values for mixed isotopes are calculated from the following:

$$A_2 = \frac{1}{\sum \frac{F_i}{A_2^i}}$$

where:

$$F_i = \frac{S_i}{S_n}$$

and

F_i = Fraction of isotope i with respect to the entire mixture

S_i = Activity of isotope i [Ci]

S_n = Total group activity [Ci]

Mixture A_2 values are determined for gas, volatile, fine and crud mixtures and are then combined for a total cask mixture A_2 value. Table 4.2-2 provides the source term and A_2 values per group for directly loaded PWR fuel release rate calculations.

Maximum Allowable Leak Rate for Viton O-Rings

On the basis of the methodology described, the maximum allowable leak rate for PWR fuel directly loaded for immediate transport in normal conditions of transport is calculated to be 3.1×10^{-5} cm^3/sec (Table 4.2-3).

Table 4.2-1 Release Fractions: Normal and Accident Conditions

Radionuclide Origin	Fraction: Normal Conditions	Fraction: Accident Conditions
Volatiles releasable	2.00E-04	2.00E-04
Fission gas releasable	0.3	0.3
Rod mass released	3.00E-05	3.00E-05
Crud spallation factor	0.15	1.0
Fraction of fuel that fails	0.03	1.0

Table 4.2-2 Allowable Release Rate Source and A_2 Values for Directly Loaded PWR Fuel: Normal Conditions

Reference 17×17 PWR Fuel[1]	Crud	Gas	Volatiles	Fines	Total
Total Activity per Assembly (Ci)	N/C[2]	4.84E+03	1.76E+05	2.70E+05	4.51E+05
Releasable Activity per Cask (Ci)	1.00E+02	1.13E+03	2.75E+01	6.32E+00	1.27E+03
Cask Volumetric Activity (Ci/cm^3)	1.35E-05	1.52E-04	3.69E-06	8.49E-07	1.70E-04
A_2 Value (Ci)	10.80	283.25	6.08	0.13	300.26
Fraction of Activity	0.079	0.894	0.022	0.005	1.000
Fraction of Activity / A_2 (1/Ci)	0.0073	0.0032	0.0036	0.0391	0.0532
			Mixture A_2 Value (Ci)		18.80

1. Based on 3% rod failure.
2. Not explicitly calculated.

Table 4.2-3 Leak Rate and Leak Test Sensitivity: Normal Conditions

Contents	O-Rings	Vol. Activity (Ci/cm^3)	Leak Rate (cm^3/sec)		
			Volumetric (L)	Air Reference (L_R)	Test Sensitivity
Directly Loaded Reference 17×17 PWR Fuel	Viton	1.7E-04	3.1E-05	3.1E-05[1]	1.6E-05[1]

1. The corresponding helium test leak rates and leak test sensitivities for the directly loaded PWR fuel configuration are 4.1×10^{-5} cm^3/sec and 2.0×10^{-5} cm^3/sec, respectively, at standard conditions.

Table 4.2-4 Cask Free Volumes and Pressures: Normal and Accident Conditions

Contents	Directly Loaded Reference PWR Fuel	
Cask Operating Condition	Normal	Accident[1]
Free Gas Volume (liters)[2]	7440	7540
Pressure (atm)[2]	1.80	5.72
Average Gas Temperature (K)	505.0	675.0

1. The accident condition for this analysis is 100% rod failure in combination with a fire accident that raises the cask temperature. This hypothetical dual-failure accident conservatively maximizes both available releasable material and cask pressure.

2. Bounding values were chosen for free volume (minimum) and pressure (maximum). This conservatively minimizes free volume and capillary diameter.

4.3 Containment Requirements For Hypothetical Accident Conditions

The NAC-STC has been designed to safely transport 26 directly loaded PWR fuel assemblies, or in the canister configuration, up to 36 Yankee Class fuel assemblies or 24 containers of GTCC waste. The structural integrity of the cask containment during hypothetical accident conditions is demonstrated in Section 2.7. Therefore, the cask containment is maintained under hypothetical accident conditions. As described in Section 2.7.11, the transportable storage canister does not fail in any of the evaluated transport accident conditions defined in 10 CFR 71.73. Consequently, for the configurations using metallic o-rings, the leaktight condition is maintained in the hypothetical accident conditions. As described in Section 4.1, metallic o-rings must be used for the direct loading of fuel for long-term storage and for the transportable storage canister loaded into the cask for transport without interim storage. Either metallic or non-metallic o-rings may be used for spent fuel that is directly loaded for transport without interim storage.

For direct loading for transport without interim storage using Viton o-rings, the containment boundary requirement under hypothetical accident conditions is met by ensuring that a leak rate limit of 1.5×10^{-3} ref·cm^3/sec is not exceeded. Calculation of this limit is provided in Section 4.3.2.

Assuming a simultaneous occurrence of a fire accident and a 100% rod failure, and on the basis of a bulk average gas temperature of 675K resulting from air in the cavity, the pressure within the cask cavity is calculated to be 5.72 atm. The hypothetical presence of air in the cask provides an upper bound on the gas temperature. This pressure represents the maximum possible cask internal pressure.

4.3.1 Fission Gas Products

The calculated amounts of fission gases contained by the design basis directly loaded and canistered PWR fuel assemblies for both normal and hypothetical accident conditions are reported in Section 4.2.2. The accident conditions assume a 100% fuel rod failure with 30% of the available tritium and 30% of the available krypton-85 being released to the cask cavity or to the canister. These gases contribute to an increase in the cask cavity pressure due to the postulated failure of the directly loaded, intact, fuel and to an increase in the canister pressure due to the postulated failure of the canistered fuel.

Other released radionuclides, including crud, volatiles, fines and particulates, are not assumed to contribute to an increase in internal pressure of either transport configuration. The GTCC waste does not contain any gaseous products and does not have a failure mode in the hypothetical

accident conditions. Consequently, there is no increase in pressure due to the GTCC contents. The Reconfigured Fuel Assemblies contain fuel already classified as failed. Consequently, the initial charge gas and the fission product gases have already been released. There is no additional release of gases in the hypothetical accident events due to the Reconfigured Fuel Assembly contents.

4.3.2 Containment of Radioactive Material

For directly loaded fuel intended for transport without interim storage using metallic o-rings, the containment boundary is tested to a leaktight condition as defined in ANSI N14.5-1997. As shown in Section 2.7 for the NAC-STC cask and in Section 2.7.11 for the transportable storage canister, the containment boundary of the cask and canister do not fail during the hypothetical accident events. Consequently, leaktight containment is maintained by both the cask and the canister in the hypothetical accident events. For the Viton o-ring configuration, the allowable leak rate in the hypothetical accident condition is 1.5×10^{-3} cm^3/sec, as shown in Section 4.3.3. The curie content of the reference PWR fuel assembly used for the analysis is provided in Section 4.2.3.

4.3.3 Calculation of Allowable Leak Rate

The allowable leak rates under hypothetical accident conditions are calculated by using the method described in Section 4.2.1.1 for normal conditions of transport. The total inventories of fission product gases, volatiles, fines and crud are calculated by using the source terms generated by SAS2H, using the release fractions. Using the A_2 values from 10 CFR 71, Appendix A (Table 4.3-1), the mixture A_2 values are determined for gas, volatile, fine and crud mixtures. Finally, the maximum allowable release rates are calculated by using the hypothetical accident conditions allowable release limit:

$$R_A = L_A C_A \leq A_2 \cdot \text{per week}$$

or

$$R_A = L_A C_A \leq 1.65\text{x}10^{-6}\ A_2 \text{ per sec}$$

where:

L_A = Volumetric gas leakage rate [cm^3/sec]

C_A = Curies per unit volume (termed "activity density") of the radioactive material that passes through the leak path [Ci/cm^3]

R_A = Release rate for accident transport conditions

The assumptions applied to the calculations for the hypothetical accident conditions are that 100% of the fuel rods fail and that 100% of the assumed crud is released. The gas, volatile, fine and crud mixture A_2 is not affected by the change in the magnitude of releasable material. However, the combined A_2 changes based on the change in activity fraction in each group.

The calculated maximum permissible release rate for the reference directly loaded PWR fuel under hypothetical accident conditions using Viton o-rings is tabulated in Table 4.3-2.

Correlation of Allowable Leak Rates to Air Standard

The maximum allowable leak rate for the hypothetical accident conditions is correlated with the standard leak rate by using the methodology described in Section 4.2.1.2. The results for the reference PWR fuel loaded for transport without interim storage, using Viton o-rings, are shown in Table 4.3-2.

4.3.4 Containment Criterion for Accident Conditions

The containment criteria of 10 CFR 71 limits the release rate in accident conditions to A_2 per week. The NAC-STC cask using metallic o-rings and the transportable storage canister are designed and tested to leaktight conditions as defined in Section 2.1 of ANSI-N14.5-1997. The allowable leak rate calculated for the Viton o-ring configuration in the hypothetical accident conditions is much greater than that required for the normal conditions of transport. Consequently, the cask meets the regulatory containment criterion for the hypothetical accident conditions in either the metallic o-ring or non-metallic o-ring configuration.

Table 4.3-1 Allowable Release Rate Source and A_2 Values for Directly Loaded PWR Fuel: Accident Conditions Using Non-Metallic O-Rings

17×17 Reference	Crud	Gas	Volatiles	Fines	Total
Total Activity per Assembly (Ci)	N/C[1]	4.84E+03	1.76E+05	2.70E+05	4.51E+05
Releasable Activity per Cask (Ci)	6.68E+02	3.78E+04	9.15E+02	2.11E+02	3.96E+04
Cask Volumetric Activity (Ci/cm^3)	8.86E-05	5.01E-03	1.21E-04	2.79E-05	5.25E-03
A_2 Value (Ci)	10.80	283.25	6.08	0.13	300.26
Fraction of Activity	0.017	0.955	0.023	0.005	1.000
Fraction of Activity / A_2 (1/Ci)	0.0016	0.0034	0.0038	0.0418	0.0505
			Mixture A_2 Value (Ci)		19.79

1 Not explicitly calculated.

Table 4.3-2 Standard Leak Rate for the Accident Condition

Contents	O-Rings	Vol. Activity (Ci/cm^3)	Leak Rate (cm^3/sec) Volumetric (L)	Leak Rate (cm^3/sec) Air Reference (L_R)
Directly Loaded Reference 17×17 PWR Fuel	X	5.2E-03	6.2E-03	1.5E-03

Table 4.3-3 Containment Parameters for Non-Metallic O-Rings in the Accident Condition

Contents	Crud Surface Activity (Ci/cm^2)	Containment Free Volume (cm^3)	Capillary Length (cm)	Capillary Diameter (cm)	Upstream Pressure (atm)	Gas Temperature (K)
Reference 17×17 PWR Fuel	7.3E-5	7.54E+6	0.597	3.0E-4	5.72	675

Note: 100 % of the fuel rods are postulated to fail in the accident condition.

4.5 Appendix

4.5.1 Metallic O-Rings

This appendix contains the manufacturer's technical bulletin for the metallic o-rings.

Helicoflex
Components Division
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Columbia, South Carolina 29290
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METALLIC O-RINGS

Fluorocarbon Metallic O-Rings

Fluorocarbon Metallic O-Rings are designed to prevent leakage of gases or liquids under adverse sealing conditions. These static, metal-to-metal seals can withstand pressures from high vacuum to 100,000 psi (6,804 atm). They can endure continuous temperatures from -425°F. up to 1,800°F. (-269°C. to 982°C.), or intermittent temperatures up to 3,000°F. (1,650°C.). They resist radiation, chlorides, corrosives, and other hostile environments. They will not deteriorate with age, either in use or in storage.

Design, Materials, Coatings, Sizes

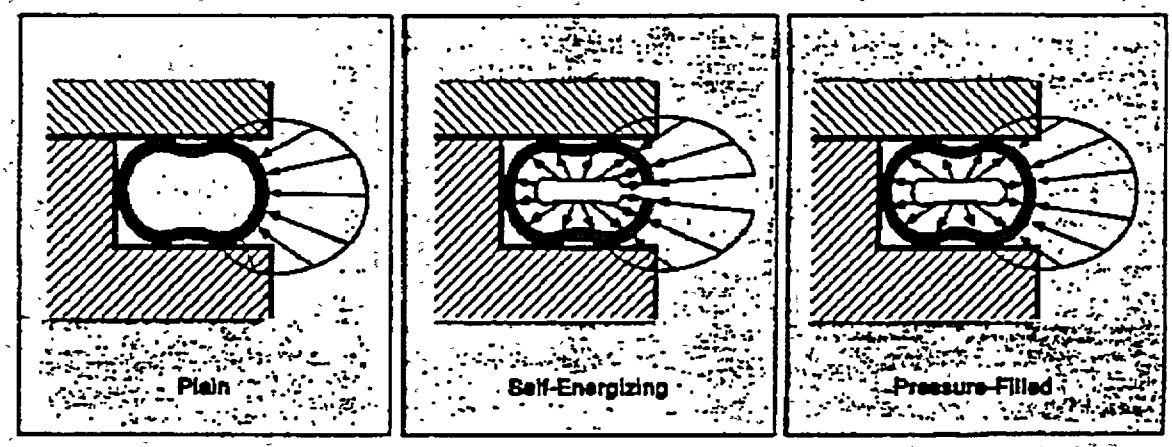
Fluorocarbon Metallic O-Rings, designated MOR, are made of metal tubing (or solid rod) which is formed into circular or other shapes and the two ends welded together. The O-Ring metal is stainless steel or other alloys. The O-Ring can be electroplated with silver, copper, indium, nickel, gold, lead or other metals, or it can be coated with Teflon. The flow of the finish material improves the sealing, especially under high pressure and/or vacuum. Since tensile strength and resilience of the seal are determined in part by metal temper, Fluorocarbon Components offers a choice of heat treating to material specification or tempering to customer specifications. Tubular or solid wire rings can be manufactured in sizes ranging up to 25 feet (7.6 m) or more in diameter, or as small as .250 inches (6.4 mm) OD.

Application Characteristics

The typical application places a Metallic O-Ring in axial compression between parallel faces which are square to the fluid passage or vessel axis. The seal is usually located in an open or closed groove in one face. It can also be located in a retainer, which eliminates the need for machining a groove (see description of retainers on page 8).

Upon compression to a predetermined fixed height the seal tubing buckles slightly, resulting in two contact areas on the seal face and maximum contact stress between the seal and the mating faces. When the flange faces are closed, the O-Ring is under compression and tends to spring back against the flanges, thus exerting a positive sealing force. If the O-Ring is the self-energizing type, the pressure of the gas or liquid on the vented side energizes the seal and further increases the sealing force by pushing the seal against the flange face.

Types of Metallic O-Rings



Plain

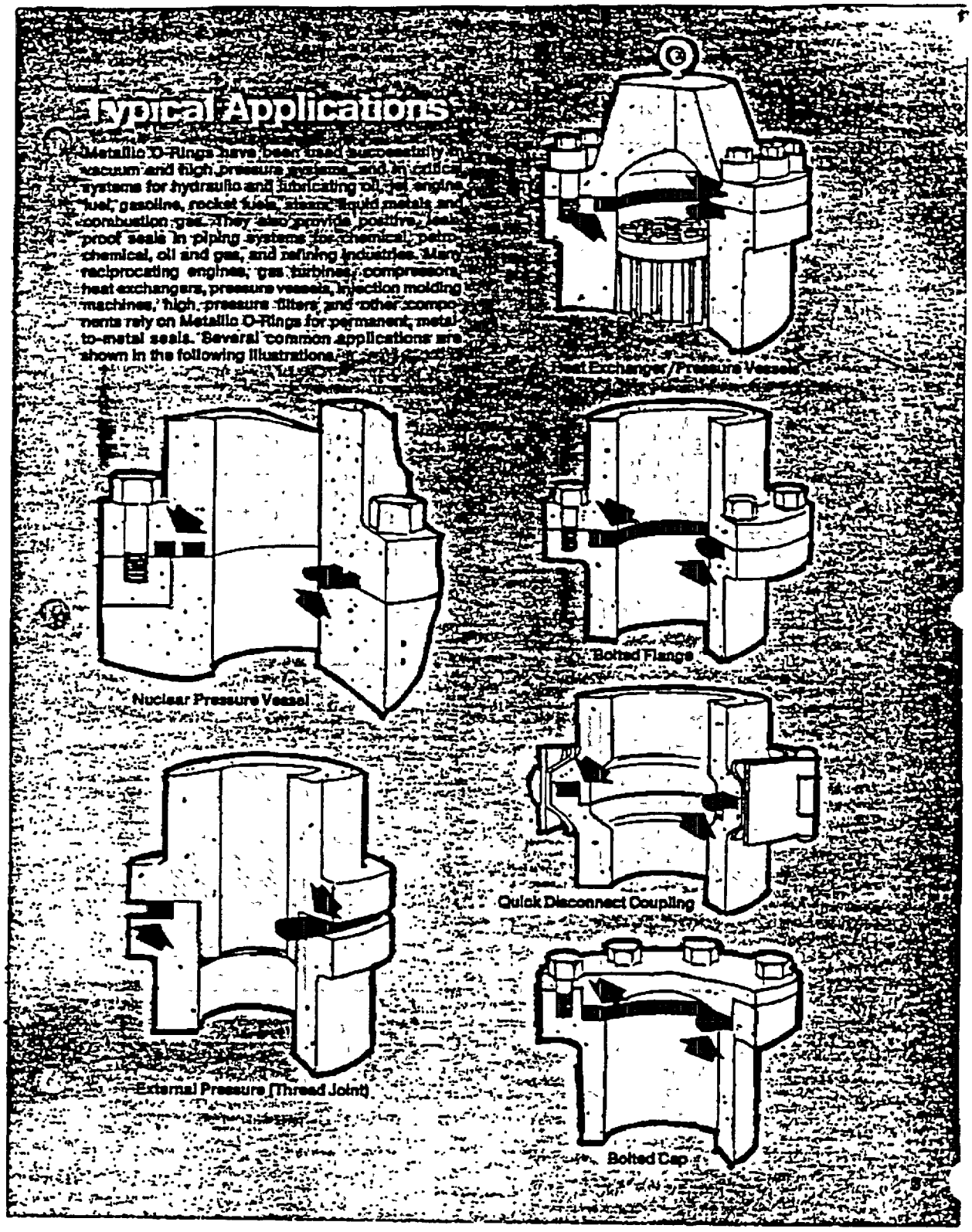
(Not Self-Energizing or Pressure-Filled)
Made of metal tubing (or solid rod) in most metals. This type is the most economical O-Ring. It is designed for low to moderate pressure and vacuum conditions.

Self-Energizing

The inner periphery of the O-Ring is vented by small holes or a slot. The pressure inside the ring becomes the same as in the system. Increasing the internal pressure increases sealing effectiveness.

Pressure-Filled

Pressure-filled O-Rings are designed for a temperature range of 800° F. to 2,000° F. (425° C. to 1093° C.). They cannot tolerate pressures as high as the self-energizing type. The ring is filled with an inert gas at about 600 psi (41 atm). At elevated temperatures, gas pressure increases, offsetting loss of strength in tubing and increasing sealing stress.


Typical Applications
Metallic O-Rings have been used successfully in vacuum and high pressure systems, and in critical systems for hydraulic and lubricating oil, jet engine fuel, gasoline, rocket fuel, steam, liquid metals and combustion gas. They also provide positive, leak proof seals in piping systems for chemical, petrochemical, oil and gas, and refining industries. Many reciprocating engines, gas turbines, compressors, heat exchangers, pressure vessels, injection molding machines, high pressure filters and other components rely on Metallic O-Rings for permanent, metal-to-metal seals. Several common applications are shown in the following illustrations.
Heat Exchanger/Pressure Vessels
Nuclear Pressure Vessel
Bolted Flange
Quick Disconnect Coupling
External Pressure (Thread Joint)
Bolted Cap

Metallic O-Ring Selection Guide

To select the proper Metallic O-Ring for a particular application, it is necessary to determine system pressure, temperature, and kind of fluid to be sealed.

1. O-Ring Type

Pressure determines if O-Ring should be self-energizing

Pressure	O-Ring Type
Vacuum to 100 psi (6.81 atm)	Self-energizing not required
100 psi (6.81 atm and above)	Self-energizing desirable

2. O-Ring Material

Temperature determines basic O-Ring material.

Temperature	O-Ring Material
Cryogenics to 500° F. (260° C.)	321 Stainless steel
to 800° F. (427° C.)	Alloy 600
to 1800° F. (982° C.)	Alloy X-750
above 1800° F. (982° C.)	Consult Factory

3. O-Ring Size

Tubing diameter is determined by ring OD, compression force desired, and available space. See complete data for O-Ring size selection on pages 6 and 7.

4. Seal Load vs. Seal Ring Diameter

Curves on page 7 show the seal load vs. seal ring diameter to various tubing outer diameters and wall thickness for stainless steel tubing. For tubing made of Alloy 600, multiply loads shown by 1.1. For Alloy X-750, multiply by 1.4.

5. O-Ring Wall Thickness

The wall thickness should be selected to provide the proper yield under compression. The data on pages 6 and 7 include the practical wall thickness dimensions that may be used for each tube diameter. If plating is used, wall thickness for seals made with .125 inch (3.2mm) tubing and smaller should cause yielding of the plating at a load of 400 lb/in (7.14 kg/mm). For tubing over .125 inch (3.2mm) diameter, 800 lb/in (14.28 kg/mm) should be required. Teflon coatings on rings will yield at 100 lb/in (1.78 kg/mm).

6. Groove Dimensions

The proper dimensions and surface finish of the groove are as important in achieving a seal as the O-Ring itself. As a general guide in the preparation of joint surfaces, the recommended groove dimensions for internal and external pressure applications are shown on page 5

Should you need further guidance and our recommendations, submit the following information regarding your application: 1. Temperature and pressure ranges. 2. Space available. 3. Material. 4. Medium to be sealed. 5. Available compression load. 6. Sketch of proposed application.

7. Coating or Plating

Coating or plating of the O-Ring will provide adherence and ductility (softness) to conform to microscopic groove or flange irregularities.

For unplated seals, liquid leakage can be estimated by the following expression:

$$Q=\frac{5.0 \times 10^{-4} P}{\mu}$$

(Q=leakage cc/sec; P=pressure difference psi and μ= liquid viscosity at operating conditions, centipoise.) If the resulting calculated leakage is 10^{-3} to 10^{-4} or less, actual leakage may be zero because of surface tension. If leakage occurs, it should be proportional to seal diameter, and in the above expression, multiplied by D/2. D=seal diameter. Actual leakage will probably be less than predicted.

For coated or plated seals, helium-leaktight joints may be made with proper O-Ring and coating or plating selections. Test results range from 10^{-6} to 10^{-8} cc/sec. and lower at one atmosphere differential. Recommended coating or plating materials are:

Temperature	Plating or Coating
Cryogenic to 500° F. (260° C.)	Teflon
to 1800° F. (982° C.)	Silver
to 2200° F. (1196° C.)	Nickel

See page 12 for other coatings and plating

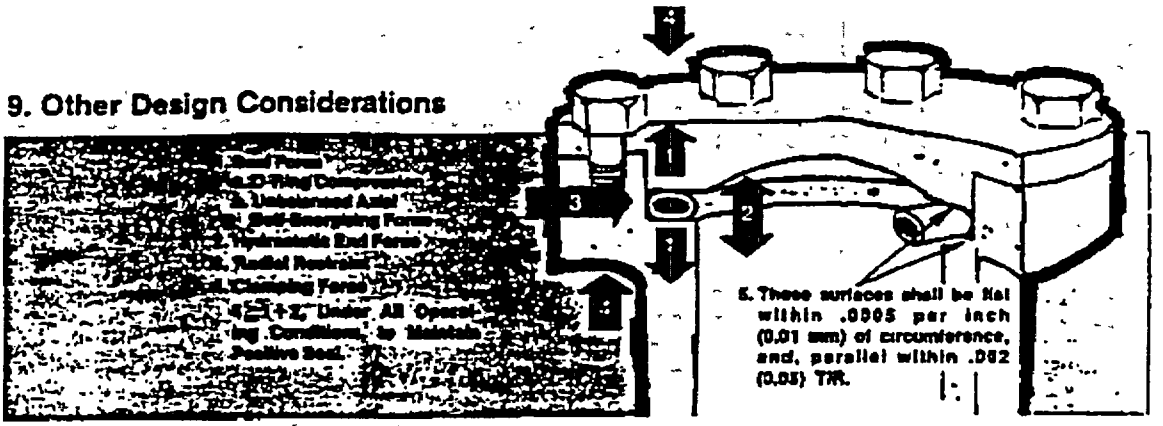
8. Sealing Surface Finish

The groove and mating flange face must have a surface finish of 16 μin. rms (0.4 μmm) for bare rings, and 32-100 μin. rms (0.8 μ-2.54 μmm) for plated or coated rings.

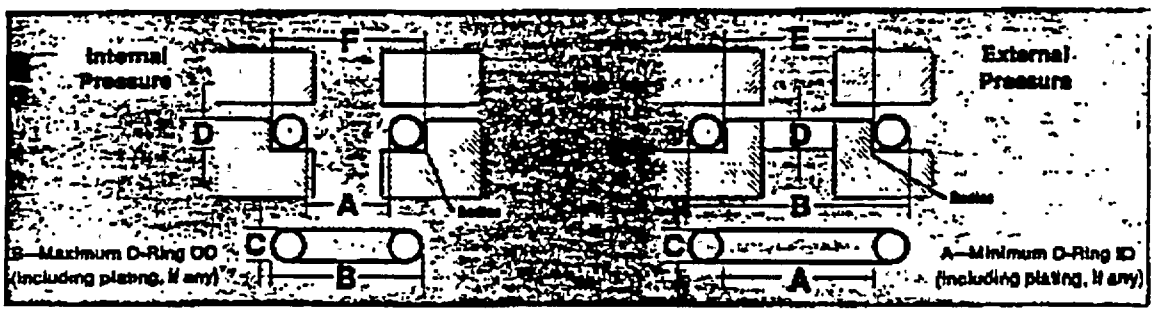
For gas, vacuum and light liquid (water), a finish of 16 μin. (0.4 μmm) rms is recommended. For medium liquids (hydraulic oils) and heavy liquids (tar or polymers) a finish of 32 μin. (0.8 μmm) rms is recommended. Machining tool marks on groove or flange face must be concentric.

Seal surfaces should be free of dirt, grit or other foreign materials.

9. Other Design Considerations



Recommended Groove Dimension



Internal Pressure				External Pressure		
C Tube Diameter Inches/mm	F Groove OD Inches/mm	D Groove Depth Inches/mm	Ring Tolerance B + .000 − .002 Inches/mm	E Groove ID Inches/mm	Minimum Groove Width Inches/mm	Springback* Inches/mm
.031	B+.004/.006	.020/.022	0.003	A—.004/.006	.042	.002
0.8	B+0.10/0.15	0.50/0.56	0.076	A—0.10/0.15	1.07	0.05
.063	B+.004/.006	.042/.045	0.003	A—.004/.006	.085	.002
1.6	B+0.10/0.15	1.07/1.14	0.076	A—0.10/0.15	2.16	0.05
.093	B+.005/.009	.065/.069	0.004	A—.005/.009	.112	.002
2.4	B+0.13/0.23	1.65/1.75	0.102	A—0.13/0.23	2.80	0.05
.125	B+.007/.012	.090/.095	0.005	A—.007/.012	.144	.003
3.2	B+0.18/0.30	2.29/2.41	0.127	A—0.18/0.30	3.66	0.08
.156	B+.008/.014	.115/.120	0.006	A—.008/.014	.182	.004
4.0	B+0.20/0.36	2.92/3.05	0.152	A—0.30/0.36	4.46	0.10
.188	B+.009/.015	.145/.150	0.007	A—.009/.015	.220	.004
4.8	B+0.23/0.38	3.68/3.8	0.178	A—0.23/0.38	5.59	0.10
.250	B+.011/.019	.195/.200	0.008	A—.011/.019	.290	.005
6.4	B+0.28/0.48	4.95/5.08	0.203	A—0.28/0.48	7.37	0.13
.375	B+.014/.029	.295/.300	0.012	A—.014/.029	.445	.009
9.5	B+0.36/0.74	7.49/7.62	0.305	A—0.36/0.74	11.3	0.23
.500	B+.020/.038	.415/.425	0.016	A—.020/.038	.645	.013
12.7	B+0.51/0.97	10.54/10.8	0.406	A—0.51/0.97	16.7	0.33
.625	B+.020/.038	.520/.530	0.016	A—.020/.038	.780	.017
15.9	B+0.51/0.97	13.21/13.46	0.406	A—0.51/0.97	19.8	0.43

Dimensions in table above are for unplated rings. Increase groove depth for .031 inch (0.8mm) cross section rings by 2 times the plating or coating thickness of plated or coated rings.

Do not increase groove depth on plated or coated rings for cross section of .063 inch (1.6mm) and larger.

*Springback figures for tube diameters up to .250 inch (6.4 mm) are for stainless steel. Springback for .375, .500 and .625 inch (9.5, 12.7 and 15.9 mm) tube diameters are for precipitation hardened Alloy 718. Other values for different materials are available.

5

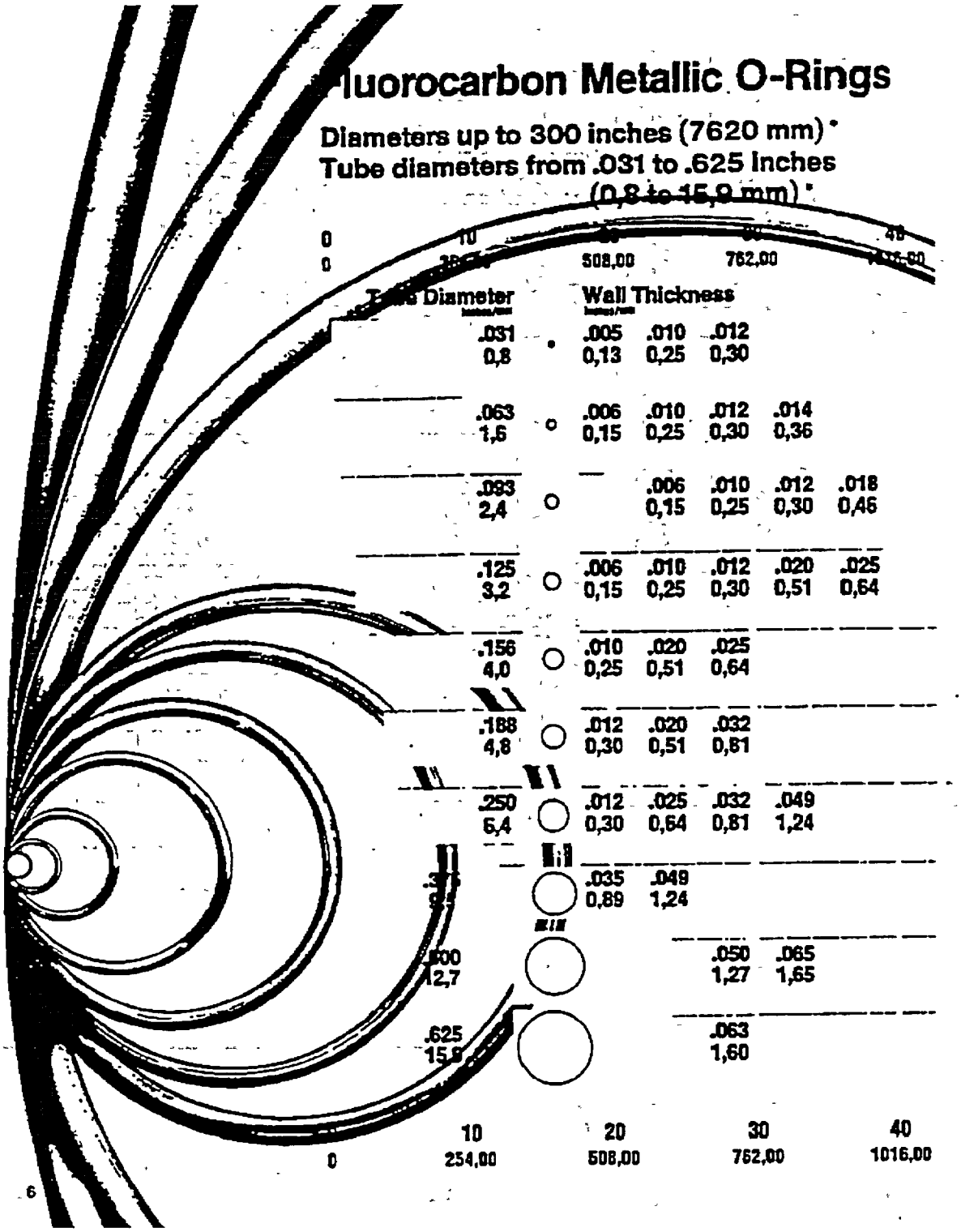
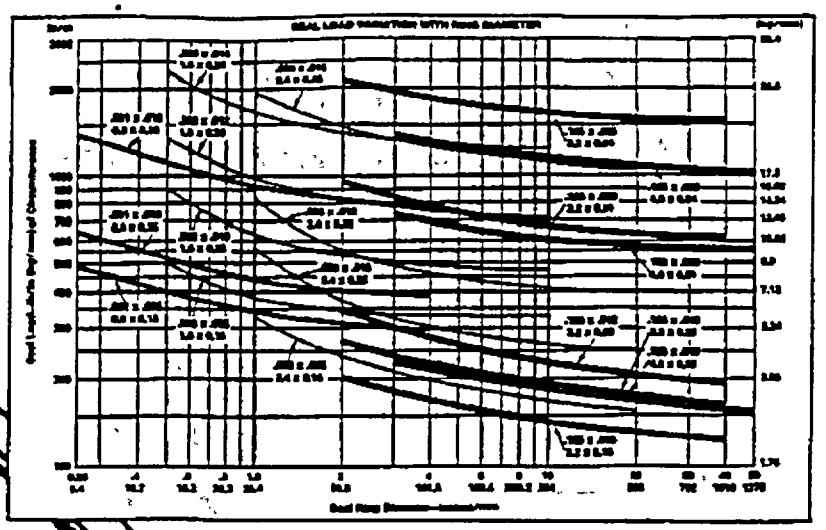

luorocarbon Metallic O-Rings
Diameters up to 300 inches (7620 mm)*
Tube diameters from .031 to .625 inches
(0,8 to 15,9 mm)*
Diameter
Wall Thickness
.031 0,8
.005 0,13
.010 0,25
.012 0,30
.063 1,6
.006 0,15
.010 0,25
.012 0,30
.014 0,36
.093 2,4
.006 0,15
.010 0,25
.012 0,30
.018 0,46
.125 3,2
.006 0,15
.010 0,25
.012 0,30
.020 0,51
.025 0,64
.156 4,0
.010 0,25
.020 0,51
.025 0,64
.188 4,8
.012 0,30
.020 0,51
.032 0,81
.250 6,4
.012 0,30
.025 0,64
.032 0,81
.049 1,24
.035 0,89
.049 1,24
.050 1,27
.065 1,65
.625 15,9
.063 1,60
0
10 254,00
20 508,00
30 762,00
40 1016,00

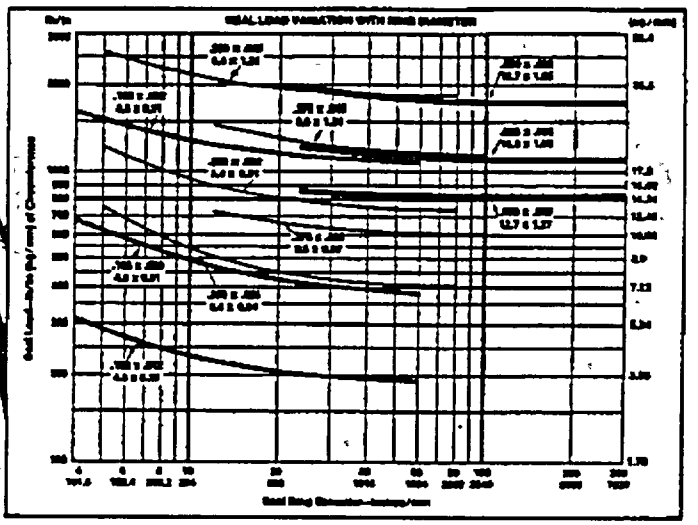
Table I



Tables I and II are for 321 stainless steel tubing.

For tubing made of Alloy 600, multiply loads shown by 1.1. For Alloy X-750, multiply by 1.41. For Alloy 718, multiply by 3.

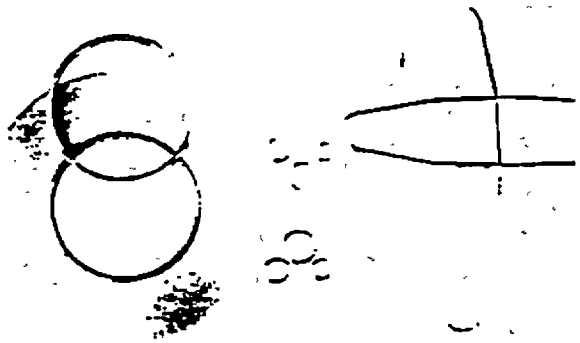
Table II



50 1270,00 | 60 1524,00 | 70 1778,00 | 80 2032,00 | 90 2286,00 | 100 2540,00 | 110 2794,00

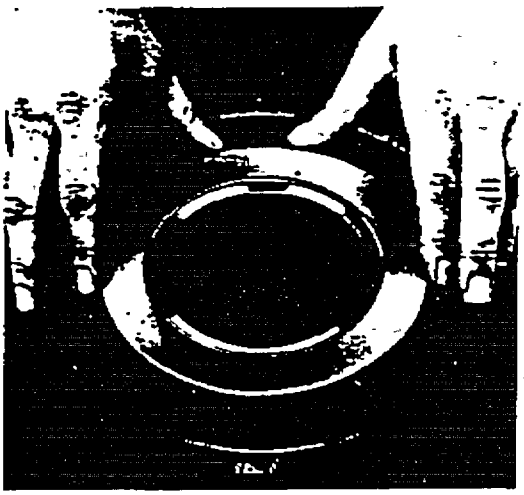
Seal Ring Diameter—Inches/mm

Retainer Assemblies



Metallic O-Rings can be used with a metal retainer plate for mechanical back-up that serves the same function as the machined groove wall in conventional installations. Retainer assemblies may incorporate several Metallic O-Rings into one all metallic assembly. The O-Rings are press-fitted without cross-section distortion, are secured against dropout and are easily handled during field assignment or retrofit programs. The retainer plate furnishes the O-Ring compression limit, controls hoop tension of the O-Ring, simplifies surface finish operation, permits interchangeability of flanges, and applies to single or multiple O-Ring requirements. A selection of several standard assemblies is described below.

ASA/API Pipe Flange Seals



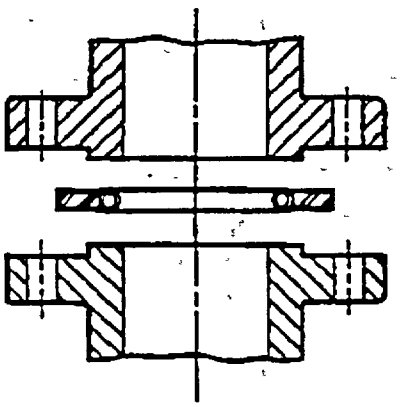
Metallic O-Rings offer static seal reliability and safety for installation or maintenance of piping. Over long periods of time, the all-metal construction of Fluorocarbon tubular Metallic O-Rings and retainer plates make them less susceptible to relaxation of sealing stresses—as compared to partially non-metallic gaskets.

In addition to their natural resilience characteristics, Metallic O-Rings provide the stability of a metal-to-metal pipe joint seal.

The natural springback of thin-wall metal tubing, and unique self-energizing design feature, create a balance of inside and outside forces which prevent collapse of the tube under pressure cycling. These same features allow Metallic O-Rings to respond to variations in sealing surface deflections without creep or cold flow, and to accommodate high and low temperature cycling. For process plant piping, they withstand temperatures from cryogenic to 1,800° F. (982° C.) and pressures from vacuum to 50 000 psi (3402 atm).

To maintain seal reliability, tubular Metallic O-Rings require less bolt stress than solid, fiber, flat metal, spiral wound or jacketed gaskets. Lower seal loads allow a greater bolt and flange safety factor for a given installation.

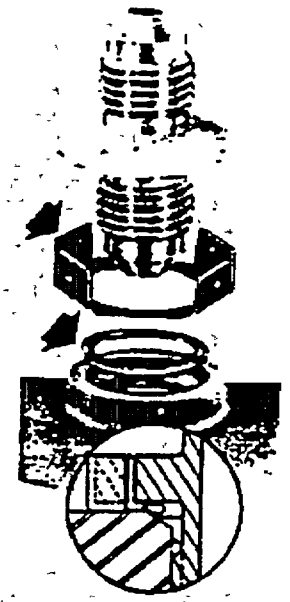
O-Rings and retainer plates are available for .250" to 24" (6.4 to 609.6 mm) pipe in all sizes of 150 to 2500 psi (10.2 to 170.1 atm) flat or raised face flanges.



8

Boss Seals

Fluorocarbon FIT-O-SEAL for boss joints combines a stainless steel retainer and a press fit Metallic O-Ring. The unit is self-positioning, controls ring compression, and can be reused. It won't deteriorate with age and is not affected by environment. Existing boss can be easily retrofitted. It can seal fuels and chemicals from high vacuum to 10,000 psi (680 atm) or higher, and will endure continuous temperatures of −452° F. (−269° C.) to 1,800° F. (982° C.). Standard seal assembly available for MS33656 fitting to MS33649 boss. Modifications available.

