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6.0 CRITICALITY EVALUATION

6.1 Discussion and Results

This chapter demonstrates that the NAC-MPC storage system containing 36 Yankee Class fuel assemblies is subcritical in accordance with the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG-1536. These requirements are interpreted to mean that the effective neutron multiplication factor of the NAC-MPC system is less than 0.95, including biases and uncertainties under normal, off-normal and accident conditions.

The NAC-MPC storage system comprises a transportable storage canister (canister), a transfer cask and a vertical concrete cask (storage cask). The canister comprises a stainless steel canister and a basket. The basket comprises 36 fuel tubes held in place with stainless steel support disks and tie rods. The transfer cask containing the canister and basket is loaded underwater in the spent fuel pool. Once loaded with fuel, the canister is drained, dried, inerted, and welded shut. The transfer cask is then used to transfer the canister to the storage cask where it is stored until transported off site.

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes a variation in moderator density and a determination of optimum moderator density. Off-normal and accident conditions are bounded by assuming the most reactive mechanical basket configuration, as well as moderator intrusion into the fuel cladding (100% fuel failure).

Under normal conditions, moderator is not present in the canister while it is in the storage cask. However, access to the environment is possible via the air inlets in the storage cask and the convective heat transfer annulus between the canister and the storage cask steel liner. This access provides paths for moderator intrusion during a flood. Under off-normal conditions, moderator intrusion into the convective heat transfer annulus is evaluated. Under accident conditions, it is hypothetically assumed that the canister confinement fails, and moderator intrusion into the canister and into the fuel cladding (100% fuel failure) is evaluated. This is a highly conservative assumption, since, as shown in Chapters 3 and 11, there are no design basis normal, off-normal or accident conditions that result in the failure of the canister confinement boundary that would allow the intrusion of water.

Criticality control in the NAC-MPC canister basket is achieved using a flux trap principle. Each of the basket tubes in the canister basket is surrounded by four BORAL sheets with a core areal density of 0.01g $^{10}B/cm^2$ (minimum), which are held in place by stainless steel cladding. The spacing of the basket tubes is maintained by the stainless steel support disks. These disks provide water gap spacings between tubes of 0.875, 0.810, or 0.750 inches, depending on the position of the fuel tube in the basket. When the canister is flooded with water, fast neutrons leaking from the fuel assemblies are thermalized in the water gaps and are absorbed in the BORAL sheets before causing a fission in an adjacent fuel assembly. This criticality control can accommodate up to 36 Yankee Class Zircaloy-clad assemblies with an initial enrichment of 4.0 wt % ^{235}U or 36 Yankee Class stainless steel-clad assemblies with an initial enrichment of 4.94 wt % ^{235}U.

The criticality evaluation of the NAC-MPC is performed with the SCALE 4.3 (ORNL) Criticality Safety Analysis Sequence (CSAS)(Landers). This sequence includes KENO-Va (Petrie) Monte Carlo analysis to determine the effective neutron multiplication factor (k_{eff}). The 27 group ENDF/B-IV neutron library (Jordan) is used in all calculations. CSAS with the 27 group library is benchmarked by comparison to 63 critical experiments relevant to Light Water Reactor (LWR) fuel in storage and transport casks.

Criticality evaluations are performed for both the transfer and storage casks under normal, off-normal and accident conditions. Considerations are given to the most reactive fuel assembly type, worst case mechanical basket configuration and variations in moderator density. The maximum effective neutron multiplication factor with bias and uncertainties for the transfer cask is 0.9021 under either normal, off-normal or accident conditions. The maximum multiplication factor with bias and uncertainties for the storage cask is 0.4503 under normal dry storage conditions and 0.9018 under the hypothetical accident conditions involving full moderator intrusion. These values reflect the following conservative conditions:

These values reflect the following conservative conditions:

1. No fuel burnup (fresh fuel assumption).
2. No fission product build up as a poison.
3. 36 Yankee Class fuel assemblies of the most reactive type.
4. UO_2 fuel density at 95% of theoretical.
5. No dissolved boron in the spent fuel pool water (water temperature 293°K).
6. 75% of the specified minimum ^{10}B loading in the BORAL plates.
7. Infinite cask array.
8. No axial leakage.
9. A most reactive mechanical configuration involving: the fuel tubes and assemblies moved toward the center of the basket, maximum fuel tube opening, minimum disk opening, maximum disk thickness and closely packed disk openings.
10. Moderator intrusion into the fuel rod clad/pellet gap under accident conditions.