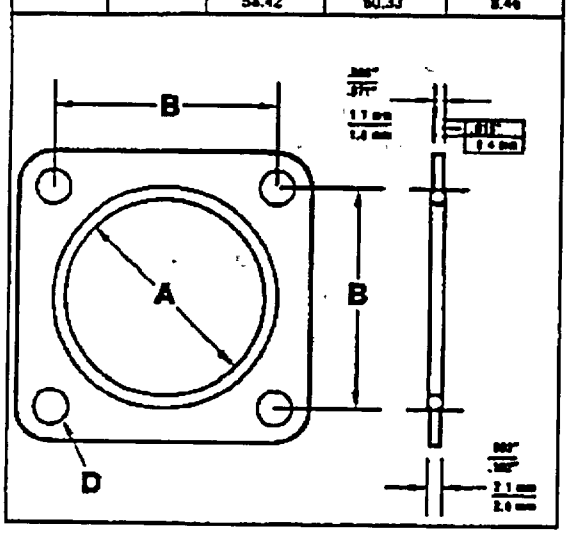


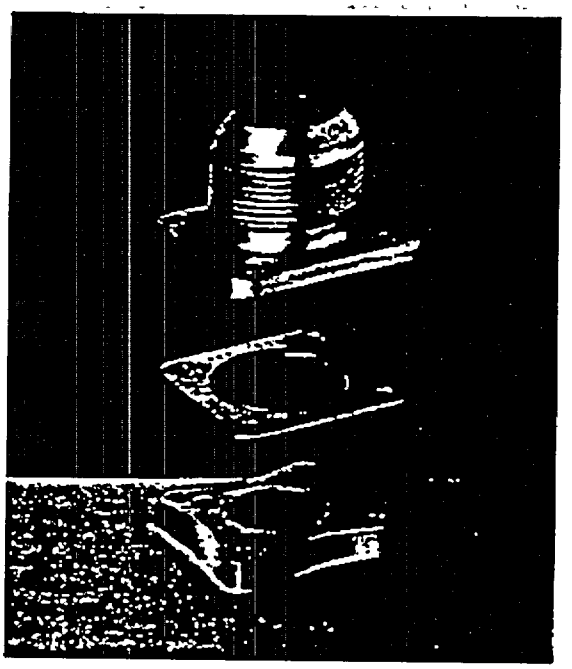
Flange-O-Seal

The Metallic O-Ring is semi-fastened into the metal retainer. The assembly is used for sealing jet engine fuel lines and exotic missile fuel lines from −452° F. (−269° C.) to 1,800° F. (982° C.).

It can be used for steel fittings MS20757 thru MS20762 and MS33786 fitting installation. The following assemblies are available from stock:

Part No.	Part No.	A Dia. inches / mm ± .005	B inches / mm ± .005	D inches / mm ± .005
−12	−12	.863 21.92	1.156 29.36	.210 5.33
−16	−16	1.113 28.27	1.312 33.32	.210 5.33
−17	−17	1.113 28.27	1.414 35.92	.271 6.88
−20	−20	1.425 36.2	1.656 42.06	.271 6.88
−24	−24	1.613 40.97	1.812 46.02	.271 6.88
−32	−32	2.300 58.42	2.375 60.33	.333 8.46





9

Nuclear Pressure Vessel Seals

The principal applications of Fluorocarbon O-Rings in nuclear power plants is the sealing of reactor pressure vessel heads. They are also specified for sealing applications on valves, steam generators, condensers, pumps, piping and other equipment components throughout the nuclear flow chart.

Fluorocarbon O-Rings can easily meet the three major requirements of nuclear applications: temperature ratings, high pressure ratings, and larger than average ring diameters (see Page 2 for specifics). Fluorocarbon Metallic O-Rings offer other significant advantages in nuclear applications: they are not normally affected by damaging environments or corrosives; they don't deteriorate with age, even in storage, and they resist radiation and chlorides.

TABLE 1 O-Ring—Alloy 718—DEFLECTION and SPRINGBACK—Inches (mm)

Load Force Unstrained /linear inch ϕ	.375 dia. x .038 wall (9.5 x 0.95)		.500 dia. x .050 wall (12.7 x 1.27)		.625 dia. x .063 wall (15.9 x 1.60)	
	2500 lb/in (45 kg/mm)		2500 lb/in (45 kg/mm)		4000 lb/in (71.5 kg/mm)	
Percentage	Deflection	Min. Springback	Deflection	Min. Springback	Deflection	Min. Springback
8%	.030 (0.76)	.009 (0.23)	.040 (1.02)	.013 (0.33)	.050 (1.27)	.017 (0.43)
10%	.037 (0.94)	.009 (0.23)	.050 (1.27)	.013 (0.33)	.062 (1.57)	.017 (0.43)
12%	.045 (1.14)	.009 (0.23)	.060 (1.52)	.013 (0.33)	.075 (1.91)	.017 (0.43)
16%*	.060 (1.52)	.009 (0.23)	.080 (2.03)	.013 (0.33)	.100 (2.54)	.017 (0.43)
17%	.064 (1.63)	.009 (0.23)	.085 (2.16)	.013 (0.33)	.106 (2.69)	.017 (0.43)

*Optimum compressible percentage. 8 to 17% compression may be utilized with UAP Inconel 718. Load forces may vary slightly below 17% inch compression.

Media to be Sealed

Media in the nuclear power plant which Fluorocarbon O-Rings can successfully seal include: ordinary (light) water, heavy water, boiling water, steam, borated water, carbon dioxide, helium, nitrogen, liquid metals including sodium, terphenyl and other phenyl fluids, and acids including boric acid.

Flange and Groove Details

Fluorocarbon O-Rings do not require expensive groove preparation and, being flexible, are easily installed. On pressure vessel head seals, a machined groove is required, the groove diameter being determined by the location of vessel rings so that minimum lift-off exists.

The O-Ring OD must be sufficiently large so that upon compression, the ring will expand and contact the groove outer wall. This limits hoop tension of the ring and provides a backup that restricts radial outward movement of the ring when the vessel is pressurized. Groove should be sufficiently wide so that the O-Ring ID does not contact the inside wall when the ring is compressed. Groove depth controls the amount of compression and the amount of load required to seat the ring. Table 1 shows the amount of flange load required to seat the seal.

The O-Ring and groove dimensions for internal and external pressure applications may be determined from the data on page 5.

Materials and Plating

Alloy 718 is the O-Ring material of choice on most nuclear sealing applications. Inconel 706 is also available. Alloy 718 used in Fluorocarbon O-Rings is annealed and age hardened, offers optimum strength and springback; and resists chlorides, radiation and corrosion. Type 304 stainless steel O-Rings are also offered for applications that are less critical and where a less expensive material will suffice.

Both Alloy 718 and Type 304 stainless steel O-Rings are available with silver plating of .004"—.006" (0.10 mm—0.15 mm) thickness. Ring OD can be controlled to .010" (0.25 mm) total tolerance after silver plating. The silver plating assures good adherence and ductility (softness) to conform to groove irregularities. Nickel plating is recommended when sealing sodium.

O-Ring Fabrication

Fluorocarbon Metallic O-Rings are fabricated by bending straight metal tubing into circular or other desired shapes. The two ends are welded together and the weld ground flush.

Where the proposed size of the fabricated O-Ring would prohibit shipping, the company offers on-site welding fabrication that meets the same quality standards as fabrication performed in our plant.

Tube and Ring Dimensions

The three most common tube diameters used for nuclear applications are shown below with the recommended relationship of tube diameter and wall thickness to the O-Ring diameter. Other tube diameters are also available for nuclear applications. See pages 6 and 7.

TABLE 2

Tube Diameter Inches/mm	Wall Thickness Inches/mm	O-Ring Diameter Inches/mm
.375 9.5	.038	Up to 180
.500 12.7	.050	120 to 260
.625 15.9	.063	220 and up

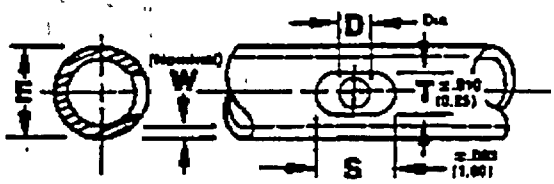
TABLE 3

O-RING DIAMETER Inches/mm	No. Slots or Holes
Up to 144 (3657.6)	8
144 (3657.6) and up.	12

*unless otherwise specified

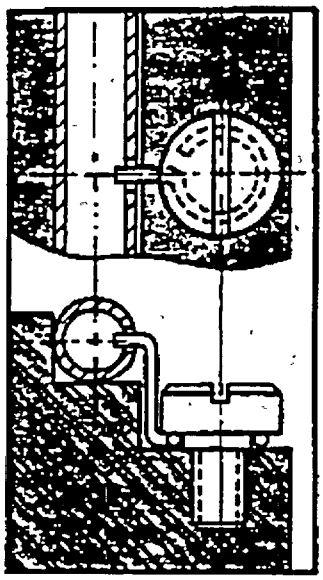
TABLE 4

SLOT or HOLE DIMENSIONS Inches (mm)



E	.375 (9.5)	.500 (12.7)	.625 (15.9)
W	.038 (1.0)	.050 (1.3)	.063 (1.6)
S	.281 (7.1)	.375 (9.5)	.438 (11.1)
T	.125 (3.2)	.205 (5.2)	.256 (6.5)
D	.070 (1.8)	.093 (2.4)	.125 (3.2)

STYLE A



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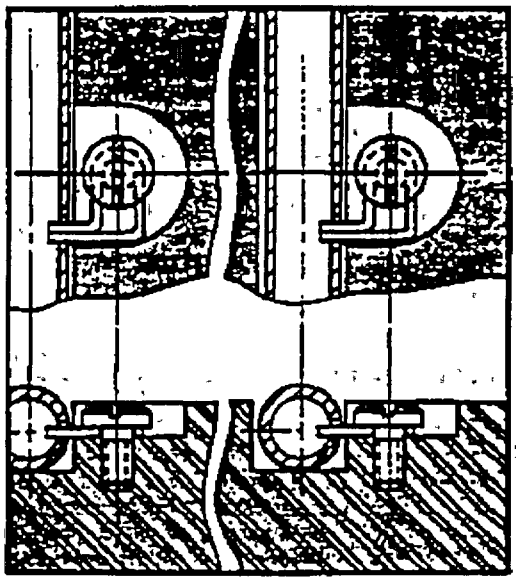
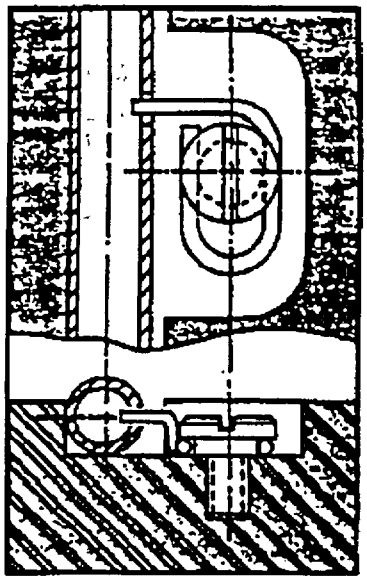


STYLE C



Retainer Clips

On nuclear pressure vessel heads, the rings are installed to the underside of the flange on the head. This requires clips to hold the rings in proper place and alignment during assembly of the head to the vessel. Slots are provided in the O-Ring to receive the retainer clips. In some instances the retainer clips are welded to the O-Ring. Instead of slots for retainer clips, drilled holes with additional self-energizing holes can be provided. The number of slots or holes and their size varies in relation to the ring and tube diameters (see Tables 3 and 4). The data shown assures installation without excessive O-Ring buckling in the groove and without endangering O-Ring strength. Different clipping methods are available, depending on vessel design, for both single and double ring applications (see drawings above—styles A, B and C).

How to Specify O-Rings

Denotes Metallic O-Ring	Tubing OD (Thirty-Seconds)	Wall Thickness (Thousandths)				
U	2	3	12	03	625	SE	A

Materials

1—Alloy 718
2—Stainless Steel 321
3—Aluminum
4—Copper
5—Alloy 600
6—Alloy X-750
7—Stainless Steel 304
8—Stainless Steel 316
9—Stainless Steel 347
X—As Specified

Metallic O-Ring OD (Inches) (Thousandths)

Type

SE—Self-energized on ID
PF—Pressure filled
NP—Not self-energized, not pressure filled
SO—Self-energized on OD
SX—Self-energized as spec.

Example:

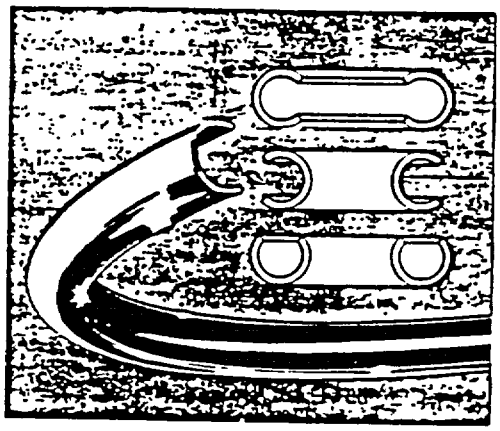
U2312-03625SEA

The above example, U2312-03625SEA, indicates a type 321 stainless steel O-Ring, 3/32" (2.38 mm) tube size, .012 (0.30 mm) wall thickness, 3.625" (92.06 mm) OD, self-energized (ID) and .001-.002" (0.03/0.05 mm) silver coating

Coatings

A—Silver	.001/.002 (0.03/0.05)	N—None	
B—Silver	.002/.003 (0.05/0.08)	P—Lead	.001/.002 (0.03/0.05)
D—Teflon®	.001/.003 (0.03/0.08)	R—Indium	.001/.002 (0.03/0.05)
E—Teflon	.003/.004 (0.08/0.10)	T—Nickel	.001/.002 (0.03/0.05)
L—Copper	.001/.002 (0.03/0.05)	V—Gold	.0005/.001 (0.02/0.03)

X—As Specified



Fluorocarbon Metallic C-Rings

Fluorocarbon Metallic C-Rings (designated MCR) are designed for static sealing on machinery or equipment and are available for internal pressure, external pressure, or axial pressure ID/OD applications. Because C-Rings are designed with an open side on the pressure side of the installation, the seal is self-energizing. Fluorocarbon C-Rings are offered in round or irregular shapes in a broad range of sizes from .126" (3.2 mm) OD x .032" (0.81 mm) free height to over 300" (7620 mm) OD x 2" (50.80 mm) free height. They are available in a wide variety of metal alloys and metallic or Teflon coatings. Sealing application temperature range is from cryogenic to 3,000°F. (1650°C.); pressure tolerances are from 10^{-10} torr to 100,000 psi (6,804 atm). Where customer requirements are large, the C-Ring provides the lowest unit price of any high performance seal on the market.

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Components Division
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Columbia, South Carolina 29290
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FAX (803) 783-4279

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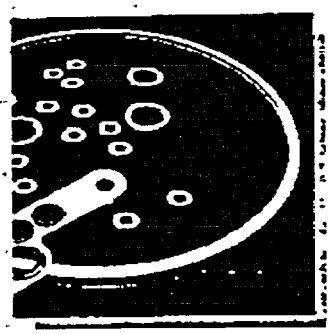
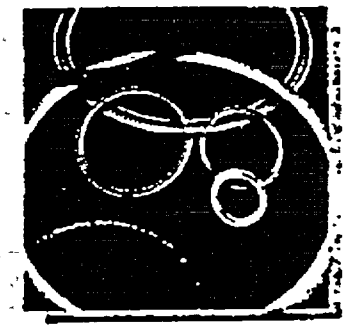
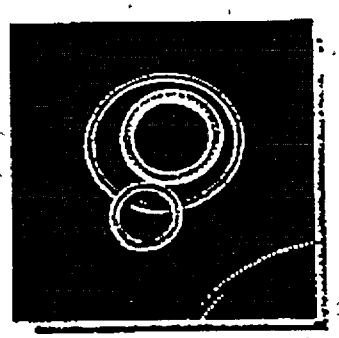
4.5.2 Blended Polytetrafluoroethylene (PTFE) O-Rings

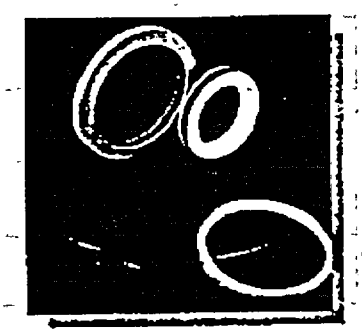
This section contains applicable technical data from a typical manufacturer of blended polytetrafluoroethylene (PTFE) o-rings. The PTFE o-rings used in the NAC-STC port covers are manufactured from virgin (unreprocessed) polytetrafluoroethylene base material filled with plastic. One product that satisfies the design requirements is the Fluoroloy K o-ring manufactured by the Furon Company, which has an operating temperature range of -450°F to +650°F. NAC has completed supplemental o-ring testing and has determined that the operating range of the PTFE o-rings can be extended to 735 °F. A description of tests performed and the results are contained in Certified Test Report D9-3362-1, Applied Technical Services, Inc., February 8, 1989.

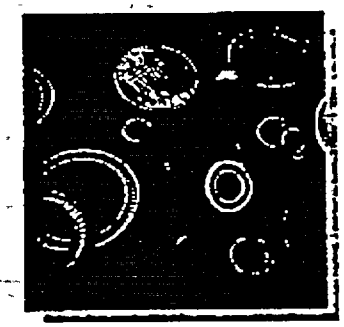
FLUOROCARBON MECHANICAL SEAL DIVISION











Omniseal® Design Handbook

14

Seal Jacket Materials

Sect 4

Fluorocarbon Seal Jacket Materials

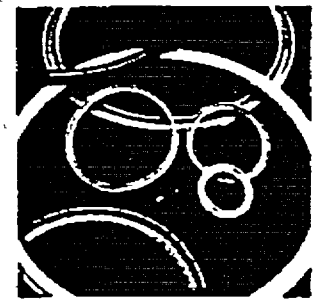
Fluorocarbon's seal materials are compounded and processed for optimum seal performance in a wide variety of sealing environments. The materials listed below are our most commonly recommended compounds, and are suitable for most applications.

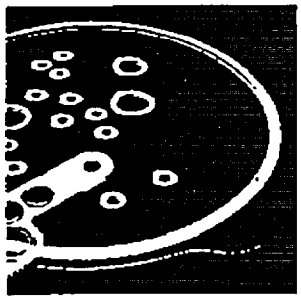
Over the years Fluorocarbon has developed over 80 different materials for seal use. These additional compounds are available should they be required in special cases. If in doubt about selection, contact our Technical Service Department for guidance. 1-800-544-0080

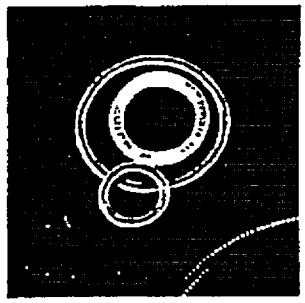
Code No.	Name and Description	Color	Application	Temperature Range Degrees °F.	Coefficient of Friction Nominal	Wear Resistance	Relative Cost 1 = Low, 5 = High
01	Fluoroloy 01 Virgin PTFE	White	Excellent for light to moderate dynamic and static service. Limited wear and heat resistance. Low gas permeability. Good cryogenic properties. Moderate to hard vacuum service. FDA approved.	+400° To -450°	.09	[illegible]	1
02	Fluoroloy S Premium PTFE	Yellow	Modified PTFE with similar properties to Fluoroloy 01 material but with substantially improved wear resistance.	+400° To -450°	.09	[illegible]	2
03	Fluoroloy SL Carbon/Graphite Filled PTFE	Gray	Excellent general purpose material for heat and wear resistance. Recommended for dry and poorly lubricated applications. Particularly suitable for water and steam service.	+500° To -450°	.09	[illegible]	3
06	Fluoroloy 06 Glass/Moly Filled PTFE	Gray	Tough, long wearing, heat resistant. Recommended for high pressure hydraulic service, steam and water. Caution: Can be abrasive running against soft metals at high surface speeds.	+450° To -450°	.09	[illegible]	1
08	Fluoroloy G Proprietary UHMWPE	Gold	Extremely tough, long wearing, but limited heat and chemical resistance. Particularly suitable for abrasive media. Recommended for long wear life under severe conditions.	+190° To -450°	.11	[illegible]	4
10	Fluoroloy K Ekonol® Filled PTFE	Tan	Proprietary plastic reinforced (filled) PTFE. Superior heat and wear resistance. Non-abrasive. Recommended for moderate to high speed dynamic service running against soft metals.	+500° To -450°	.15	[illegible]	3
12	Fluoroloy 12 Graphite Filled PTFE	Black	Excellent general purpose material with good heat and wear resistance. Non-abrasive. Compatible with all hydraulic fluids and most chemicals. Good in water and non-lubricating fluids.	+500° To -450°	.09	[illegible]	2
14	Fluorogold Premium Glass Filled PTFE	Yellow	Proprietary fiber glass filled PTFE with excellent heat, wear and chemical resistance. Good cryogenic properties. Caution: Can be abrasive running against soft metals at high surface speeds. Excellent material for back-up rings.	+500° To -450°	.09	[illegible]	3
23	Fluoroloy 23 Virgin Tefzel®	Clear	Thermoplastic with superior resistance to nuclear radiation, but limited heat and wear resistance. Not recommended for general purpose sealing.	+300° To -150°	.50	[illegible]	5
24	Fluoroloy B Carbon/Graphite Filled PTFE	Black	Similar to Fluoroloy SL material but increased hardness and wear resistance. Excellent in steam and water under severe conditions. Improved creep and extrusion resistance at higher temperatures. Good for back-up rings.	+500° To -450°	.10	[illegible]	4
33	Fluoroloy 33 Premium Filled PTFE	Black	Excellent wear material for higher temperatures, pressures and speeds. Excellent in water and water base solubond. Superior in dry or poorly lubricated applications. Can be abrasive running against soft metals.	+500° To -450°	.09	[illegible]	3
34	Fluoroloy 34 Polyester Elastomer	Cream	Elastomeric material with good wear and abrasion resistance, but limited chemical and temperature resistance. Excellent in hydraulic oils and water. Not recommended for steam.	+300° To -100°	.18	[illegible]	4
36	Fluoroloy 36 Glass/Moly Filled PTFE	Gray	Similar to Fluoroloy 06 material but somewhat softer for improved sealing at low pressure. Can be abrasive running against soft metals.	+500° To -450°	.09	[illegible]	1
49	Fluorowhite Proprietary UHMWPE	White	Proprietary composite with extremely good wear and abrasion resistance, but limited heat and chemical resistance. Meets FDA requirements.	+190° To -450°	.11	[illegible]	4
55	Fluoroloy 55 Virgin Peek	Tan	A high modulus material with excellent high temperature resistance. Recommended for back-up rings only.	+500° To -100°	N/A	N/A	5

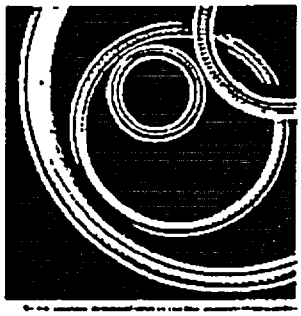
® Ekonol is a registered trademark of SCHICO Co.

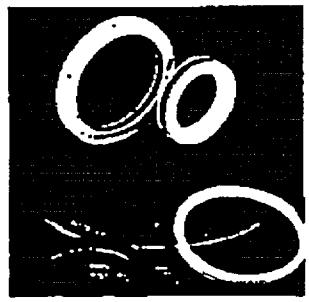
®Tefzel is a registered trademark of DuPont Corporation.

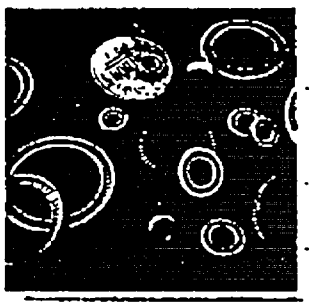












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4.5.3 Expansion Foam

This section contains the manufacturer's technical bulletin for the material used to allow for the expansion of the neutron shield as the cask heats up.

Foamega® Brand Cellular Silicones

New Products...New Versatility...New Applications

Foamega® Brand Cellular Silicones, a unique family of products, possess a wide range of physical properties that meet the challenging and demanding applications presented by industry.

Design engineers are recognizing that, because of their light weight, low compressibility and resistance to compression set, they are excellent for gasketing, sealing, sound and vibration damping and thermal insulation.

Foamega offers many exceptional properties and characteristics:

- Withstands extremes in chemical and climatic environments.
- Maintains flexibility and compressibility over a temperature range of −65°F to +450°F.
- Is inherently inert and stable, non-degradable, and ozone and UV-resistant.
- Certain grades are UL-recognized for flame resistance and produce no toxic by-products upon forced combustion.
- Minimal water absorption, maximum 5 percent.
- Easy application to all surfaces, using silicone bonding adhesives; also available with either acrylic or silicone pressure-sensitive adhesives.
- Non-corrosive to metal surfaces.
- Available 1/16" to 1" thick (no laminations) in continuous lengths, 36" wide. Continuous length allows for the most efficient utilization of material during conversion or fabrication into pre-cut shapes or gasket stripping.

Typical Physical Properties

Product	Density Lbs/Ft.³ (Typical)	Compression Deflection 20%@25°C Psi	Compression Set 50%@22 Hr./225°F % (Max.)	Tensile Strength Psi (Min.)	Elongation % (Min.)	Color
Low Density/Flame Retardant FOAM						
HT-[illegible]	14	5-7	10	25	100	White
General Purpose SPONGE						
HT-600 Medium	22	6-14	15	25	60	Red
HT-620 Firm	26	12-20	15	40	60	Grey / Black
Low Compression Set SPONGE						
HT-610 Medium	22	6-14	5	25	60	Red
HT-630 Soft	16	2-7	5	25	60	Grey / Black
Low Compression Set/Flame Retardant SPONGE						
HT-660 Medium	22	6-14	5	25	60	Red
HT-670 Soft	16	2-7	5	25	60	Grey / Blue

Specifications

Product	A-[illegible]	A-[illegible]	MIL-R-6130 Type II, Cl. BAC	MIL-R-[illegible]	Boeing BMS 1-[illegible]	Boeing BMS 1-[illegible]	Boeing BMS 1-[illegible]	Douglas DMS [illegible]	Douglas DMS [illegible]	Lockheed LAC-[illegible]	Lockheed [illegible]	General Dynamics [illegible]	UL 1[illegible]	[illegible]	[illegible]
HT-[illegible]						X									
HT-600	X		X		X			X			X	X	X	X	X
HT-620		X						X			X	X			
HT-610	X		X	X								X			
HT-630												X			
HT-660	X		X			X			X	X			X	X	X
HT-670						X			X	X					

Tolerances

Size	Tolerance
1/16"	+1/32−1/64
1/8"	±1/32
3/16"	±1/32
1/4"	+3/64−1/32
3/8"	±1/16
1/2"	±1/8
5/8"	±1/8
3/4"	±1/32
1"	±1/64

. . . the High-Performance Silicone with 10 Ways to Improve Product Performance

1 Insulates in two ways—against electrical current and against heat and cold. Foamega has good dielectric properties that make it ideal for applications requiring electrical insulation, *plus* thermal insulation and one or more of Foamega's other attributes—in computers and other electronic equipment, in microwave ovens and other appliances, in lighting fixtures and in numerous other applications. Its low thermal conductivity gives Foamega an advantage when it is used as gasketing around metal window and door frames and between metal and glazing.

2 Handles heat and cold in a range from −65°F to +450°F. While other materials tend to become dry and brittle and to disintegrate when subjected to heat, Foamega retains its form and density. Foamega HT-603 and HT-850 are UL-listed for fire resistance, are self-extinguishing in a maximum of 10-15 seconds under forced combustion, and produce no toxic by-products. They are quite possibly the best materials for use as fire barriers in automobiles, as bulkhead seals and fire stops in aircraft, as a backup to upholstery and slipcover materials used in aircraft, automobiles, hotels and motels, hospitals and other institutions. In applications requiring heat-resistance, non-combustibility and freedom from dangerous fumes and gases, Foamega proves its value in saving lives and property.

3 Stands up to pressure. Low compression set at high and low temperatures is one of the reasons Foamega makes such excellent gasketing for engine exhaust manifolds, cooling systems and other high-temperature, high-pressure applications.

4 Cushions vibration and stops the wear and tear it can cause. Vibrational damping in aircraft, in automobile steering systems, in air conditioners and other appliances, in laboratory instruments and in hundreds of other applications is an important Foamega contribution. Wherever vibrations can cause a potential hazard, an interference with operation of other systems or merely an annoyance, look to Foamega for a most-efficient solution.

5 Quiets noise. Foamega foam and sponge are not only sound-absorptive by nature, they also provide one of the best means for stopping the distracting, irritating noises of hard surfaces contacting hard surfaces. Automobile dash panels, for example, often hide a potential for squeaks and rattles that need not exist—with Foamega "treatment."

6 Deters water damage. Foamega does not absorb water and provides an impermeable barrier to water incursion when used as washers, "O" rings and other forms of gasketing. Being non-conductive and non-corrosive also, it is perfect for water seals around electrical and electronic components. For watercraft, it is highly effective in making hatches and portholes watertight. For automobiles, it provides a moisture barrier around windshields and other glass. Sidelight: Foamega is also impervious to fungus, insect infestation and rodent damage.

7 Resists chemicals. Foamega is inherently inert and stable and is non-degradable in most chemicals. It resists ozone and UV radiation (Bisco silicone products are used for nuclear shielding in hundreds of nuclear power plants.) For these reasons it is able to perform in environments that rule out use of many other materials.

8 Keeps out weather in all its forms—heat, cold, wind, rain and snow. Foamega's low level of thermal conductivity, its non-water absorptive qualities, and its ability to form a tight seal recommend its use for gasketing building components, lighting fixtures and other items requiring a tight weather seal.

9 Stays flexible at temperatures as low as −100°F and as high as 600°F.

10 Installs easily by means of silicone adhesive bonding. Additionally, all Foamega products come with either acrylic (350°F) or silicone (450°F) pressure-sensitive adhesive pre-applied.

Foamega—a complex of benefits

When you use Foamega for any of the above reasons, you get a combination of advantages—not merely the one you seek. For example: use Foamega for thermal insulation between glass and metal and you also get excellent vibration damping that can prevent fracturing of glass. Use it as a weather barrier on electronics exposed to the elements and you gain insulation values as well.

Few, if any, other materials offer the multiple advantages of Foamega.

How can Foamega help you?

Only a limited number of Foamega's applications are mentioned here. Hundreds more are possible, depending on your needs and imagination. Agencies like NASA and DOT are presently evaluating Foamega for fireblocking and related applications.

Bisco Products stands ready to help you—with evaluating your present products in terms of Foamega capabilities, and with custom design and engineering services.

We welcome your inquiry.

bisco
One of the Brand Companies

bisco products, inc.
1420 renaissance drive
park ridge, illinois 60068
(312) 298-1200
telex 282482

The properties listed herein are typical values and should not be used for writing specifications.

8/087.5M

4.5.4 Fireblock Protective Coating

This section contains the manufacturer's technical data for the material used to preclude a lead melt during fabrication welding or a fire accident.

FPC PROPERTIES

Description	Typical Values	Test Methods
FLAMMABILITY PROPERTIES		
Surface Flammability (20 mm) Flame spread index	0	ASTM E 162
Optical density of smoke (smoldering or burning)		ASTM E 662
90 seconds	3	
4 minutes	10	
maximum (20 minutes)	68	
Toxic gas generation (Flaming Mode)		Boeing BSS 7239
CO (max)	362 ppm	
HCl	10 ppm	
SO_2	4 ppm	
HF, HBr, $COCl_2$, NO_2	Less than 2 ppm	
Heat Release rate	Peak 67kW/m² 2 min. total 3MW min/m²	FAA 14CFR Part 25 Appendix F Part III (O S U)
Horizontal burn through @ 1800 degrees F	no failure after 4 hrs.	BISCO Test TM115 1
Flame Resistance (UL)	94 V0	UL 94
Flame & Glow	less than 1 sec. (self extinguishing)	
Char length	0	
THERMAL PROPERTIES		
Thermal Conductivity (140°F) (K factor)	Approx. 630 BTU in/hr ft²/°F	ASTM C 177 (1/8" TH)
Thermal Resistance (R factor)	Approx. 216 hrs ft²/°F/BTU	ASTM C 177 (1/8" TH)
Sound Transmission Loss (STC)	17	ASTM E 90
ELECTRICAL PROPERTIES		
Dielectric Strength	60 volts/mil - min	ASTM D 149 (1/8" TH)
Volume Resistivity	4.4 x 10¹⁴ ohm/cm	ASTM D 257 (1/8" TH)
Power Factor @ 100 HZ	054	ASTM D 150 (1/8" TH)
Dielectric constant @ 100 HZ	1 90	ASTM D 150 (1/8" TH)

[illegible]

For more information or samples, please contact

bisco products, inc.
1420 renaissance drive
park ridge, illinois 60068
(312) 298-1200
telex 282-482

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2/88

FROM BISCO PRODUCTS

FPC*® (Fireblock Silicone Foam).. *A lightweight, flexible, elastomeric silicone foam with extraordinary fire barrier properties*

*Patent Pending

HOW SUPPLIED

FPC (fireblock silicone foam) is provided in continuous rolls or converted into 2" or 3" wide tape with and without pressure sensitive adhesive. Custom sheets or forms are prepared to customer specifications.

Cell structure	Modified closed cell silicone foam on fiberglass
Color	White
Density	32 lbs/cu ft
Thickness	From .062" to .250"
Width	Up to 36"
Length	Continuous Rolls

All materials manufactured in the USA

MATERIAL ADVANTAGES

- Non combustible
- Zero flame spread
- Low smoke generation
- Non toxic.
- Lightweight, resilient, flexible, conformable
- Effective thermal, acoustical and dielectric properties
- Superior UV resistance
- Combines readily with structural or decorative materials

APPLICATIONS

- **AIRCRAFT/AEROSPACE INDUSTRY** Firewall protection, cable and conduit insulation, engine compartment protection, interiors (ceiling, walls, floors, galley liner), structural composite protection, cargo lining
- **MILITARY INDUSTRY.** High performance fire/thermal insulation, sound transmission insulation, cable, conduit and pipe insulation, hull insulation, armoury, packaging materials
- **MASS TRANSIT INDUSTRY.** Cable and conduit insulation car underbodies, truck and brake areas, battery box transformer; control box, third rail protector, arc protection, firewall, noise dampening powerships, sealing
- **OTHER INDUSTRY APPLICATIONS.** Gasketing, welding blankets and curtains, cable, conduit and pipe insulation, electric arc isolation, appliance insulation

ANOTHER BREAKTHROUGH SILICONE PRODUCT FROM BISCO

Lightweight, flexible, elastomeric FPC silicone foam has extraordinary fire blocking properties. When valuable, crucially important equipment must withstand fire and intense heat to function, FPC assures performance. FPC, used in combination with structural composite and other engineering materials, adds two safe cards fully to the most stringent industry requirements.

FPC simply will not burn. Tests show that only a 1/16" layer is needed to block a 1900°F flame for several hours.

Bisco's FPC also possesses other physical characteristics typical of silicone elastomeric foams. It is inherently non toxic and most corrosion and can be used in sensitive medical and electronic applications.

ABOUT BISCO PRODUCTS, INC.

Bisco Products, Inc., one of the Beard Companies, has developed specialty, high performance products to meet many unique needs of industry.

For applications requiring fire safety or a high degree of thermal or chemical resistance, we manufacture a variety of solid or cellular elastomeric sheets, including fabric reinforced materials. These products are used by aerospace, electronics, automotive and medical industries. Other manufactured products we have radiation shielding and radiation resistant materials and systems for the nuclear power and defense industries.

4.5.5 Viton O-Rings

This appendix provides a description of the leak testing performed using the Viton o-rings at temperatures exceeding the manufacturer's elevated temperature limit. In addition, it also contains the o-ring manufacturer's material report on the Viton material.

NAC, with the aid of an independent laboratory, performed leak testing in excess of 550°F to demonstrate the capability of Viton to perform at the elevated temperature and to determine the leak rate of the alternate port cover design at the elevated temperature. It was determined that the alternate port cover o-ring maintains its sealing capability at a temperature of 575°F after prolonged heating above 400°F. Testing was done in accordance with NAC Specifications. Two fixtures were put into a thermal test chamber. All the fittings attached to the test assemblies were checked and confirmed leaktight. The assemblies were heated in a manner that conservatively approximates the fire-transient analysis and one fixture was held at a temperature above 550°F for more than 4 hours, 37 minutes. The region inside the port cover was evacuated to below 2 psia, backfilled with helium at 0 psig, evacuated and backfilled again and then leak checked. The leak test procedure emulates the testing of the o-ring with one atmosphere of pressure acting on the o-ring during the test. The data pertinent to the test is:

	Test Assembly 16	Test Assembly 64	Fire-Transient
Time Above 400°F	~6:32 hours	~5:52 hours	4:37 hours
Time Above 550°F	~5:05 hours	~4:25 hours	0 hours
Maximum Seal Temperature	~575°F	~575°F	547°F

The test temperature of 550°F was selected because it approximates the maximum calculated o-ring temperature in the fire-transient analysis. The duration was selected because it is the calculated duration that the o-ring is above the manufacturer's maximum recommended o-ring temperature of 400°F. This results in a conservative test due to the slower heat-up rate of the oven compared to the heat-up rate of the port cover in the fire-transient analysis.

Each test assembly was leak checked after the temperature test, while at a temperature of approximately 575°F. The measured leak rate for each of the assemblies was less than 4.0×10^{-8} atm-cc/sec. In conclusion, the Viton o-rings can provide a leaktight seal, in accordance with ANSI N14.5-1997, at an elevated temperature.

Sep-17-99 03:35P P.01

Parker Seals

Software Version: 2.0 9/17/99

Customer Identification

Company:	NAC International
Contact:	George Carver
Project Name:	
Address:	
City:	Zip Code:
State:	
Telephone No.:	770-447-1797 fax
Date/Time:	9-17-1999 15:27

Ordering Specifications

Application:	O-ring Only
Compound Number:	V0835-75
Size:	

Compound Information

Search Parameter

Material Selection Method:	Compound Search
Contained Media:	
Desired Temperature Range	
High:	
Low:	

Selected Material Information

Durometer (Shore A):	75
Polymer:	Fluorocarbon GLT - LOWTEMP COMPOUND.
Temperature	
Normal High:	400 °F
Extended High:	400 °F
Normal Low:	-40 °F
Color:	Black
Static Application Only:	No
Military Spec.:	MIL-R-83485
AMS NAS Spec.:	None
SAE/ASTM Spec.:	None

Seal Size Information

Sizing Selection Method:	Known: O-ring P/N. Search for. O-ring dimensions

Sep-17-99 03:35P P.02

Parker

Compound Data Sheet
O-Ring Division United States

MATERIAL REPORT

REPORT NUMBER. KJ0835
DATE: 10/10/89

TITLE: Test of Parker Compound V0835-75 to MIL-R-83485, Type I.

PURPOSE: To determine if V0835-75 meets MIL-R-83485, Type I.

CONCLUSION: V0835-75 meets the above specification.

Parker O-Ring Division
2360 Palumbo Drive
Lexington, Kentucky 40509
(606) 269-2351

Sep-17-99 03:35P P.03

REPORT DATA

Report Number: KJ0835

ORIGINAL	MIL-R-83485 TYPE 1, O-RINGS & COMPRESSION SEALS	V0835-75 ACTUAL VALUES
Specific Gravity	As determined	1 75
Hardness points	75 ± 5	78
Tensile Strength, psi. min.	1600	1708
Elongation, % min.	120	180
Temperature Retraction, 10% (TR-10), °F, max.	-20	-22
AFTER AIR AGING, 70 HRS @ 75° + 5°F, Compression Set		
% of original deflection, max.	25	-- (14)
AFTER AGING, 70 HRS. @ 75°F IN TT-S-735, TYPE III		
Hardness Change, pts.	+5	77 (-1)
Tensile Strength decrease, %, max	30	1662 (-3)
Elongation decrease, %, max.	20	165 (-8)
Volume change, %, max	1 to 10	-- (+2)
AFTER AIR AGING, 70 HRS. @ 528° ± 5°F		
Hardness change, pts	+5	78 (0)
Tensile Strength decrease, % max	35	1136 (-33)
Elongation decrease, %, max.	10	235 (+31)
Weight loss, %, max	12	-- (-7)
AFTER AIR AGING, 166 HRS @ 347° ± 5°F, COMPRESSION SET		
% of original deflection, max.	25	-- (15)
18 hrs cooling		-- (24)
AFTER AIR AGING, 22 HRS @ 392° ± 5°F, COMPRESSION SET		
% of original deflection, max	20	-- (11)

Sep-17-99 03:35P P.04

AFTER AGING, 70 HRS @ 347°MIL-R-83485 ±5°F in AMS-3021	MIL-R-83485 TYPE 1, O-RINGS % COMPRESSION SEALS	V0835-75 ACTUAL VALUES
Hardness change, pts	+0, -15	73
Tensile Strength decrease, %, max.	35	1406 (-18)
Elongation decrease, %, max.	20	171 (-5)
Volume change, %	1 to 20	-- (+15)
Compression set, % of original deflection, max.	10	-- 7
18 hr. cooling		-- 9

4.5.6 Sample Input File

This section provides a sample SAS2H input file employed in the containment analysis of the directly loaded 17×17 fuel at 60,000 MWD/MTU and 3.5 wt % ^{235}U.

Sample File

```
=SAS2H       PARM=(HALT09,SKIPSHIPDATA)
Class 1 - aa17b - STC Hybrid17 (Rev 0) - 3.5 w/o U235, 60000 MWD/MTU, 5 - 16 years cool time
27GROUPNDF4 LATTICECELL
UO2         1 0.943 900 92235 3.5 92238 96.5 END
ZIRCALLOY  2 1.0 620 END
H2O         3 DEN=0.725 1.0 580 END
ARBM-BORMOD 0.725 1 1 0 0 5000 100 3 550.0E-6 580 END
ZIRCALLOY  4 1.0 580 END
H2O         5 DEN=0.725 0.9772 580 END
ZIRCALLOY  5 0.0228 580 END
END COMP
SQUAREPITCH 1.2598 0.8192 1 3 0.9500 2 0.8360 0 END
NPIN=264 FUEL=365.760 NCYC=3 NLIB=3 PRIN=6 LIGH=5
INPL=1 NUMH=24 NUMI=1 MXTUBE=4 ORTU=0.6025 SRTU=0.5644 END
POWER=18.5535 BURN=499.7636 DOWN=60 END
POWER=18.5535 BURN=499.7636 DOWN=60 END
POWER=18.5535 BURN=499.7636 DOWN=1461 END
FE 0.6738 CR 0.1900 NI 0.1150 MN 0.0200 CO 0.0012
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 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**  4.0 E T
COOLING 5 - 16 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
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$$  F6
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 YEARS AND ACTINIDE GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
```

Sample Input File (Continued)

```
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  4.0 E T
COOLING 5 - 16 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
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$$  F5
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 YEARS AND LIGHT ELEMENT 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**  4.0 E T
COOLING 5 - 16 YEARS AND LIGHT ELEMENT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
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$$  F4
83**  1.40e+7  1.20e+7  1.00e+7  8.00e+6   6.50e+6  5.00e+6
      4.00e+6  3.00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1.00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
56$$ F0  T
END
```

Chapter 5

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5.0 SHIELDING EVALUATION

The NAC-STC uses an optimized multiwall design to provide the most efficient shielding arrangement possible, and to comply with 10 CFR 71 limits. This chapter provides a description of the NAC-STC shield design, design basis contents, and the conservative shielding analyses used to determine the transport dose rates.