Analysis of simultaneous moderator density variation inside and outside either the transfer or storage casks shows a monotonic decrease in reactivity with decreasing moderator density. Thus, the full moderator density condition bounds any off-normal or accident situation. Analysis of moderator intrusion into the storage cask heat transfer annulus with the dry canister shows a slight decrease in reactivity from the completely dry condition.

The NAC-MPC storage system containing 36 Yankee Class fuel assemblies of the most reactive type in the most reactive configuration is well below the 0.95 regulatory criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

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6.2 Package Fuel Loading

The NAC-MPC storage system can safely transfer and store 36 Yankee Class fuel assemblies. As shown in Figures 6.3-2 and 6.3-3, there are 37 fuel tube positions in the support and heat transfer disks that form the canister basket. Loading of fuel in the center tube position is prevented by the design of the top weldment, which blocks this position (Drawing 455-892). The various Yankee Class assemblies to be transferred and stored in the NAC-MPC are presented in Table 6.2-1. Five vendor categories, each with two fuel rod configurations (types), are available within the Yankee Class. These are: Combustion Engineering (CE) 16 x 16 Type A and Type B, two categories of Exxon 16 x 16 Type A and Type B, United Nuclear 16 x 16 Type A and Type B, and Westinghouse 18 x 18 stainless steel clad Type A and Type B. See Figures 6.2-1, 6.2-2 and 6.2-3 for the fuel array configurations. The Combustion Engineering manufactured fuel has the same fuel rod arrays for Types A and B as the Exxon fuel. The Type A and Type B fuel array configurations allow a cruciform control rod to be inserted between assemblies during core operation. The most reactive Yankee Class fuel assembly is the United Nuclear, Type A, 16 x 16 fuel assembly with 4.0 wt % ^{235}U initial enrichment. This fuel assembly type bounds all of the Yankee Class fuel assemblies, including the Westinghouse stainless steel clad fuel with a 4.94 wt % ^{235}U initial enrichment. The United Nuclear Type A fuel assembly with 4.0 wt % ^{235}U initial enrichment is the design basis fuel assembly used in NAC-MPC storage system criticality evaluations. To preclude any potential increase in reactivity due to empty fuel rod positions in the spent fuel assembly, any fuel rods removed from the assembly lattice must be replaced with solid filler rods fabricated from Zircaloy or Type 304 stainless steel.

A canister may contain one or more reconfigured fuel assemblies. The reconfigured fuel assembly is designed to confine the Yankee Class spent fuel rods, or portions thereof, which are classified as failed fuel and to maintain the geometric configuration of those fuel rods. This assembly can accept up to 64 full length spent fuel rods in an eight by eight array of tubes.

The reconfigured fuel assembly consists of a shell (square tube with end fittings), a basket assembly and 64 fuel tubes. Reconfigured fuel assembly parameters are presented in Table 6.2-2. The external dimensions of the shell are the same as those of a standard Yankee Class fuel assembly and all materials are stainless steel. It is designed such that it can be handled in the same manner as a standard Yankee Class fuel assembly. The spent fuel is confined in the

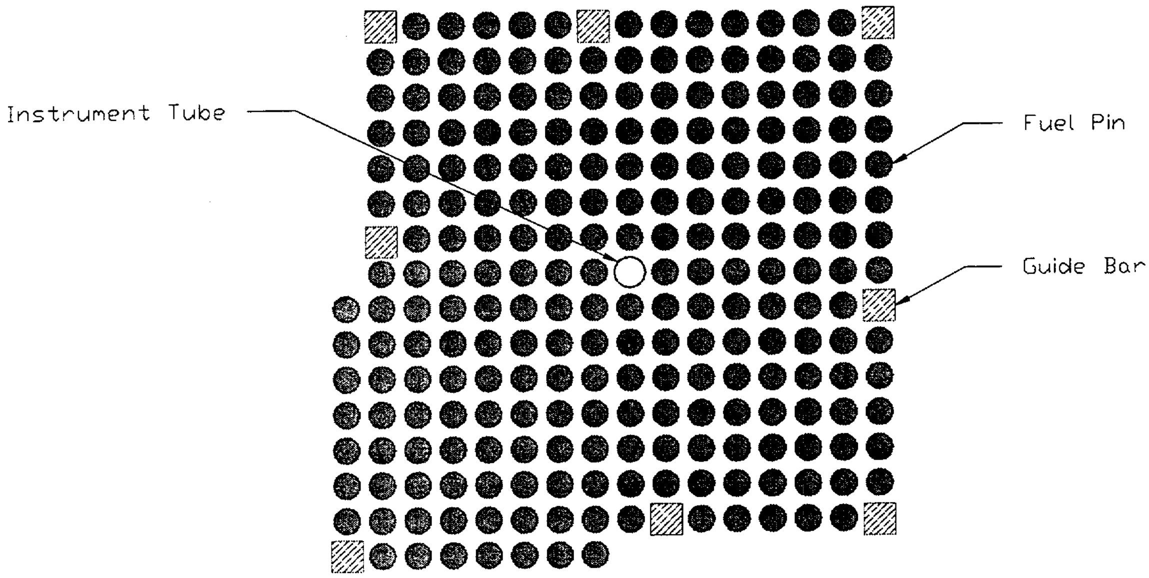
fuel tubes. The tubes are supported by a basket assembly within the shell and have end plugs with drilled holes to permit draining, drying and inerting with helium. The shell has holes in the top and bottom fittings to permit draining, drying and inerting of the assembly.

The total number of full length pins that can be placed in the reconfigured fuel assembly is less than the number that are in the Yankee Class fuel assemblies (maximum of 64 versus 256 rods). Consequently, the reactivity of the reconfigured fuel assembly, even with the most reactive fuel rods, is less than the design basis fuel assembly used in criticality evaluations.

A comparison of the reactivity of the reconfigured fuel assembly to intact assemblies is made in conjunction with the most reactive assembly evaluation in Section 6.4.3.1.