The NAC-STC is designed to safely transport intact spent fuel assemblies in two configurations: directly loaded and canistered. In the directly loaded configuration, standard PWR fuel assemblies are placed directly into a fuel basket installed in the cask cavity. In the canistered configuration, a sealed transportable storage canister loaded with fuel assemblies is placed in an empty cask cavity with top and bottom spacers. In the directly loaded configuration, the NAC-STC can transport up to 26 standard PWR fuel assemblies. In the canistered configuration, the NAC-STC can transport up to 36 Yankee Class fuel assemblies.

For directly loaded fuel, the shielding evaluation considers reference fuel assemblies in 14×14, 15×15, 16×16 and 17×17 array sizes. The reference fuel assemblies have parameters selected from all of the fuel assemblies of the same array size to maximize the shielding source terms. The design basis fuel for the canistered configuration is the Yankee Class, Combustion Engineering, Type A, 16×16 PWR fuel assembly.

The NAC-STC can also safely transport Greater Than Class C (GTCC) waste in a canistered configuration. The GTCC waste, consisting of activated steel, is placed in a container (see Figure 5.1-4) that is the same size as a Yankee Class fuel assembly. Up to 24 GTCC containers can be loaded into the GTCC canister.

The NAC-STC is assigned a nominal Transport Index for shielding of 21 (TI = 21) based on the requirement of 10 CFR 71.4 and the analysis of Section 5.1.4. The maximum dose rate at 1 meter from the NAC-STC in normal conditions of transport is 20.3 mrem per hour, based on the directly loaded reference fuel. The actual measured dose rate is expected to be less.

The shielding evaluation for directly loaded fuel, canistered fuel and GTCC waste demonstrates compliance with 10 CFR 71 limits. The dose rates for the canistered Yankee Class fuel and

GTCC waste dose rates are shown to be significantly less than those for the directly loaded fuel configuration for both normal and accident conditions.

The shielding evaluation of the directly loaded configuration is performed using the SAS2H sequence (Hermann, 1995) of the SCALE-4.3 package for the PC (ORNL, 1995). This sequence uses the computer code ORIGEN-S (Hermann, 1989) to calculate the source terms. The MCBEND (AEA Technology, 2000) computer code is used to calculate the cask dose rates for normal transport and hypothetical accident conditions. The shielding analyses show that the dose rates are below regulatory limits.

The shielding evaluation of the Yankee Class canister fuel and GTCC waste is performed using SCALE 4.3 for the PC (ORNL, 1995). This code uses SAS2H (Herman, 1995) to calculate source terms. 1D shielding evaluations were performed using SAS1 (Knight, 1995). The shielding analyses show that the dose rates are well below the regulatory limits stated in 10 CFR 71 and are well below the dose rates reported for the directly loaded fuel.

Directly Loaded Fuel

The directly loaded basket construction is based on a tube and disk design. PWR fuel is loaded into 26 fuel tubes fabricated from Type 304 stainless steel sheets. BORAL or TalBor neutron absorber is encased in stainless steel on the outside face of the fuel tube. Twenty 5/8-inch thick aluminum disks are spaced between thirty-three 1/2-inch thick Type 17-4 PH stainless steel support disks to provide heat transfer. Radial shielding of PWR fuel in the directly loaded basket is provided by the multi-wall design of the NAC-STC cask body. Axial shielding is provided by the cask body closure lids and end forgings and the impact limiters.

Canistered Fuel and GTCC Waste

The canister containing Yankee Class fuel or GTCC waste is placed in the NAC-STC cavity with top and bottom spacers. The placement of the canister between the top and bottom spacers effectively precludes the source regions from streaming through areas above and below the neutron shield and tapered regions of the lead. In addition to the radial and axial shielding provided by the cask body and lids, radial and axial shielding is provided by the canister 5/8 inch shell, the 8 inches of stainless steel from the canister lids and 1 inch of steel from the canister bottom.

5.1 Discussion and Results

The radiation protection provided by the NAC-STC is in the form of solid multi-walled shielding materials, which totally surround the fuel. These shielding materials include steel and lead for gamma shielding and a borated polymer (NS-4-FR) for neutron shielding. The multi-walled arrangement of steel and lead in the NAC-STC provides optimal weight for gamma attenuation. The NS-4-FR neutron shielding material has a hydrogen density close to that of water and serves to moderate fast neutrons, which are then captured in the boron. Boron capture in the neutron shield minimizes the contribution of secondary capture gammas to surface dose rates.

The NAC-STC uses a multi-walled arrangement for both radial and axial shields. The arrangement of the radial gamma shielding in the cask body is a 1.5-inch thick stainless steel inner shell and a 2.65-inch thick stainless steel outer shell with a 3.70-inch thick lead filled annulus between them. The radial neutron shield is arranged around the outer steel shell with a 5.5-inch thick NS-4-FR layer, covered by a 0.25-inch (6 mm) thick neutron shield shell. The bottom of the cask contains a steel/NS-4-FR/steel shield arrangement with the two stainless steel components providing 11.65 inches of gamma shielding and 2 inches of NS-4-FR neutron shielding. The top of the cask has shields in the form of two closure lids. The inner lid also has a steel/NS-4-FR/steel arrangement with 6.0 inches of steel below 2 inches of NS-4-FR and 1.0 inch of steel above it. The outer lid is a 5.25-inch thick steel disk.

5.1.1 Design Criteria

The shielding design criteria for the NAC-STC meets the requirements of 10 CFR 71 and IAEA Safety Standard Series No. ST-1. For normal conditions, the dose rate limits specified in 10 CFR 71.47 and paragraph 572 of IAEA Safety Standard Series No. ST-1 for consignments under exclusive use are: 1,000 mrem/hour on the surface of the enclosed package, 200 mrem/hour on the outer surfaces of transport vehicle and 10 mrem/hour at 2 meters from the vertical planes represented by the outer lateral surfaces of the transport vehicle. The cask surface dose rate is less than 200 mrem/hour, except at the gap between the neutron shield and the upper impact limiter and at the rotation trunnions, where the maximum dose rate is 366 mrem/hr. The maximum dose rate at the personnel barrier, which is the accessible surface of the package, adjacent to the gap between the neutron shield and upper impact limiter, is significantly less than 200 mrem/hr. Note: The cask tie-down structure that is present at this location is conservatively not considered. The 10 mrem/hr criterion has also been met at all locations 2 meters from the railcar. Under hypothetical accident conditions, 10 CFR 71.51 and IAEA Safety Standard Series

No. ST-1, paragraph 656, specify a dose rate limit of 1,000 mrem/hour at 1 meter from the surface of the cask. This criterion has also been met at all locations.

The accessible surface of the package is defined as a personnel barrier that will be on the same plane as the outer radial surface of the top half of the impact limiters. The personnel barrier will attach to the edge of the railcar between the impact limiters. The personnel barrier location is shown in Drawing 423-901.

5.1.2 Design Basis Fuel

The NAC-STC has two configurations for transport of design basis fuel: directly loaded and canistered. The design basis fuel for the directly loaded configuration is described in Section 5.1.2.1. The second configuration is for canistered Yankee Class fuel and GTCC waste. The design basis fuel for shielding for this configuration is described in Section 5.1.2.2.

5.1.2.1 Design Basis Directly Loaded Fuel

The NAC-STC can transport up to 26 directly loaded, intact PWR fuel assemblies over a range of burnups, initial ^{235}U enrichments, and minimum allowable cool times. The general fuel characteristics for directly loaded fuel are given in Table 5.1-1. Detailed material and geometry descriptions for the fuel types evaluated are provided in Section 5.2. Reference fuel assemblies have been developed and analyzed to envelope PWR fuel for 14×14, 15×15, 16×16, and 17×17 array sizes. These assemblies are constructed by surveying assembly data for assemblies less than 165 inches in length (the length of the STC cavity) and using bounding fuel parameters to maximize fuel mass (MTU) and hardware source terms. Decay heats and dose rates have been calculated for a finite range of burnups, initial ^{235}U enrichments, and cool times to generate an allowable loading table, or minimum cool timetable. Adherence to the cool timetable ensures that heat load and dose rate limits will not be exceeded.

Three-dimensional dose rates are calculated using a response function methodology. Each of the four fuel assembly array sizes is analyzed over a range of source regions and source types with unit source in each relevant energy group. Source types considered are fuel neutron, fuel gamma, fuel secondary gamma (n-gamma), in-core fuel hardware (grid spacers, steel guide tubes, etc.), plenum, and end fitting hardware. These sources are analyzed in a finite number of energy groups with a unit source in each group. The scalar product of source term and response function allows for the creation of large arrays of dose rate results, whether they are for a single detector, or the maximum or average over a detector surface. In this analysis, detector maximum responses have been used exclusively to generate minimum cool timetables.

5.1.2.2 Design Basis Yankee Class Canistered Fuel and GTCC Waste

The design basis fuel for the Yankee Class canistered configuration for shielding purposes is the Combustion Engineering (CE), Type A, 16×16 PWR assembly with an initial enrichment of 3.7 wt % ^{235}U, a uranium mass of 239.4 kilograms, a burnup of 36,000 MWD/MTU and 8.0-year cooling time. To meet maximum cask decay heat limits, an 8.1-year cool time is required. The 8.0-year cooled source terms are conservatively used as the shielding design basis. The dose rates resulting from this assembly are higher than those of the other Yankee Class fuels: CE Type B, and Westinghouse, Exxon, and United Nuclear Type A and B fuel assemblies. The design basis Yankee Class fuel characteristics are given in Table 5.1-1. The design basis Yankee Class fuel physical parameters are presented in Table 5.1-2. The design basis canister fuel assembly source terms are presented in Table 5.1-3, and a sketch of the fuel assembly is shown in Figure 5.1-3.

Source terms and dose rate evaluations concluded that for the Westinghouse, United Nuclear, and CE Yankee Class fuel assemblies at 32,000 MWD/MTU require minimum cooling times of 19, 11 and 7 years, respectively. The minimum enrichments for these assemblies are 4.94, 4.0 and 3.5 wt %, respectively. Exxon fuel, with a burnup of 36,000 MWD/MTU and a minimum initial enrichment of 3.5 wt %, requires a minimum cooling time of 16 years for assemblies containing steel hardware in the active fuel region, and 9 years for assemblies with Zircaloy hardware.

The NAC-STC can also safely transport Yankee GTCC waste. The GTCC waste, consisting of activated steel, is placed in a container (see Drawing 455-888 and Figure 5.1-4) that is the same size as a Yankee Class fuel assembly. Up to 24 GTCC containers can be loaded into the GTCC canister basket. The GTCC canister is loaded in the NAC-STC for transport.

The design basis gamma source for Yankee GTCC waste is determined from dose rate measurements and chemical assay of the GTCC waste. This gamma source is primarily due to the activation of the core baffle from 30 years of neutron flux exposure and to a lesser extent from surface contamination. The design basis source term for the GTCC waste canister is 9.493×10^{15} photon/s, which is equivalent to 125,000 curies of ^{60}Co. The design basis thermal output is 1.93 kW.

The transportable storage 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. Due to the low number of rods, the reconfigured assembly fuel mass is significantly less than the fuel mass contained in the design basis fuel assemblies. Because source term (neutron and gamma) is directly proportional to fuel mass, for a given burnup, the reconfigured assembly source term is bounded by that of the design basis Yankee Class fuel assemblies. The lower source term of the 64 rod reconfigured assembly more than offsets any reduced self shielding associated with its lower mass. In addition, each Reconfigured Fuel Assembly fuel rod is placed within a steel enveloping rod. Consequently, a rigorous shielding analysis is not required for the Reconfigured Fuel Assembly.

5.1.3 Shielding Materials

The shielding materials are selected and arranged to minimize cask weight while maintaining overall shield effectiveness. Lead and steel are chosen as effective gamma radiation shields, and NS-4-FR is provided to efficiently moderate and absorb the neutron radiation, while minimizing the generation of secondary gamma radiation.

5.1.4 Results

For both the directly loaded and the canistered transport configurations, this section demonstrates that the NAC-STC satisfies the regulatory criteria of 10 CFR 71.47 and paragraph 572 of IAEA Safety Standard Series No. ST-1 under normal transport conditions; and 10 CFR 71.51(a) and paragraph 656 of IAEA Safety Standard Series No. ST-1 for hypothetical accident conditions. Specifically, for an exclusive use shipment in an enclosed transport vehicle, the dose rates remain less than 1,000 mrem/hour on the surface of the package, less than 200 mrem/hour at all locations on the surface of the personnel barrier and less than 10 mrem/hour at all locations 2 meters from the edge of the railcar (any point 2 meters from the vertical planes projected from the outer edges of the conveyance). Also, under hypothetical accident conditions, the dose rate is less than 1,000 mrem/hr at 1-meter from the surface of the package. Therefore, the NAC-STC satisfies the shielding criteria of 10 CFR 71 and IAEA Safety Standard Series No. ST-1.

5.1.4.1 Results of the Shielding Evaluation for Directly Loaded Fuel

The maximum dose rates calculated for the normal transport conditions are shown in Table 5.1-4, with locations of the maximum dose rates shown in Figure 5.1-2. Cask surface dose rates do not exceed the regulatory limit for a closed transport vehicle of 1,000 mrem/hour at the surface

of the package. The dose rates at 2 meters from the railcar comply with the 10 mrem/hour regulatory limit.

The maximum normal conditions surface dose rate at the cask radial midplane is 41 mrem/hour. The highest dose rate, occurring on the surface of the cask at the gap between the radial neutron shield and the upper impact limiter, is 366.4 mrem/hour. All cask surface dose rates are much less than 1,000 mrem/hour. Ducting of neutrons through the copper/stainless steel fins is considered in Section 5.4.1.1. The results of the ducting evaluation show that this phenomenon has a very small effect on the total cask dose rate. Azimuthal variations in the calculated dose rate are considered in the explicit heat fin and neutron shield model. The neutron dose rate increase resulting from the ducting is offset by the reduction of the gamma dose rate resulting from the additional shielding provided by the fins.

Table 5.1-5 provides accident dose rates that could occur in the event of the loss of all gaseous elements in the neutron shield combined with radial and axial lead slumps due to cask side and end drops. Although the neutron shield material exceeds its safe operating temperature limits in the fire accident, a complete loss of neutron shielding is not credible for the NAC-STC. Some of the neutron shielding capability may be lost, however, as a result of the fire accident. Therefore, the accident shielding calculations conservatively assume a complete loss of gaseous elements in the neutron shielding. In the event of a cask end drop, it is possible for the lead gamma shielding to slump and fill the annular gap (if one exists) created by the cooling of the lead after fabrication. For worst case conditions, this accident could create a 2.35-inch gap at the top or bottom of the lead annulus. If the cask is subject to a side drop, the lead gamma shielding could slump and create a void on the upper side of the cask. An evaluation of this accident shows the lead thickness may be reduced by a maximum of 0.928-inch. The dose rates shown in Table 5.1-5 show that neither the loss of the neutron shielding nor the slumping of the lead will result in a dose rate that exceeds the hypothetical accident dose rate limit of 1,000 mrem/hour at 1 meter from the cask surface.

Therefore, the NAC-STC fulfills the design criteria of Chapter 1 in that under normal transport conditions, the maximum dose rates are less than 1,000 mrem/hour on the surface of the package, less than 200 mrem/hour at all locations at the surface of the personnel barrier, and less than 10 mrem/hour at all locations 2 meters from the personnel barrier. The cask also satisfies the hypothetical accident criteria of 1,000 mrem/hour at 1 meter from the cask surface.

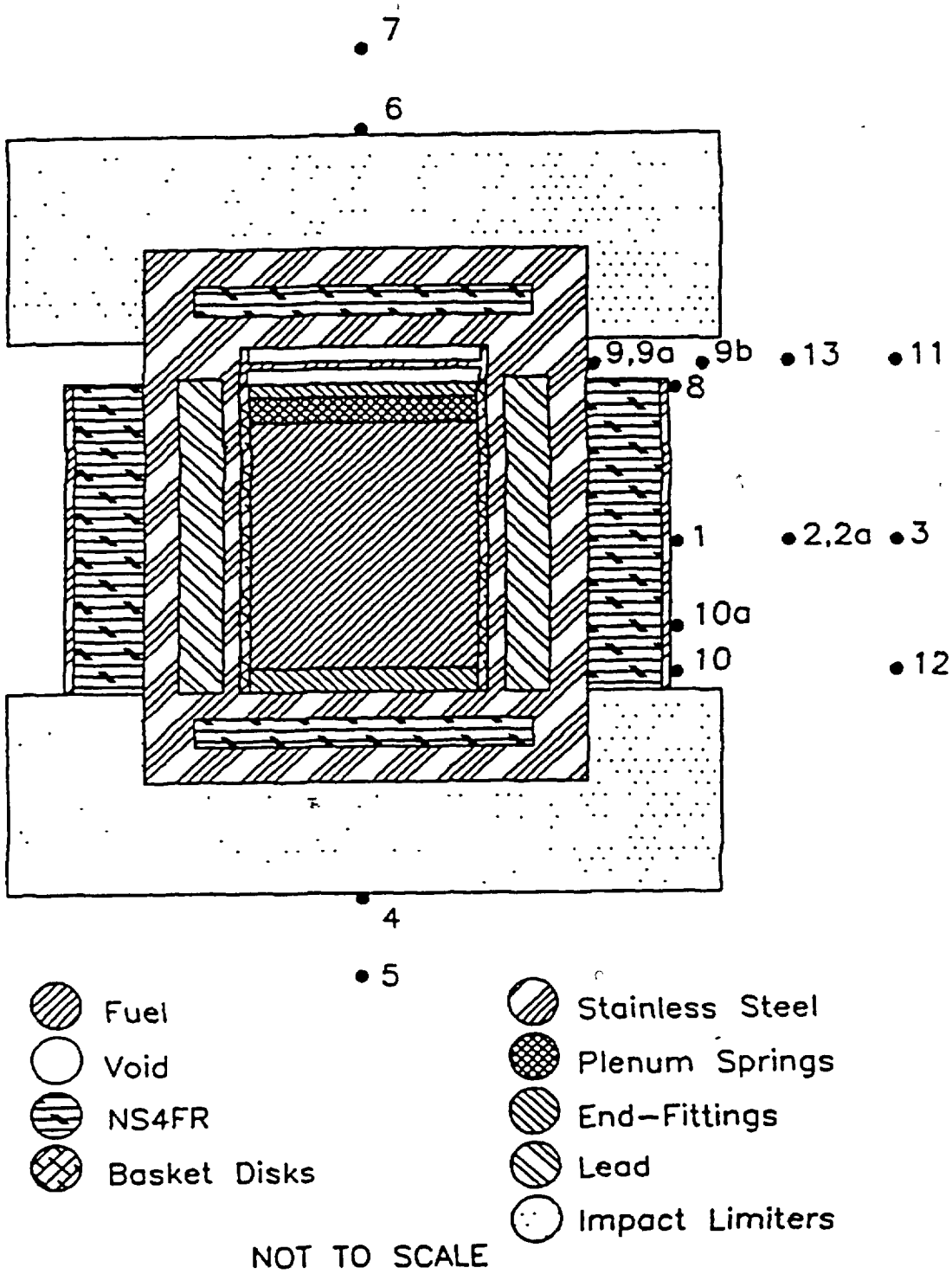
5.1.4.2 Shielding Evaluation for Yankee Class Canistered Fuel and GTCC Waste

A 1-D radial and axial shielding analysis was performed for both the canistered Yankee Class fuel and GTCC waste under normal and hypothetical accident conditions. The dose rates for canistered fuel (Combustion Engineering, 36,000 MWD/MTU, 8-year cooled) are provided in Tables 5.1-6 and 5.1-7. These dose rates are provided in Tables 5.1-8 and 5.1-9 for GTCC waste. Under normal conditions, the canister is positioned in the cavity with top and bottom spacers, and the impact limiters are in place on the cask. Under accident conditions (i.e., 30-foot drop and fire accident), the radial midplane results assume loss of neutron shielding. A complete loss of neutron shielding is not credible for the NAC-STC. However, because of the elevated fire accident temperatures, the neutron shields exceed their safe operating limits and some neutron shielding capability may be lost. Also, in the axial models, it is assumed that the cavity spacers are crushed, the impact limiters are lost, and the canister is positioned at either the top or the bottom of the cavity.

The maximum calculated dose at the surface of the cask centerline when loaded with canistered Yankee Class fuel in normal conditions of transport is 10.25 mrem/hour. This is much less than the 41 mrem/hour for the same location with the directly loaded reference fuel in the cask. In the accident condition involving a loss of neutron shielding and lead slump, a maximum dose rate of 262.76 mrem/hour is calculated at 1 meter from the radial midplane of the NAC-STC. This is also much less than the directly loaded reference fuel accident dose rates shown in Table 5.1-5 and is well below 10 CFR 71 regulatory limits.

The maximum calculated dose at the surface of the cask centerline when loaded with GTCC waste under normal conditions of transport is 7.03 mrem/hour. This is much less than the 41 mrem/hour calculated for the same location with the directly loaded design basis fuel in the cask. In the accident condition, a maximum dose rate of 55.77 mrem/hour is calculated at 1 meter from the radial surface of the NAC-STC. This is also much less than the directly loaded design basis fuel accident dose rates shown in Table 5.1-5 and is well below 10 CFR 71 regulatory limits.

Figure 5.1-1 Detector Locations for Yankee Class Canistered Fuel and GTCC Waste



NOT TO SCALE

Detector locations are described in Tables 5.1-5, 5.1-6 and 5.1-7.

Figure 5.1-2 Maximum Dose Rate Locations for the Three-Dimensional Directly Loaded Fuel Analysis in Normal Conditions

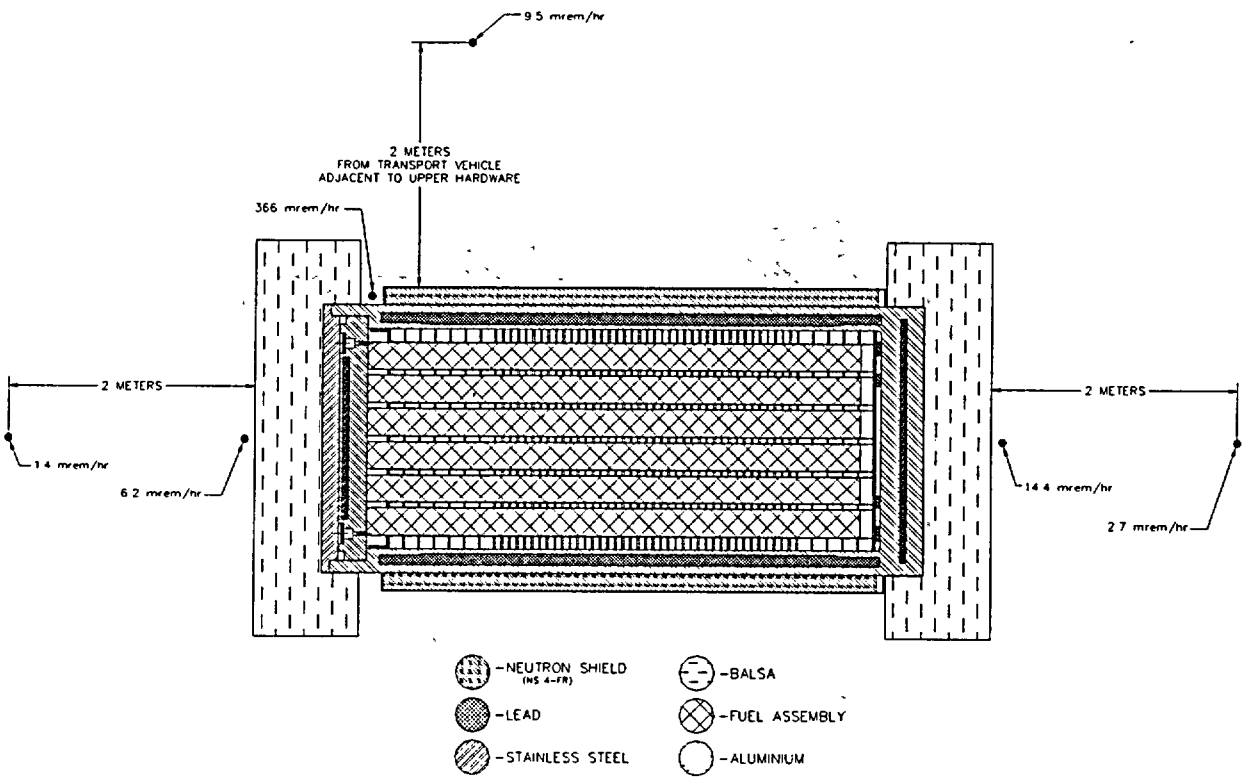


Table 5.1-1 Type, Form, Quantity and Potential Sources of the Fuel Used for Design Basis Directly Loaded and Canistered Fuel

	Design Basis Directly Loaded Fuel	Design Basis Canistered Fuel
Fuel Type	• PWR, 14×14, 15×15, 16×16 and 17×17 • Array-dependent maximum uranium mass • Variable minimum initial ^{235}U enrichment • 45,000 MWD/MTU maximum burnup • 0.85 kW per assembly maximum decay heat, 22.1 kW per cask for 26 assemblies • Variable minimum cool time	• Yankee Class PWR Combustion Engineering, 16×16 Type A • 239.4 kg maximum uranium mass • 3.7 wt % maximum initial ^{235}U enrichment[1] • 36,000 MWD/MTU maximum burnup[2] • 0.347 kW per assembly maximum decay heat, 12.5 kW per cask for 36 assemblies • 8.1 years (or more) decay time after reactor discharge[2]
Fuel form	Intact assemblies	Intact assemblies
Quantity	26 design basis fuel assemblies	36 design basis fuel assemblies
Heat Load	22.1 kilowatts, thermal per cask	12.5 kilowatts, thermal per cask
Sources of Fuel	Commercial PWR nuclear power reactors	Commercial Yankee Class nuclear power reactors

1. 3.7 wt % ^{235}U is used for the 36,000 MWD/MTU fuel assembly shielding source terms. It yields higher source terms than the 3.9 wt % used in the criticality analysis
2. Yankee Class Westinghouse, United Nuclear and Combustion Engineering (3.5 wt % ^{235}U) fuel assemblies with burnups up to 32,000 MWD/MTU require minimum cool times of 19, 11 and 7 years, respectively. Exxon assemblies with burnups up to 36,000 MWD/MTU require a minimum cool time of 16 years for assemblies containing steel hardware in the active fuel region and 9 years for assemblies with Zircaloy hardware.

Table 5.1-2 Design Basis Yankee-MPC Canistered Fuel - Physical Parameters

PARAMETER	VALUE
Assembly Rod Array	16×16
Assembly Weight, lb	776
Assembly Length, in	111.79
Active Fuel Length, in	91
No. of Fuel Rods	231
Rod Pitch, in	0.472
Cladding Material	Zircaloy-4
Rod Diameter, in	0.365
Cladding Thickness, in	0.024
Pellet Diameter, in	0.3105
Pellet Material	UO_2 (sintered)
Maximum Fuel Rod Pressure, psig	315
Theoretical Density, percent	95
Maximum Initial Enrichment, wt % ^{235}U	3.9
Design Basis Burnup, MWD/MTU	36,000
Weight of U, kg (typical)	239.4
Weight of UO_2, kg (typical)	271.6
Upper End-Fitting, kg/assembly	5.5
Lower End-Fitting, kg/assembly	5.18
Upper Plenum Springs, kg/assembly	0.762
Upper Plenum Grid Grid/assembly	0.590
Lower Plenum Grid/assembly	NA

Table 5.1-5 Directly Loaded Fuel Maximum Dose Rates for Hypothetical Accident Conditions

Detector	Source	Surface[1]		1 meter[1]	
		mrem/hr[2]	RSD	mrem/hr[2]	RSD
Top Axial	Neutron	31.3	0.5%	23.4	0.9%
	Gamma	20.5	0.8%	10.9	2.7%
	Total	51.8	0.5%	34.3	1.1%
Radial[3]	Neutron	1586	0.2%	578	0.2%
	Gamma	52	6.6%	27	5.1%
	Total	1638	0.3%	605	0.3%
Bottom Axial	Neutron	119.3	0.3%	51.2	6.3%
	Gamma	67.2	0.8%	17.9	0.9%
	Total	186.5	0.3%	69.1	4.7%

1. The hypothetical accident conditions include a loss of all oxygen, hydrogen, and nitrogen in the radial neutron shield material and radial and axial lead slumps.
2. Dose rates are rounded to the indicated precision.
3. The azimuthal maximum radial dose rates are 1729 (1.9%) and 665 (4.4%) mrem/hr at the surface and at 1 meter from the surface, respectively.

Table 5.1-6 Combined Top, Radial Midplane and Bottom Dose Rates for Canistered Yankee Class Fuel in Normal Conditions of Transport

Location	Detector I.D.	Radiation	Dose Rate (mrem/hr)
Radial Surface, fuel midplane	1	Fuel Gamma	3.89
		Fuel Neutron	3.46
		(n,γ)	2.90
		TOTAL	10.25
Radial, 1m from cask surface, fuel midplane	2	Fuel Gamma	1.73
		Fuel Neutron	1.29
		(n,γ)	1.09
		TOTAL	4.11
Radial, 2m from transport vehicle, fuel midplane[1]	3	Fuel Gamma	0.79
		Fuel Neutron	0.52
		(n,γ)	0.41
		TOTAL	1.72
Bottom impact limiter surface, axial centerline	4	Fuel Gamma	0.09
		Upper Plenum Gamma	0.13
		Top Endfitting Gamma	0.37
		Fuel Neutron	0.01
		(n,γ)	0.04
		TOTAL	0.64
Bottom, 2m from surface of impact limiter, axial centerline	5	Fuel Gamma	0.05
		Upper Plenum Gamma	0.07
		Top Endfitting Gamma	0.00*
		Fuel Neutron	0.00*
		(n,γ)	0.02
		TOTAL	0.14
Top impact limiter surface, axial centerline	6	Fuel Gamma	0.00*
		Upper Plenum Gamma	0.00*
		Top Endfitting Gamma	0.00*
		Fuel Neutron	0.00*
		(n,γ)	0.00*
		TOTAL	0.00
Top, 2m from surface of impact limiter, axial centerline	7	Fuel Gamma	0.00*
		Upper Plenum Gamma	0.00*
		Top Endfitting Gamma	0.00*
		Fuel Neutron	0.00*
		(n,γ)	0.00*
		TOTAL	0.00

*values are less than 0.005.

5.2 Source Specification

This section presents the source specifications for the directly loaded fuel and for the Yankee-MPC fuel and GTCC waste configurations.

5.2.1 Directly Loaded Fuel Source Specification

The directly loaded NAC-STC is designed to safely transport a range of 14×14, 15×15, 16×16, and 17×17 fuel assemblies. The analyzed fuel assemblies are reference fuel assemblies, with assembly geometry and activated hardware masses chosen to maximum uranium loading (MTU) and activated hardware source term.

In order to generate a minimum cool time table for directly loaded fuel, each fuel assembly is analyzed over a range of burnups, initial ^{235}U enrichments and cool times. Fuel assembly burnup is evaluated from 30,000 MWD/MTU to 45,000 MWD/MTU in 5,000 MWD/MTU increments. Initial ^{235}U enrichments are evaluated from 1.7 to 4.5 wt % ^{235}U in 0.2 wt % increments. Cool times range from 5 to 40 years with varying increments. This matrix creates a total of 1,080 source terms for each assembly (4 burnups × 15 enrichments × 18 cool times).

Neutron and gamma source terms for the directly loaded design basis fuel are calculated with the ORIGEN-S computer code (Hermann, 1989) as part of the SAS2H sequence (Hermann, 1995) in the SCALE 4.3 code package for the PC (ORNL, 1995). ORIGEN-S also calculates the gamma spectrum, the neutron spectrum, and the concentration of radiologically important isotopes such as ^{3}H, ^{131}Xe, ^{129}I, ^{85}Kr, ^{134}Cs, ^{137}Cs and ^{60}Co. Reactor operating conditions assumed for the analysis are shown in Table 5.2-3. The SAS2H-generated source spectra are rebinned onto the standard 28 group neutron and 22 group gamma scheme used in MCBEND as shown in Tables 5.2-8 and 5.2-9, respectively. Source terms are generated for the fuel and fuel assembly hardware. The hardware activation is calculated by light element transmutation using the in-core neutron flux spectrum produced by the SAS2H neutronics model.

The fuel-dependent input data for the shielding and source term evaluations of directly loaded design basis PWR assemblies are given in Table 5.2-2. Fuel assembly parameters have been selected to maximize fuel mass and, therefore, fuel source terms. Fuel assembly hardware masses have likewise been selected to maximize hardware source term.

Fuel assembly parameters used in the SAS2H source term analysis and the MCBEND shielding analysis are identical. Parameters necessary to generate SAS2H input are shown in Table 5.2-4.

Fuel neutron, fuel gamma, and hardware gamma radiation contribute at varying levels to cask dose rates due to significant changes in the material composition of the cask shields at different radial and axial locations. As such, no single source term produces a bounding set of dose rates at all locations. For example, the radial maximum surface dose rate (normal conditions) of 366 mrem/hr is produced by a 40,000 MWD/MTU, 2.3 wt % ^{235}U, 10-year cooled source term, shown in Table 5.2-12. Top axial maximum dose rates (normal conditions) are produced by a 30,000 MWD/MTU, 2.3 wt % ^{235}U, 6-year cooled source term. By employing the response function method to calculate maximum dose rates, the limiting source term becomes a result of the analysis, rather than an input, and the limiting source term and dose rate are captured for radial and axial detectors and normal and accident conditions.

The end-fitting, plenum spring and grid spacer activations are calculated by ORIGEN-S using the same burnup cycle as the fuel. The fuel hardware masses activated are provided in Table 5.2-2 for the directly loaded fuel. The grid spacers and other fuel hardware in the core region are conservatively assumed to be exposed to 100 percent of the flux in the core. For the plenum springs, the grid spacers in the plenum region, and the bottom end-fittings, 20 percent of the flux in the core is used for irradiation purposes. For the top end-fittings, 10 percent of the flux in the core is used for irradiation purposes. These irradiation values are taken from Luksic. The amount of ^{59}Co present in the grid spacers and end-fittings was taken as 1.2 gram per kilogram of material, irrespective of being Inconel or Type 304 stainless steel. However, the value is conservative for both stainless steel and Inconel, as most nuclear-grade material specifications require less than 1 gram of ^{59}Co per kilogram of metal. It is conservatively assumed that all of the cobalt is ^{59}Co. When ^{59}Co absorbs a neutron, it becomes ^{60}Co.

5.2.1.1 Directly Loaded Fuel Neutron Source

As described in Section 5.2.1, a total of 1,080 neutron source terms have been calculated for each directly loaded fuel assembly. Neutron source terms have been rebinned onto the MCBEND 28 group structure, shown in Table 5.2-8. The neutron source results from actinide spontaneous fission and from (α,n) reactions with 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 of ^{238}Pu with oxygen. The neutron spectrum from spontaneous fission is based on fission spectrum

measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions are 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 that of the standard MCBEND 28 group structure using ORIGEN-S as part of the source term decay evaluation.

The effect of subcritical neutron multiplication is not directly computed in the MCBEND analysis conducted for directly loaded fuel, due to difficulties in adequately biasing the calculation. Instead, 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 the dry cask conditions of transport, the system k_{eff} is taken as 0.4, with a resulting scale factor of 1.67. This scale factor is input as a scaling factor on the source strength input in MCBEND.

5.2.1.2 Directly Loaded Fuel Gamma Sources

As described in Section 5.2.1, 1,080 gamma source terms have been calculated for each directly loaded fuel assembly. Gamma source terms have been rebinned onto the MCBEND 22 group structure, shown in Table 5.2-9, using ORIGEN-S as part of the source term decay evaluation. The hardware gamma spectrum for directly loaded fuel 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 these spectra is based on the irradiation of 1 kg of stainless steel in the in-core 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 kilograms of steel or inconel material in the plenum, upper end fitting or 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 (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) and 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). Activated mass in each region and the corresponding flux factor are summarized

in Table 5.2-10 for each array size. In the case of CE 16×16 fuel, which has a longer plenum, the upper end fitting (upper nozzle) flux factor is reduced to 0.05 (Luksic).

5.2.1.3 Directly Loaded Fuel Source Axial Profiles

The design basis axial burnup profile used in the directly loaded fuel shielding evaluations is shown in Figure 5.2-1. This profile is converted to a set of line segments suitable for input into the MCBEND shielding code. The converted profile assures that the burnup peak of the more detailed profile shown in Figure 5.2-1 is bounded while conserving the average burnup (i.e., the area under the curve is maintained as to not add source). Neutron and gamma source profiles are computed based on the relation between burnup, B, and source strength, S, in the form:

$$S = aB^b$$

where parameters a and b are determined based on fits to SAS2H computed source rates at various fuel burnups. The parameter a is simply a scaling factor and is not relevant to the analysis. For neutron sources, parameter b is 4.22. For gamma sources, the relation between burnup and source rate is linear and b is 1.0. The resulting gamma source profile is therefore identical to the burnup profile. Table 5.2–11 gives the resulting neutron and gamma source rate profiles for directly loaded fuel. 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 5.2–4.

5.2.2 Yankee Class Fuel and GTCC Waste Source Specification

The canistered fuel design basis source terms are based on the CE 16×16 Yankee Class fuel assembly with a burnup of 36,000 MWD/MTU and 8.1 years cooling time. An enrichment of 3.7 wt % ^{235}U is selected to maximize the neutron source for this type of fuel. Dose rates associated with the Yankee Class Westinghouse, United Nuclear, and CE (3.5 wt % ^{235}U) fuel types at 32,000 MWD/MTU are bounded by the canister fuel design basis for cooling times of 19, 11 and 7 years, respectively. Exxon fuel at 36,000 MWD/MTU with steel or Zircaloy fuel hardware is bounded by the canister fuel design basis for cooling times of 16 and 9 years, respectively.

Neutron and gamma source terms for the canistered design basis fuel are calculated with the SAS2H code sequence of the SCALE 4.3 code package for the PC. SAS2H includes an

XSDRNPM neutronics model of the fuel assembly and ORIGEN-S fuel depletion/source term calculations. The canister fuel assembly input data for SAS2H is summarized in Table 5.2-1. Source terms are generated for both UO_2 fuel and fuel assembly hardware. The hardware activation is calculated by light element transmutation using the in-core 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 (Luksic).

5.2.2.1 Yankee Class Fuel Neutron Source

The Yankee Class canistered fuel neutron spectrum is shown in Table 5.2-5. The neutron source results from actinide spontaneous fission and from (α,n) reactions with 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 of ^{238}Pu with oxygen. The neutron spectrum from spontaneous fission is based on fission spectrum measurements of ^{235}U and ^{252}Cf. Neutron spectra from (α,n) reactions are 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 that of the SCALE 27 group neutron cross-section library.

5.2.2.2 Yankee Class Fuel and Yankee GTCC Waste Gamma Sources

The design basis gamma spectrum for Yankee Class canistered fuel is shown in Table 5.2-6. The fuel gamma radiation source consists primarily of decay gammas from fission products. Actinides also emit a significant amount of gamma radiation. The gamma source strength depends on the irradiation period and the cooling time after discharge from the reactor core.

An additional source of gamma radiation is from ^{59}Co activation in the fuel hardware materials. The fuel hardware gamma spectrum for canistered fuel is shown in Table 5.2-7. The gamma spectrum for the decay of ^{60}Co in the activated hardware was calculated using ORIGEN-S. The total source in each hardware region depends on the flux used to irradiate the region and the mass of material in that region. The default gamma energy group spectrum of the ORIGEN-S code differs from that of the standard 18-group gamma library of the SCALE-4.0 package. To account for the differences in the energy groups, the source spectra from the fuel and hardware gamma sources were rebinned to the SCALE-4.0 18-group structure using ORIGEN-S. This

method regroups the source based on the actual energy spectrum of each specific nuclide, yielding more accurate results than those achieved by simply multiplying the individual energy group source strength by the ratio of the old to new mean energies of each respective group.

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 these spectra is based on the irradiation of 1 kg of stainless steel in the in-core flux spectrum produced by the SAS2H neutronics calculation. This activated hardware spectra is used for the design basis GTCC waste spectra, but the magnitude is scaled up from 103 curies of ^{60}Co in the 1 kg of activated hardware to 1.25×10^5 curies ^{60}Co in the GTCC waste.

The activated fuel assembly hardware source terms are found by multiplying the source strength from 1 kilogram by the kilograms of steel or inconel material in the plenum, upper end fitting or 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 (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) and 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).

5.2.2.3 Yankee Class Fuel Source Axial Profiles

The Yankee Class fuel axial burnup profile used in the shielding evaluations is shown in Figure 5.2-2. This is based on core calculations of Yankee Class fuel in the range of 30,000 to 36,000 MWD/MTU of burnup. This burnup profile has a peaking factor of 1.15. Thus, a peaking factor of 1.15 is applied to the radial midplane gamma dose rates and a peaking factor of $(1.15)^{4.2}$ = 1.80 is applied to the radial midplane neutron dose rates reported in Tables 5.1-6 and 5.1-7.

The design basis gamma source profile for Yankee GTCC waste (activated stainless steel core baffle) is shown in Figure 5.2-3. A GTCC gamma source peaking factor of 1.23 is determined from actual dose rate measurements of the GTCC waste containers. This peaking factor is due to the activation of the core baffle from 30 years of neutron flux exposure. This neutron flux exposure produces an activation profile similar to the chopped cosine axial shape of the neutron flux during reactor operation. The GTCC source term includes an estimated contribution from crud (as surface contamination).

Table 5.2-1 Design Basis Yankee Class Fuel Input Parameters for SAS2 H

Parameter	Value
Basket Configuration	Canistered
Fuel assembly type	CE 16×16 Yankee Class
Weight of U, kg/assembly	239.4
In core grids, kg/assembly	2.36 (4 Zirc)
Plenum spring, kg/assembly	0.762
Grids in plenum springs, kg/assembly	0.590 (Zirc)
Upper end fittings, kg/assembly	5.5
Lower end fittings, kg/assembly	5.2
Lower Plenum Hardware, kg/assembly	1.73
Fuel enrichment, wt.% ^{235}U	3.7
Fuel burnup, MWD/MTU	36,000
Cooling time	8
Burnup cycle, power cycles, down cycles	2 cycles of 496 days 1 of 60 days
Burnup, MWD/assembly	8,618
Irradiation power, MW	8.486
^{59}Co concentration in steel hardware, g/kg	1.2
Irradiation flux, grid spacers in core region grid spacers in plenum region upper plenum springs upper end-fittings lower end-fittings lower plenum hardware	100% 20% 20% 10% 10% 20%
Fuel temperature, K	787
Clad temperature, K	600
Coolant temperature, K	551
Boron content in coolant, ppm (by weight)	800

Table 5.2-2 Directly Loaded Three-Dimensional PWR Reference Fuel Assembly Descriptions

Parameter Description	Reference Fuel Assembly			
	14×14	15×15	16×16	17×17
Fuel Rod Height [inch]	152.360	152.756	146.499	152.300
Top End-Cap Height [inch]	0.685	0.685	0.750	0.685
Bottom End-Cap Height [inch]	0.685	0.685	0.891	0.895
Active Fuel Region Height [inch]	145.2	144.0	136.7	144.0
Fuel Rod Diameter [inch]	0.422	0.422	0.382	0.374
Fuel Clad Thickness [inch]	0.023	0.024	0.025	0.022
Fuel Pellet Diameter [inch]	0.367	0.367	0.325	0.323
Array	14	15	16	17
Fuel Rod Pitch [inch]	0.556	0.563	0.506	0.496
Number of Guide Tubes	16	20	4	24
Guide Tube OD [inch]	0.481	0.484	1.115	0.474
Guide Tube Thickness [inch]	0.034	0.015	0.026	0.015
Number of Instrument Tubes	1	1	1	1
Instrument Tube OD [inch]	0.481	0.484	1.115	0.474
Instrument Tube Thickness [inch]	0.034	0.015	0.026	0.015
Fuel Assembly Height [inch]	161.100	160.100	158.129	161.693
Fuel Assembly Width [inch]	7.763	8.449	8.100	8.430
Lower Nozzle Height [inch]	2.738	2.738	3.821	2.421
Upper Nozzle Height [inch]	3.500	3.480	6.821	3.480
Gap Fuel Rod to Bottom Nozzle [inch]	0.000	0.813	0.000	0.791
Gap Fuel Rod to Top Nozzle [inch]	2.502	0.313	0.988	2.701
Upper Plenum Region Height [inch]	5.790	7.386	8.158	6.720
Number of Fuel Rods	179	204	236	264
Calculated MTU [MTU]	0.4144	0.4671	0.4025	0.4636
Lower Nozzle Hardware Mass [kg]	7.893	5.680	5.400	6.307
In-core Hardware Mass [kg][1]	14.880	17.450	1.360	5.440
Upper Plenum Hardware Mass [kg]	8.050	4.120	10.700	5.410
Upper Nozzle Hardware Mass [kg]	9.890	11.840	9.500	7.850

1. Reference literature indicates the use of stainless steel guide/instrument tubes and/or steel grids in early generations of 14×14 and 15×15 assemblies, with later generations switching to Zircaloy components. To provide a bounding fuel description, the higher steel mass present in the early generations of these fuels was employed in the source term and shielding models.

Table 5.2-3 PWR Fuel Reactor Operating Conditions for Directly Loaded Fuel

Reference Assembly Parameter	14×14	15×15	16×16	17×17
Assembly Power, MW	13.72	16.33	16.62	18.55
Fuel Temperature, K	900	900	900	900
Clad Temperature, K	620	620	620	620
Moderator Temperature, K	580	580	580	580
Moderator Density, g/cc	0.725	0.725	0.725	0.725
Boron, ppm	550	550	550	550
Down Time, days	60	60	60	60

Table 5.2-4 PWR Cycle Length Calculation for Directly Loaded Fuel Source Terms

Reference Fuel Type	Burnup [MWD/MTU]	% TD	Pellet OD [cm]	Active Length [cm]	Number of Rods	Volume [cm^3]	MTU [MTU]	Assy Power [MW]	Number of Cycles	Cycle Length [days]
14×14	30000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	2	453.14
	35000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	352.45
	40000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	402.80
	45000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	453.14
	50000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	503.49
	55000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	553.84
	60000	0.95	0.9332	368.808	179	4.52E+04	0.4144	13.72	3	604.19
15×15	30000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	2	429.15
	35000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	333.78
	40000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	381.46
	45000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	429.15
	50000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	476.83
	55000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	524.51
	60000	0.95	0.9319	365.76	204	5.09E+04	0.4671	16.33	3	572.20
16×16	30000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	2	363.26
	35000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	282.53
	40000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	322.90
	45000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	363.26
	50000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	403.62
	55000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	443.98
	60000	0.95	0.8255	347.218	236	4.39E+04	0.4025	16.62	3	484.34
17×17	30000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	2	374.82
	35000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	291.53
	40000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	333.18
	45000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	374.82
	50000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	416.47
	55000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	458.12
	60000	0.943	0.8192	365.76	264	5.09E+04	0.4636	18.55	3	499.76

Table 5.2-11 Directly Loaded Fuel Axial Gamma and Neutron Source Profiles

% Core Height	Burnup Profile	Gamma Interval	Neutron Interval
0.0	0.30	--	--
2.5	0.55	4.250E-01	4.322E-02
5.0	0.80	6.750E-01	2.351E-01
10.0	1.00	9.000E-01	6.950E-01
20.0	1.20	1.100E+00	1.579E+00
40.0	1.20	1.200E+00	2.158E+00
60.0	1.10	1.150E+00	1.827E+00
70.0	1.05	1.075E+00	1.362E+00
80.0	0.95	1.000E+00	1.017E+00
90.0	0.78	8.650E-01	5.779E-01
92.5	0.70	7.400E-01	2.862E-01
95.0	0.60	6.500E-01	1.689E-01
97.5	0.50	5.500E-01	8.474E-02
100.0	0.40	4.500E-01	3.729E-02

Table 5.2-12 Directly Loaded 14×14 Fuel Assembly Spectra at 40,000 MWD/MTU, 2.3 wt % ^{235}U, 10 Years Cool Time in MCBEND Group Format

Group	Fuel Neutron [neutrons/sec/assy]	Fuel Gamma [photons/sec/assy]	Fuel Hardware [photons/sec/kg]
1	0.000E+00	0.0000E+00	0.0000E+00
2	2.224E+04	9.8892E+03	0.0000E+00
3	9.268E+04	1.9127E+05	0.0000E+00
4	3.079E+05	9.0084E+05	0.0000E+00
5	9.658E+05	4.5923E+06	0.0000E+00
6	2.593E+06	1.1443E+07	0.0000E+00
7	4.476E+06	3.8389E+08	2.6368E-15
8	1.498E+07	3.1958E+09	3.6815E+04
9	2.543E+07	4.1373E+10	2.3742E+07
10	3.434E+07	9.7271E+10	6.7752E-06
11	8.165E+07	2.9870E+12	6.3110E+00
12	1.275E+08	4.4115E+13	2.2492E+12
13	3.319E+07	2.0530E+13	2.3708E+12
14	1.151E+07	8.5789E+13	9.9650E+08
15	2.977E+02	1.4229E+15	4.1857E+06
16	0.000E+00	1.3765E+14	1.2053E+07
17	0.000E+00	2.5948E+13	1.9070E+08
18	0.000E+00	4.3836E+13	1.4535E+08
19	0.000E+00	1.6029E+14	2.9272E+09
20	0.000E+00	1.9875E+14	1.2134E+10
21	0.000E+00	4.8210E+14	3.4773E+10
22	0.000E+00	3.2604E+14	4.1497E+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	3.370E+08	2.9511E+15	4.7127E+12

5.3 Model Specification

The radiation protection provided by the NAC-STC is in the form of solid multi-walled shielding materials, which totally surround the fuel. These shielding materials include steel and lead for gamma shielding and a borated polymer (NS-4-FR) for neutron shielding. The multi-walled arrangement of steel and lead in the NAC-STC provides optimal weight for gamma attenuation. The NS-4-FR neutron shielding material has a hydrogen density close to that of water and serves to moderate fast neutrons, which are then captured in the boron. Boron capture in the neutron shield minimizes the contribution of secondary capture gammas to surface dose rates.

The NAC-STC uses a multi-walled arrangement for both radial and axial shields. The arrangement of the radial gamma shielding in the cask body is a 1.5-inch thick stainless steel inner shell and a 2.65-inch thick stainless steel outer shell with a 3.70-inch lead annulus between them. The radial neutron shield is arranged around the outer steel shell with a 5.5-inch minimum, 5.925-inch maximum thickness of NS-4-FR that is covered by a 0.236-inch (6 mm) thick neutron shield shell. Variations in the neutron shield thickness result from filling the cavity formed by the multifaceted neutron shield shell and the cylindrical cask outer shell with NS-4-FR. The minimum shield thickness is obtained at the heat transfer fin location and increases towards the cask corners. As indicated in Section 5.3.2.1, an equivalent cylindrical shield has a 5.52-inch thickness (conservatively assuming that the expansion foam in the cavity retains its maximum thickness). The bottom of the cask contains a steel/NS-4-FR/steel shield arrangement with the two stainless steel components providing 11.65 inches of gamma shielding and 2 inches of NS-4-FR neutron shielding. The top of the cask has shields in the form of two closure lids. The inner lid also has a steel/NS-4-FR/steel arrangement with 6.0 inches of steel below 2 inches of NS-4-FR and 1.0 inch of steel above it. The outer lid is a 5.25-inch thick steel disk.

5.3.1 Directly Loaded Fuel Model

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 fuel tubes in 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 details, including support disks, heat

transfer disks, and top and bottom weldments are explicitly modeled. Cask body 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, bodies such as cylinders and rectangular parallelpipeds, 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 both radial and axial detector locations and for normal and hypothetical accident conditions.

5.3.1.1 Directly Loaded Fuel Assembly Model

Based on the fuel parameters provided in Table 5.2-2, homogenized treatments of fuel assembly source regions are developed. The homogenized fuel assembly is represented in the model as a stack of boxes with 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 homogenizations for the four design basis assemblies are shown in Table 5.3-1 based on the detailed three-dimensional data in Table 5.2-2. 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 during all transport conditions. Combined with the fuel rod clad, fuel material, and guide/instrument tube materials the void accounts for the total fuel region volume. The clad region is Zircaloy (density 6.55 g/cm^3) for all four design basis

assemblies. The resulting regional compositions on an atom/barn-cm basis are shown in Table 5.3-2.

Fuel assembly non-fuel regions are homogenized as shown in Tables 5.3-3 and 5.3-4 for stainless steel and Zircaloy materials, respectively. Using the detailed dimensions in Table 5.2-2, the axial source regions are modeled as follows: the gap between the lower nozzle and the fuel rod (if present) and the fuel rod bottom end-cap 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. The only material included in the homogenized region is stainless steel for the upper end fitting and combinations of Zircaloy and stainless steel in the upper plenum and lower end fitting regions. Zircaloy in these regions is due to end caps and the portion of the fuel rod cladding in the upper plenum. Volume fractions of material are based on the modeled regional volume and the volume of stainless steel or Zircaloy present as computed from the modeled mass and density (7.92 g/cm^3 for stainless steel and 6.55 g/cm^3 for Zircaloy).

5.3.1.2 Directly Loaded Basket Model

For a given fuel type, the MCBEND description of the basket elements forms a common sub-model employed in the transport cask analysis. The key features of the model are the detailed representation of fuel tubes, basket support and heat transfer disks, and weldment structures.

5.3.1.3 Description of MCBEND NAC-STC Model

The three-dimensional model of the NAC-STC cask containing design basis fuel assemblies is based on the following features:

Normal conditions:

- Radial neutron shield and shield shell (includes heat fins in the neutron shield)
- All balsa upper and lower impact limiters (100% balsa chosen for conservatism)

Accident conditions:

- Top axial lead slump
- Bottom axial lead slump
- Radial lead slump
- Radial neutron shield and shield shell with removal of oxygen, hydrogen, and nitrogen from NS-4-FR material definition
- Loss of upper and lower impact limiters

Features common to both the normal and accident conditions models are the inner lid vent and drain ports, the inner lid neutron shield, the bottom forging neutron shield, the annular expansion foam region below the neutron shield (modeled conservatively as void), radial neutron shield heat fins, and the lower rotating trunnions.

Detailed model parameters used in creating the three-dimensional model are taken directly from the License Drawings. Elevations associated with the transport cask three-dimensional features are established with respect to the center bottom of the NAC-STC cavity for the MCBEND combinatorial model. The three-dimensional NAC-STC models are shown in Figures 5.3-1 through 5.3-3.

5.3.1.4 Directly Loaded Configuration Shield Regional Densities

Based on the homogenization described in Section 5.3.1.1, the resulting active fuel regional densities are shown in Table 5.3-2 for the design basis directly loaded fuel assemblies. Material compositions for remaining structural and shield materials are shown in Table 5.3-5. Compositions for fuel assembly non-fuel regions are equivalent to the stainless steel and Zircaloy compositions in Table 5.3-5 scaled by the material volume fractions shown in Tables 5.3-3 and 5.3-4.

5.3.2 Yankee-MPC Fuel and GTCC Waste Models

This section provides the radial and axial shielding models used for the Yankee-MPC canistered fuel and GTCC waste.

5.3.2.1 Yankee-MPC Fuel and GTCC Waste Radial Shielding Model

One-dimensional cylindrical SAS1 models are used to evaluate radial midplane dose rates for the NAC-STC containing design basis canister fuel and GTCC waste. In both cases, the source region is transformed into an equivalent cylindrical volume. In the case of the canister fuel region, this volume is based on the periphery of the fuel basket tubes and has an equivalent radius of 30.63 inches (77.80 cm). The fuel assembly source regions are homogenized into the volumes defined by the fuel/basket equivalent radius and the fuel regional elevations defined in Figure 5.1-3. Since the canister basket contains an explicit heat transfer region with aluminum heat transfer disks, an additional middle fuel region is defined with this material for the radial midplane evaluation. The remaining cask body regions are modeled using the exact dimensions

of the cask except for the radial neutron shield. Its thickness varies as a result of its polygon shape. An equivalent thickness of 5.52 inches (14.02 cm) is modeled to conserve the actual neutron shield volume (see Figure 5.3-4). To account for axial leakage, an axial buckling equivalent to the active fuel height is applied. In the accident situation, the neutron shield material, NS-4-FR, is voided. An axial peaking factor of 1.15 and 1.80 is applied to the radial midplane gamma and neutron results, respectively, to account for the axial burnup profile as described in Section 5.2.3.

Radial models are also constructed for the Westinghouse, United Nuclear and Exxon fuel types to determine minimum cool time based on shielding constraints. By performing shielding analysis rather than source term magnitude comparisons, spectrum differences are taken into account. Shielding analysis of the Exxon assembly at 10 years cooling is not required, since its neutron and gamma source is lower in each energy group and its mass (and therefore its self-shielding) is identical to the design basis assembly.

In the case of the GTCC waste, the volume is based on the interior periphery of the GTCC basket support wall and has an equivalent radius of 23.47 inches (59.61 cm). The GTCC source region is homogenized into the volume defined by the GTCC basket interior periphery and the container height of 98.25 inches (249.56 cm [See Figure 5.1-4]). This gives a GTCC source volume of 170,023 inches^3 (2.786×10^6 cm^3). The GTCC basket support wall is also cylindrical with a 2.5-inch (6.35-cm) thickness. The remaining cask body regions are modeled using the exact dimensions of the cask, except for the radial neutron shield that is again modeled with an equivalent thickness of 5.52 inches (14.02 cm [See Figure 5.3-7]). To account for axial leakage, an axial buckling equivalent to the container height of 98.35 inches is applied. In the accident situation, the neutron shield material, NS-4-FR, is voided. An axial peaking factor of 1.23 is applied to the radial midplane results to account for gamma source peaking as described in Section 5.2.3.

5.3.2.2 Yankee-MPC Fuel and GTCC Waste Axial Shielding Models

One-dimensional slab SAS1 models are used to evaluate top and bottom dose rates for the NAC-STC containing design basis canister fuel and GTCC waste. The top axial model begins at either the active fuel or homogenized GTCC waste canister source midplane and proceeds along the cask centerline to the surface of the top impact limiter. Similarly, the NAC-STC bottom axial model begins at either the canistered fuel or homogenized GTCC waste canister center and ends at the bottom impact limiter. See Figures 5.3-5 and 5.3-6 for the canistered fuel axial shielding

models and Figures 5.3-8 and 5.3-9 for the canistered GTCC waste axial shielding models. To account for transverse radial leakage, radial bucklings equal to the equivalent diameter of the source regions are applied. In the accident situation, the impact limiters are lost, the canister is positioned on either the top or bottom cavity surface, and the NS-4-FR neutron shield material, including that in the bottom forging, is considered to be lost.

5.3.2.3 Cask Regional Material Compositions – Yankee Class Fuel and GTCC Waste

The densities of the materials used in the shielding evaluations for canister fuel and GTCC waste are calculated using the effective fuel radius and source regional elevation. See Figure 5.1-3 for the design basis canistered fuel source zones and elevations. In the case of the canistered Yankee Class fuel, the homogenized source regions include a top fuel, middle fuel (heat transfer zone), bottom fuel, top plenum, bottom plenum, and the top and bottom end-fittings. The structural and heat transfer disks exterior to the fuel/basket region are also homogenized in the one-dimensional radial models. Similarly, the GTCC waste density is based on homogenizing the mass of GTCC waste into the volume defined by the equivalent radius and the height of the container. The homogenized densities and nuclide concentrations are shown in Table 5.3-6.

Figure 5.3-1 Three-Dimensiornal MCBEND Model for Directly Loaded Fuel - Normal Conditions - Axial Detail

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-2 Three-Dimensional MCBEND Model for Directly Loaded Fuel - Accident Conditions - Axial Detail

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-3 Three-Dimensional MCBEND Model for Directly Loaded Fuel - Radial Detail

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-4 One-Dimensional Radial Shielding Model for Canistered Fuel

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-5 One-Dimensional Bottom Axial Shielding Model for Canistered Fuel

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-6 Onie-Dimehsional Top Axial Model for Canistered Fuel

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-7 One-Dimensional Radial Shielding Model for Canistered GTCC Waste

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-8 One-Dimensional Bottom Axial Model for Canistered GTCC Waste

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Figure 5.3-9 One-Dimensional Top Axial Model for Canistered GTCC Waste

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

Table 5.3-1 Directly Loaded Fuel Region Homogenization

Reference Fuel Type	Component	Volume Fraction of Components			
		UO_2	Void	Clad	Interstitial
14×14	Fuel	3.1489E-01	--	--	--
	Gap	--	1.6671E-02	--	--
	Clad	--	--	8.3877E-02	--
	Guide Tube	--	--	1.2662E-02	--
	Instrument Tube	--	--	7.9139E-04	--
	Inside Tubes	--	--	--	3.7699E-02
	Interstitial	--	--	--	5.3341E-01
	Total	3.1489E-01	1.6671E-02	9.7331E-02	5.7111E-01
15×15	Fuel	3.0214E-01	--	--	--
	Gap	--	1.1135E-02	--	--
	Clad	--	--	8.6427E-02	--
	Guide Tube	--	--	6.1920E-03	--
	Instrument Tube	--	--	3.0960E-04	--
	Inside Tubes	--	--	--	4.7622E-02
	Interstitial	--	--	--	5.4618E-01
	Total	3.0214E-01	1.1135E-02	9.2929E-02	5.9380E-01
16×16	Fuel	2.9840E-01	--	--	--
	Gap	--	1.2993E-02	--	--
	Clad	--	--	1.0086E-01	--
	Guide Tube	--	--	5.4230E-03	--
	Instrument Tube	--	--	1.3558E-03	--
	Inside Tubes	--	--	--	6.7633E-02
	Interstitial	--	--	--	5.1334E-01
	Total	2.9840E-01	1.2993E-02	1.0763E-01	5.8097E-01
17×17	Fuel	3.0346E-01	--	--	--
	Gap	--	1.2613E-02	--	--
	Clad	--	--	9.2078E-02	--
	Guide Tube	--	--	7.3113E-03	--
	Instrument Tube	--	--	3.0464E-04	--
	Inside Tubes	--	--	--	5.4568E-02
	Interstitial	--	--	--	5.2967E-01
	Total	3.0346E-01	1.2613E-02	9.9694E-02	5.8424E-01

Table 5.3-2 Directly Loaded Fuel Homogenized Fuel Elemental Densities

Element	Density [atom/b-cm]			
	14x14 (3.92 g/cm^3)	15x15 (3.75 g/cm^3)	16x16 (3.81 g/cm^3)	17x17 (3.79 g/cm^3)
Cr	7.38366E-06	7.04970E-06	8.16503E-06	7.56288E-06
Fe	1.37490E-05	1.31272E-05	1.52040E-05	1.40828E-05
Hf	2.15094E-07	2.05366E-07	2.37856E-07	2.20315E-07
Ni	6.54113E-07	6.24528E-07	7.23334E-07	6.69990E-07
O	1.46478E-02	1.40545E-02	1.38846E-02	1.40137E-02
Sn	4.85117E-05	4.63175E-05	5.36454E-05	4.96892E-05
U	7.31477E-03	7.01858E-03	6.93178E-03	6.99729E-03
Zr	4.12775E-03	3.94106E-03	4.56457E-03	4.22794E-03

Table 5.3-3 Directly Loaded Fuel Assembly Activated Hardware Region Homogenization

Reference Fuel Type	Region	Mass SS [kg/assy]	SS Volume [cm^3/assy]	Height [cm]	Volume [cm^3/assy]	Volume Fraction
14×14	Lower Nozzle	7.89	9.9659E+02	8.6944	3.3804E+03	2.9482E-01
	Upper Plenum	8.05	1.0164E+03	22.8016	8.8653E+03	1.1465E-01
	Upper Nozzle	9.89	1.2487E+03	8.8900	3.4564E+03	3.6128E-01
15×15	Lower Nozzle	5.68	7.1717E+02	10.7607	4.9559E+03	1.4471E-01
	Upper Plenum	4.12	5.2020E+02	21.2941	9.8070E+03	5.3044E-02
	Upper Nozzle	11.84	1.4949E+03	8.8392	4.0709E+03	3.6723E-01
16×16	Lower Nozzle	5.40	6.8182E+02	11.9685	5.0661E+03	1.3458E-01
	Upper Plenum	10.70	1.3510E+03	25.1358	1.0640E+04	1.2698E-01
	Upper Nozzle	9.50	1.1995E+03	17.3253	7.3336E+03	1.6356E-01
17×17	Lower Nozzle	6.31	7.9634E+02	10.4324	4.7831E+03	1.6649E-01
	Upper Plenum	5.41	6.8308E+02	25.6684	1.1768E+04	5.8043E-02
	Upper Nozzle	7.85	9.9116E+02	8.8392	4.0526E+03	2.4457E-01

Table 5.3-4 Directly Loaded Fuel Assembly Zircaloy Hardware Region Homogenization

Reference Fuel Type	Region	Mass Zirc [kg/assy]	Zirc Volume [cm^3/assy]	Height [cm]	Volume [cm^3/assy]	Volume Fraction
14×14	Lower Nozzle	1.84	2.8103E+02	8.6944	3.3804E+03	8.3137E-02
	Upper Plenum	4.98	7.6064E+02	22.8016	8.8653E+03	8.5800E-02
15×15	Lower Nozzle	2.10	3.2029E+02	10.7607	4.9559E+03	6.4628E-02
	Upper Plenum	6.99	1.0670E+03	21.2941	9.8070E+03	1.0880E-01
16×16	Lower Nozzle	2.59	3.9492E+02	11.9685	5.0661E+03	7.7953E-02
	Upper Plenum	7.97	1.2170E+03	25.1358	1.0640E+04	1.1439E-01
17×17	Lower Nozzle	2.79	4.2540E+02	10.4324	4.7831E+03	8.8938E-02
	Upper Plenum	6.85	1.0462E+03	25.6684	1.1768E+04	8.8896E-02

Table 5.3-5 Regional Densities for Directly Loaded Cask Structural and Shield Materials

Material	Element	Density [atom/b-cm]	Density [g/cm^3]
Stainless Steel	Cr	1.65112E-02	7.92
	Fe	6.31986E-02	
	Ni	6.50094E-03	
Zircaloy	Cr	7.58615E-05	6.55
	Fe	1.41261E-04	
	Hf	2.20993E-06	
	Ni	6.72052E-06	
	O	2.46540E-04	
	Sn	4.98421E-04	
	Zr	4.24095E-02	
Aluminum	Al	6.02626E-02	2.70
Lead	Pb	3.20871E-02	11.04
NS-4-FR	Al	7.80000E-03	1.63
	B	4.27500E-04	
	C	2.26000E-02	
	H	5.85000E-02	
	N	1.39000E-03	
	O	2.61000E-02	
Heat Fin	Cu	3.62309E-02	8.35
	Fe	3.61117E-02	
	Cr	9.43448E-03	
	Ni	3.71464E-03	
Balsa	C	2.78553E-03	0.125
	H	4.64261E-03	
	O	2.32135E-03	
NS-4-FR (Fire)	Al	7.80000E-03	0.81
	B	4.27500E-04	
	C	2.26000E-02	

Table 5.3-6 Canistered Fuel and GTCC Material Compositions

Zone/Material	Density (g/cc)	Nuclides	Density (atom/b-cm)
Middle Fuel Zone			
UO_2	2.2769	^{234}U	2.79304E-07
		^{235}U	3.65635E-05
		^{238}U	5.04141E-03
		O	1.01565E-02
Zircaloy	0.6417	Zr	4.23638E-03
SS304	0.3420	Cr	7.52598E-04
		Mn	7.49779E-05
		Fe	2.56318E-03
		Ni	3.33394E-04
Aluminum	0.1091	Al	2.43503E-03
B_4C	0.0101	^{10}B	8.76394E-05
		^{11}B	3.52760E-04
		C	1.10100E-04
Middle Basket/Disk Zone			
SS304	0.9543	Cr	2.10001E-03
		Mn	2.09215E-04
		Fe	7.15218E-03
		Ni	9.30286E-04
Aluminum	0.2920	Al	6.51722E-03
Top Fuel/Basket Zone			
UO_2	2.2769	^{234}U	2.79304E-07
		^{235}U	3.65635E-05
		^{238}U	5.04141E-03
		O	1.01565E-02
Zircaloy		Zr	4.04558E-03
SS304	0.3084	Cr	6.78658E-04
		Mn	6.76116E-05
		Fe	2.31136E-03
		Ni	3.00639E-04
Aluminum	0.0622	Al	1.38826E-03
B_4C	0.0101	^{10}B	8.76394E-05
		^{11}B	3.52760E-04
		C	1.10100E-04
Top Plenum Zone			
Zircaloy	0.5718	Zr	3.77491E-03
SS304	.04821	Cr	1.48517E-03
		Mn	1.05692E-04
		Fe	3.61319E-03
		Ni	4.69968E-04

Table 5.3-6 Canistered Fuel and GTCC Material Compositions (Continued)

Material/Zone	Density (g/cc)	Nuclides	Density (atom/b-cm)
Top End Fitting Zone			
SS304	0.6749	Cr	1.74286E-02
		Mn	1.47961E-04
		Fe	5.05816E-03
		Ni	6.57917E-04
Bottom Fuel/Basket Zone			
UO_2	2.2769	^{234}U	2.79304E-07
		^{235}U	3.65635E-05
		^{238}U	5.04141E-03
		O	1.01565E-02
Zircaloy	0.6128	Zr	4.04558E-03
SS304	0.2350	Cr	6.49170E-04
		Mn	6.46739E-05
		Fe	2.21093E-03
		Ni	2.87577E-04
Aluminum	0.0622	Al	1.38826E-03
B4C	0.0101	^{10}B	8.76394E-05
		^{11}B	3.52760E-04
		C	1.10100E-04
Bottom Plenum Zone			
Zircaloy	0.6128	Zr	4.0455E-03
SS304	1.0529	Cr	2.31699E-03
		Mn	2.30831E-03
		Fe	7.89115E-03
		Ni	1.02640E-03
Bottom Endfitting Zone			
SS304	0.9664	Cr	2.12664E-03
		Mn	2.11867E-04
		Fe	7.24287E-03
		Ni	9.42082E-04
GTCC Waste and Container			
SS304	3.29	Cr	7.2399E-03
		Mn	7.2128E-04
		Fe	2.4658E-02
		Ni	3.2072E-03

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5.4 Shielding Evaluation

The techniques used to perform gamma and neutron dose rate calculations for the NAC-STC in the directly loaded and canistered configurations are described below, including descriptions of the computer codes and methods that were used in the shielding analyses of the cask.

5.4.1 Computer Code Descriptions and Results

5.4.1.1 Directly Loaded Fuel Configuration

To calculate three-dimensional NAC-STC dose rates and define a minimum cool time table, a response function approach is taken to the shielding evaluation. Instead of running numerous direct-solution cases at a discrete matrix of burnups, enrichments, and cool times, three-dimensional dose rate response function cases are executed, thereby evaluating the dose contribution of a "unit" source in each significant energy group in each source region. Six sets of response functions are required based on the defined source regions: fuel gamma, fuel neutron, fuel n-gamma, lower end-fitting gamma, upper plenum gamma and upper end-fitting gamma. Fuel hardware contributions to dose rates are evaluated using the fuel gamma response functions. For each source region, a subset of the 28 neutron and 22 gamma energy groups is evaluated to increase the efficiency of the analysis. Fuel gamma doses are calculated using gamma groups 7 through 16; fuel neutron and fuel n-gamma doses are calculated using neutron groups 2 through 15; and hardware sources are calculated using gamma groups 12 through 14. Neutron groups 1 and 16 through 28 contain no neutron source. The hardware source is dominated by the ^{60}Co source, which resides in groups 12 through 14. Fuel gamma groups 7 through 16 are selected based on the integrated source energy in each group (Source magnitude drops by a factor of 1,000 when moving from fuel group 7 to group 6.). The choice of energy groups evaluated is verified by running "direct" solutions using the complete spectrum and demonstrating that the total dose is reproduced within the Monte Carlo error of the analysis. Sample comparisons of the dose response method (DRM) to direct-solution cases are shown in Figures 5.4-7 and 5.4-8 for normal and accident conditions, respectively. As shown, the dose response method reproduces direct solution results within the uncertainty of the analysis. Since the dose response method evaluates each source energy line individually, and therefore avoids statistical sampling within the energy group structure of the source, the results of the dose response method tend towards smaller Monte Carlo uncertainty bands.

Calculational Methods

The shielding evaluation of the directly loaded configuration is performed using MCBEND. Source terms include fuel neutron, fuel gamma and gamma contributions from activated hardware. As described in Section 5.2.1.3, the evaluation includes the effect of fuel burnup peaking on fuel neutron and gamma source terms.

The MCBEND shielding model described in Section 5.3.1 is utilized with the source terms described in Section 5.2.1 to estimate the dose rate profiles at various distances from the side, top and bottom of the cask for both normal and accident conditions. 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 side of the cask. Axial biasing is performed to estimates dose rates on the top and bottom of the cask.

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.

MCBEND Flux-to-Dose Conversion Factors

The ANSI/ANS 6.1.1-1977 flux-to-dose rate conversion factors are used in all shielding evaluations for directly loaded fuel. The ANSI/ANS gamma and neutron dose conversion factors are shown in Table 5.4-1 and Table 5.4-2. The number of energy/conversion factor pairs was increased to 133 neutron and 371 gamma pairs by a log-log interpolation scheme indicated as appropriate in ANSI/ANS 6.1.1-1977.

Loading Table for Directly Loaded Fuel

Three-dimensional radial response functions are generated for PWR fuel assemblies for both normal and accident conditions. Based on preliminary analysis, two bounding axial shift scenarios have been established: 1) maximum fuel assembly shift upward in the cask cavity

without a corresponding shift in the basket and 2) no fuel assembly or basket shift. For axial biasing, the limiting shift scenario corresponds exactly to the position of the fuel assembly in the cavity, i.e., top dose rates are maximized when the fuel assembly is shifted up and bottom dose rates are maximized when the fuel assembly is as far down in the cavity as possible. For radial biasing, the two different shift scenarios are limiting for different transport conditions. The maximum fuel assembly axial shift is limiting for normal conditions because upper plenum and upper end fitting hardware move adjacent to the location in the radial shield where the radial lead shield ends. The limiting shift is downward for accident conditions due to the bottom axial lead slump, which is adjacent to the lower end fitting hardware source.

The first step in determining limiting PWR dose rates for the directly loaded cask is the generation of dose rate response functions for generation of minimum cool time tables. For each array size, at each of 4 burnup, 15 enrichment, and 18 cool time combinations, dose rate profiles are calculated for both normal and accident transport conditions. Using these dose rate profiles, the maximum radial dose rates at 2 meters from the railcar are tabulated for normal conditions.

Minimum cool times are calculated to ensure that a decay heat limit of 850 W/assembly is not exceeded and that the dose rate at 2 meters from the railcar does not exceed 9.5 mrem/hr. The 9.5 mrem/hr analysis limit was chosen to provide margin against the 10 mrem/hr regulatory limit. Cool times needed to reach these limits are calculated using linear interpolation on the entire array of maximum dose rates. The linear interpolation is valid because of the exponential decrease in source term and, thus, dose rate as a function of time. The interpolated cool time is rounded up to the next integer year. A sample minimum cool time generation for the 14×14 reference assembly at 40,000 MWD/MTU is shown in Table 5.4-3. Repeating this analysis for all fuel types and burnups results in the complete loading table shown in Table 5.4-5. Based on the loading table, maximum radial dose rates for each fuel type are shown in Table 5.4-4.

The minimum cool times are used to calculate maximum accident condition dose rates at 1 meter from the cask. The 1000 mrem/hr limit is not exceeded at any of the calculated minimum cool times.

Based on the radial dose rate results for normal and accident conditions and their application to the minimum cool time table, the 14×14 reference assembly provides maximum dose rates. Thus, top axial and bottom axial response functions have been executed for this assembly only. This ensures that the maximum axial dose rates for the directly loaded system are captured, and that variations in burnup, enrichment and minimum cool time are thoroughly examined.

A summary of the limiting source terms for each transport condition and detector biasing is given below. All limiting source terms are taken from the 14×14 reference fuel assembly.

Detector Biasing	Normal Conditions			Accident Conditions		
	Burnup [MWD/MTU]	Enrichment [wt % ^{235}U]	Cool Time [Years]	Burnup [MWD/MTU]	Enrichment [wt % ^{235}U]	Cool Time [Years]
Radial	40,000	2.3	10	45,000	2.3	14
Top Axial	30,000	2.3	6	45,000	2.3	14
Bottom Axial	40,000	2.3	10	45,000	2.3	14

Three-Dimensional Dose Rates for Directly Loaded Fuel

Further detail on the three-dimensional dose rates are presented in Figures 5.4-1 through 5.4-6 for the limiting 14×14 reference assembly. Maximum dose rates are tabulated in Tables 5.4-6 and 5.4-7.

The maximum normal conditions surface dose rate is 366 mrem/hr at an axial elevation between the radial neutron shield and the upper impact limiter. At 1 meter from the surface of the neutron shield shell, the maximum dose rate is 20.3 mrem/hr. This dose rate defines the transport index. The maximum normal conditions dose rate at 2 meters from the cask railcar is 9.5 mrem/hr and occurs at an axial elevation adjacent to the upper plenum and upper end-fitting elevations. The maximum accident conditions dose rate at 1 meter from the cask is 665 mrem/hr and occurs at the cask midplane. The top and bottom axial dose rates are small when compared to the radial dose rate for the same transport conditions.

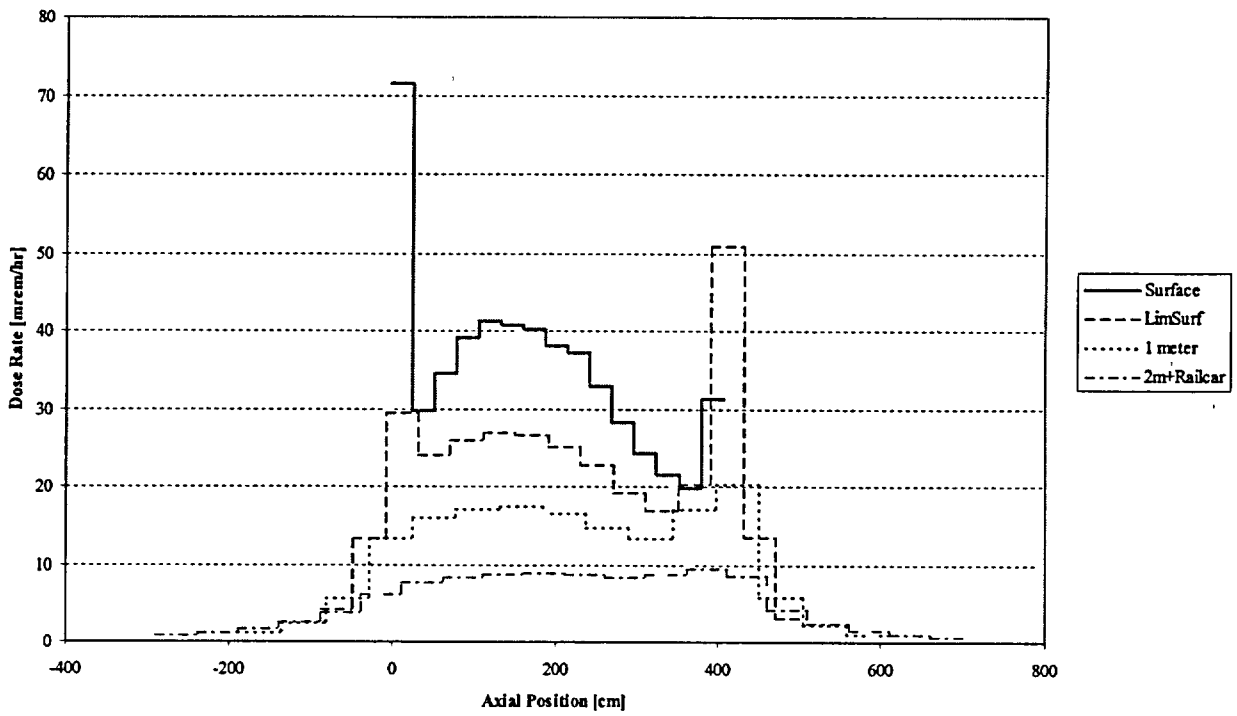
Dose rate variations from heat fins in the neutron shield are examined explicitly using azimuthal detectors that span the entire length of the neutron shield. As shown in Figure 5.4-4, peaks in the neutron dose rate correspond to dips in the gamma dose rate, and vice versa. Thus, the neutron dose rate increase resulting from the ducting is offset by the reduction of the gamma dose rate resulting from the additional shielding provided by the fins.

Detector descriptions for dose rates on the side of the STC are given in Tables 5.4-8 and 5.4-9 for normal and accident conditions, respectively. Note that an axial height of 0.0 cm corresponds to the bottom of the STC cavity.

5.4.1.2 Canistered Yankee Class Fuel and GTCC Waste

Shielding evaluations of canistered Yankee Class fuel and GTCC waste are performed with SCALE 4.3 for the PC (ORNL, 1995). In particular, SCALE 4.3 shielding analysis sequence SAS2H (Herman, 1995) is used to generate source terms for the design basis fuel and GTCC waste hardware and SAS1 (Knight, 1995) is used to perform one-dimensional radial and axial shielding analysis. Transverse leakage is accounted for by the use of radial and axial bucklings. The 27 group neutron, 18 group gamma, coupled cross section library (27N-18COUPLE) based on ENDF/B-IV (Jordan, 1995) is used in all shielding evaluations. Fuel source terms include fuel neutron, fuel gamma, and activated hardware gamma. GTCC waste hardware source terms are based on core baffle activated hardware characterization from dose rate measurements and baffle material chemical assay. Dose rate evaluations include the effect of fuel burnup peaking on fuel neutron and gamma source terms.

Figure 5.4-1 Radial Dose Rate Profiles for Directly Loaded Fuel in Normal Conditions of Transport



Note: The dose rate at the surface of the cask between the neutron shield and the upper impact limiter is 366.3 (0.2%) mrem/hr.