Figure 6.2-1 Yankee Class Type A and Type B Exxon and CE Fuel Assembly Arrays

Type A



Type B

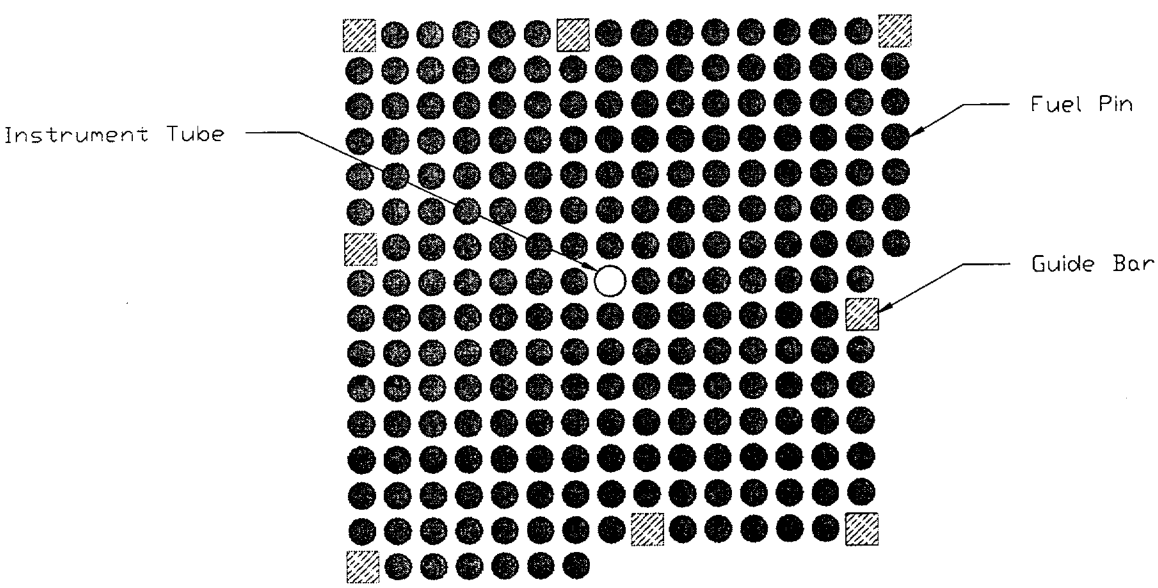
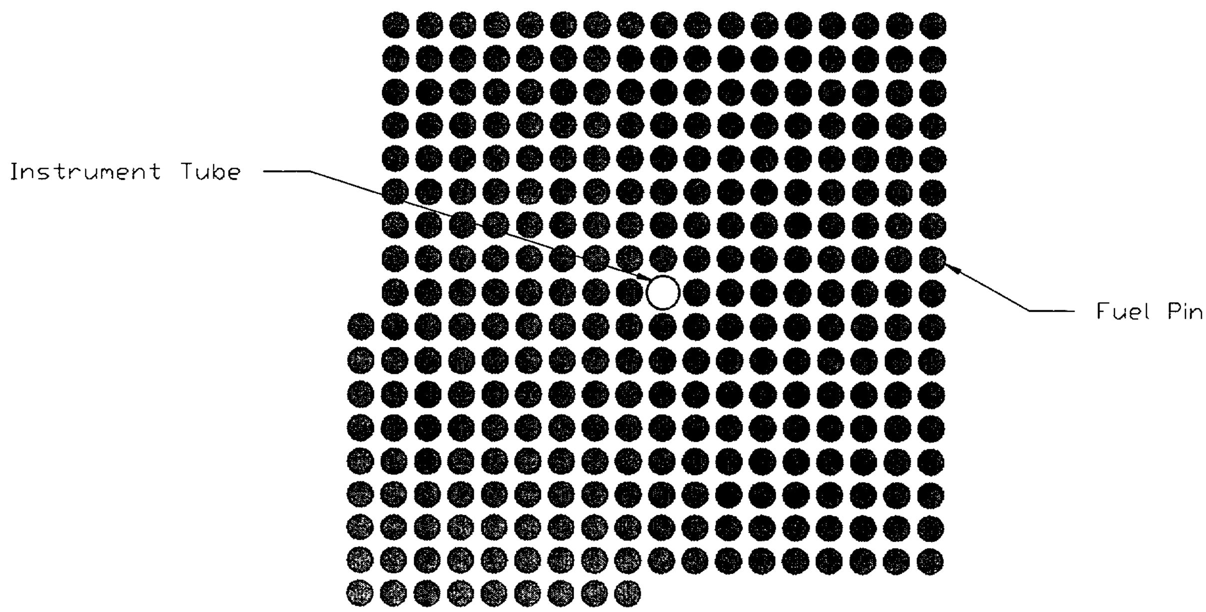