Figure 5.4-4 Azimuthal Radial Surface Dose Rate Profile by Source Type over Heat Fin Axial Extent for Directly Loaded Fuel in Normal Conditions of Transport

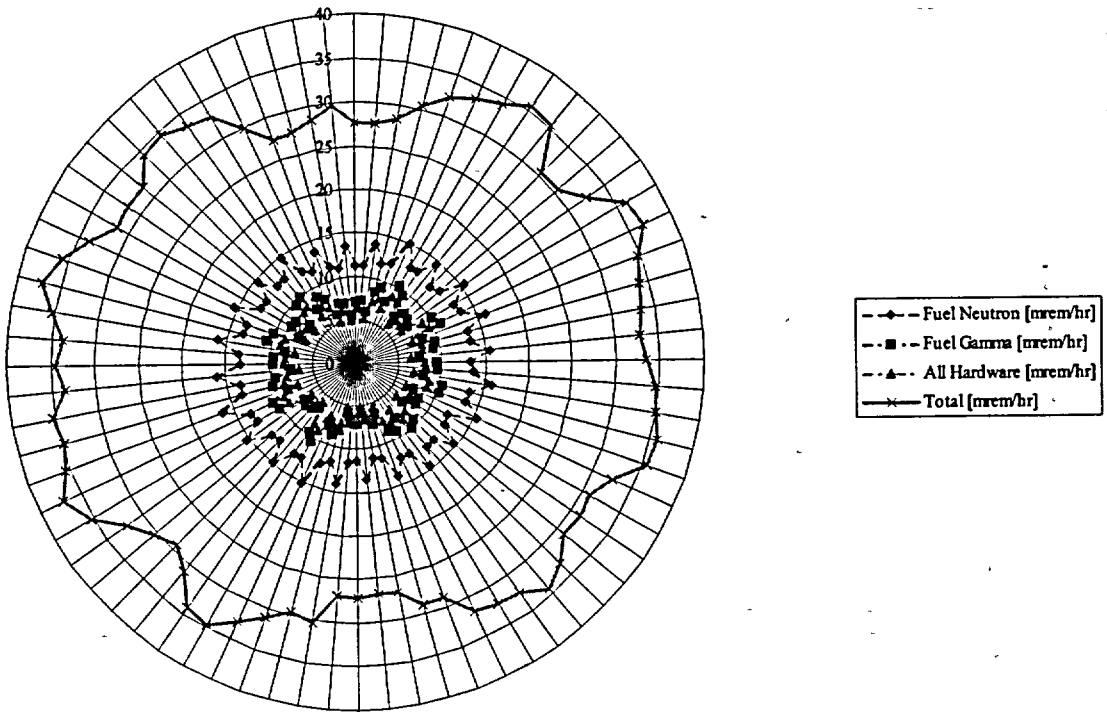


Figure 5.4-5 Radial Dose Rate Profile by Source Type at 1 meter for Directly Loaded Fuel in the Accident Condition

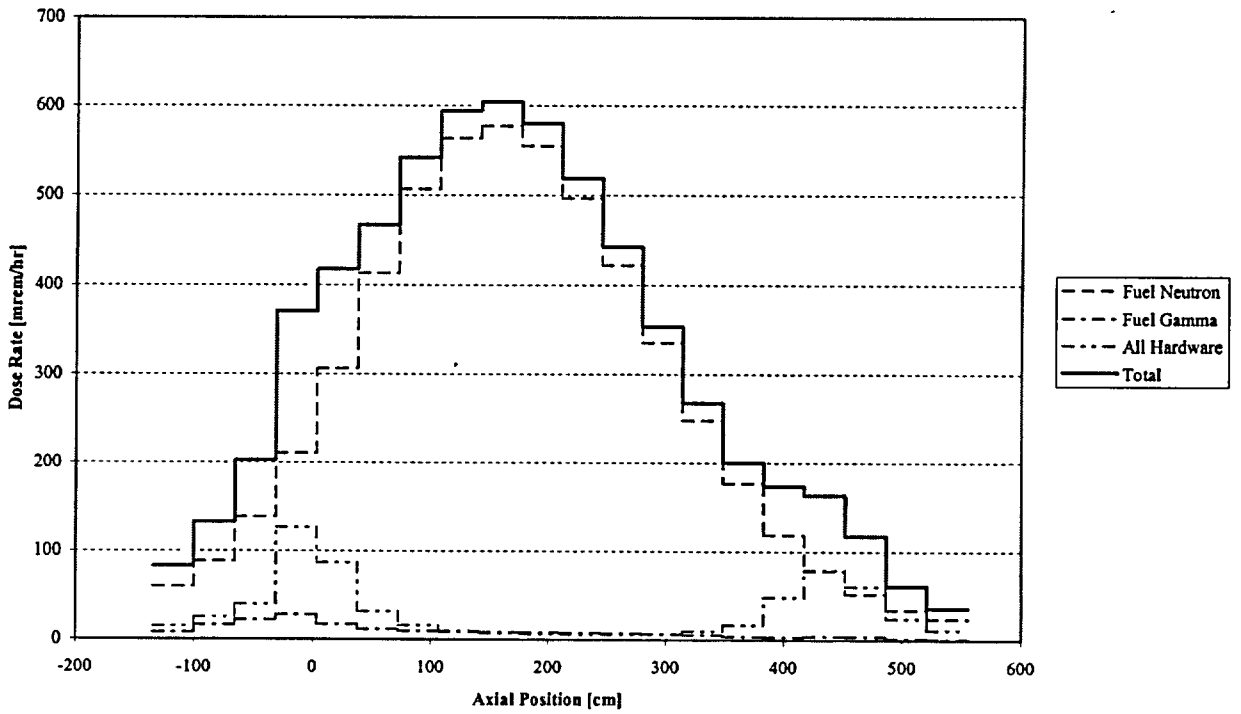


Figure 5.4-6 Azimuthal Radial Dose Rate Profile at 1 meter for Directly Loaded Fuel in the Accident Condition

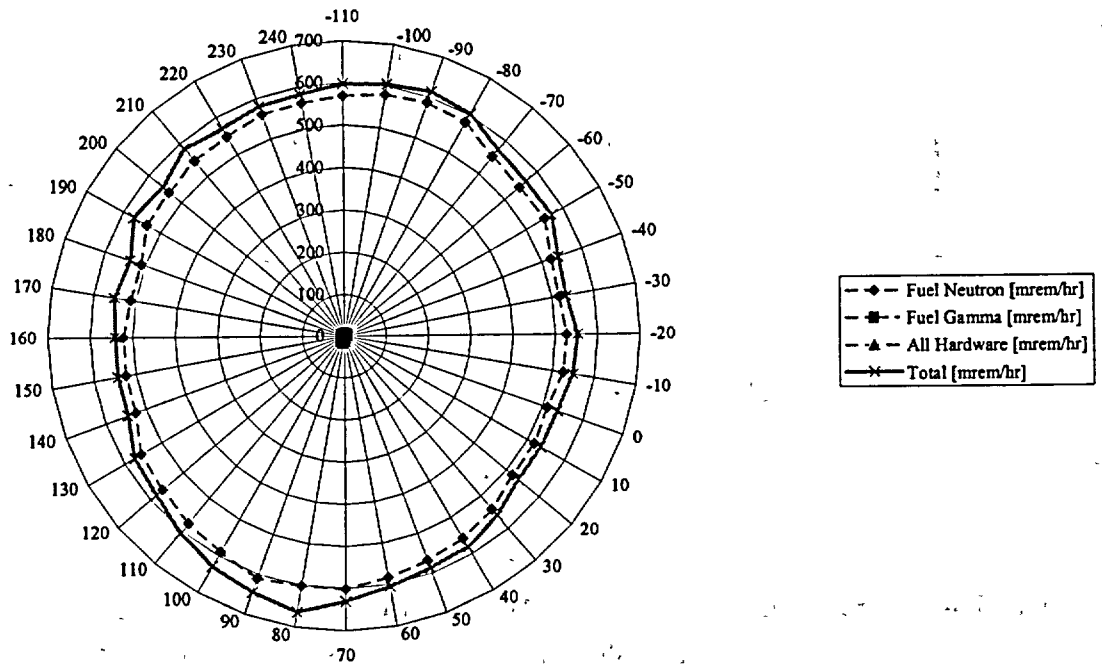


Figure 5.4-7 Graphical Comparison of Normal Conditions Radial 2m+Railcar Dose Rate Profile for DRM and Direct Solution – 14×14 Assembly at 40,000 MWD/MTU, 3.7 wt % ^{235}U, 7 Years Cool Time

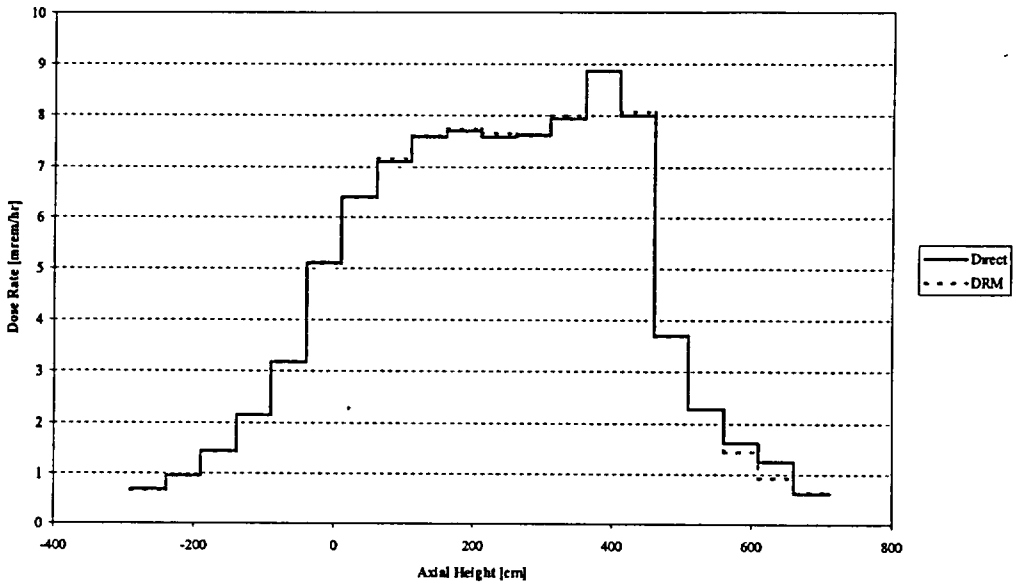


Figure 5.4-8 Graphical Comparison of Accident Conditions Radial 1m Dose Rate Profile for DRM and Direct Solution – 15×15 Assembly at 40,000 MWD/MTU, 3.7 wt % ^{235}U, 7 Years Cool Time

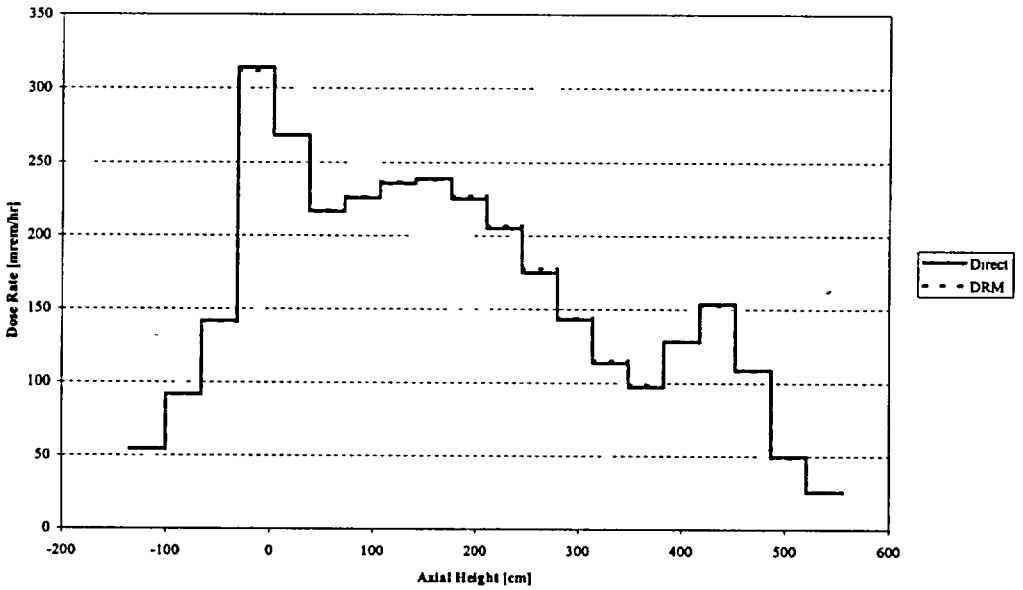


Table 5.4-1 ANSI/ANS 6.1.1-1977 Neutron Flux-to-Dose Conversion Factors

Energy, E [MeV]	Response [(rem/hr)/(n/cm^2/sec)]
20.0	2.27E-04
14.0	2.08E-04
10.0	1.47E-04
7.0	1.47E-04
5.0	1.56E-04
2.5	1.25E-04
1.0	1.32E-04
5.0E-01	9.26E-05
1.0E-01	2.17E-05
1.0E-02	3.56E-06
1.0E-03	3.76E-06
1.0E-04	4.18E-06
1.0E-05	4.54E-06
1.0E-06	4.46E-06
1.0E-07	3.67E-06
2.5E-08	3.67E-06

Table 5.4-2 ANSI/ANS 6.1.1-1977 Gamma Flux-to-Dose Conversion Factors

Energy, E [MeV]	Response [(rem/hr)/(γ/cm²/sec)]	Energy, E [MeV]	Response [(rem/hr)/(γ/cm²/sec)]
15.0	1.33E-05	1.0	1.98E-06
13.0	1.18E-05	0.8	1.68E-06
11.0	1.03E-05	0.7	1.52E-06
9.0	8.77E-06	0.65	1.44E-06
7.5	7.66E-06	0.6	1.36E-06
6.75	7.11E-06	0.55	1.27E-06
6.25	6.74E-06	0.5	1.17E-06
5.75	6.37E-06	0.45	1.08E-06
5.25	6.01E-06	0.4	9.85E-07
5.0	5.80E-06	0.35	8.78E-07
4.75	5.60E-06	0.3	7.59E-07
4.25	5.23E-06	0.25	6.31E-07
3.75	4.83E-06	0.2	5.01E-07
3.25	4.41E-06	0.15	3.79E-07
2.8	4.01E-06	0.1	2.83E-07
2.6	3.82E-06	0.07	2.58E-07
2.2	3.42E-06	0.05	2.90E-07
1.8	2.99E-06	0.03	5.82E-07
1.4	2.51E-06	0.01	3.96E-06

Table 5.4-3 Minimum Cooling Time Evaluation for 14×14 Reference Fuel

Enrichment [wt % ^{235}U]	Minimum Cooling Time (Years) 40,000 MWD/MTU			Active Constraint
	Decay Heat 850 W/assy	2m+Railcar 9.5 mrem/hr	Limiting	
1.7	-	-	-	-
1.9	6.2	11.6	12	2m+Railcar
2.1	6.1	10.8	11	2m+Railcar
2.3	6.0	10.0	10	2m+Railcar
2.5	5.9	9.3	10	2m+Railcar
2.7	5.8	8.7	9	2m+Railcar
2.9	5.8	8.2	9	2m+Railcar
3.1	5.7	7.7	8	2m+Railcar
3.3	5.6	7.3	8	2m+Railcar
3.5	5.6	6.9	7	2m+Railcar
3.7	5.5	6.5	7	2m+Railcar
3.9	5.5	6.2	7	2m+Railcar
4.1	5.4	5.9	6	2m+Railcar
4.3	5.4	5.7	6	2m+Railcar
4.5	5.3	5.6	6	2m+Railcar

Table 5.4-4 Radial Dose Rate Loading Table Results for Directly Loaded Fuel in Normal Conditions of Transport

Assembly	Source Term			Radial Dose Rate [mrem/hr]	
	Burnup [MWD/MTU]	Enrichment [wt % ^{235}U]	Cool Time [years]	Surface	2m+Railcar
14×14	40,000	2.3	10	366.3	9.5
15×15	40,000	2.5	9	337.8	9.4
16×16	40,000	1.9	9	317.4	9.2
17×17	40,000	2.3	9	358.9	9.2

Table 5.4-5 Loading Table for Directly Loaded PWR Fuel

Minimum Initial Enrichment wt % ^{235}U (E)	Burnup ≤30 GWD/MTU Minimum Cooling Time [years]				30< Burnup ≤35 GWD/MTU Minimum Cooling Time [years]			
	14×14	15×15	16×16	17×17	14×14	15×15	16×16	17×17
1.7 ≤ E < 1.9	8	7	6	7	10	10	7	9
1.9 ≤ E < 2.1	7	7	5	7	9	9	7	8
2.1 ≤ E < 2.3	7	7	5	6	9	8	6	8
2.3 ≤ E < 2.5	6	6	5	6	8	8	6	7
2.5 ≤ E < 2.7	6	6	5	6	8	7	6	7
2.7 ≤ E < 2.9	6	6	5	5	7	7	5	6
2.9 ≤ E < 3.1	6	5	5	5	7	7	5	6
3.1 ≤ E < 3.3	5	5	5	5	7	6	5	6
3.3 ≤ E < 3.5	5	5	5	5	6	6	5	6
3.5 ≤ E < 3.7	5	5	5	5	6	6	5	6
3.7 ≤ E < 3.9	5	5	5	5	6	6	5	6
3.9 ≤ E < 4.1	5	5	5	5	6	6	5	6
4.1 ≤ E < 4.3	5	5	5	5	5	6	5	6
4.3 ≤ E < 4.5	-	-	-	5	-	-	-	6
E ≥ 4.5	-	-	-	5	-	-	-	6

Minimum Initial Enrichment wt % ^{235}U (E)	35< Burnup ≤40 GWD/MTU Minimum Cooling Time [years]				40< Burnup ≤45 GWD/MTU Minimum Cooling Time [years]			
	14×14	15×15	16×16	17×17	14×14	15×15	16×16	17×17
1.7 ≤ E < 1.9	-	-	-	-	-	-	-	-
1.9 ≤ E < 2.1	12	13	9	11	-	-	-	-
2.1 ≤ E < 2.3	11	11	8	10	-	-	-	-
2.3 ≤ E < 2.5	10	10	8	9	14	15	12	14
2.5 ≤ E < 2.7	10	9	7	9	13	14	10	12
2.7 ≤ E < 2.9	9	9	7	8	12	12	9	11
2.9 ≤ E < 3.1	9	8	6	8	11	11	8	10
3.1 ≤ E < 3.3	8	8	6	7	10	10	8	9
3.3 ≤ E < 3.5	8	7	6	7	10	10	7	9
3.5 ≤ E < 3.7	7	7	6	7	9	9	7	9
3.7 ≤ E < 3.9	7	7	6	7	9	9	7	9
3.9 ≤ E < 4.1	7	7	6	7	8	9	7	9
4.1 ≤ E < 4.3	6	7	6	7	8	8	7	9
4.3 ≤ E < 4.5	-	-	-	7	-	-	-	8
E ≥ 4.5	-	-	-	7	-	-	-	8

Table 5.4-6 Detector Maximum Dose Rates for Directly Loaded Fuel in Normal Conditions of Transport

Detector	Source	Surface		2 meter	
		mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	0.4	0.2%	0.1	0.2%
	Fuel Gamma	0.2	0.8%	0.0	1.1%
	Fuel Hardware	0.3	1.8%	0.0	2.2%
	Fuel N-Gamma	0.1	1.3%	0.0	1.4%
	Upper Plenum	2.1	0.5%	0.4	0.5%
	Upper Nozzle	3.0	0.6%	0.6	0.6%
	Lower Nozzle	0.0	0.0%	0.0	0.0%
	Total	6.1	0.3%	1.3	0.3%
Radial	Fuel Neutron	152.2	0.3%	2.9	0.3%
	Fuel Gamma	2.2	3.8%	1.2	0.8%
	Fuel Hardware	6.1	5.7%	0.5	4.4%
	Fuel N-Gamma	1.4	4.7%	0.8	0.9%
	Upper Plenum	87.2	0.4%	1.8	0.4%
	Upper Nozzle	117.3	0.4%	2.2	0.5%
	Lower Nozzle	0.0	15.0%	0.0	0.8%
	Total	366.3	0.2%	9.5	0.3%
Bottom Axial	Fuel Neutron	4.0	0.3%	0.7	0.2%
	Fuel Gamma	0.7	1.1%	0.1	0.7%
	Fuel Hardware	2.3	0.9%	0.4	4.1%
	Fuel N-Gamma	0.4	1.3%	0.1	0.9%
	Upper Plenum	0.0	0.0%	0.0	0.0%
	Upper Nozzle	0.0	0.0%	0.0	0.0%
	Lower Nozzle	7.0	0.8%	1.3	0.7%
	Total	14.3	0.4%	2.6	0.7%

Note: Dose rates at 2 meter locations radially are 2 meters from the railcar. Dose rates at 2 meter locations axially are measured from the ends of the impact limiters.

Table 5.4-7 Detector Maximum Dose Rates for Directly Loaded Fuel in Accident Conditions

Detector	Source	Surface		1 meter	
		mrem/hr	RSD	mrem/hr	RSD
Top Axial	Fuel Neutron	31.2	0.5%	23.3	0.9%
	Fuel Gamma	1.8	2.6%	1.2	2.0%
	Fuel Hardware	1.5	4.6%	0.9	30.2%
	Fuel N-Gamma	0.5	1.3%	0.4	2.8%
	Upper Plenum	11.8	1.0%	6.2	1.0%
	Upper Nozzle	4.8	1.7%	2.0	2.0%
	Lower Nozzle	0.0	0.0%	0.0	0.0%
	Total	51.7	0.5%	34.1	1.1%
Radial	Fuel Neutron	1585.5	0.2%	577.8	0.2%
	Fuel Gamma	15.2	1.5%	8.1	0.9%
	Fuel Hardware	27.8	12.2%	11.8	11.7%
	Fuel N-Gamma	8.3	1.8%	4.3	1.1%
	Upper Plenum	0.0	0.0%	0.1	2.6%
	Upper Nozzle	0.0	0.0%	0.1	5.4%
	Lower Nozzle	0.0	44.5%	2.4	0.6%
	Total	1636.7	0.3%	604.6	0.3%
Bottom Axial	Fuel Neutron	119.3	0.3%	51.2	6.3%
	Fuel Gamma	20.5	1.2%	5.4	1.3%
	Fuel Hardware	5.0	4.7%	1.4	4.4%
	Fuel N-Gamma	5.4	1.1%	1.5	1.2%
	Upper Plenum	0.0	0.0%	0.0	0.0%
	Upper Nozzle	0.0	0.0%	0.0	0.0%
	Lower Nozzle	36.3	1.1%	9.6	1.3%
	Total	186.5	0.3%	69.1	4.7%

Note: The azimuthal maximum radial dose rates are 1728.3 (1.8%) and 663.9 (4.4%) mrem/hr at the surface and at 1 meter from the surface, respectively.

Table 5.4-8 Directly Loaded Radial Detector Description for Normal Conditions of Transport

Description	Inner Radius [cm]	Axial				Azimuthal	
		Lower [cm]	Upper [cm]	Divisions	Band [cm]	Divisions	Start Angle
Surface	124.71	-3.81	406.70	15	27.37	1	0
Package	110.11	406.70	425.60	1	18.90	1	0
Heat Fin	125.71	44.38	405.50	1	361.12	72	2.5
Trunnion	126.71	-3.81	19.05	1	22.86	36	5
2m+Railcar	357.48	-289.92	710.69	20	50.03	1	0

Table 5.4-9 Directly Loaded Radial Detector Description for Accident Conditions of Transport

Description	Inner Radius [cm]	Axial				Azimuthal	
		Lower [cm]	Upper [cm]	Divisions	Band [cm]	Divisions	Start Angle
Surface	124.71	-34.67	455.45	15	32.67	1	0
Surface Azi.	125.71	185.68	215.68	1	30.00	36	-110
1m	210.11	-134.67	555.45	20	34.51	1	0
1m Azi.	211.11	185.68	215.68	1	30.00	36	-110

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5.5 Sample Input Files

This section contains sample input files employed in the shielding evaluations of the NAC-STC.

5.5.1 Sample Input Files for Directly Loaded Fuel

Sample input files for directly loaded fuel are provided in Figures 5.5-1 through 5.5-4.

Figure 5.5-1 SASH Input File for Directly Loaded 14x14 Fuel at 40,000 MWD/MTU and 2.3 wt % ^{235}U

```
=SAS2H       PARM=(HALT09,SKIPSHIPDATA)
Class 1 - aal4b - STC Hybrid14 (Rev 0) - 2.3 w/o U235, 40000 MWD/MTU, 5 - 16 years cool time
27GROUPNDF4 LATTICECELL
UO2          1 0.950 900 92235 2.3 92238 97.7 END
ZIRCALLOY  2 1.0 620 END
H2O          3 DEN=0.725 1.0 580 END
ARBM-BORMOD 0.725 1 1 0 0 5000 100 3 550.0E-6 580 END
ZIRCALLOY  4 1.0 580 END
H2O          5 DEN=0.725 0.9476 580 END
ZIRCALLOY  5 0.0524 580 END
END COMP
SQUAREPITCH 1.4122 0.9332 1 3 1.0719 2 0.9576 0 END
NPIN=179 FUEL=368.808 NCYC=3 NLIB=3 PRIN=6 LIGH=5
INPL=1 NUMH=16 NUMI=1 MXTUBE=4 ORTU=0.6102 SRTU=0.5239 END
POWER=13.7183 BURN=402.7954 DOWN=60 END
POWER=13.7183 BURN=402.7954 DOWN=60 END
POWER=13.7183 BURN=402.7954 DOWN=1461 END
FE 0.6738 CR 0.1900 NI 0.1150 MN 0.0200 CO 0.0012
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 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**  4.0 E T
COOLING 5 - 16 YEARS AND FISSION PRODUCT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7 0 8.0 9.0 10 0 12.0 14.0 16.0
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$$  F6
83**  1.40e+7  1 20e+7  1.00e+7  8.00e+6   6 50e+6  5 00e+6
      4.00e+6  3 00e+6  2.50e+6  2.00e+6   1.66e+6  1.44e+6
      1.22e+6  1 00e+6  0.80e+6  0.60e+6   0.40e+6  0.30e+6
      0.20e+6  0.10e+6  0.05e+6  0.02e+6   0.01e+6
84**  1.46e+7  1.36e+7  1.25e+7  1.125e+7  1.00e+7
      8.25e+6  7.00e+6  6.07e+6  4.72e+6   3.68e+6
      2.87e+6  1.74e+6  0.64e+6  0.39e+6   0.11e+6
      6.74e+4  2.48e+4  9.12e+3  2.95e+3   9.61e+2
      3.54e+2  1.66e+2  4.81e+1  1.60e+1   4.00e+0
      1.50e+0  5.50e-1  7.09e-2  1.00e-5   T
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
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FISSION PRODUCT GAMMA SPECTRA IN AEA GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 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**  4.0 E T
COOLING 5 - 16 YEARS AND ACTINIDE GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
65$$  A4 1 A7 1 A10 1 A25 1 A28 1 A31 1 A46 1 A49 1 A52 1 E
61**  F.00000001
```

Figure 5.5-1 SASH Input File for Directly Loaded 14x14 Fuel at 40,000 MWD/MTU and 2.3 wt% ^{235} (Continued)

```
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 GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
ACTINIDE GAMMA SPECTRA IN AEA GROUPS
56$$ F0  T
END
=ORIGENS
0$$  A4 21 A8 26 A10 51 71  E
1$$  1 1T
COOLING 5 - 16 YEARS AND LIGHT ELEMENT GAMMA REBIN
3$$  21 0 1 28 A33 22 E
54$$  A8 1 E T
35$$  0 T
56$$  0 9 A13 -2 5 3 E
57**  4.0 E T
COOLING 5 - 16 YEARS AND LIGHT ELEMENT GAMMA REBIN
SINGLE REACTOR ASSEMBLY
60** 5.0 6.0 7.0 8.0 9.0 10.0 12.0 14.0 16.0
65$$  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 AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
LIGHT ELEMENT AEA GROUP STRUCTURE
56$$ F0  T
END
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions

```
columns 1 200
*
*   NAC-STC - aa14b_07g - Fuel Gamma - Radial
*   Dry Cavity Conditions
*   Normal Transport Conditions
*   Transport Model Revision v1.5.1.0
*   Shielding Revision v1.5
*   STC Source Profile
*   Cobalt Concentration of 1.2 g/kg
*   Fuel Assembly Shift = Cavity, Basket Shift = None
*
* Parameters
*
@samps =    10000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit     1000m
    seeds    33113    94930
    chime every    [@samps/10]    samples
    report interim results
    sbd    30s
    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 1 - aa14b - STC Hybrid14 (Rev 0)
PART    1    NEST
BOX    M5        0.0000    0.0000    0.0000    19.7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0.0000    0.0000    0.0000    19.7180    19.7180    377.5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    19.7180    19.7180    409.1940    ! upper nozzle
* Fuel Assembly Type B - Class 1 - aa14b - STC Hybrid14 (Rev 0)
PART    2    NEST
BOX    M5        0.0000    0.0000    0.0000    19.7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0.0000    0.0000    0.0000    19.7180    19.7180    377.5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    19.7180    19.7180    409.1940    ! upper nozzle
* Fuel Assembly in Tube (Type A) v1.1
PART    3
BOX    1    1.4135    1.4135    9.9060    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.1
PART    4
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
BOX    1    1.4135    1.4135    9.9060    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.2
PART    5    CLUSTER
BOX    P3    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type A with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419.1000    ! Support disk opening width
*  Type B Disk Opening with Tube v1.2
PART    6    CLUSTER
BOX    P4    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type B with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419.1000    ! Support disk opening width
* STC Basket v1.2
PART    7
BOX    1    -38.9153    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 1
BOX    2    -11.7272    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 2
BOX    3    15.4610    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 3
BOX    4    -70.7136    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 4
BOX    5    -38.9153    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 5
BOX    6    -11.7272    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 6
BOX    7    15.4610    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 7
BOX    8    47.2592    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 8
BOX    9    -70.7136    1.8669    0 0000    23.4544    23.4544    419.1000    ! Basket Opening 9
BOX    10    -38.9153    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 10
BOX    11    -11.7272    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 11
BOX    12    15.4610    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 12
BOX    13    47 2592    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 13
BOX    14    -70.7136    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 14
BOX    15    -38.9153    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 15
BOX    16    -11.7272    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 16
BOX    17    15.4610    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 17
BOX    18    47.2592    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 18
BOX    19    -70.7136    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 19
BOX    20    -38.9153    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 20
BOX    21    -11.7272    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 21
BOX    22    15.4610    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 22
BOX    23    47.2592    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 23
BOX    24    -38.9153    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 24
BOX    25    -11.7272    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 25
BOX    26    15.4610    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 26
ZROD    27    0.0000    0.0000    0.0000    89.9922    419.1000    ! Basket stack to cavity height
ZONES
/Opening01/    P5    +1
/Opening02/    P5    +2
/Opening03/    P5    +3
/Opening04/    P6    +4
/Opening05/    P5    +5
/Opening06/    P5    +6
/Opening07/    P5    +7
/Opening08/    P6    +8
/Opening09/    P5    +9
/Opening10/    P5    +10
/Opening11/    P5    +11
/Opening12/    P5    +12
/Opening13/    P5    +13
/Opening14/    P5    +14
/Opening15/    P5    +15
/Opening16/    P5    +16
/Opening17/    P5    +17
/Opening18/    P5    +18
/Opening19/    P6    +19
/Opening20/    P5    +20
/Opening21/    P5    +21
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
/Opening22/    P5    +22
/Opening23/    P6    +23
/Opening24/    P5    +24
/Opening25/    P5    +25
/Opening26/    P5    +26
/Basket/    H1    +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
VOLUMES    UNITY
* Basket in Cask Cavity v1.2
PART    8    NEST
ZROD    P7    0.0000    0.0000    0.0000    89.9922    419.1000        ! Basket inserted - Includes gap to lid
ZROD    H5    0.0000    0.0000    0.0000    90.1700    419.1000        ! Inserts flood matl to id of stc
* Transport Cask Inner Lid - With Ports v1.5.1.0
PART    9
ZROD    1    0.0000    0.0000    0.0000    100.3300    18.0848                ' Inner lid base
ZROD    2    0.0000    0.0000    18.0848    92.5957    4.7752                ! Inner lid cap
ZROD    3    0.0000    77.9907    0.0000    8.2931    22.8600                ! Drain port
ZROD    4    0.0000    -77 9907    0.0000    8.2931    22.8600                ! Vent port
ZROD    5    0.0000    0.0000    15.2400    85.6234    5.0800                ! Neutron shield
ZROD    6    0.0000    77.9907    15.2400    10.1600    5.0800                ! Cut circle 1 for neutron shield
ZROD    7    0.0000    -77.9907    15.2400    10.1600    5.0800                ! Cut circle 2 for neutron shield
BOX    8    -10.1600    77.9907    15.2400    20.3200    7.6327    5.0800            ! Cut box 1 for neutron shield
BOX    9    -10.1600    -85.6234    15.2400    20.3200    7.6327    5.0800            ! Cut box 2 for neutron shield
ZROD    10    0.0000    0.0000    0.0000    100.3300    22.8600                ' Container
ZONES
/Container/    M0    +10    -1    -2
/LidBase1/    M16    +1    -3    -4    -5    -6    -7
        -8    -9
/LidBase2/    M16    +1    +8    -6
/LidBase3/    M16    +1    +9    -7
/LidBase4/    M16    +1    +6    -3
/LidBase5/    M16    +1    +7    -4
/Nshield/    M15    +5    -6    -7    -8    -9
/LidCap1/    M16    +2    -3    -4    -5    -6    -7
        -8    -9
/LidCap2/    M16    +2    +8    -6
/LidCap3/    M16    +2    +9    -7
/LidCap4/    M16    +2    +6    -3
/LidCap5/    M16    +2    +7    -4
/DrainPort/    P10    +3
/VentPort/    P10    +4
VOLUMES UNITY
* Transport Cask Inner Lid Port Model - With Covers v1.5.1 0
PART    10    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.2700    10 8966                ! Bottom cylinder
ZROD    M0    0.0000    0.0000    10 8966    4.1275    7.5184                ' Middle cylinder
ZROD    M16    0.0000    0.0000    18 4150    8.2931    2.5400                ! Cover
ZROD    M0    0.0000    0.0000    20.9550    8.2931    1.9050                ! Top cylinder
ZROD    M16    0.0000    0.0000    0.0000    8.2931    22.8600                ' Inner lid material
*Transport Cask - Normal Conditions v1.5.1.0
PART    11
ZROD    1    0.0000    0.0000    -34.6710    110.1090    490.1184                ! Transport Cask
ZROD    2    0.0000    0.0000    0.0000    90.1700    419.1000                ! Cavity
ZROD    3    0.0000    0.0000    -20.8280    100.1776    5.0800                ! Bottom neutron shield
ZROD    4    0.0000    0.0000    419.1000    100.3300    22.8600                ! Inner lid
ZROD    5    0.0000    0.0000    0.0000    103.4034    408.9400                ! Lead shield cavity
ZROD    6    0.0000    0.0000    0.0000    95.2500    30.4800                ' Inner shell lower
ZCONE    7    0.0000    0.0000    30.4800    95.2500    93.9800    7.6200            ! Inner shell lower cone
ZROD    8    0.0000    0.0000    38.1000    93.9800    332.7400                ! Inner shell middle
ZCONE    9    0.0000    0.0000    370.8400    93.9800    95.2500    7.6200            ! Inner shell upper cone
ZROD    10    0.0000    0.0000    378.4600    95.2500    30.4800                ! Inner shell upper
ZROD    11    0.0000    0.0000    0.0000    103.2891    408.9400                ! Lead shield
ZROD    12    0.0000    0.0000    -3.8100    124.7140    410.5148                ! Radial neutron shield shell
ZROD    13    0.0000    0.0000    -2.6100    124.0790    408.1148                ! Radial neutron shield
ZP    14    2.4700                    ! Insulation (void) cut plane
ZCONE    15    0 0000    0.0000    19.0500    124.7140    113.9190    24.1300            ! Top of rotating trunnion
BOX    16    -124.7140    -12.7000    -3.8100    249.4280    25.4000    22.8600            ! Bottom of rotating trunnion
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
BOX   17  -114.2238  -12.7000  -3.8100  228.4476  25.4000  22.8600          ! Bottom of rotating trunnion base
BOX   18  -124.7140  -7.6200  -3.8100  249.4280  15.2400  15.2400          ! Trunnion void box
XROD  19  -124.7140  0.0000  11.4300  7.6200  249.4280                     ! Trunnion void circle
BOX   20  -124.7140  -12.7000  -3.8100  249.4280  25.4000  46.9900          ! Trunnion extent box
ZSEC  21  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  14.6584  15.3416  ! Heat fin 1
ZSEC  22  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  29.6584  30.3416  ! Heat fin 2
ZSEC  23  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  44.6584  45.3416  ! Heat fin 3
ZSEC  24  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  59.6584  60.3416  ! Heat fin 4
ZSEC  25  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  74.6584  75.3416  ! Heat fin 5
ZSEC  26  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  89.6584  90.3416  ! Heat fin 6
ZSEC  27  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  104.6584  105.3416  ! Heat fin 7
ZSEC  28  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  119.6584  120.3416  ! Heat fin 8
ZSEC  29  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  134.6584  135.3416  ! Heat fin 9
ZSEC  30  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  149.6584  150.3416  ! Heat fin 10
ZSEC  31  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  164.6584  165.3416  ! Heat fin 11
ZSEC  32  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  179.6584  180.3416  ! Heat fin 12
ZSEC  33  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  194.6584  195.3416  ! Heat fin 13
ZSEC  34  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  209.6584  210.3416  ! Heat fin 14
ZSEC  35  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  224.6584  225.3416  ! Heat fin 15
ZSEC  36  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  239.6584  240.3416  ! Heat fin 16
ZSEC  37  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  254.6584  255.3416  ! Heat fin 17
ZSEC  38  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  269.6584  270.3416  ! Heat fin 18
ZSEC  39  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  284.6584  285.3416  ! Heat fin 19
ZSEC  40  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  299.6584  300.3416  ! Heat fin 20
ZSEC  41  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  314.6584  315.3416  ! Heat fin 21
ZSEC  42  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  329.6584  330.3416  ! Heat fin 22
ZSEC  43  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  344.6584  345.3416  ! Heat fin 23
ZSEC  44  0.0000  0.0000  -2.6100  110.1090  124.0790  408.1148  359.6584  360.3416  ! Heat fin 24
ZROD  45  0.0000  0.0000  425.6024  162.5600  85.0900                  ! Upper impact limiter
ZROD  46  0.0000  0.0000  -89.9160  162.5600  85.0900                  ! Lower impact limiter
ZROD  47  0.0000  0.0000  426.2374  161.9250  83.8200                  ! Inside upper limiter shell
ZROD  48  0.0000  0.0000  -89.2810  161.9250  83.8200                  ! Inside lower limiter shell
ZROD  49  0.0000  0.0000  425.6024  110.7440  30.4800                  ! Upper end cap
ZROD  50  0.0000  0.0000  -35.3060  110.7440  30.4800                  ! Lower end cap
ZROD  51  0.0000  0.0000  -89.9160  162.5600  600.6084                 ! Container
ZROD  52  0.0000  0.0000  -3.8100  125.7140  27.3677                   ! Surface detector #1
ZROD  53  0.0000  0.0000  23.5577  125.7140  27.3677                   ! Surface detector #2
ZROD  54  0.0000  0.0000  50.9253  125 7140  27.3677                   ! Surface detector #3
ZROD  55  0.0000  0.0000  78.2930  125.7140  27.3677                   ! Surface detector #4
ZROD  56  0.0000  0.0000  105.6606  125.7140  27.3677                  ! Surface detector #5
ZROD  57  0.0000  0.0000  133.0283  125.7140  27.3677                  ! Surface detector #6
ZROD  58  0.0000  0.0000  160.3959  125.7140  27.3677                  ! Surface detector #7
ZROD  59  0.0000  0.0000  187.7636  125.7140  27.3677                  ! Surface detector #8
ZROD  60  0.0000  0.0000  215.1312  125.7140  27.3677                  ! Surface detector #9
ZROD  61  0.0000  0.0000  242.4989  125.7140  27.3677                  ! Surface detector #10
ZROD  62  0.0000  0.0000  269.8665  125.7140  27.3677                  ! Surface detector #11
ZROD  63  0.0000  0.0000  297.2342  125.7140  27.3677                  ! Surface detector #12
ZROD  64  0.0000  0.0000  324.6018  125.7140  27.3677                  ! Surface detector #13
ZROD  65  0.0000  0.0000  351.9695  125.7140  27.3677                  ! Surface detector #14
ZROD  66  0.0000  0.0000  379.3371  125.7140  27.3677                  ! Surface detector #15
ZROD  67  0.0000  0.0000  406.7048  111.1090  18.8976                  ! Package detector betw. NS and UpLim
ZSEC  68  0 0000  0.0000  44.3800  125.7140  126.7140  361.1248  2.5000  7.5000  ! Heat fin azi detector #1
ZSEC  69  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  7.5000  12.5000  ! Heat fin azi detector #2
ZSEC  70  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  12.5000  17.5000  ! Heat fin azi detector #3
ZSEC  71  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  17.5000  22.5000  ! Heat fin azi detector #4
ZSEC  72  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  22.5000  27.5000  ! Heat fin azi detector #5
ZSEC  73  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  27.5000  32.5000  ! Heat fin azi detector #6
ZSEC  74  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  32.5000  37.5000  ! Heat fin azi detector #7
ZSEC  75  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  37.5000  42.5000  ! Heat fin azi detector #8
ZSEC  76  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  42.5000  47.5000  ! Heat fin azi detector #9
ZSEC  77  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  47.5000  52.5000  ! Heat fin azi detector
#10
ZSEC  78  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  52.5000  57.5000  ! Heat fin azi detector
#11
ZSEC  79  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  57.5000  62.5000  ! Heat fin azi detector
#12
ZSEC  80  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  62.5000  67.5000  ! Heat fin azi detector
#13
ZSEC  81  0.0000  0.0000  44.3800  125.7140  126.7140  361.1248  67.5000  72.5000  ! Heat fin azi detector
#14
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
ZSEC  82   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   72.5000   77.5000   ! Heat fin azi detector
#15
ZSEC  83   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   77.5000   82.5000   ! Heat fin azi detector
#16
ZSEC  84   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   82.5000   87.5000   ! Heat fin azi detector
#17
ZSEC  85   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   87.5000   92.5000   ! Heat fin azi detector
#18
ZSEC  86   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   92.5000   97.5000   ! Heat fin azi detector
#19
ZSEC  87   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   97.5000   102.5000  ! Heat fin azi detector
#20
ZSEC  88   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   102.5000  107.5000  ! Heat fin azi detector
#21
ZSEC  89   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   107.5000  112.5000  ! Heat fin azi detector
#22
ZSEC  90   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   112.5000  117.5000  ! Heat fin azi detector
#23
ZSEC  91   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   117.5000  122.5000  ! Heat fin azi detector
#24
ZSEC  92   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   122.5000  127.5000  ! Heat fin azi detector
#25
ZSEC  93   0 0000   0.0000   44.3800   125.7140   126.7140   361.1248   127.5000  132.5000  ! Heat fin azi detector
#26
ZSEC  94   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   132.5000  137.5000  ! Heat fin azi detector
#27
ZSEC  95   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   137.5000  142.5000  ! Heat fin azi detector
#28
ZSEC  96   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   142.5000  147.5000  ! Heat fin azi detector
#29
ZSEC  97   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   147.5000  152.5000  ! Heat fin azi detector
#30
ZSEC  98   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   152.5000  157.5000  ! Heat fin azi detector
#31
ZSEC  99   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   157.5000  162.5000  ! Heat fin azi detector
#32
ZSEC  100  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   162.5000  167.5000  ! Heat fin azi detector
#33
ZSEC  101  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   167.5000  172.5000  ! Heat fin azi detector
#34
ZSEC  102  0 0000   0.0000   44.3800   125.7140   126.7140   361.1248   172.5000  177.5000  ! Heat fin azi detector
#35
ZSEC  103  0.0000   0.0000   44.3800   125.7140   126.7140   361 1248   177.5000  182.5000  ! Heat fin azi detector
#36
ZSEC  104  0 0000   0.0000   44.3800   125.7140   126.7140   361 1248   182.5000  187.5000  ! Heat fin azi detector
#37
ZSEC  105  0 0000   0.0000   44.3800   125.7140   126.7140   361.1248   187.5000  192.5000  ! Heat fin azi detector
#38
ZSEC  106  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   192.5000  197.5000  ! Heat fin azi detector
#39
ZSEC  107  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   197.5000  202.5000  ! Heat fin azi detector
#40
ZSEC  108  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   202.5000  207.5000  ! Heat fin azi detector
#41
ZSEC  109  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   207.5000  212.5000  ! Heat fin azi detector
#42
ZSEC  110  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   212.5000  217.5000  ! Heat fin azi detector
#43
ZSEC  111  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   217.5000  222.5000  ! Heat fin azi detector
#44
ZSEC  112  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   222.5000  227.5000  ! Heat fin azi detector
#45
ZSEC  113  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   227.5000  232.5000  ! Heat fin azi detector
#46
ZSEC  114  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   232.5000  237.5000  ! Heat fin azi detector
#47
ZSEC  115  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   237.5000  242.5000  ! Heat fin azi detector
#48
ZSEC  116  0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   242.5000  247.5000  ! Heat fin azi detector
#49
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
ZSEC    117   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    247.5000    252.5000 ! Heat fin azi detector
#50
ZSEC    118   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    252.5000    257.5000 ! Heat fin azi detector
#51
ZSEC    119   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    257.5000    262.5000 ! Heat fin azi detector
#52
ZSEC    120   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    262.5000    267.5000 ! Heat fin azi detector
#53
ZSEC    121   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    267.5000    272.5000 ! Heat fin azi detector
#54
ZSEC    122   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    272.5000    277.5000 ! Heat fin azi detector
#55
ZSEC    123   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    277.5000    282.5000 ! Heat fin azi detector
#56
ZSEC    124   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    282.5000    287.5000 ! Heat fin azi detector
#57
ZSEC    125   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    287.5000    292.5000 ! Heat fin azi detector
#58
ZSEC    126   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    292.5000    297.5000 ! Heat fin azi detector
#59
ZSEC    127   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    297.5000    302.5000 ! Heat fin azi detector
#60
ZSEC    128   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    302.5000    307.5000 ! Heat fin azi detector
#61
ZSEC    129   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    307.5000    312.5000 ! Heat fin azi detector
#62
ZSEC    130   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    312.5000    317.5000 ! Heat fin azi detector
#63
ZSEC    131   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    317.5000    322.5000 ! Heat fin azi detector
#64
ZSEC    132   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    322.5000    327.5000 ! Heat fin azi detector
#65
ZSEC    133   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    327.5000    332.5000 ! Heat fin azi detector
#66
ZSEC    134   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    332.5000    337.5000 ! Heat fin azi detector
#67
ZSEC    135   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    337.5000    342.5000 ! Heat fin azi detector
#68
ZSEC    136   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    342.5000    347.5000 ! Heat fin azi detector
#69
ZSEC    137   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    347.5000    352.5000 ! Heat fin azi detector
#70
ZSEC    138   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    352.5000    357.5000 ! Heat fin azi detector
#71
ZSEC    139   0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    357.5000    362.5000 ! Heat fin azi detector
#72
ZSEC    140   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    5.0000    15.0000    ! Rotating trunnion det#1
ZSEC    141   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    15.0000    25.0000    ! Rotating trunnion det#2
ZSEC    142   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    25.0000    35.0000    ! Rotating trunnion det#3
ZSEC    143   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    35.0000    45.0000    ! Rotating trunnion det#4
ZSEC    144   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    45.0000    55.0000    ! Rotating trunnion det#5
ZSEC    145   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    55.0000    65.0000    ! Rotating trunnion det#6
ZSEC    146   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    65.0000    75.0000    ! Rotating trunnion det#7
ZSEC    147   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    75.0000    85.0000    ! Rotating trunnion det#8
ZSEC    148   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    85.0000    95.0000    ! Rotating trunnion det#9
ZSEC    149   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    95.0000    105.0000    ! Rotating trunnion
det#10
ZSEC    150   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    105.0000    115.0000    ! Rotating trunnion
det#11
ZSEC    151   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    115.0000    125.0000    ! Rotating trunnion
det#12
ZSEC    152   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    125.0000    135.0000    ! Rotating trunnion
det#13
ZSEC    153   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    135.0000    145.0000    ! Rotating trunnion
det#14
ZSEC    154   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    145.0000    155.0000    ! Rotating trunnion
det#15
ZSEC    155   0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    155.0000    165.0000    ! Rotating trunnion
det#16
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
ZSEC    156    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    165.0000    175.0000    ! Rotating trunnion
det#17
ZSEC    157    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    175.0000    185.0000    ! Rotating trunnion
det#18
ZSEC    158    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    185.0000    195.0000    ! Rotating trunnion
det#19
ZSEC    159    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    195.0000    205.0000    ! Rotating trunnion
det#20
ZSEC    160    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    205.0000    215.0000    ! Rotating trunnion
det#21
ZSEC    161    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    215.0000    225.0000    ! Rotating trunnion
det#22
ZSEC    162    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    225.0000    235.0000    ! Rotating trunnion
det#23
ZSEC    163    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    235.0000    245.0000    ! Rotating trunnion
det#24
ZSEC    164    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    245.0000    255.0000    ! Rotating trunnion
det#25
ZSEC    165    0 0000    0.0000    -3.8100    126.7140    127.7140    22.8600    255.0000    265.0000    ! Rotating trunnion
det#26
ZSEC    166    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    265.0000    275.0000    ! Rotating trunnion
det#27
ZSEC    167    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    275.0000    285.0000    ! Rotating trunnion
det#28
ZSEC    168    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    285.0000    295.0000    ! Rotating trunnion
det#29
ZSEC    169    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    295.0000    305.0000    ! Rotating trunnion
det#30
ZSEC    170    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    305.0000    315.0000    ! Rotating trunnion
det#31
ZSEC    171    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    315.0000    325.0000    ! Rotating trunnion
det#32
ZSEC    172    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    325.0000    335.0000    ! Rotating trunnion
det#33
ZSEC    173    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    335.0000    345.0000    ! Rotating trunnion
det#34
ZSEC    174    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    345.0000    355.0000    ! Rotating trunnion
det#35
ZSEC    175    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    355.0000    365.0000    ! Rotating trunnion
det#36
ZROD    176    0.0000    0.0000    -4.8260    135.7630    430.4284                ! Personnel barrier surface
ZROD    177    0 0000    0.0000    -4.8260    136.7630    28.6952                 ! Personnel barrier det #1
ZROD    178    0.0000    0.0000    23.8692    136.7630    28.6952                 ! Personnel barrier det #2
ZROD    179    0 0000    0.0000    52.5645    136.7630    28.6952                 ! Personnel barrier det #3
ZROD    180    0.0000    0.0000    81.2597    136.7630    28.6952                 ! Personnel barrier det #4
ZROD    181    0.0000    0.0000    109.9549    136.7630    28.6952                ! Personnel barrier det #5
ZROD    182    0.0000    0.0000    138.6501    136.7630    28.6952                ! Personnel barrier det #6
ZROD    183    0.0000    0.0000    167.3454    136.7630    28.6952                ! Personnel barrier det #7
ZROD    184    0.0000    0.0000    196.0406    136.7630    28.6952                ! Personnel barrier det #8
ZROD    185    0.0000    0.0000    224.7358    136.7630    28.6952                ! Personnel barrier det #9
ZROD    186    0.0000    0.0000    253.4310    136.7630    28.6952                ! Personnel barrier det #10
ZROD    187    0.0000    0.0000    282.1263    136.7630    28.6952                ! Personnel barrier det #11
ZROD    188    0.0000    0.0000    310.8215    136.7630    28.6952                ! Personnel barrier det #12
ZROD    189    0.0000    0.0000    339.5167    136.7630    28.6952                ! Personnel barrier det #13
ZROD    190    0.0000    0.0000    368.2119    136.7630    28.6952                ! Personnel barrier det #14
ZROD    191    0.0000    0.0000    396.9072    136.7630    28.6952                ! Personnel barrier det #15
ZONES
/Cavity/    P8    +2
/OuterShell/    M16    +1    -2    -3    -4    -5
/InnerShell1/    M16    +6    -2
/InnerShell2/    M16    +7    -2
/InnerShell3/    M16    +8    -2
/InnerShell4/    M16    +9    -2
/InnerShell5/    M16    +10    -2
/InnerLid/    P9    +4
/BotNShield/    M15    +3
/LeadShield/    M14    +11    -6    -7    -8    -9    -10
/LeadShieldGap/    M0    +5    -11
/RadNShieldShell1/    M16    +12    -13    -1    -20
/RadNShieldShell2/    M16    +12    -13    -1    +20    -15    -16
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
/RadNShield1/    M15    +13    -1    -21    -22    -23    -24    -25
        -26    -27    -28    -29    -30    -31    -32
        -33    -34    -35    -36    -37    -38    -39
        -40    -41    -42    -43    -44    +14    -20
/RadNShield2/    M15    +13    -1    -32    -44    +20    -15    -16
/InsulationVoid/    M0    +13    -1    -14    -20
/RotTrunUpper/    M16    +15    -1    +20    +12
/RotTrunLower/    M16    +17    -1    +12
/RotTrunSide/    M16    +16    +12    -17    -18    -19
/RotTrunBoxVoid/    M0    +18    +12    -17
/RotTrunCircVoid/    M0    +19    -18    -17    +12
/HeatFin1/    M18    +21    +14
/HeatFin2/    M18    +22    +14
/HeatFin3/    M18    +23    +14
/HeatFin4/    M18    +24    +14
/HeatFin5/    M18    +25    +14
/HeatFin6/    M18    +26    +14
/HeatFin7/    M18    +27    +14
/HeatFin8/    M18    +28    +14
/HeatFin9/    M18    +29    +14
/HeatFin10/    M18    +30    +14
/HeatFin11/    M18    +31    +14
/HeatFin12/    M18    +32    +14    -15    -16
/HeatFin13/    M18    +33    +14
/HeatFin14/    M18    +34    +14
/HeatFin15/    M18    +35    +14
/HeatFin16/    M18    +36    +14
/HeatFin17/    M18    +37    +14
/HeatFin18/    M18    +38    +14
/HeatFin19/    M18    +39    +14
/HeatFin20/    M18    +40    +14
/HeatFin21/    M18    +41    +14
/HeatFin22/    M18    +42    +14
/HeatFin23/    M18    +43    +14
/HeatFin24/    M18    +44    +14    -15    -16
/UpLimShell/    M16    +45    -47    -49
/UpLimEnd/    M16    +49    -1
/LoLimShell/    M16    +46    -48    -50
/LoLimEnd/    M16    +50    -1
/UpBalsa/    M19    +47    -49
/LoBalsa/    M19    +48    -50
/InsidePersBarr/    M0    +176    -1    -12    -45    -46    -67    -52
        -53    -54    -55    -56    -57    -58    -59
        -60    -61    -62    -63    -64    -65    -66
        -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    -99    -100    -101    -102
        -103    -104    -105    -106    -107    -108    -109
        -110    -111    -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    -149    -150    -151
        -152    -153    -154    -155    -156    -157    -158
        -159    -160    -161    -162    -163    -164    -165
        -166    -167    -168    -169    -170    -171    -172
        -173    -174    -175
/SurfaceDet1/    M0    +52    -12
/SurfaceDet2/    M0    +53    -12
/SurfaceDet3/    M0    +54    -12
/SurfaceDet4/    M0    +55    -12
/SurfaceDet5/    M0    +56    -12
/SurfaceDet6/    M0    +57    -12
/SurfaceDet7/    M0    +58    -12
/SurfaceDet8/    M0    +59    -12
/SurfaceDet9/    M0    +60    -12
/SurfaceDet10/    M0    +61    -12
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
/SurfaceDet11/    MO    +62    -12
/SurfaceDet12/    MO    +63    -12
/SurfaceDet13/    MO    +64    -12
/SurfaceDet14/    MO    +65    -12
/SurfaceDet15/    MO    +66    -12
/PackageDet/    MO    +67    -1
/HeatFinAziDet1/    MO    +68
/HeatFinAziDet2/    MO    +69
/HeatFinAziDet3/    MO    +70
/HeatFinAziDet4/    MO    +71
/HeatFinAziDet5/    MO    +72
/HeatFinAziDet6/    MO    +73
/HeatFinAziDet7/    MO    +74
/HeatFinAziDet8/    MO    +75
/HeatFinAziDet9/    MO    +76
/HeatFinAziDet10/    MO    +77
/HeatFinAziDet11/    MO    +78
/HeatFinAziDet12/    MO    +79
/HeatFinAziDet13/    MO    +80
/HeatFinAziDet14/    MO    +81
/HeatFinAziDet15/    MO    +82
/HeatFinAziDet16/    MO    +83
/HeatFinAziDet17/    MO    +84
/HeatFinAziDet18/    MO    +85
/HeatFinAziDet19/    MO    +86
/HeatFinAziDet20/    MO    +87
/HeatFinAziDet21/    MO    +88
/HeatFinAziDet22/    MO    +89
/HeatFinAziDet23/    MO    +90
/HeatFinAziDet24/    MO    +91
/HeatFinAziDet25/    MO    +92
/HeatFinAziDet26/    MO    +93
/HeatFinAziDet27/    MO    +94
/HeatFinAziDet28/    MO    +95
/HeatFinAziDet29/    MO    +96
/HeatFinAziDet30/    MO    +97
/HeatFinAziDet31/    MO    +98
/HeatFinAziDet32/    MO    +99
/HeatFinAziDet33/    MO    +100
/HeatFinAziDet34/    MO    +101
/HeatFinAziDet35/    MO    +102
/HeatFinAziDet36/    MO    +103
/HeatFinAziDet37/    MO    +104
/HeatFinAziDet38/    MO    +105
/HeatFinAziDet39/    MO    +106
/HeatFinAziDet40/    MO    +107
/HeatFinAziDet41/    MO    +108
/HeatFinAziDet42/    MO    +109
/HeatFinAziDet43/    MO    +110
/HeatFinAziDet44/    MO    +111
/HeatFinAziDet45/    MO    +112
/HeatFinAziDet46/    MO    +113
/HeatFinAziDet47/    MO    +114
/HeatFinAziDet48/    MO    +115
/HeatFinAziDet49/    MO    +116
/HeatFinAziDet50/    MO    +117
/HeatFinAziDet51/    MO    +118
/HeatFinAziDet52/    MO    +119
/HeatFinAziDet53/    MO    +120
/HeatFinAziDet54/    MO    +121
/HeatFinAziDet55/    MO    +122
/HeatFinAziDet56/    MO    +123
/HeatFinAziDet57/    MO    +124
/HeatFinAziDet58/    MO    +125
/HeatFinAziDet59/    MO    +126
/HeatFinAziDet60/    MO    +127
/HeatFinAziDet61/    MO    +128
/HeatFinAziDet62/    MO    +129
/HeatFinAziDet63/    MO    +130
/HeatFinAziDet64/    MO    +131
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
/HeatFinAziDet65/    M0    +132
/HeatFinAziDet66/    M0    +133
/HeatFinAziDet67/    M0    +134
/HeatFinAziDet68/    M0    +135
/HeatFinAziDet69/    M0    +136
/HeatFinAziDet70/    M0    +137
/HeatFinAziDet71/    M0    +138
/HeatFinAziDet72/    M0    +139
/RotTrunDet1/    M0    +140
/RotTrunDet2/    M0    +141
/RotTrunDet3/    M0    +142
/RotTrunDet4/    M0    +143
/RotTrunDet5/    M0    +144
/RotTrunDet6/    M0    +145
/RotTrunDet7/    M0    +146
/RotTrunDet8/    M0    +147
/RotTrunDet9/    M0    +148
/RotTrunDet10/    M0    +149
/RotTrunDet11/    M0    +150
/RotTrunDet12/    M0    +151
/RotTrunDet13/    M0    +152
/RotTrunDet14/    M0    +153
/RotTrunDet15/    M0    +154
/RotTrunDet16/    M0    +155
/RotTrunDet17/    M0    +156
/RotTrunDet18/    M0    +157
/RotTrunDet19/    M0    +158
/RotTrunDet20/    M0    +159
/RotTrunDet21/    M0    +160
/RotTrunDet22/    M0    +161
/RotTrunDet23/    M0    +162
/RotTrunDet24/    M0    +163
/RotTrunDet25/    M0    +164
/RotTrunDet26/    M0    +165
/RotTrunDet27/    M0    +166
/RotTrunDet28/    M0    +167
/RotTrunDet29/    M0    +168
/RotTrunDet30/    M0    +169
/RotTrunDet31/    M0    +170
/RotTrunDet32/    M0    +171
/RotTrunDet33/    M0    +172
/RotTrunDet34/    M0    +173
/RotTrunDet35/    M0    +174
/RotTrunDet36/    M0    +175
/PersBarrDet1/    M0    +177    -176
/PersBarrDet2/    M0    +178    -176
/PersBarrDet3/    M0    +179    -176
/PersBarrDet4/    M0    +180    -176
/PersBarrDet5/    M0    +181    -176
/PersBarrDet6/    M0    +182    -176
/PersBarrDet7/    M0    +183    -176
/PersBarrDet8/    M0    +184    -176
/PersBarrDet9/    M0    +185    -176
/PersBarrDet10/    M0    +186    -176
/PersBarrDet11/    M0    +187    -176
/PersBarrDet12/    M0    +188    -176
/PersBarrDet13/    M0    +189    -176
/PersBarrDet14/    M0    +190    -176
/PersBarrDet15/    M0    +191    -176
/Container/    M0    +51    -45    -46    -177    -178    -179    -180
        -181    -182    -183    -184    -185    -186    -187
        -188    -189    -190    -191
VOLUMES    52*1.0        15*2.1531E+04        1.3133E+04        72*3.9775E+03
        36*5.0756E+02        15*2.4568E+04        1.0
* Transport Cask Detector Description v1.5.1.0
PART    12
* Radial Detector DRA (Surface) Bodies
* Radial Detector DRA+ (Package) Bodies
* Radial Detector DRAA (HeatFin) Bodies
* Radial Detector DRAB (RotTrun) Bodies
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
* Radial Detector DRB (PersBarr) Bodies
* Radial Detector DRC (LimSurf) Bodies
ZROD    1                0.0000    0.0000    -89.9160  162.5600  600.6084
ZROD    2                0.0000    0.0000    -89.9160  163.5600  40.0406
ZROD    3                0.0000    0.0000    -49.8754  163.5600  40.0406
ZROD    4                0.0000    0.0000    -9.8349   163.5600  40.0406
ZROD    5                0.0000    0.0000    30.2057   163.5600  40.0406
ZROD    6                0.0000    0.0000    70.2462   163.5600  40.0406
ZROD    7                0.0000    0.0000    110.2868  163.5600  40.0406
ZROD    8                0.0000    0.0000    150.3274  163.5600  40.0406
ZROD    9                0.0000    0.0000    190.3679  163.5600  40.0406
ZROD    10               0.0000    0.0000    230.4085  163.5600  40.0406
ZROD    11               0.0000    0.0000    270.4490  163.5600  40.0406
ZROD    12               0.0000    0.0000    310.4896  163.5600  40.0406
ZROD    13               0.0000    0.0000    350.5302  163.5600  40.0406
ZROD    14               0.0000    0.0000    390.5707  163.5600  40.0406
ZROD    15               0.0000    0.0000    430.6113  163.5600  40.0406
ZROD    16               0.0000    0.0000    470.6518  163.5600  40.0406
* Radial Detector DRD (1m) Bodies
ZROD    17               0.0000    0.0000    -189 9160 224.7140  800.6084
ZROD    18               0.0000    0.0000    -189.9160 225.7140  53.3739
ZROD    19               0.0000    0.0000    -136.5421 225.7140  53.3739
ZROD    20               0.0000    0.0000    -83.1682  225.7140  53.3739
ZROD    21               0.0000    0.0000    -29.7943  225.7140  53.3739
ZROD    22               0.0000    0.0000    23.5796   225.7140  53.3739
ZROD    23               0.0000    0.0000    76.9535   225.7140  53.3739
ZROD    24               0.0000    0.0000    130.3274  225.7140  53.3739
ZROD    25               0.0000    0.0000    183.7013  225.7140  53.3739
ZROD    26               0.0000    0.0000    237.0751  225.7140  53.3739
ZROD    27               0.0000    0.0000    290.4490  225.7140  53.3739
ZROD    28               0.0000    0.0000    343.8229  225.7140  53.3739
ZROD    29               0.0000    0.0000    397.1968  225.7140  53.3739
ZROD    30               0.0000    0.0000    450.5707  225.7140  53.3739
ZROD    31               0.0000    0.0000    503.9446  225.7140  53.3739
ZROD    32               0.0000    0.0000    557.3185  225.7140  53.3739
* Radial Detector DRE (1m+LimSurf) Bodies
ZROD    33               0.0000    0.0000    -239.9160 262.5600  900.6084
ZROD    34               0.0000    0.0000    -239.9160 263.5600  60.0406
ZROD    35               0.0000    0.0000    -179.8754 263.5600  60.0406
ZROD    36               0.0000    0.0000    -119.8349 263.5600  60.0406
ZROD    37               0.0000    0.0000    -59.7943  263.5600  60.0406
ZROD    38               0.0000    0.0000    0.2462    263.5600  60.0406
ZROD    39               0.0000    0.0000    60.2868   263.5600  60.0406
ZROD    40               0.0000    0.0000    120.3274  263 5600  60.0406
ZROD    41               0.0000    0.0000    180.3679  263.5600  60.0406
ZROD    42               0.0000    0.0000    240.4085  263 5600  60.0406
ZROD    43               0.0000    0.0000    300.4490  263.5600  60.0406
ZROD    44               0.0000    0.0000    360.4896  263.5600  60 0406
ZROD    45               0.0000    0.0000    420.5302  263 5600  60.0406
ZROD    46               0.0000    0.0000    480.5707  263.5600  60 0406
ZROD    47               0.0000    0.0000    540.6113  263.5600  60.0406
ZROD    48               0.0000    0.0000    600.6518  263.5600  60.0406
* Radial Detector DRF (2m+Railcar) Bodies
ZROD    49               0.0000    0.0000    -289.9160 357.4800  1000.6084
ZROD    50               0.0000    0.0000    -289.9160 358.4800  50.0304
ZROD    51               0.0000    0.0000    -239 8856 358.4800  50.0304
ZROD    52               0.0000    0.0000    -189.8552 358.4800  50.0304
ZROD    53               0.0000    0.0000    -139.8247 358.4800  50.0304
ZROD    54               0.0000    0.0000    -89.7943  358.4800  50.0304
ZROD    55               0.0000    0.0000    -39.7639  358.4800  50.0304
ZROD    56               0.0000    0.0000    10.2665   358.4800  50.0304
ZROD    57               0.0000    0.0000    60.2969   358.4800  50.0304
ZROD    58               0.0000    0.0000    110.3274  358.4800  50.0304
ZROD    59               0.0000    0.0000    160.3578  358.4800  50.0304
ZROD    60               0.0000    0.0000    210.3882  358.4800  50.0304
ZROD    61               0.0000    0.0000    260.4186  358.4800  50.0304
ZROD    62               0.0000    0.0000    310.4490  358.4800  50.0304
ZROD    63               0.0000    0.0000    360.4795  358.4800  50.0304
ZROD    64               0.0000    0.0000    410.5099  358.4800  50.0304
ZROD    65               0.0000    0.0000    460.5403  358.4800  50.0304
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
ZROD      66                0.0000    0.0000    510.5707  358.4800  50.0304
ZROD      67                0.0000    0.0000    560.6011  358.4800  50.0304
ZROD      68                0.0000    0.0000    610.6316  358.4800  50.0304
ZROD      69                0.0000    0.0000    660.6620  358.4800  50.0304
* Radial Detector DRG (4m) Bodies
ZROD      70                0.0000    0.0000    -489.9160 524.7140  1400.6084
ZROD      71                0.0000    0.0000    -489.9160 525.7140  70.0304
ZROD      72                0.0000    0.0000    -419.8856 525.7140  70.0304
ZROD      73                0.0000    0.0000    -349.8552 525.7140  70.0304
ZROD      74                0.0000    0.0000    -279.8247 525.7140  70.0304
ZROD      75                0.0000    0.0000    -209.7943 525.7140  70.0304
ZROD      76                0.0000    0.0000    -139.7639 525.7140  70.0304
ZROD      77                0.0000    0.0000    -69.7335  525.7140  70.0304
ZROD      78                0.0000    0.0000    0.2969    525.7140  70.0304
ZROD      79                0.0000    0.0000    70.3274   525.7140  70.0304
ZROD      80                0.0000    0.0000    140.3578  525.7140  70.0304
ZROD      81                0.0000    0.0000    210 3882  525.7140  70.0304
ZROD      82                0.0000    0.0000    280.4186  525.7140  70.0304
ZROD      83                0.0000    0.0000    350.4490  525.7140  70.0304
ZROD      84                0.0000    0.0000    420.4795  525.7140  70.0304
ZROD      85                0.0000    0.0000    490.5099  525.7140  70.0304
ZROD      86                0.0000    0.0000    560.5403  525.7140  70.0304
ZROD      87                0.0000    0.0000    630.5707  525.7140  70.0304
ZROD      88                0.0000    0.0000    700.6011  525.7140  70.0304
ZROD      89                0.0000    0.0000    770.6316  525.7140  70.0304
ZROD      90                0.0000    0.0000    840.6620  525.7140  70.0304
* World
ZROD      91                0.0000    0.0000    -539.9160 574.7140  1500.6084
* External Void
ZROD      92                0.0000    0.0000    -589.9160 624.7140  1600.6084

ZONES
/TransportCask/     P11       +1
* Detector DRC (LimSurf)
/DRC01/   M0        +2        -1
/DRC02/   M0        +3        -1
/DRC03/   M0        +4        -1
/DRC04/   M0        +5        -1
/DRC05/   M0        +6        -1
/DRC06/   M0        +7        -1
/DRC07/   M0        +8        -1
/DRC08/   M0        +9        -1
/DRC09/   M0        +10       -1
/DRC10/   M0        +11       -1
/DRC11/   M0        +12       -1
/DRC12/   M0        +13       -1
/DRC13/   M0        +14       -1
/DRC14/   M0        +15       -1
/DRC15/   M0        +16       -1
/Void/    M0        +17       -1
                    -2        -3        -4        -5        -6        -7
                    -8        -9        -10       -11       -12       -13
                    -14       -15       -16
* Detector DRD (1m)
/DRD01/   M0        +18       -17
/DRD02/   M0        +19       -17
/DRD03/   M0        +20       -17
/DRD04/   M0        +21       -17
/DRD05/   M0        +22       -17
/DRD06/   M0        +23       -17
/DRD07/   M0        +24       -17
/DRD08/   M0        +25       -17
/DRD09/   M0        +26       -17
/DRD10/   M0        +27       -17
/DRD11/   M0        +28       -17
/DRD12/   M0        +29       -17
/DRD13/   M0        +30       -17
/DRD14/   M0        +31       -17
/DRD15/   M0        +32       -17
/Void/    M0        +33       -17
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
                    -18       -19       -20       -21       -22       -23
                    -24       -25       -26       -27       -28       -29
                    -30       -31       -32
* Detector DRE (1m+LimSurf)
/DRE01/   MO        +34       -33
/DRE02/   MO        +35       -33
/DRE03/   MO        +36       -33
/DRE04/   MO        +37       -33
/DRE05/   MO        +38       -33
/DRE06/   MO        +39       -33
/DRE07/   MO        +40       -33
/DRE08/   MO        +41       -33
/DRE09/   MO        +42       -33
/DRE10/   MO        +43       -33
/DRE11/   MO        +44       -33
/DRE12/   MO        +45       -33
/DRE13/   MO        +46       -33
/DRE14/   MO        +47       -33
/DRE15/   MO        +48       -33
/Void/    MO        +49       -33
                    -34       -35       -36       -37       -38       -39
                    -40       -41       -42       -43       -44       -45
                    -46       -47       -48
* Detector DRF (2m+Railcar)
/DRF01/   MO        +50       -49
/DRF02/   MO        +51       -49
/DRF03/   MO        +52       -49
/DRF04/   MO        +53       -49
/DRF05/   MO        +54       -49
/DRF06/   MO        +55       -49
/DRF07/   MO        +56       -49
/DRF08/   MO        +57       -49
/DRF09/   MO        +58       -49
/DRF10/   MO        +59       -49
/DRF11/   MO        +60       -49
/DRF12/   MO        +61       -49
/DRF13/   MO        +62       -49
/DRF14/   MO        +63       -49
/DRF15/   MO        +64       -49
/DRF16/   MO        +65       -49
/DRF17/   MO        +66       -49
/DRF18/   MO        +67       -49
/DRF19/   MO        +68       -49
/DRF20/   MO        +69       -49
/Void/    MO        +70       -49
                    -50       -51       -52       -53       -54       -55
                    -56       -57       -58       -59       -60       -61
                    -62       -63       -64       -65       -66       -67
                    -68       -69
* Detector DRG (4m)
/DRG01/   MO        +71       -70
/DRG02/   MO        +72       -70
/DRG03/   MO        +73       -70
/DRG04/   MO        +74       -70
/DRG05/   MO        +75       -70
/DRG06/   MO        +76       -70
/DRG07/   MO        +77       -70
/DRG08/   MO        +78       -70
/DRG09/   MO        +79       -70
/DRG10/   MO        +80       -70
/DRG11/   MO        +81       -70
/DRG12/   MO        +82       -70
/DRG13/   MO        +83       -70
/DRG14/   MO        +84       -70
/DRG15/   MO        +85       -70
/DRG16/   MO        +86       -70
/DRG17/   MO        +87       -70
/DRG18/   MO        +88       -70
/DRG19/   MO        +89       -70
/DRG20/   MO        +90       -70
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
/Void/    M0        +91       -70
                    -71       -72       -73       -74       -75       -76
                    -77       -78       -79       -80       -81       -82
                    -83       -84       -85       -86       -87       -88
                    -89       -90
/ExtVoid/ M-2000    +92       -91
Volumes
                    1.0       15*4.1023E+04       1.0       15*7.5527E+04       1.0       15*9.9238E+04
                    1.0       20*1.1253E+05       1 0       20*2.3110E+05       1.0       1.0
end

*
* Unit 5 Splitting Geometry for Radial Detectors - Gamma
*
begin splitting geometry
    r    35    fill    0.0000
                    n    10    89.9922
                    n    1    93.9800
                    n    16    103.4034
                    n    1    110.1090
                    n    5    124.0790
                    n    1    124.7140
                    n    1    167.5600


    z    48    fill    -94.9160
                    n    1    -89.9160
                    n    1    -89.2810
                    n    2    -35.3060
                    n    1    -34.6710
                    n    2    -20.8280
                    n    2    -15.7480
                    n    3    0.0000
                    n    5    18.6004
                    n    13    387.4084
                    n    2    410.2100
                    n    3    419.1000
                    n    0    419.1000
                    n    3    434.3400
                    n    2    439.4200
                    n    3    455.4474
                    n    1    456.0824
                    n    2    510.0574
                    n    1    510.6924
                    n    1    515.6924

end

*
* Unit 6 - Source Geometry for Fuel Gamma
*
begin source geometry
    r    10    fill    0.0000    n    10    89.9922
    z    13
        18.6004    27.8206    37.0408    55.4812    92.3620    166.1236
        239.8852    276.7660    313.6468    350.5276    359.7478    368.9680
        378.1882    387.4084
end

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

*
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
* Unit 8 Importance Map - Radial
*
begin importance map
    calculate
    targets    15
    part    12
    zones
        2    3    4    5    6
        7    8    9    10    11
        12    13    14    15    16
    strengths
        1.0E+02    1.0E+02    5.0E+01    5.0E+01    5.0E+01
        1.0E+01    1.0E+01    1.0E+00    1.0E+01    1.0E+01
        5.0E+01    5.0E+01    5.0E+01    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 - Radial
*
begin scoring data
    flux
    part    11
    from    53    to    67    ' DRA
    some    68            ! DRA+
    from    69    to    140    ! DRAA
    from    141    to    176    ! DRAB
    from    177    to    191    ' DRB
    part    12
    from    2    to    16    ! DRC
    from    18    to    32    ' DRD
    from    34    to    48    ' DRE
    from    50    to    69    ' DRF
    from    71    to    90    ! DRG
    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
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
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
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
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
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
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
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
6.2952E-01      1.4075E-03
6.2450E-01      1.3994E-03
6.1952E-01      1.3915E-03
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
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
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

FIGURE WITHHELD AS SENSITIVE UNCLASSIFIED INFORMATION

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
[illegible]	6.0255E-04
[illegible]	5.8881E-04
2.2865E-01	5.7538E-04
2.2361E-01	5.6226E-04
[illegible]	5.4943E-04
[illegible]	5.3690E-04
2.0913E-01	5.2466E-04
[illegible]	5.1269E-04
[illegible]	5.0100E-04
[illegible]	4.8721E-04
1.8882E-01	4.7380E-04
[illegible]	4.6076E-04
[illegible]	4.4808E-04
1.7321E-01	4.3575E-04
1.6829E-01	4.2376E-04
[illegible]	4.1210E-04
[illegible]	4.0075E-04
1.5438E-01	3.8973E-04
[illegible]	3.7900E-04
[illegible]	3.6809E-04
[illegible]	3.5749E-04
1.3282E-01	3.4720E-04
[illegible]	3.3721E-04
[illegible]	3.2750E-04
1.1761E-01	3.1807E-04
1.1293E-01	3.0892E-04
[illegible]	3.0002E-04
[illegible]	2.9139E-04
1.0000E-01	2.8300E-04
[illegible]	2.8039E-04
[illegible]	2.7781E-04
[illegible]	2.7526E-04
8.6704E-02	2.7272E-04
[illegible]	2.7021E-04
[illegible]	2.6772E-04
7.7906E-02	2.6526E-04
7.5176E-02	2.6282E-04
[illegible]	2.6040E-04
[illegible]	2.5800E-04
6.7684E-02	2.6103E-04
[illegible]	2.6410E-04
[illegible]	2.6721E-04
[illegible]	2.7035E-04
5.9161E-02	2.7353E-04
[illegible]	2.7675E-04
[illegible]	2.8000E-04
5.3481E-02	2.8330E-04
5.1711E-02	2.8663E-04
[illegible]	2.9000E-04
[illegible]	3.1092E-04
4.5144E-02	3.3335E-04
[illegible]	3.5740E-04
[illegible]	3.8318E-04
[illegible]	4.1083E-04
3.6801E-02	4.4047E-04
[illegible]	4.7224E-04
[illegible]	5.0631E-04
3.1572E-02	5.4284E-04
[illegible]	5.8200E-04
[illegible]	7.0502E-04
[illegible]	8.5404E-04
2.1577E-02	1.0346E-03
[illegible]	1.2532E-03
[illegible]	1.5181E-03
[illegible]	1.8390E-03

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
        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
* STC Basket Hole Description v1.2
* Hole    1    General Basket Structure
PLATE
0    0    1
7
417.8300    0            ' Top of Basket
389.4976    -2            ! Top of Highest Support Disk
326.4316    -7            ! Resume support disk only
79.2376    -4            ! Start of support+heat disk region
17.4396    -6            ' Bottom of Lowest Support Disk
0.0000    -3            ' Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole    2    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ' number of radial points
85.5472
89.9922
3                ' number of axial intervals
389.4976                ' Top of diskstack
400.5580                ' Bottom of weldment
403.0980                ! Top of weldment plate
417.8300                ' Void to top of basket
0    0            ' Material below weldment
10    10            ' Plate Material
0    10            ' Flange
0                ! Outside material

* Hole    3    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ' number of radial points
89.9922
1                ' number of axial intervals
3.8100
6.3500                ' Coordinates inherited from PLATE Hole
10                ' Plate Material
0                ! Outside material

* Hole    4    Support disk and heat transfer disk stack
PLATE
origin    0    0    79.2376    ' Origin
0    0    1
4
cell    12.3597            ! Sets up a repeating lattice of cells
12.3597    0            ' flood matl
7.6086    0            ' water gap
6.0211    11            ' aluminium disk
1.2700    0            ! water gap
9                ! steel disk

* Hole    5    Flood material model
PLATE
0    0    1
1
417.8300    0            ! Above flooded region
0                ! Flooded region

* Hole    6    Support disk stack lower
PLATE
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
origin    0    0    17.4396    ! Origin
0    0    1
2
cell    12.3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                ! steel disk

* Hole    7    Support disk stack upper
PLATE
origin    0    0    326.4316    ! Origin
0    0    1
2
cell    12.3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                ! steel disk

end

*
* Unit 15 Source Strength - Fuel Gamma
*
* Class 1 - aa14b - STC Hybrid14 (Rev 0) - Fuel Gamma - Group 7 Reponse
begin source strength
    component        6.9739E-06    ! 1/volume (1/1.4339E+05)
    component    r    10*1.0
    component    z
        4.2500E-01    6.7500E-01    9.0000E-01    1.1000E+00    1.2000E+00    1.1500E+00
        1.0750E+00    1.0000E+00    8.6500E-01    7.4000E-01    6.5000E-01    5.5000E-01
        4.5000E-01
    component    energy
        6*0.0
        1.0000E+00
        15*0.0

end

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

*
* Unit 31 Tabular Output
*
begin tabular output
    /Case trnNrmDryRadFg_aa14b_07g - Det DRA - Surface - Response/
    response    interim
    number    some    1
    region    from    121    to    135
    output to file    also
    /Case trnNrmDryRadFg_aa14b_07g - Det DRB - PersBarr - Response/
    response
    number    some    1
    region    from    245    to    259
    output to file    also
    /Case trnNrmDryRadFg_aa14b_07g - Det DRC - LimSurf - Response/
    response
    number    some    1
    region    from    262    to    276
    output to file    also
    /Case trnNrmDryRadFg_aa14b_07g - Det DRD - 1m - Response/
    response
    number    some    1
    region    from    278    to    292
    output to file    also
    /Case trnNrmDryRadFg_aa14b_07g - Det DRE - 1m+LimSurf - Response/
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
    response
    number    some    1
    region    from    294    to    308
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    gamma
normalise
nmixtures    3
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
atoms    mixture    3
            c    2.8571E-01
            h    4.7619E-01
            o    2.3810E-01
*
* Materials List - Dry Conditions - v1.2 - Class 1 - aa14b - STC Hybrid14 (Rev 0) Fuel
*
nmaterials    20
volume                          ! Homogenized aa14b Fuel
material    1
    mixture    1    density    10.4120    prop    3.1489E-01    ! UO2 mixture at 3.7%
    void               prop    1.6671E-02    ' Gap
    zircalloy        density    6.5500    prop    9.7331E-02    ! Tube, clad
    void               prop    5.7111E-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    0.2948
    zircalloy        density    6.5500    prop    0.0831
    void               prop    0.6220
volume                          ' Upper Nozzle Material
material    6
    stainless 3041 steel        density    7.9200    prop    0 3613
    void               prop    0.6387
volume                          ! Upper Plenum Material
material    7
    stainless 3041 steel        density    7.9200    prop    0.1147
    zircalloy        density    6.5500    prop    0.0858
    void               prop    0.7995
*
* Materials List - Common Materials - v1.2
*
volume                          ' Tube wall and cover sheet
material    8
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                          ! Structural Disk Material
material    9
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                          ! Weldment Material
material    10
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                          ! Heat Transfer Disk Material
```

Figure 5.5-2 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Normal Conditions (Continued)

```
material    11
    aluminium                prop    1.0000
volume                            ! Canister Material
material    12
    stainless 3041 steel        density    7.9200    prop    1.0000
atoms                             ! Transfer steel
material    13        density    0            !  (SCALE carbon steel)

        c            prop    3.9250E-03
        fe            prop    8.3498E-02
volume                            ! Lead
material    14
    pb        density    11.0400    prop    1.0000
atoms                             ! NS-4-FR
material    15        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    16
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                            ! Vent port middle cylinder
material    17
    stainless 3041 steel        density    7.9200    prop    0.5000
    void                prop    0.5000
volume                            ! Heat fins for transport cask
material    18
    cu        density    8.9200    prop    0.4286
    stainless 3041 steel        density    7.9200    prop    0.5714
volume                            ! Balsa
material    19
    mixture    3    density    0.1250    prop    1.0000
volume                            ! Redwood
material    20
    mixture    3    density    0.3870    prop    1.0000
end
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions

```
columns 1 200
*
*   NAC-STC - aa14b_02g - Fuel Neutron - Radial
*   Dry Cavity Conditions
*   Normal Transport Conditions
*   Transport Model Revision v1.5.1.0
*   Shielding Revision v1.5
*   STC Source Profile
*   Cobalt Concentration of 1.2 g/kg
*   Fuel Assembly Shift = Cavity, Basket Shift = None
*
* Parameters
*
@samps =    5000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit     1000m
    seeds    61444    14676
    chime every    [@samps/10]    samples
    report interim results
    sbd    30s
    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 1 - aa14b - STC Hybrid14 (Rev 0)
PART    1    NEST
BOX    M5        0.0000    0.0000    0.0000    19.7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0.0000    0.0000    0.0000    19.7180    19.7180    377 5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    19.7180    19.7180    409 1940    ! upper nozzle
* Fuel Assembly Type B - Class 1 - aa14b - STC Hybrid14 (Rev 0)
PART    2    NEST
BOX    M5        0.0000    0.0000    0.0000    19.7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0 0000    0.0000    0.0000    19.7180    19.7180    377 5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0 0000    0.0000    0.0000    19.7180    19.7180    409 1940    ! upper nozzle
* Fuel Assembly in Tube (Type A) v1.1
PART    3
BOX    1    1.4135    1.4135    9.9060    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of basket cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.1
PART    4
BOX    1    1.4135    1.4135    9.9060    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of basket cavity
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.2
PART    5    CLUSTER
BOX    P3    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type A with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419.1000    ! Support disk opening width
*  Type B Disk Opening with Tube v1.2
PART    6    CLUSTER
BOX    P4    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type B with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419.1000    ! Support disk opening width
* STC Basket v1.2
PART    7
BOX    1    -38.9153    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 1
BOX    2    -11.7272    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 2
BOX    3    15.4610    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 3
BOX    4    -70.7136    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 4
BOX    5    -38.9153    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 5
BOX    6    -11.7272    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 6
BOX    7    15.4610    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 7
BOX    8    47.2592    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 8
BOX    9    -70.7136    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 9
BOX    10    -38.9153    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 10
BOX    11    -11.7272    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 11
BOX    12    15.4610    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 12
BOX    13    47.2592    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 13
BOX    14    -70.7136    -25 3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 14
BOX    15    -38.9153    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 15
BOX    16    -11.7272    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 16
BOX    17    15.4610    -25.3213    0 0000    23.4544    23.4544    419.1000    ! Basket Opening 17
BOX    18    47.2592    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 18
BOX    19    -70.7136    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 19
BOX    20    -38.9153    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 20
BOX    21    -11.7272    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 21
BOX    22    15.4610    -52.5094    0.0000    23 4544    23.4544    419.1000    ! Basket Opening 22
BOX    23    47.2592    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 23
BOX    24    -38.9153    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 24
BOX    25    -11.7272    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 25
BOX    26    15.4610    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 26
ZROD    27    0.0000    0.0000    0.0000    89.9922    419.1000    ! Basket stack to cavity height
ZONES
/Opening01/    P5    +1
/Opening02/    P5    +2
/Opening03/    P5    +3
/Opening04/    P6    +4
/Opening05/    P5    +5
/Opening06/    P5    +6
/Opening07/    P5    +7
/Opening08/    P6    +8
/Opening09/    P5    +9
/Opening10/    P5    +10
/Opening11/    P5    +11
/Opening12/    P5    +12
/Opening13/    P5    +13
/Opening14/    P5    +14
/Opening15/    P5    +15
/Opening16/    P5    +16
/Opening17/    P5    +17
/Opening18/    P5    +18
/Opening19/    P6    +19
/Opening20/    P5    +20
/Opening21/    P5    +21
/Opening22/    P5    +22
/Opening23/    P6    +23
/Opening24/    P5    +24
/Opening25/    P5    +25
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
/Opening26/    P5    +26
/Basket/    H1    +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
VOLUMES    UNITY
* Basket in Cask Cavity v1.2
PART    8    NEST
ZROD    P7    0.0000    0.0000    0.0000    89.9922    419.1000        ! Basket inserted - Includes gap to lid
ZROD    H5    0.0000    0.0000    0.0000    90.1700    419.1000        ! Inserts flood matl to id of stc
* Transport Cask Inner Lid - With Ports v1.5.1.0
PART    9
ZROD    1    0.0000    0.0000    0.0000    100.3300    18.0848                ! Inner lid base
ZROD    2    0.0000    0.0000    18.0848    92.5957    4.7752                ! Inner lid cap
ZROD    3    0.0000    77.9907    0.0000    8.2931    22.8600                ! Drain port
ZROD    4    0.0000    -77.9907    0.0000    8.2931    22.8600                ! Vent port
ZROD    5    0.0000    0.0000    15.2400    85.6234    5.0800                ! Neutron shield
ZROD    6    0.0000    77.9907    15.2400    10.1600    5.0800                ! Cut circle 1 for neutron shield
ZROD    7    0.0000    -77.9907    15.2400    10.1600    5.0800                ! Cut circle 2 for neutron shield
BOX    8    -10.1600    77.9907    15.2400    20.3200    7 6327    5.0800        ! Cut box 1 for neutron shield
BOX    9    -10.1600    -85.6234    15.2400    20.3200    7.6327    5.0800        ! Cut box 2 for neutron shield
ZROD    10    0.0000    0.0000    0.0000    100.3300    22.8600                ! Container
ZONES
/Container/    M0    +10    -1    -2
/LidBase1/    M16    +1    -3    -4    -5    -6    -7
        -8    -9
/LidBase2/    M16    +1    +8    -6
/LidBase3/    M16    +1    +9    -7
/LidBase4/    M16    +1    +6    -3
/LidBase5/    M16    +1    +7    -4
/Nshield/    M15    +5    -6    -7    -8    -9
/LidCap1/    M16    +2    -3    -4    -5    -6    -7
        -8    -9
/LidCap2/    M16    +2    +8    -6
/LidCap3/    M16    +2    +9    -7
/LidCap4/    M16    +2    +6    -3
/LidCap5/    M16    +2    +7    -4
/DrainPort/    P10    +3
/VentPort/    P10    +4
VOLUMES UNITY
* Transport Cask Inner Lid Port Model - With Covers v1.5.1.0
PART    10    CLUSTER
ZROD    M0    0.0000    0.0000    0.0000    1.2700    10.8966                ! Bottom cylinder
ZROD    M0    0.0000    0.0000    10.8966    4.1275    7.5184                ! Middle cylinder
ZROD    M16    0.0000    0.0000    18.4150    8.2931    2.5400                ! Cover
ZROD    M0    0.0000    0.0000    20.9550    8.2931    1.9050                ! Top cylinder
ZROD    M16    0.0000    0.0000    0.0000    8.2931    22.8600                ! Inner lid material
*Transport Cask - Normal Conditions v1.5.1.0
PART    11
ZROD    1    0.0000    0 0000    -34 6710    110.1090    490.1184                ! Transport Cask
ZROD    2    0.0000    0.0000    0.0000    90.1700    419.1000                ! Cavity
ZROD    3    0.0000    0 0000    -20.8280    100.1776    5 0800                ! Bottom neutron shield
ZROD    4    0.0000    0.0000    419.1000    100.3300    22.8600                ! Inner lid
ZROD    5    0 0000    0.0000    0.0000    103.4034    408 9400                ! Lead shield cavity
ZROD    6    0 0000    0.0000    0.0000    95.2500    30.4800                ! Inner shell lower
ZCONE    7    0.0000    0.0000    30.4800    95.2500    93.9800    7.6200        ! Inner shell lower cone
ZROD    8    0.0000    0.0000    38.1000    93.9800    332.7400                ! Inner shell middle
ZCONE    9    0.0000    0.0000    370.8400    93.9800    95.2500    7.6200        ! Inner shell upper cone
ZROD    10    0.0000    0.0000    378.4600    95.2500    30.4800                ! Inner shell upper
ZROD    11    0.0000    0.0000    0.0000    103.2891    408.9400                ! Lead shield
ZROD    12    0.0000    0.0000    -3.8100    124.7140    410.5148                ! Radial neutron shield shell
ZROD    13    0.0000    0.0000    -2.6100    124.0790    408.1148                ! Radial neutron shield
ZP    14    2.4700                    ! Insulation (void) cut plane
ZCONE    15    0.0000    0.0000    19.0500    124.7140    113.9190    24.1300        ! Top of rotating trunnion
BOX    16    -124.7140    -12.7000    -3.8100    249.4280    25.4000    22.8600        ! Bottom of rotating trunnion
BOX    17    -114.2238    -12.7000    -3.8100    228.4476    25.4000    22.8600        ! Bottom of rotating trunnion base
BOX    18    -124.7140    -7.6200    -3.8100    249 4280    15.2400    15.2400        ! Trunnion void box
XROD    19    -124.7140    0.0000    11.4300    7.6200    249.4280                ! Trunnion void circle
BOX    20    -124.7140    -12.7000    -3.8100    249 4280    25.4000    46.9900        ! Trunnion extent box
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZSEC   21   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   14.6584   15.3416   ! Heat fin 1
ZSEC   22   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   29.6584   30.3416   ! Heat fin 2
ZSEC   23   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   44.6584   45.3416   ! Heat fin 3
ZSEC   24   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   59.6584   60.3416   ! Heat fin 4
ZSEC   25   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   74.6584   75.3416   ! Heat fin 5
ZSEC   26   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   89.6584   90.3416   ! Heat fin 6
ZSEC   27   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   104.6584   105.3416   ! Heat fin 7
ZSEC   28   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   119.6584   120.3416   ! Heat fin 8
ZSEC   29   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   134.6584   135.3416   ! Heat fin 9
ZSEC   30   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   149.6584   150.3416   ! Heat fin 10
ZSEC   31   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   164.6584   165.3416   ! Heat fin 11
ZSEC   32   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   179.6584   180.3416   ! Heat fin 12
ZSEC   33   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   194.6584   195.3416   ! Heat fin 13
ZSEC   34   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   209.6584   210.3416   ! Heat fin 14
ZSEC   35   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   224.6584   225.3416   ! Heat fin 15
ZSEC   36   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   239.6584   240.3416   ! Heat fin 16
ZSEC   37   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   254.6584   255.3416   ! Heat fin 17
ZSEC   38   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   269.6584   270.3416   ! Heat fin 18
ZSEC   39   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   284.6584   285.3416   ! Heat fin 19
ZSEC   40   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   299.6584   300.3416   ! Heat fin 20
ZSEC   41   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   314.6584   315.3416   ! Heat fin 21
ZSEC   42   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   329.6584   330.3416   ! Heat fin 22
ZSEC   43   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   344.6584   345.3416   ! Heat fin 23
ZSEC   44   0.0000   0.0000   -2.6100   110.1090   124.0790   408.1148   359.6584   360.3416   ! Heat fin 24
ZROD   45   0.0000   0.0000   425.6024   162.5600   85.0900   ! Upper impact limiter
ZROD   46   0.0000   0.0000   -89.9160   162.5600   85.0900   ! Lower impact limiter
ZROD   47   0.0000   0.0000   426.2374   161.9250   83.8200   ! Inside upper limiter shell
ZROD   48   0.0000   0.0000   -89.2810   161.9250   83.8200   ! Inside lower limiter shell
ZROD   49   0.0000   0.0000   425.6024   110.7440   30.4800   ! Upper end cap
ZROD   50   0.0000   0.0000   -35.3060   110.7440   30.4800   ! Lower end cap
ZROD   51   0.0000   0.0000   -89.9160   162.5600   600.6084   ! Container
ZROD   52   0.0000   0.0000   -3.8100   125.7140   27.3677   ! Surface detector #1
ZROD   53   0.0000   0.0000   23.5577   125.7140   27.3677   ! Surface detector #2
ZROD   54   0.0000   0.0000   50.9253   125.7140   27.3677   ! Surface detector #3
ZROD   55   0.0000   0.0000   78.2930   125.7140   27.3677   ! Surface detector #4
ZROD   56   0.0000   0.0000   105.6606   125.7140   27.3677   ! Surface detector #5
ZROD   57   0.0000   0.0000   133.0283   125.7140   27.3677   ! Surface detector #6
ZROD   58   0.0000   0.0000   160.3959   125.7140   27.3677   ! Surface detector #7
ZROD   59   0.0000   0.0000   187.7636   125.7140   27.3677   ! Surface detector #8
ZROD   60   0.0000   0.0000   215.1312   125.7140   27.3677   ! Surface detector #9
ZROD   61   0.0000   0.0000   242.4989   125.7140   27.3677   ! Surface detector #10
ZROD   62   0.0000   0.0000   269.8665   125.7140   27.3677   ! Surface detector #11
ZROD   63   0.0000   0.0000   297.2342   125.7140   27.3677   ! Surface detector #12
ZROD   64   0.0000   0.0000   324.6018   125.7140   27.3677   ! Surface detector #13
ZROD   65   0.0000   0.0000   351.9695   125.7140   27.3677   ! Surface detector #14
ZROD   66   0 0000   0.0000   379.3371   125.7140   27.3677   ! Surface detector #15
ZROD   67   0.0000   0.0000   406.7048   111.1090   18.8976   ! Package detector betw. NS and UpLim
ZSEC   68   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   2.5000   7.5000   ! Heat fin azi detector #1
ZSEC   69   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   7.5000   12.5000   ! Heat fin azi detector #2
ZSEC   70   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   12.5000   17.5000   ! Heat fin azi detector #3
ZSEC   71   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   17.5000   22.5000   ! Heat fin azi detector #4
ZSEC   72   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   22.5000   27.5000   ! Heat fin azi detector #5
ZSEC   73   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   27.5000   32.5000   ! Heat fin azi detector #6
ZSEC   74   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   32.5000   37.5000   ! Heat fin azi detector #7
ZSEC   75   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   37.5000   42.5000   ! Heat fin azi detector #8
ZSEC   76   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   42.5000   47.5000   ! Heat fin azi detector #9
ZSEC   77   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   47.5000   52.5000   ! Heat fin azi detector
#10
ZSEC   78   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   52.5000   57.5000   ! Heat fin azi detector
#11
ZSEC   79   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   57.5000   62.5000   ! Heat fin azi detector
#12
ZSEC   80   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   62.5000   67.5000   ! Heat fin azi detector
#13
ZSEC   81   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   67.5000   72.5000   ! Heat fin azi detector
#14
ZSEC   82   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   72.5000   77.5000   ! Heat fin azi detector
#15
ZSEC   83   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   77.5000   82.5000   ! Heat fin azi detector
#16
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZSEC    84    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    82.5000    87.5000    ! Heat fin azi detector
#17
ZSEC    85    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    87.5000    92.5000    ! Heat fin azi detector
#18
ZSEC    86    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    92.5000    97.5000    ! Heat fin azi detector
#19
ZSEC    87    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    97.5000    102.5000   ! Heat fin azi detector
#20
ZSEC    88    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    102.5000   107.5000   ! Heat fin azi detector
#21
ZSEC    89    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    107.5000   112.5000   ! Heat fin azi detector
#22
ZSEC    90    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    112.5000   117.5000   ! Heat fin azi detector
#23
ZSEC    91    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    117.5000   122.5000   ! Heat fin azi detector
#24
ZSEC    92    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    122.5000   127.5000   ! Heat fin azi detector
#25
ZSEC    93    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    127.5000   132.5000   ! Heat fin azi detector
#26
ZSEC    94    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    132.5000   137.5000   ! Heat fin azi detector
#27
ZSEC    95    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    137.5000   142.5000   ! Heat fin azi detector
#28
ZSEC    96    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    142.5000   147.5000   ! Heat fin azi detector
#29
ZSEC    97    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    147.5000   152.5000   ! Heat fin azi detector
#30
ZSEC    98    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    152.5000   157.5000   ! Heat fin azi detector
#31
ZSEC    99    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    157.5000   162.5000   ! Heat fin azi detector
#32
ZSEC    100    0 0000    0.0000    44.3800    125.7140    126.7140    361.1248    162.5000   167.5000 ! Heat fin azi detector
#33
ZSEC    101    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    167.5000   172.5000 ! Heat fin azi detector
#34
ZSEC    102    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    172.5000   177.5000 ! Heat fin azi detector
#35
ZSEC    103    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    177.5000   182.5000 ! Heat fin azi detector
#36
ZSEC    104    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    182.5000   187.5000 ! Heat fin azi detector
#37
ZSEC    105    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    187.5000   192.5000 ! Heat fin azi detector
#38
ZSEC    106    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    192.5000   197.5000 ! Heat fin azi detector
#39
ZSEC    107    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    197.5000   202.5000 ! Heat fin azi detector
#40
ZSEC    108    0 0000    0.0000    44.3800    125.7140    126.7140    361.1248    202.5000   207.5000 ! Heat fin azi detector
#41
ZSEC    109    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    207.5000   212.5000 ! Heat fin azi detector
#42
ZSEC    110    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    212.5000   217.5000 ! Heat fin azi detector
#43
ZSEC    111    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    217.5000   222.5000 ! Heat fin azi detector
#44
ZSEC    112    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    222.5000   227.5000 ! Heat fin azi detector
#45
ZSEC    113    0.0000    0.0000    44.3800    125.7140    126 7140    361.1248    227.5000   232.5000 ! Heat fin azi detector
#46
ZSEC    114    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    232.5000   237.5000 ! Heat fin azi detector
#47
ZSEC    115    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    237.5000   242.5000 ! Heat fin azi detector
#48
ZSEC    116    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    242.5000   247.5000 ! Heat fin azi detector
#49
ZSEC    117    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    247.5000   252.5000 ! Heat fin azi detector
#50
ZSEC    118    0.0000    0.0000    44.3800    125.7140    126.7140    361.1248    252.5000   257.5000 ! Heat fin azi detector
#51
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZSEC  119   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   257.5000   262.5000 ! Heat fin azi detector
#52
ZSEC  120   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   262.5000   267.5000 ! Heat fin azi detector
#53
ZSEC  121   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   267.5000   272.5000 ! Heat fin azi detector
#54
ZSEC  122   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   272.5000   277.5000 ! Heat fin azi detector
#55
ZSEC  123   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   277.5000   282.5000 ! Heat fin azi detector
#56
ZSEC  124   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   282.5000   287.5000 ! Heat fin azi detector
#57
ZSEC  125   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   287.5000   292.5000 ! Heat fin azi detector
#58
ZSEC  126   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   292.5000   297.5000 ! Heat fin azi detector
#59
ZSEC  127   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   297.5000   302.5000 ! Heat fin azi detector
#60
ZSEC  128   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   302.5000   307.5000 ! Heat fin azi detector
#61
ZSEC  129   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   307.5000   312.5000 ! Heat fin azi detector
#62
ZSEC  130   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   312.5000   317.5000 ! Heat fin azi detector
#63
ZSEC  131   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   317.5000   322.5000 ! Heat fin azi detector
#64
ZSEC  132   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   322.5000   327.5000 ! Heat fin azi detector
#65
ZSEC  133   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   327.5000   332.5000 ! Heat fin azi detector
#66
ZSEC  134   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   332.5000   337.5000 ! Heat fin azi detector
#67
ZSEC  135   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   337.5000   342.5000 ! Heat fin azi detector
#68
ZSEC  136   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   342.5000   347.5000 ! Heat fin azi detector
#69
ZSEC  137   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   347.5000   352.5000 ! Heat fin azi detector
#70
ZSEC  138   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   352.5000   357.5000 ! Heat fin azi detector
#71
ZSEC  139   0.0000   0.0000   44.3800   125.7140   126.7140   361.1248   357.5000   362.5000 ! Heat fin azi detector
#72
ZSEC  140   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   5.0000   15.0000   ! Rotating trunnion det#1
ZSEC  141   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   15.0000   25.0000   ! Rotating trunnion det#2
ZSEC  142   0.0000   0.0000   -3.8100   126.7140   127.7140   22 8600   25.0000   35.0000   ! Rotating trunnion det#3
ZSEC  143   0 0000   0.0000   -3.8100   126.7140   127.7140   22.8600   35.0000   45.0000   ! Rotating trunnion det#4
ZSEC  144   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   45.0000   55.0000   ! Rotating trunnion det#5
ZSEC  145   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   55.0000   65.0000   ! Rotating trunnion det#6
ZSEC  146   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   65.0000   75.0000   ! Rotating trunnion det#7
ZSEC  147   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   75.0000   85.0000   ! Rotating trunnion det#8
ZSEC  148   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   85.0000   95.0000   ! Rotating trunnion det#9
ZSEC  149   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   95.0000   105.0000   ! Rotating trunnion
det#10
ZSEC  150   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   105.0000   115.0000   ! Rotating trunnion
det#11
ZSEC  151   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   115.0000   125.0000   ! Rotating trunnion
det#12
ZSEC  152   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   125.0000   135.0000   ! Rotating trunnion
det#13
ZSEC  153   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   135.0000   145.0000   ! Rotating trunnion
det#14
ZSEC  154   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   145.0000   155.0000   ! Rotating trunnion
det#15
ZSEC  155   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   155.0000   165.0000   ! Rotating trunnion
det#16
ZSEC  156   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   165.0000   175.0000   ! Rotating trunnion
det#17
ZSEC  157   0.0000   0.0000   -3.8100   126.7140   127.7140   22.8600   175.0000   185.0000   ! Rotating trunnion
det#18
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZSEC    158    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    185.0000    195.0000    ! Rotating trunnion
det#19
ZSEC    159    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    195.0000    205.0000    ! Rotating trunnion
det#20
ZSEC    160    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    205.0000    215.0000    ! Rotating trunnion
det#21
ZSEC    161    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    215.0000    225.0000    ! Rotating trunnion
det#22
ZSEC    162    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    225.0000    235.0000    ! Rotating trunnion
det#23
ZSEC    163    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    235.0000    245.0000    ! Rotating trunnion
det#24
ZSEC    164    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    245.0000    255.0000    ! Rotating trunnion
det#25
ZSEC    165    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    255.0000    265.0000    ! Rotating trunnion
det#26
ZSEC    166    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    265.0000    275.0000    ! Rotating trunnion
det#27
ZSEC    167    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    275.0000    285.0000    ! Rotating trunnion
det#28
ZSEC    168    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    285.0000    295 0000    ! Rotating trunnion
det#29
ZSEC    169    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    295.0000    305.0000    ! Rotating trunnion
det#30
ZSEC    170    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    305.0000    315.0000    ! Rotating trunnion
det#31
ZSEC    171    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    315.0000    325.0000    ! Rotating trunnion
det#32
ZSEC    172    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    325.0000    335.0000    ! Rotating trunnion
det#33
ZSEC    173    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    335.0000    345.0000    ! Rotating trunnion
det#34
ZSEC    174    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    345.0000    355.0000    ! Rotating trunnion
det#35
ZSEC    175    0.0000    0.0000    -3.8100    126.7140    127.7140    22.8600    355.0000    365.0000    ! Rotating trunnion
det#36
ZROD    176    0.0000    0.0000    -4.8260    135.7630    430.4284                ! Personnel barrier surface
ZROD    177    0.0000    0.0000    -4.8260    136.7630    28.6952                 ! Personnel barrier det #1
ZROD    178    0.0000    0.0000    23.8692    136.7630    28.6952                 ! Personnel barrier det #2
ZROD    179    0.0000    0.0000    52.5645    136.7630    28.6952                 ! Personnel barrier det #3
ZROD    180    0.0000    0.0000    81.2597    136.7630    28.6952                 ! Personnel barrier det #4
ZROD    181    0.0000    0.0000    109.9549    136.7630    28.6952                ! Personnel barrier det #5
ZROD    182    0.0000    0.0000    138.6501    136.7630    28.6952                ! Personnel barrier det #6
ZROD    183    0.0000    0.0000    167.3454    136.7630    28.6952                ! Personnel barrier det #7
ZROD    184    0.0000    0.0000    196.0406    136.7630    28.6952                ! Personnel barrier det #8
ZROD    185    0.0000    0.0000    224.7358    136.7630    28.6952                ! Personnel barrier det #9
ZROD    186    0.0000    0.0000    253.4310    136.7630    28.6952                ! Personnel barrier det #10
ZROD    187    0.0000    0.0000    282.1263    136.7630    28 6952                ! Personnel barrier det #11
ZROD    188    0.0000    0.0000    310.8215    136.7630    28.6952                ! Personnel barrier det #12
ZROD    189    0.0000    0.0000    339.5167    136.7630    28.6952                ! Personnel barrier det #13
ZROD    190    0.0000    0.0000    368.2119    136.7630    28.6952                ! Personnel barrier det #14
ZROD    191    0 0000    0.0000    396.9072    136.7630    28.6952                ! Personnel barrier det #15
ZONES
/Cavity/    P8    +2
/OuterShell/    M16    +1    -2    -3    -4    -5
/InnerShell1/    M16    +6    -2
/InnerShell2/    M16    +7    -2
/InnerShell3/    M16    +8    -2
/InnerShell4/    M16    +9    -2
/InnerShell5/    M16    +10    -2
/InnerLid/    P9    +4
/BotNShield/    M15    +3
/LeadShield/    M14    +11    -6    -7    -8    -9    -10
/LeadShieldGap/    M0    +5    -11
/RadNShieldShell1/    M16    +12    -13    -1    -20
/RadNShieldShell2/    M16    +12    -13    -1    +20    -15    -16
/RadNShield1/    M15    +13    -1    -21    -22    -23    -24    -25
        -26    -27    -28    -29    -30    -31    -32
        -33    -34    -35    -36    -37    -38    -39
        -40    -41    -42    -43    -44    +14    -20
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
/RadNShield2/    M15    +13    -1    -32    -44    +20    -15    -16
/InsulationVoid/    M0    +13    -1    -14    -20
/RotTrunUpper/    M16    +15    -1    +20    +12
/RotTrunLower/    M16    +17    -1    +12
/RotTrunSide/    M16    +16    +12    -17    -18    -19
/RotTrunBoxVoid/    M0    +18    +12    -17
/RotTrunCircVoid/    M0    +19    -18    -17    +12
/HeatFin1/    M18    +21    +14
/HeatFin2/    M18    +22    +14
/HeatFin3/    M18    +23    +14
/HeatFin4/    M18    +24    +14
/HeatFin5/    M18    +25    +14
/HeatFin6/    M18    +26    +14
/HeatFin7/    M18    +27    +14
/HeatFin8/    M18    +28    +14
/HeatFin9/    M18    +29    +14
/HeatFin10/    M18    +30    +14
/HeatFin11/    M18    +31    +14
/HeatFin12/    M18    +32    +14    -15    -16
/HeatFin13/    M18    +33    +14
/HeatFin14/    M18    +34    +14
/HeatFin15/    M18    +35    +14
/HeatFin16/    M18    +36    +14
/HeatFin17/    M18    +37    +14
/HeatFin18/    M18    +38    +14
/HeatFin19/    M18    +39    +14
/HeatFin20/    M18    +40    +14
/HeatFin21/    M18    +41    +14
/HeatFin22/    M18    +42    +14
/HeatFin23/    M18    +43    +14
/HeatFin24/    M18    +44    +14    -15    -16
/UpLimShell/    M16    +45    -47    -49
/UpLimEnd/    M16    +49    -1
/LoLimShell/    M16    +46    -48    -50
/LoLimEnd/    M16    +50    -1
/UpBalsa/    M19    +47    -49
/LoBalsa/    M19    +48    -50
/InsidePersBarr/    M0    +176    -1    -12    -45    -46    -67    -52
        -53    -54    -55    -56    -57    -58    -59
        -60    -61    -62    -63    -64    -65    -66
        -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    -99    -100    -101    -102
        -103    -104    -105    -106    -107    -108    -109
        -110    -111    -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    -149    -150    -151
        -152    -153    -154    -155    -156    -157    -158
        -159    -160    -161    -162    -163    -164    -165
        -166    -167    -168    -169    -170    -171    -172
        -173    -174    -175
/SurfaceDet1/    M0    +52    -12
/SurfaceDet2/    M0    +53    -12
/SurfaceDet3/    M0    +54    -12
/SurfaceDet4/    M0    +55    -12
/SurfaceDet5/    M0    +56    -12
/SurfaceDet6/    M0    +57    -12
/SurfaceDet7/    M0    +58    -12
/SurfaceDet8/    M0    +59    -12
/SurfaceDet9/    M0    +60    -12
/SurfaceDet10/    M0    +61    -12
/SurfaceDet11/    M0    +62    -12
/SurfaceDet12/    M0    +63    -12
/SurfaceDet13/    M0    +64    -12
/SurfaceDet14/    M0    +65    -12
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
/SurfaceDet15/    M0    +66    -12
/PackageDet/    M0    +67    -1
/HeatFinAziDet1/    M0    +68
/HeatFinAziDet2/    M0    +69
/HeatFinAziDet3/    M0    +70
/HeatFinAziDet4/    M0    +71
/HeatFinAziDet5/    M0    +72
/HeatFinAziDet6/    M0    +73
/HeatFinAziDet7/    M0    +74
/HeatFinAziDet8/    M0    +75
/HeatFinAziDet9/    M0    +76
/HeatFinAziDet10/    M0    +77
/HeatFinAziDet11/    M0    +78
/HeatFinAziDet12/    M0    +79
/HeatFinAziDet13/    M0    +80
/HeatFinAziDet14/    M0    +81
/HeatFinAziDet15/    M0    +82
/HeatFinAziDet16/    M0    +83
/HeatFinAziDet17/    M0    +84
/HeatFinAziDet18/    M0    +85
/HeatFinAziDet19/    M0    +86
/HeatFinAziDet20/    M0    +87
/HeatFinAziDet21/    M0    +88
/HeatFinAziDet22/    M0    +89
/HeatFinAziDet23/    M0    +90
/HeatFinAziDet24/    M0    +91
/HeatFinAziDet25/    M0    +92
/HeatFinAziDet26/    M0    +93
/HeatFinAziDet27/    M0    +94
/HeatFinAziDet28/    M0    +95
/HeatFinAziDet29/    M0    +96
/HeatFinAziDet30/    M0    +97
/HeatFinAziDet31/    M0    +98
/HeatFinAziDet32/    M0    +99
/HeatFinAziDet33/    M0    +100
/HeatFinAziDet34/    M0    +101
/HeatFinAziDet35/    M0    +102
/HeatFinAziDet36/    M0    +103
/HeatFinAziDet37/    M0    +104
/HeatFinAziDet38/    M0    +105
/HeatFinAziDet39/    M0    +106
/HeatFinAziDet40/    M0    +107
/HeatFinAziDet41/    M0    +108
/HeatFinAziDet42/    M0    +109
/HeatFinAziDet43/    M0    +110
/HeatFinAziDet44/    M0    +111
/HeatFinAziDet45/    M0    +112
/HeatFinAziDet46/    M0    +113
/HeatFinAziDet47/    M0    +114
/HeatFinAziDet48/    M0    +115
/HeatFinAziDet49/    M0    +116
/HeatFinAziDet50/    M0    +117
/HeatFinAziDet51/    M0    +118
/HeatFinAziDet52/    M0    +119
/HeatFinAziDet53/    M0    +120
/HeatFinAziDet54/    M0    +121
/HeatFinAziDet55/    M0    +122
/HeatFinAziDet56/    M0    +123
/HeatFinAziDet57/    M0    +124
/HeatFinAziDet58/    M0    +125
/HeatFinAziDet59/    M0    +126
/HeatFinAziDet60/    M0    +127
/HeatFinAziDet61/    M0    +128
/HeatFinAziDet62/    M0    +129
/HeatFinAziDet63/    M0    +130
/HeatFinAziDet64/    M0    +131
/HeatFinAziDet65/    M0    +132
/HeatFinAziDet66/    M0    +133
/HeatFinAziDet67/    M0    +134
/HeatFinAziDet68/    M0    +135
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
/HeatFinAziDet69/    M0    +136
/HeatFinAziDet70/    M0    +137
/HeatFinAziDet71/    M0    +138
/HeatFinAziDet72/    M0    +139
/RotTrunDet1/    M0    +140
/RotTrunDet2/    M0    +141
/RotTrunDet3/    M0    +142
/RotTrunDet4/    M0    +143
/RotTrunDet5/    M0    +144
/RotTrunDet6/    M0    +145
/RotTrunDet7/    M0    +146
/RotTrunDet8/    M0    +147
/RotTrunDet9/    M0    +148
/RotTrunDet10/    M0    +149
/RotTrunDet11/    M0    +150
/RotTrunDet12/    M0    +151
/RotTrunDet13/    M0    +152
/RotTrunDet14/    M0    +153
/RotTrunDet15/    M0    +154
/RotTrunDet16/    M0    +155
/RotTrunDet17/    M0    +156
/RotTrunDet18/    M0    +157
/RotTrunDet19/    M0    +158
/RotTrunDet20/    M0    +159
/RotTrunDet21/    M0    +160
/RotTrunDet22/    M0    +161
/RotTrunDet23/    M0    +162
/RotTrunDet24/    M0    +163
/RotTrunDet25/    M0    +164
/RotTrunDet26/    M0    +165
/RotTrunDet27/    M0    +166
/RotTrunDet28/    M0    +167
/RotTrunDet29/    M0    +168
/RotTrunDet30/    M0    +169
/RotTrunDet31/    M0    +170
/RotTrunDet32/    M0    +171
/RotTrunDet33/    M0    +172
/RotTrunDet34/    M0    +173
/RotTrunDet35/    M0    +174
/RotTrunDet36/    M0    +175
/PersBarrDet1/    M0    +177    -176
/PersBarrDet2/    M0    +178    -176
/PersBarrDet3/    M0    +179    -176
/PersBarrDet4/    M0    +180    -176
/PersBarrDet5/    M0    +181    -176
/PersBarrDet6/    M0    +182    -176
/PersBarrDet7/    M0    +183    -176
/PersBarrDet8/    M0    +184    -176
/PersBarrDet9/    M0    +185    -176
/PersBarrDet10/    M0    +186    -176
/PersBarrDet11/    M0    +187    -176
/PersBarrDet12/    M0    +188    -176
/PersBarrDet13/    M0    +189    -176
/PersBarrDet14/    M0    +190    -176
/PersBarrDet15/    M0    +191    -176
/Container/    M0    +51    -45    -46    -177    -178    -179    -180
        -181    -182    -183    -184    -185    -186    -187
        -188    -189    -190    -191
VOLUMES    52*1.0        15*2.1531E+04        1.3133E+04        72*3.9775E+03
        36*5.0756E+02        15*2.4568E+04        1.0
* Transport Cask Detector Description v1.5.1.0
PART    12
* Radial Detector DRA (Surface) Bodies
* Radial Detector DRA+ (Package) Bodies
* Radial Detector DRAA (HeatFin) Bodies
* Radial Detector DRAB (RotTrun) Bodies
* Radial Detector DRB (PersBarr) Bodies
* Radial Detector DRC (LimSurf) Bodies
ZROD      1                    0.0000    0.0000    -89.9160  162.5600  600.6084
ZROD      2                    0.0000    0.0000    -89.9160  163.5600  40.0406
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
ZROD     3                0.0000    0.0000    -49.8754  163.5600  40.0406
ZROD     4                0.0000    0.0000    -9.8349   163.5600  40.0406
ZROD     5                0.0000    0.0000    30.2057   163.5600  40.0406
ZROD     6                0.0000    0.0000    70.2462   163.5600  40.0406
ZROD     7                0.0000    0.0000    110.2868  163.5600  40.0406
ZROD     8                0.0000    0.0000    150.3274  163.5600  40.0406
ZROD     9                0.0000    0.0000    190.3679  163.5600  40.0406
ZROD     10               0.0000    0.0000    230.4085  163.5600  40.0406
ZROD     11               0.0000    0.0000    270.4490  163.5600  40.0406
ZROD     12               0.0000    0.0000    310.4896  163.5600  40.0406
ZROD     13               0.0000    0.0000    350.5302  163.5600  40.0406
ZROD     14               0.0000    0.0000    390.5707  163.5600  40.0406
ZROD     15               0.0000    0.0000    430.6113  163.5600  40.0406
ZROD     16               0.0000    0.0000    470.6518  163.5600  40.0406
* Radial Detector DRD (1m) Bodies
ZROD     17               0 0000    0.0000    -189.9160 224.7140  800.6084
ZROD     18               0.0000    0.0000    -189.9160 225.7140  53.3739
ZROD     19               0.0000    0.0000    -136.5421 225.7140  53.3739
ZROD     20               0.0000    0.0000    -83.1682  225.7140  53.3739
ZROD     21               0.0000    0.0000    -29.7943  225.7140  53.3739
ZROD     22               0.0000    0.0000    23.5796   225.7140  53.3739
ZROD     23               0.0000    0.0000    76.9535   225.7140  53.3739
ZROD     24               0.0000    0.0000    130.3274  225.7140  53.3739
ZROD     25               0.0000    0.0000    183.7013  225.7140  53.3739
ZROD     26               0.0000    0.0000    237.0751  225.7140  53.3739
ZROD     27               0.0000    0.0000    290.4490  225.7140  53.3739
ZROD     28               0.0000    0.0000    343.8229  225.7140  53.3739
ZROD     29               0.0000    0.0000    397.1968  225.7140  53.3739
ZROD     30               0.0000    0.0000    450.5707  225.7140  53.3739
ZROD     31               0.0000    0.0000    503.9446  225.7140  53.3739
ZROD     32               0.0000    0.0000    557.3185  225.7140  53.3739
* Radial Detector DRE (1m+LimSurf) Bodies
ZROD     33               0.0000    0.0000    -239.9160 262.5600  900.6084
ZROD     34               0 0000    0.0000    -239.9160 263.5600  60.0406
ZROD     35               0 0000    0.0000    -179.8754 263.5600  60.0406
ZROD     36               0.0000    0.0000    -119.8349 263.5600  60 0406
ZROD     37               0.0000    0.0000    -59.7943  263.5600  60.0406
ZROD     38               0 0000    0.0000    0.2462    263.5600  60.0406
ZROD     39               0.0000    0.0000    60.2868   263.5600  60.0406
ZROD     40               0.0000    0.0000    120.3274  263.5600  60.0406
ZROD     41               0.0000    0.0000    180.3679  263.5600  60.0406
ZROD     42               0.0000    0.0000    240 4085  263.5600  60.0406
ZROD     43               0.0000    0.0000    300.4490  263.5600  60.0406
ZROD     44               0.0000    0.0000    360.4896  263.5600  60.0406
ZROD     45               0.0000    0.0000    420.5302  263.5600  60.0406
ZROD     46               0.0000    0.0000    480.5707  263.5600  60.0406
ZROD     47               0.0000    0.0000    540.6113  263.5600  60.0406
ZROD     48               0.0000    0.0000    600 6518  263.5600  60.0406
* Radial Detector DRF (2m+Railcar) Bodies
ZROD     49               0.0000    0.0000    -289.9160 357.4800  1000.6084
ZROD     50               0.0000    0.0000    -289.9160 358.4800  50.0304
ZROD     51               0.0000    0.0000    -239.8856 358.4800  50.0304
ZROD     52               0.0000    0.0000    -189.8552 358.4800  50.0304
ZROD     53               0.0000    0.0000    -139.8247 358.4800  50.0304
ZROD     54               0.0000    0.0000    -89.7943  358.4800  50.0304
ZROD     55               0.0000    0.0000    -39.7639  358.4800  50.0304
ZROD     56               0.0000    0.0000    10.2665   358.4800  50.0304
ZROD     57               0.0000    0.0000    60.2969   358.4800  50.0304
ZROD     58               0.0000    0.0000    110.3274  358.4800  50.0304
ZROD     59               0.0000    0.0000    160.3578  358.4800  50.0304
ZROD     60               0.0000    0.0000    210.3882  358.4800  50.0304
ZROD     61               0.0000    0.0000    260.4186  358.4800  50.0304
ZROD     62               0.0000    0.0000    310.4490  358.4800  50.0304
ZROD     63               0.0000    0.0000    360.4795  358.4800  50.0304
ZROD     64               0.0000    0.0000    410.5099  358.4800  50.0304
ZROD     65               0.0000    0.0000    460.5403  358.4800  50.0304
ZROD     66               0.0000    0.0000    510.5707  358.4800  50.0304
ZROD     67               0.0000    0.0000    560.6011  358.4800  50.0304
ZROD     68               0.0000    0.0000    610.6316  358.4800  50.0304
ZROD     69               0.0000    0.0000    660.6620  358.4800  50.0304
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
* Radial Detector DRG (4m) Bodies
ZROD    70          0.0000    0.0000    -489.9160 524.7140  1400.6084
ZROD    71          0.0000    0.0000    -489.9160 525.7140  70.0304
ZROD    72          0.0000    0.0000    -419.8856 525.7140  70.0304
ZROD    73          0.0000    0.0000    -349.8552 525.7140  70.0304
ZROD    74          0.0000    0.0000    -279.8247 525.7140  70.0304
ZROD    75          0.0000    0.0000    -209.7943 525.7140  70.0304
ZROD    76          0.0000    0.0000    -139.7639 525.7140  70.0304
ZROD    77          0.0000    0.0000    -69.7335  525.7140  70.0304
ZROD    78          0.0000    0.0000    0.2969    525.7140  70.0304
ZROD    79          0.0000    0.0000    70.3274   525.7140  70.0304
ZROD    80          0.0000    0.0000    140.3578  525.7140  70.0304
ZROD    81          0.0000    0.0000    210.3882  525.7140  70.0304
ZROD    82          0.0000    0.0000    280.4186  525.7140  70.0304
ZROD    83          0.0000    0.0000    350.4490  525.7140  70.0304
ZROD    84          0.0000    0.0000    420.4795  525.7140  70.0304
ZROD    85          0.0000    0.0000    490.5099  525.7140  70.0304
ZROD    86          0.0000    0.0000    560.5403  525.7140  70.0304
ZROD    87          0.0000    0.0000    630.5707  525.7140  70.0304
ZROD    88          0.0000    0.0000    700.6011  525.7140  70.0304
ZROD    89          0.0000    0.0000    770.6316  525.7140  70.0304
ZROD    90          0.0000    0.0000    840.6620  525.7140  70.0304
* World
ZROD    91          0.0000    0.0000    -539.9160 574.7140  1500.6084
* External Void
ZROD    92          0.0000    0.0000    -589.9160 624.7140  1600.6084

ZONES
/TransportCask/     P11       +1
* Detector DRC (LimSurf)
/DRC01/   M0        +2        -1
/DRC02/   M0        +3        -1
/DRC03/   M0        +4        -1
/DRC04/   M0        +5        -1
/DRC05/   M0        +6        -1
/DRC06/   M0        +7        -1
/DRC07/   M0        +8        -1
/DRC08/   M0        +9        -1
/DRC09/   M0        +10       -1
/DRC10/   M0        +11       -1
/DRC11/   M0        +12       -1
/DRC12/   M0        +13       -1
/DRC13/   M0        +14       -1
/DRC14/   M0        +15       -1
/DRC15/   M0        +16       -1
/Void/    M0        +17       -1
                    -2        -3        -4        -5        -6        -7
                    -8        -9        -10       -11       -12       -13
                    -14       -15       -16
* Detector DRD (1m)
/DRD01/   M0        +18       -17
/DRD02/   M0        +19       -17
/DRD03/   M0        +20       -17
/DRD04/   M0        +21       -17
/DRD05/   M0        +22       -17
/DRD06/   M0        +23       -17
/DRD07/   M0        +24       -17
/DRD08/   M0        +25       -17
/DRD09/   M0        +26       -17
/DRD10/   M0        +27       -17
/DRD11/   M0        +28       -17
/DRD12/   M0        +29       -17
/DRD13/   M0        +30       -17
/DRD14/   M0        +31       -17
/DRD15/   M0        +32       -17
/Void/    M0        +33       -17
                    -18       -19       -20       -21       -22       -23
                    -24       -25       -26       -27       -28       -29
                    -30       -31       -32
* Detector DRE (1m+LimSurf)
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
/DRE01/   M0      +34      -33
/DRE02/   M0      +35      -33
/DRE03/   M0      +36      -33
/DRE04/   M0      +37      -33
/DRE05/   M0      +38      -33
/DRE06/   M0      +39      -33
/DRE07/   M0      +40      -33
/DRE08/   M0      +41      -33
/DRE09/   M0      +42      -33
/DRE10/   M0      +43      -33
/DRE11/   M0      +44      -33
/DRE12/   M0      +45      -33
/DRE13/   M0      +46      -33
/DRE14/   M0      +47      -33
/DRE15/   M0      +48      -33
/Void/    M0      +49      -33
                  -34      -35      -36      -37      -38      -39
                  -40      -41      -42      -43      -44      -45
                  -46      -47      -48
* Detector DRF (2m+Railcar)
/DRF01/   M0      +50      -49
/DRF02/   M0      +51      -49
/DRF03/   M0      +52      -49
/DRF04/   M0      +53      -49
/DRF05/   M0      +54      -49
/DRF06/   M0      +55      -49
/DRF07/   M0      +56      -49
/DRF08/   M0      +57      -49
/DRF09/   M0      +58      -49
/DRF10/   M0      +59      -49
/DRF11/   M0      +60      -49
/DRF12/   M0      +61      -49
/DRF13/   M0      +62      -49
/DRF14/   M0      +63      -49
/DRF15/   M0      +64      -49
/DRF16/   M0      +65      -49
/DRF17/   M0      +66      -49
/DRF18/   M0      +67      -49
/DRF19/   M0      +68      -49
/DRF20/   M0      +69      -49
/Void/    M0      +70      -49
                  -50      -51      -52      -53      -54      -55
                  -56      -57      -58      -59      -60      -61
                  -62      -63      -64      -65      -66      -67
                  -68      -69
* Detector DRG (4m)
/DRG01/   M0      +71      -70
/DRG02/   M0      +72      -70
/DRG03/   M0      +73      -70
/DRG04/   M0      +74      -70
/DRG05/   M0      +75      -70
/DRG06/   M0      +76      -70
/DRG07/   M0      +77      -70
/DRG08/   M0      +78      -70
/DRG09/   M0      +79      -70
/DRG10/   M0      +80      -70
/DRG11/   M0      +81      -70
/DRG12/   M0      +82      -70
/DRG13/   M0      +83      -70
/DRG14/   M0      +84      -70
/DRG15/   M0      +85      -70
/DRG16/   M0      +86      -70
/DRG17/   M0      +87      -70
/DRG18/   M0      +88      -70
/DRG19/   M0      +89      -70
/DRG20/   M0      +90      -70
/Void/    M0      +91      -70
                  -71      -72      -73      -74      -75      -76
                  -77      -78      -79      -80      -81      -82
                  -83      -84      -85      -86      -87      -88
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
                    -89        -90
/ExtVoid/ M-2000    +92        -91
Volumes
                    1.0        15*4.1023E+04      1.0      15*7.5527E+04      1.0      15*9.9238E+04
                    1.0        20*1.1253E+05      1.0      20*2.3110E+05      1.0      1.0
end

*
* Unit 5 Splitting Geometry for Radial Detectors - Neutron
*
begin splitting geometry
    r    29    fill    0.0000
                    n    10    89.9922
                    n    2    93.9800
                    n    2    103.4034
                    n    3    110.1090
                    n    10    124.0790
                    n    1    124.7140
                    n    1    167.5600


    z    61    fill    -94.9160
                    n    1    -89.9160
                    n    1    -89.2810
                    n    4    -35.3060
                    n    1    -34.6710
                    n    5    -20.8280
                    n    4    -15.7480
                    n    6    0.0000
                    n    1    18.6004
                    n    13    387.4084
                    n    1    410.2100
                    n    1    419.1000
                    n    0    419.1000
                    n    6    434.3400
                    n    4    439.4200
                    n    6    455.4474
                    n    1    456.0824
                    n    4    510.0574
                    n    1    510.6924
                    n    1    515.6924

end

*
* Unit 6 - Source Geometry for Fuel Neutron
*
begin source geometry
    r    10    fill    0.0000    n    10    89.9922
    z    13
        18.6004    27.8206    37.0408    55.4812    92.3620    166.1236
        239.8852    276.7660    313 6468    350.5276    359.7478    368.9680
        378.1882    387.4084
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 - Radial
*
begin importance map
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
    calculate
    targets    15
    part    12
    zones
        2    3    4    5    6
        7    8    9    10    11
        12    13    14    15    16
    strengths
        1.0E+02    1.0E+02    5.0E+01    5.0E+01    5.0E+01
        1.0E+01    1.0E+01    1.0E+00    1.0E+01    1.0E+01
        5.0E+01    5.0E+01    5.0E+01    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 - Radial
*
begin scoring data
    flux
    part    11
    from    53    to    67    ' DRA
    some    68            ' DRA+
    from    69    to    140    ' DRAA
    from    141    to    176    ' DRAB
    from    177    to    191    ' DRB
    part    12
    from    2    to    16    ! DRC
    from    18    to    32    ! DRD
    from    34    to    48    ! DRE
    from    50    to    69    ' DRF
    from    71    to    90    ' DRG
    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
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
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
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
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
        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
* STC Basket Hole Description v1.2
* Hole    1    General Basket Structure
PLATE
0    0    1
7
417.8300    0            ! Top of Basket
389.4976    -2            ! Top of Highest Support Disk
326.4316    -7            ! Resume support disk only
79.2376    -4            ! Start of support+heat disk region
17.4396    -6            ! Bottom of Lowest Support Disk
0.0000    -3            ! Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole    2    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ! number of radial points
85.5472
89.9922
3                ! number of axial intervals
389.4976                ! Top of diskstack
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
400.5580                ! Bottom of weldment
403.0980                ! Top of weldment plate
417.8300                ! Void to top of basket
0    0            ! Material below weldment
10    10            ! Plate Material
0    10            ! Flange
0                 ! Outside material

* Hole    3    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                 ! number of radial points
89.9922
1                 ! number of axial intervals
3.8100
6.3500                ! Coordinates inherited from PLATE Hole
10                ! Plate Material
0                 ! Outside material

* Hole    4    Support disk and heat transfer disk stack
PLATE
origin    0    0    79.2376    ! Origin
0    0    1
4
cell    12.3597            ! Sets up a repeating lattice of cells
12.3597    0            ! flood matl
7.6086    0            ! water gap
6 0211    11            ! aluminium disk
1.2700    0            ! water gap
9                 ! steel disk

* Hole    5    Flood material model
PLATE
0    0    1
1
417.8300    0            ! Above flooded region
0                 ! Flooded region

* Hole    6    Support disk stack lower
PLATE
origin    0    0    17.4396    ! Origin
0    0    1
2
cell    12.3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                 ! steel disk

* Hole    7    Support disk stack upper
PLATE
origin    0    0    326.4316    ! Origin
0    0    1
2
cell    12.3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                 ! steel disk

end

*
* Unit 15 Source Strength - Fuel Neutron
*
* Class 1 - aa14b - STC Hybrid14 (Rev 0) - Fuel Neutron - Group 2 Reponse
begin source strength
    component        1.6667E+00    ! Subcritical multiplication factor
    component        6.9739E-06    ! 1/volume (1/1.4339E+05)
    component    r    10*1.0
    component    z
        4.3222E-02    2.3510E-01    6.9499E-01    1.5792E+00    2.1585E+00    1.8268E+00
        1.3619E+00    1.0170E+00    5.7791E-01    2.8622E-01    1.6890E-01    8.4742E-02
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
        3.7293E-02
    component    energy
        1*0.0
        1.0000E+00
        26*0.0


end

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

*
* Unit 31 Tabular Output
*
begin tabular output
    /Case trnNrmDryRadFn_aa14b_02g - Det DRA - Surface - Response/
    response    interim
    number    some    1
    region    from    121    to    135
    output to file    also
    /Case trnNrmDryRadFn_aa14b_02g - Det DRB - PersBarr - Response/
    response
    number    some    1
    region    from    245    to    259
    output to file    also
    /Case trnNrmDryRadFn_aa14b_02g - Det DRC - LimSurf - Response/
    response
    number    some    1
    region    from    262    to    276
    output to file    also
    /Case trnNrmDryRadFn_aa14b_02g - Det DRD - 1m - Response/
    response
    number    some    1
    region    from    278    to    292
    output to file    also
    /Case trnNrmDryRadFn_aa14b_02g - Det DRE - 1m+LimSurf - Response/
    response
    number    some    1
    region    from    294    to    308
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    dice
normalise
nmixtures    3
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
atoms    mixture    3
            c    2.8571E-01
            h    4.7619E-01
            o    2.3810E-01
*
* Materials List - Dry Conditions - v1.2 - Class 1 - aa14b - STC Hybrid14 (Rev 0) Fuel
*
nmaterials    20
volume                          ! Homogenized aa14b Fuel
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
material    1
    mixture    1    density    10.4120    prop    3.1489E-01    ! UO2 mixture at 3.7%
    void                prop    1.6671E-02    ! Gap
    zircalloy        density    6.5500    prop    9.7331E-02    ! Tube, clad
    void                prop    5.7111E-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    0.2948
    zircalloy        density    6.5500    prop    0 0831
    void                prop    0.6220
volume                            ! Upper Nozzle Material
material    6
    stainless 3041 steel        density    7.9200    prop    0.3613
    void                prop    0.6387
volume                            ! Upper Plenum Material
material    7
    stainless 3041 steel        density    7.9200    prop    0.1147
    zircalloy        density    6.5500    prop    0.0858
    void                prop    0.7995
*
* Materials List - Common Materials - v1.2
*
volume                            ! Tube wall and cover sheet
material    8
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                            ! Structural Disk Material
material    9
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                            ! Weldment Material
material    10
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                            ! Heat Transfer Disk Material
material    11
    aluminium                prop    1.0000
volume                            ! Canister Material
material    12
    stainless 3041 steel        density    7.9200    prop    1.0000
atoms                             ! Transfer steel
material    13        density    0            ! (SCALE carbon steel)

        c            prop    3.9250E-03
        fe           prop    8.3498E-02
volume                            ! Lead
material    14
    pb        density    11.0400    prop    1.0000
atoms                             ! NS-4-FR
material    15        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    16
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                            ! Vent port middle cylinder
material    17
    stainless 3041 steel        density    7.9200    prop    0.5000
    void                prop    0.5000
```

Figure 5.5-3 MCBEND Input File for Directly Loaded 14x14 Fuel Neutron Response from Energy Group 2 – Normal Conditions (Continued)

```
volume                          ! Heat fins for transport cask
material    18
    cu        density    8.9200    prop    0.4286
    stainless 3041 steel        density    7.9200    prop    0.5714
volume                          ! Balsa
material    19
    mixture    3    density    0.1250    prop    1.0000
volume                          ! Redwood
material    20
    mixture    3    density    0.3870    prop    1.0000
end
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions

```
columns 1 200
*
*   NAC-STC - aa14b_07g - Fuel Gamma - Radial
*   Dry Cavity Conditions
*   Accident Transport Conditions
*   Transport Model Revision v1.6.2.0
*   Shielding Revision v1.6
*   STC Source Profile
*   Cobalt Concentration of 1.2 g/kg
*   Fuel Assembly Shift = None, Basket Shift = None
*
* Parameters
*
@samps =    10000000

*
* Unit 1 Control Data
*
begin control data
    run
    sample limit     @samps
    time limit     1000m
    seeds    82896    43596
    chime every    [@samps/10]    samples
    report interim results
    sbd    30s
    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 1 - aa14b - STC Hybrid14 (Rev 0)
PART    1    NEST
BOX    M5        0 0000    0.0000    0.0000    19 7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0.0000    0.0000    0.0000    19.7180    19.7180    377.5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    19.7180    19.7180    409.1940    ! upper nozzle
* Fuel Assembly Type B - Class 1 - aa14b - STC Hybrid14 (Rev 0)
PART    2    NEST
BOX    M5        0.0000    0.0000    0.0000    19.7180    19.7180    8.6944    ! lower nozzle
BOX    M1    S    0.0000    0.0000    0.0000    19.7180    19.7180    377.5024    ! fuel
BOX    M7        0.0000    0.0000    0.0000    19.7180    19.7180    400.3040    ! top plenum
BOX    M6        0.0000    0.0000    0.0000    19.7180    19.7180    409.1940    ! upper nozzle
* Fuel Assembly in Tube (Type A) v1.1
PART    3
BOX    1    1.4135    1.4135    0.0000    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of STC cavity
ZONES
/Fuel Assembly/    P1    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
* Fuel Assembly in Tube (Type B) v1.1
PART    4
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
BOX    1    1.4135    1.4135    0.0000    19.7180    19.7180    409.1940    ! Fuel assembly
BOX    2    0.1219    0.1219    0.0000    22.3012    22.3012    419.1000    ! Space inside tube
BOX    3    0.0000    0.0000    6.3500    22.5450    22.5450    392.9380    ! Fuel tube
BOX    4    0.0000    0.0000    0.0000    22.5450    22.5450    419.1000    ! Container body - extent of STC cavity
ZONES
/Fuel Assembly/    P2    +1
/Space in Tube/    H5    +2    -1
/Fuel Tube/    M8    +3    -2
/Container/    H5    +4    -3    -2    -1
VOLUMES UNITY
*  Type A Disk Opening with Tube v1.2
PART    5    CLUSTER
BOX    P3    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type A with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419.1000    ! Support disk opening width
*  Type B Disk Opening with Tube v1.2
PART    6    CLUSTER
BOX    P4    0.4547    0.4547    0.0000    22.5450    22.5450    419.1000    ! Fuel tube type B with fuel assy
BOX    H5    0.0000    0.0000    0.0000    23.4544    23.4544    419 1000    ! Support disk opening width
* STC Basket v1.2
PART    7
BOX    1    -38.9153    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 1
BOX    2    -11.7272    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 2
BOX    3    15.4610    56.2432    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 3
BOX    4    -70.7136    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 4
BOX    5    -38.9153    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 5
BOX    6    -11.7272    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 6
BOX    7    15.4610    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 7
BOX    8    47.2592    29.0551    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 8
BOX    9    -70.7136    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 9
BOX    10    -38.9153    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 10
BOX    11    -11.7272    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 11
BOX    12    15.4610    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 12
BOX    13    47.2592    1.8669    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 13
BOX    14    -70.7136    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 14
BOX    15    -38.9153    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 15
BOX    16    -11.7272    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 16
BOX    17    15.4610    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 17
BOX    18    47.2592    -25.3213    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 18
BOX    19    -70 7136    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 19
BOX    20    -38.9153    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 20
BOX    21    -11.7272    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 21
BOX    22    15.4610    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 22
BOX    23    47.2592    -52.5094    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 23
BOX    24    -38.9153    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 24
BOX    25    -11.7272    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 25
BOX    26    15 4610    -79.6976    0.0000    23.4544    23.4544    419.1000    ! Basket Opening 26
ZROD    27    0.0000    0 0000    0.0000    89.9922    419.1000    ! Basket stack to cavity height
ZONES
/Opening01/    P5    +1
/Opening02/    P5    +2
/Opening03/    P5    +3
/Opening04/    P6    +4
/Opening05/    P5    +5
/Opening06/    P5    +6
/Opening07/    P5    +7
/Opening08/    P6    +8
/Opening09/    P5    +9
/Opening10/    P5    +10
/Opening11/    P5    +11
/Opening12/    P5    +12
/Opening13/    P5    +13
/Opening14/    P5    +14
/Opening15/    P5    +15
/Opening16/    P5    +16
/Opening17/    P5    +17
/Opening18/    P5    +18
/Opening19/    P6    +19
/Opening20/    P5    +20
/Opening21/    P5    +21
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
/Opening22/   P5   +22
/Opening23/   P6   +23
/Opening24/   P5   +24
/Opening25/   P5   +25
/Opening26/   P5   +26
/Basket/   H1   +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
VOLUMES   UNITY
* Basket in Cask Cavity v1.2
PART   8   NEST
ZROD   P7   0.0000   0.0000   0.0000   89.9922   419.1000   ! Basket inserted - Includes gap to lid
ZROD   H5   0.0000   0.0000   0.0000   90.1700   419.1000   ! Inserts flood matl to id of stc
* Transport Cask Inner Lid - With Ports v1.6.2.0
PART   9
ZROD   1   0.0000   0.0000   0.0000   100.3300   18.0848   ! Inner lid base
ZROD   2   0.0000   0.0000   18.0848   92.5957   4.7752   ! Inner lid cap
ZROD   3   0.0000   77.9907   0.0000   8.2931   22.8600   ! Drain port
ZROD   4   0.0000   -77.9907   0.0000   8.2931   22.8600   ! Vent port
ZROD   5   0.0000   0.0000   15.2400   85.6234   5.0800   ! Neutron shield
ZROD   6   0.0000   77.9907   15.2400   10.1600   5.0800   ! Cut circle 1 for neutron shield
ZROD   7   0.0000   -77.9907   15.2400   10.1600   5.0800   ! Cut circle 2 for neutron shield
BOX   8   -10.1600   77.9907   15.2400   20.3200   7.6327   5.0800   ! Cut box 1 for neutron shield
BOX   9   -10.1600   -85.6234   15.2400   20.3200   7.6327   5.0800   ! Cut box 2 for neutron shield
ZROD   10   0.0000   0.0000   0.0000   100.3300   22.8600   ! Container
ZONES
/Container/   M0   +10   -1   -2
/LidBase1/   M16   +1   -3   -4   -5   -6   -7
        -8   -9
/LidBase2/   M16   +1   +8   -6
/LidBase3/   M16   +1   +9   -7
/LidBase4/   M16   +1   +6   -3
/LidBase5/   M16   +1   +7   -4
/Nshield/   M15   +5   -6   -7   -8   -9
/LidCap1/   M16   +2   -3   -4   -5   -6   -7
        -8   -9
/LidCap2/   M16   +2   +8   -6
/LidCap3/   M16   +2   +9   -7
/LidCap4/   M16   +2   +6   -3
/LidCap5/   M16   +2   +7   -4
/DrainPort/   P10   +3
/VentPort/   P10   +4
VOLUMES UNITY
* Transport Cask Inner Lid Port Model - With Covers v1.6.2.0
PART   10   CLUSTER
ZROD   M0   0.0000   0.0000   0.0000   1.2700   10.8966   ! Bottom cylinder
ZROD   M0   0.0000   0.0000   10.8966   4.1275   7.5184   ! Middle cylinder
ZROD   M16   0.0000   0.0000   18.4150   8.2931   2.5400   ! Cover
ZROD   M0   0.0000   0.0000   20.9550   8.2931   1.9050   ! Top cylinder
ZROD   M16   0 0000   0.0000   0.0000   8.2931   22.8600   ! Inner lid material
* Transport Cask - Accident Conditions v1.6.2.0
PART   11
ZROD   1   0.0000   0.0000   -34.6710   110.1090   490.1184   ! Transport Cask
ZROD   2   0.0000   0.0000   0.0000   90.1700   419.1000   ! Cavity
ZROD   3   0.0000   0.0000   -20.8280   100.1776   5.0800   ! Bottom neutron shield
ZROD   4   0.0000   0.0000   419.1000   100.3300   22.8600   ! Inner lid
ZROD   5   0.0000   0.0000   0.0000   103.4034   408.9400   ! Lead shield cavity
ZROD   6   0.0000   0.0000   0.0000   95.2500   30.4800   ! Inner shell lower
ZCONE   7   0.0000   0.0000   30.4800   95.2500   93.9800   7.6200   ! Inner shell lower cone
ZROD   8   0.0000   0.0000   38.1000   93.9800   332.7400   ! Inner shell middle
ZCONE   9   0.0000   0.0000   370.8400   93.9800   95.2500   7.6200   ! Inner shell upper cone
ZROD   10   0.0000   0.0000   378.4600   95.2500   30.4800   ! Inner shell upper
ZP   11   402.9752   ! Top axial lead slump cut plane
ZP   12   5.9648   ! Bottom axial lead slump cut plane
YP   13   100.9322   ! Radial lead slump cut plane
ZROD   14   0.0000   0.0000   -3.8100   124.7140   410.5148   ! Radial neutron shield shell
ZROD   15   0.0000   0.0000   -2.6100   124.0790   408.1148   ! Radial neutron shield
ZP   16   2.4700   ! Insulation (void) cut plane
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
ZCONE   17   0.0000    0.0000    19.0500    124.7140    113.9190    24.1300          ! Top of rotating trunnion
BOX     18   -124.7140   -12.7000   -3.8100    249.4280    25.4000    22.8600         ! Bottom of rotating trunnion
BOX     19   -114.2238   -12.7000   -3.8100    228.4476    25.4000    22.8600         ! Bottom of rotating trunnion base
BOX     20   -124.7140   -7.6200   -3.8100    249.4280    15.2400    15.2400         ! Trunnion void box
XROD    21   -124.7140   0.0000    11.4300    7.6200    249.4280                    ! Trunnion void circle
BOX     22   -124.7140   -12.7000   -3.8100    249.4280    25.4000    46.9900         ! Trunnion extent box
ZSEC    23   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    14.6584    15.3416    ! Heat fin 1
ZSEC    24   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    29.6584    30.3416    ! Heat fin 2
ZSEC    25   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    44.6584    45.3416    ! Heat fin 3
ZSEC    26   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    59.6584    60.3416    ! Heat fin 4
ZSEC    27   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    74.6584    75.3416    ! Heat fin 5
ZSEC    28   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    89.6584    90.3416    ! Heat fin 6
ZSEC    29   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    104.6584    105.3416    ! Heat fin 7
ZSEC    30   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    119.6584    120.3416    ! Heat fin 8
ZSEC    31   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    134.6584    135.3416    ! Heat fin 9
ZSEC    32   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    149.6584    150.3416    ! Heat fin 10
ZSEC    33   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    164.6584    165.3416    ! Heat fin 11
ZSEC    34   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    179.6584    180.3416    ! Heat fin 12
ZSEC    35   0.0000    0.0000    -2.6100    110.1090    124 0790    408.1148    194.6584    195.3416    ! Heat fin 13
ZSEC    36   0.0000    0.0000    -2.6100    110.1090    124 0790    408.1148    209.6584    210.3416    ! Heat fin 14
ZSEC    37   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    224.6584    225.3416    ! Heat fin 15
ZSEC    38   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    239.6584    240.3416    ! Heat fin 16
ZSEC    39   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    254.6584    255.3416    ! Heat fin 17
ZSEC    40   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    269.6584    270.3416    ! Heat fin 18
ZSEC    41   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    284.6584    285.3416    ! Heat fin 19
ZSEC    42   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    299.6584    300.3416    ! Heat fin 20
ZSEC    43   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    314.6584    315.3416    ! Heat fin 21
ZSEC    44   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    329.6584    330.3416    ! Heat fin 22
ZSEC    45   0.0000    0.0000    -2.6100    110.1090    124.0790    408.1148    344.6584    345.3416    ! Heat fin 23
ZSEC    46   0.0000    0.0000    -2.6100    110.1090    124.0790    408 1148    359.6584    360.3416    ! Heat fin 24
ZROD    47   0.0000    0.0000    -34.6710    124.7140    490.1184                    ! Container
ZONES
/Cavity/    P8    +2
/OuterShell/    M16    +1    -2    -3    -4    -5
/InnerShell1/    M16    +6    -2
/InnerShell2/    M16    +7    -2
/InnerShell3/    M16    +8    -2
/InnerShell4/    M16    +9    -2
/InnerShell5/    M16    +10    -2
/InnerLid/    P9    +4
/BotNShield/    M15    +3
/LeadShield/    M14    +5    -6    -7    -8    -9    -10
        +12    -11    -13
/TopSlumpVoid/    M0    +5    -10    +11
/BotSlumpVoid/    M0    +5    -6    -12
/RadVoid/    M0    +5    -11    +13    +12
/RadNShieldShell1/    M16    +14    -15    -1    -22
/RadNShieldShell2/    M16    +14    -15    -1    +22    -17    -18
/RadNShield1/    M21    +15    -1    -23    -24    -25    -26    -27    -28
        -29    -30    -31    -32    -33    -34    -35    -36
        -37    -38    -39    -40    -41    -42    -43    -44
        -45    -46    +16    -22
/RadNShield2/    M21    +15    -1    +22    -17    -18    -34    -46
/InsulationVoid/    M0    +15    -1    -16    -22
/RotTrunUpper/    M16    +17    +22    +14    -1
/RotTrunLower/    M16    +19    +14    -1
/RotTrunSide/    M16    +18    +14    -19    -20    -21
/RotTrunBoxVoid/    M0    +20    +14    -19
/RotTrunCircVoid/    M0    +21    +14    -19    -20
/HeatFin1/    M18    +23
/HeatFin2/    M18    +24
/HeatFin3/    M18    +25
/HeatFin4/    M18    +26
/HeatFin5/    M18    +27
/HeatFin6/    M18    +28
/HeatFin7/    M18    +29
/HeatFin8/    M18    +30
/HeatFin9/    M18    +31
/HeatFin10/    M18    +32
/HeatFin11/    M18    +33
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
/HeatFin12/    M18    +34    -17    -18
/HeatFin13/    M18    +35
/HeatFin14/    M18    +36
/HeatFin15/    M18    +37
/HeatFin16/    M18    +38
/HeatFin17/    M18    +39
/HeatFin18/    M18    +40
/HeatFin19/    M18    +41
/HeatFin20/    M18    +42
/HeatFin21/    M18    +43
/HeatFin22/    M18    +44
/HeatFin23/    M18    +45
/HeatFin24/    M18    +46    -17    -18
/Container/    M0    +47    -1    -14
VOLUMES UNITY
* Transport Cask Detector Description v1.6.2.0
PART    12
* Radial Detector DRA (Surface) Bodies
ZROD      1                0.0000    0.0000    -34.6710  124.7140  490.1184
ZROD      2                0.0000    0.0000    -34.6710  125.7140  32.6746
ZROD      3                0.0000    0.0000    -1.9964   125.7140  32.6746
ZROD      4                0.0000    0.0000    30.6781   125.7140  32.6746
ZROD      5                0.0000    0.0000    63.3527   125.7140  32.6746
ZROD      6                0.0000    0.0000    96.0272   125.7140  32.6746
ZROD      7                0.0000    0.0000    128.7018  125.7140  32.6746
ZROD      8                0.0000    0.0000    161.3764  125.7140  32.6746
ZROD      9                0.0000    0.0000    194.0509  125.7140  32.6746
ZROD      10               0.0000    0.0000    226.7255  125.7140  32.6746
ZROD      11               0.0000    0.0000    259.4000  125.7140  32.6746
ZROD      12               0.0000    0.0000    292.0746  125.7140  32.6746
ZROD      13               0.0000    0.0000    324.7492  125.7140  32.6746
ZROD      14               0.0000    0.0000    357.4237  125.7140  32.6746
ZROD      15               0.0000    0.0000    390.0983  125.7140  32.6746
ZROD      16               0.0000    0.0000    422.7728  125.7140  32.6746
* Radial Detector DRAA (SurfaceAzi) Bodies
ZROD      17               0.0000    0.0000    -35.6710  125.7140  492.1184
*   Band 1 Bodies
ZSEC      18               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  250.0000  260.0000
ZSEC      19               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  260.0000  270.0000
ZSEC      20               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  270.0000  280.0000
ZSEC      21               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  280.0000  290.0000
ZSEC      22               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  290.0000  300.0000
ZSEC      23               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  300.0000  310.0000
ZSEC      24               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  310.0000  320.0000
ZSEC      25               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  320.0000  330.0000
ZSEC      26               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  330.0000  340.0000
ZSEC      27               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  340.0000  350.0000
ZSEC      28               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  350.0000  360.0000
ZSEC      29               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  0.0000    10.0000
ZSEC      30               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  10.0000   20.0000
ZSEC      31               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  20.0000   30.0000
ZSEC      32               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  30.0000   40.0000
ZSEC      33               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  40.0000   50.0000
ZSEC      34               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  50.0000   60.0000
ZSEC      35               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  60.0000   70.0000
ZSEC      36               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  70.0000   80.0000
ZSEC      37               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  80.0000   90.0000
ZSEC      38               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  90.0000   100.0000
ZSEC      39               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  100.0000  110.0000
ZSEC      40               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  110.0000  120.0000
ZSEC      41               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  120.0000  130.0000
ZSEC      42               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  130.0000  140.0000
ZSEC      43               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  140.0000  150.0000
ZSEC      44               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  150.0000  160.0000
ZSEC      45               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  160.0000  170.0000
ZSEC      46               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  170.0000  180.0000
ZSEC      47               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  180.0000  190.0000
ZSEC      48               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  190.0000  200.0000
ZSEC      49               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  200.0000  210.0000
ZSEC      50               0.0000    0.0000    178.0984  125.7140  126.7140  30.0000  210.0000  220.0000
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
ZSEC      51                0.0000    0.0000    178.0984  125.7140  126.7140  30.0000   220.0000  230.0000
ZSEC      52                0.0000    0.0000    178.0984  125.7140  126.7140  30.0000   230.0000  240.0000
ZSEC      53                0.0000    0.0000    178.0984  125.7140  126.7140  30.0000   240.0000  250.0000
* Radial Detector DRB (1m) Bodies
ZROD      54                0.0000    0.0000    -134.6710 210.1090  690.1184
ZROD      55                0.0000    0.0000    -134.6710 211.1090  34.5059
ZROD      56                0.0000    0.0000    -100.1651 211.1090  34.5059
ZROD      57                0.0000    0.0000    -65.6592  211.1090  34.5059
ZROD      58                0.0000    0.0000    -31.1532  211.1090  34.5059
ZROD      59                0.0000    0.0000    3.3527    211.1090  34.5059
ZROD      60                0.0000    0.0000    37.8586   211.1090  34.5059
ZROD      61                0.0000    0.0000    72.3645   211.1090  34.5059
ZROD      62                0.0000    0.0000    106.8704  211.1090  34.5059
ZROD      63                0.0000    0.0000    141.3764  211.1090  34.5059
ZROD      64                0.0000    0.0000    175.8823  211.1090  34.5059
ZROD      65                0.0000    0.0000    210.3882  211.1090  34.5059
ZROD      66                0 0000    0.0000    244.8941  211.1090  34 5059
ZROD      67                0.0000    0.0000    279.4000  211.1090  34.5059
ZROD      68                0.0000    0.0000    313.9060  211.1090  34.5059
ZROD      69                0.0000    0.0000    348.4119  211.1090  34.5059
ZROD      70                0.0000    0.0000    382.9178  211.1090  34.5059
ZROD      71                0.0000    0.0000    417.4237  211.1090  34.5059
ZROD      72                0.0000    0.0000    451.9296  211.1090  34.5059
ZROD      73                0.0000    0.0000    486.4356  211.1090  34.5059
ZROD      74                0.0000    0.0000    520.9415  211.1090  34.5059
* Radial Detector DRBA (1mAzi) Bodies
ZROD      75                0.0000    0.0000    -135.6710 211.1090  692.1184
*   Band 1 Bodies
ZSEC      76                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   250.0000  260.0000
ZSEC      77                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   260.0000  270.0000
ZSEC      78                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   270.0000  280.0000
ZSEC      79                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   280.0000  290.0000
ZSEC      80                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   290.0000  300.0000
ZSEC      81                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   300.0000  310.0000
ZSEC      82                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   310.0000  320.0000
ZSEC      83                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   320.0000  330.0000
ZSEC      84                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   330.0000  340.0000
ZSEC      85                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   340.0000  350.0000
ZSEC      86                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   350.0000  360.0000
ZSEC      87                0 0000    0.0000    178.0984  211.1090  212.1090  30.0000   0.0000    10.0000
ZSEC      88                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   10.0000   20.0000
ZSEC      89                0 0000    0.0000    178.0984  211.1090  212.1090  30.0000   20.0000   30.0000
ZSEC      90                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   30.0000   40.0000
ZSEC      91                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   40.0000   50.0000
ZSEC      92                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   50.0000   60.0000
ZSEC      93                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   60.0000   70.0000
ZSEC      94                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   70.0000   80.0000
ZSEC      95                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   80.0000   90.0000
ZSEC      96                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   90.0000   100.0000
ZSEC      97                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   100.0000  110.0000
ZSEC      98                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   110.0000  120.0000
ZSEC      99                0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   120.0000  130.0000
ZSEC      100               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   130.0000  140.0000
ZSEC      101               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   140.0000  150.0000
ZSEC      102               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   150.0000  160.0000
ZSEC      103               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   160.0000  170.0000
ZSEC      104               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   170.0000  180.0000
ZSEC      105               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   180.0000  190.0000
ZSEC      106               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   190.0000  200.0000
ZSEC      107               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   200.0000  210.0000
ZSEC      108               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   210.0000  220.0000
ZSEC      109               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   220.0000  230.0000
ZSEC      110               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   230.0000  240.0000
ZSEC      111               0.0000    0.0000    178.0984  211.1090  212.1090  30.0000   240.0000  250.0000
* World
ZROD      112               0.0000    0.0000    -185.6710 261.1090  792.1184
* External Void
ZROD      113               0.0000    0.0000    -235.6710 311.1090  892.1184

ZONES
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
/TransportCask/     P11     +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
/DRA13/   M0        +14     -1
/DRA14/   M0        +15     -1
/DRA15/   M0        +16     -1
/Void/    M0        +17     -1
                    -2      -3      -4      -5      -6      -7
                    -8      -9      -10     -11     -12     -13
                    -14     -15     -16
* Detector DRAA (SurfaceAzi)
/DRAA0101/          M0      +18
/DRAA0102/          M0      +19
/DRAA0103/          M0      +20
/DRAA0104/          M0      +21
/DRAA0105/          M0      +22
/DRAA0106/          M0      +23
/DRAA0107/          M0      +24
/DRAA0108/          M0      +25
/DRAA0109/          M0      +26
/DRAA0110/          M0      +27
/DRAA0111/          M0      +28
/DRAA0112/          M0      +29
/DRAA0113/          M0      +30
/DRAA0114/          M0      +31
/DRAA0115/          M0      +32
/DRAA0116/          M0      +33
/DRAA0117/          M0      +34
/DRAA0118/          M0      +35
/DRAA0119/          M0      +36
/DRAA0120/          M0      +37
/DRAA0121/          M0      +38
/DRAA0122/          M0      +39
/DRAA0123/          M0      +40
/DRAA0124/          M0      +41
/DRAA0125/          M0      +42
/DRAA0126/          M0      +43
/DRAA0127/          M0      +44
/DRAA0128/          M0      +45
/DRAA0129/          M0      +46
/DRAA0130/          M0      +47
/DRAA0131/          M0      +48
/DRAA0132/          M0      +49
/DRAA0133/          M0      +50
/DRAA0134/          M0      +51
/DRAA0135/          M0      +52
/DRAA0136/          M0      +53
/Void/    M0        +54     -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
* Detector DRB (1m)
/DRB01/   M0        +55     -54
/DRB02/   M0        +56     -54
/DRB03/   M0        +57     -54
/DRB04/   M0        +58     -54
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
/DRB05/   M0      +59      -54
/DRB06/   M0      +60      -54
/DRB07/   M0      +61      -54
/DRB08/   M0      +62      -54
/DRB09/   M0      +63      -54
/DRB10/   M0      +64      -54
/DRB11/   M0      +65      -54
/DRB12/   M0      +66      -54
/DRB13/   M0      +67      -54
/DRB14/   M0      +68      -54
/DRB15/   M0      +69      -54
/DRB16/   M0      +70      -54
/DRB17/   M0      +71      -54
/DRB18/   M0      +72      -54
/DRB19/   M0      +73      -54
/DRB20/   M0      +74      -54
/Void/    M0      +75      -54
                  -55      -56      -57      -58      -59      -60
                  -61      -62      -63      -64      -65      -66
                  -67      -68      -69      -70      -71      -72
                  -73      -74
* Detector DRBA (1mAzi)
/DRBA0101/        M0       +76
/DRBA0102/        M0       +77
/DRBA0103/        M0       +78
/DRBA0104/        M0       +79
/DRBA0105/        M0       +80
/DRBA0106/        M0       +81
/DRBA0107/        M0       +82
/DRBA0108/        M0       +83
/DRBA0109/        M0       +84
/DRBA0110/        M0       +85
/DRBA0111/        M0       +86
/DRBA0112/        M0       +87
/DRBA0113/        M0       +88
/DRBA0114/        M0       +89
/DRBA0115/        M0       +90
/DRBA0116/        M0       +91
/DRBA0117/        M0       +92
/DRBA0118/        M0       +93
/DRBA0119/        M0       +94
/DRBA0120/        M0       +95
/DRBA0121/        M0       +96
/DRBA0122/        M0       +97
/DRBA0123/        M0       +98
/DRBA0124/        M0       +99
/DRBA0125/        M0       +100
/DRBA0126/        M0       +101
/DRBA0127/        M0       +102
/DRBA0128/        M0       +103
/DRBA0129/        M0       +104
/DRBA0130/        M0       +105
/DRBA0131/        M0       +106
/DRBA0132/        M0       +107
/DRBA0133/        M0       +108
/DRBA0134/        M0       +109
/DRBA0135/        M0       +110
/DRBA0136/        M0       +111
/Void/    M0      +112     -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     -107     -108     -109     -110     -111
/ExtVoid/ M-2000  +113     -112
Volumes
                  1.0      15*2.5706E+04     1.0      36*6.6085E+02     1 0     20*4.5662E+04
                  1.0      36*1.1080E+03     1.0      1 0
end
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
*
* Unit 5 Splitting Geometry for Radial Detectors - Gamma
*
begin splitting geometry
    r    37    fill    0.0000
                  n    10    89.9922
                  n    1    93.9800
                  n    16    103.4034
                  n    3    110.1090
                  n    5    124.0790
                  n    1    124.7140
                  n    1    129.7140


    z    38    fill    -39.6710
                  n    1    -34.6710
                  n    2    -20.8280
                  n    2    -15.7480
                  n    3    0.0000
                  n    2    8.6944
                  n    13    377.5024
                  n    2    400.3040
                  n    3    409.1940
                  n    1    419.1000
                  n    3    434.3400
                  n    2    439.4200
                  n    3    455.4474
                  n    1    460.4474

end

*
* Unit 6 - Source Geometry for Fuel Gamma
*
begin source geometry
    r    10    fill    0.0000    n    10    89.9922
    z    13
        8.6944    17.9146    27.1348    45.5752    82.4560    156.2176
        229.9792    266.8600    303.7408    340.6216    349.8418    359.0620
        368.2822    377.5024
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    15
    part    12
    zones
        2    3    4    5    6
        7    8    9    10    11
        12    13    14    15    16
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
    strengths
        1.0E+02    1.0E+02    5.0E+01    5.0E+01    5.0E+01
        1.0E+01    1.0E+01    1.0E+00    1.0E+01    1.0E+01
        5.0E+01    5.0E+01    5.0E+01    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 - Radial
*
begin scoring data
    flux
    part    12
    from    2    to    16    ! DRA
    from    18    to    53    ! DRAA
    from    55    to    74    ! DRB
    from    76    to    111    ! DRBA
    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
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
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
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
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
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
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

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
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

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
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
[illegible]         6.0255E-04
[illegible]         5.8881E-04
2.2865E-01          5.7538E-04
2.2361E-01          5.6226E-04
[illegible]         5.4943E-04
[illegible]         5.3690E-04
2.0913E-01          5.2466E-04
[illegible]         5.1269E-04
[illegible]         5.0100E-04
1.9433E-01          4.8721E-04
1.8882E-01          4.7380E-04
[illegible]         4.6076E-04
```

FIGURE WITHHELD AS

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (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
* STC Basket Hole Description v1.2
* Hole    1    General Basket Structure
PLATE
0    0    1
7
417.8300    0            ! Top of Basket
389.4976    -2            ! Top of Highest Support Disk
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
326.4316    -7            ! Resume support disk only
79.2376    -4            ! Start of support+heat disk region
17.4396    -6            ! Bottom of Lowest Support Disk
0.0000    -3            ! Bottom of Basket
0.0000    0            ! Basket Offset
0

* Hole    2    Top Weldment Disk - no structure above the weldment disk
RZMESH
2                ' number of radial points
85.5472
89.9922
3                ! number of axial intervals
389.4976                ! Top of diskstack
400.5580                ! Bottom of weldment
403.0980                ! Top of weldment plate
417.8300                ! Void to top of basket
0    0            ! Material below weldment
10    10            ! Plate Material
0    10            ! Flange
0                ! Outside material

* Hole    3    Bottom Weldment Disk - no structure in the weldment disk support
RZMESH
1                ' number of radial points
89.9922
1                ! number of axial intervals
3.8100
6.3500                ! Coordinates inherited from PLATE Hole
10                ! Plate Material
0                ' Outside material

* Hole    4    Support disk and heat transfer disk stack
PLATE
origin    0    0    79.2376    ! Origin
0    0    1
4
cell    12.3597            ! Sets up a repeating lattice of cells
12.3597    0            ' flood matl
7 6086    0            ' water gap
6.0211    11            ' aluminium disk
1 2700    0            ' water gap
9                ' steel disk

* Hole    5    Flood material model
PLATE
0    0    1
1
417.8300    0            ' Above flooded region
0                ' Flooded region

* Hole    6    Support disk stack lower
PLATE
origin    0    0    17.4396    ! Origin
0    0    1
2
cell    12 3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                ! steel disk

* Hole    7    Support disk stack upper
PLATE
origin    0    0    326.4316    ! Origin
0    0    1
2
cell    12.3596            ! Sets up a repeating lattice of cells
12.3596    0            ! flood matl
1.2700    0            ! water gap
9                ! steel disk
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
end

*
* Unit 15 Source Strength - Fuel Gamma
*
* Class 1 - aa14b - STC Hybrid14 (Rev 0) - Fuel Gamma - Group 7 Reponse
begin source strength
    component        6.9739E-06     ' 1/volume (1/1.4339E+05)
    component    r    10*1.0
    component    z
        4.2500E-01    6.7500E-01    9.0000E-01    1.1000E+00    1.2000E+00    1.1500E+00
        1.0750E+00    1.0000E+00    8.6500E-01    7.4000E-01    6.5000E-01    5.5000E-01
        4.5000E-01
    component    energy
        6*0.0
        1.0000E+00
        15*0.0

end

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

*
* Unit 31 Tabular Output
*
begin tabular output
    /Case trnAccDryRadFg_aa14b_07g - Det DRA - Surface - Response/
    response    interim
    number    some    1
    region    from    118    to    132
    output to file    also
    /Case trnAccDryRadFg_aa14b_07g - Det DRAA - SurfaceAzi - Response/
    response
    number    some    1
    region    from    134    to    169
    output to file    also
    /Case trnAccDryRadFg_aa14b_07g - Det DRB - 1m - Response/
    response
    number    some    1
    region    from    171    to    190
    output to file    also
    /Case trnAccDryRadFg_aa14b_07g - Det DRBA - 1mAzi - Response/
    response
    number    some    1
    region    from    192    to    227
    output to file    also
end

*
* Unit 32 Material Specification
*
begin material specification
type    gamma
normalise
nmixtures    3
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
atoms    mixture    3
            c    2.8571E-01
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
          h    4.7619E-01
          o    2.3810E-01
*
* Materials List - Dry Conditions - v1.3 - Class 1 - aa14b - STC Hybrid14 (Rev 0) Fuel
*
nmaterials    21
volume                          ! Homogenized aa14b Fuel
material    1
    mixture    1    density    10.4120    prop    3 1489E-01    ! UO2 mixture at 3.7%
    void               prop    1 6671E-02    ' Gap
    zircalloy        density    6 5500    prop    9.7331E-02    ' Tube, clad
    void               prop    5.7111E-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    0.2948
    zircalloy        density    6 5500    prop    0 0831
    void               prop    0.6220
volume                          ! Upper Nozzle Material
material    6
    stainless 3041 steel        density    7.9200    prop    0.3613
    void               prop    0.6387
volume                          ' Upper Plenum Material
material    7
    stainless 3041 steel        density    7.9200    prop    0.1147
    zircalloy        density    6.5500    prop    0.0858
    void               prop    0.7995
*
* Materials List - Common Materials - v1.3
*
volume                          ' Tube wall and cover sheet
material    8
    stainless 3041 steel        density    7 9200    prop    1.0000
volume                          ' Structural Disk Material
material    9
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                          ' Weldment Material
material    10
    stainless 3041 steel        density    7.9200    prop    1.0000
volume                          ' Heat Transfer Disk Material
material    11
    aluminium                prop    1.0000
volume                          ' Canister Material
material    12
    stainless 3041 steel        density    7.9200    prop    1.0000
atoms                           ! Transfer steel
material    13        density    0            !  (SCALE carbon steel)

        c            prop    3.9250E-03
        fe            prop    8.3498E-02
volume                          ! Lead
material    14
    pb        density    11.0400    prop    1.0000
atoms                           ' NS-4-FR
material    15        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
```

Figure 5.5-4 MCBEND Input File for Directly Loaded 14x14 Fuel Gamma Response from Energy Group 7 – Accident Conditions (Continued)

```
volume                          ! Stainless Steel 304
material    16
    stainless 304l steel        density    7.9200    prop    1.0000
volume                          ! Vent port middle cylinder
material    17
    stainless 304l steel        density    7.9200    prop    0.5000
    void                prop    0.5000
volume                          ! Heat fins for transport cask
material    18
    cu        density    8.9200    prop    0.4286
    stainless 304l steel        density    7.9200    prop    0.5714
volume                          ! Balsa
material    19
    mixture    3    density    0.1250    prop    1.0000
volume                          ! Redwood
material    20
    mixture    3    density    0.3870    prop    1.0000
atoms                           ! NS-4-FR @ fire conditions
material    21        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
end
```

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