Figure 6.2-2 Yankee Class Type A and Type B Westinghouse Fuel Assembly Arrays

Type A



Type B

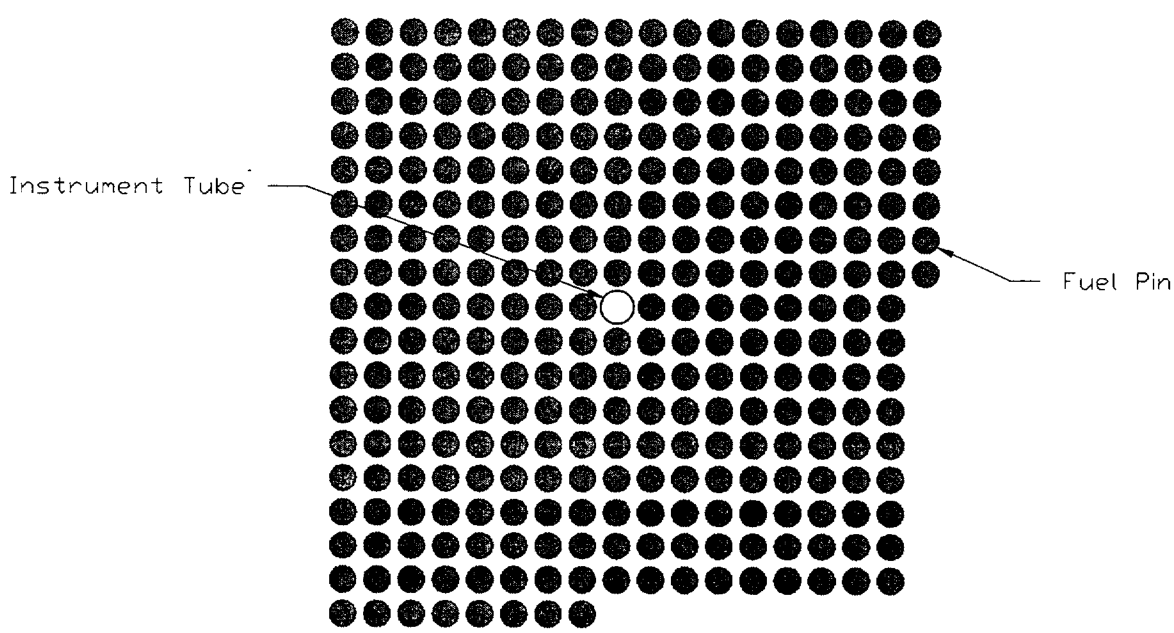
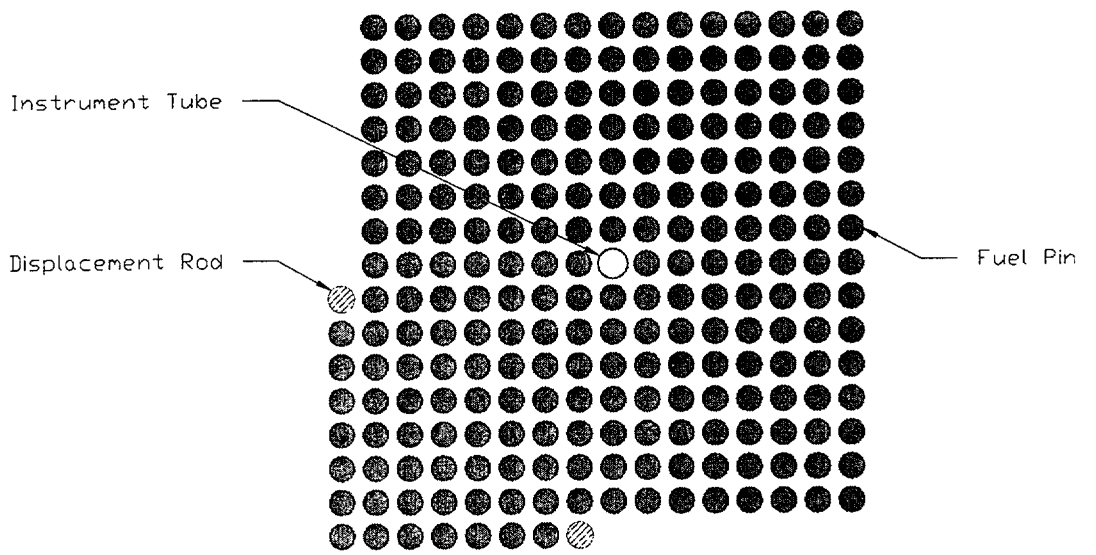


Figure 6.2-3 Yankee Class Type A and Type B United Nuclear Fuel Assembly Arrays

Type A



Type B

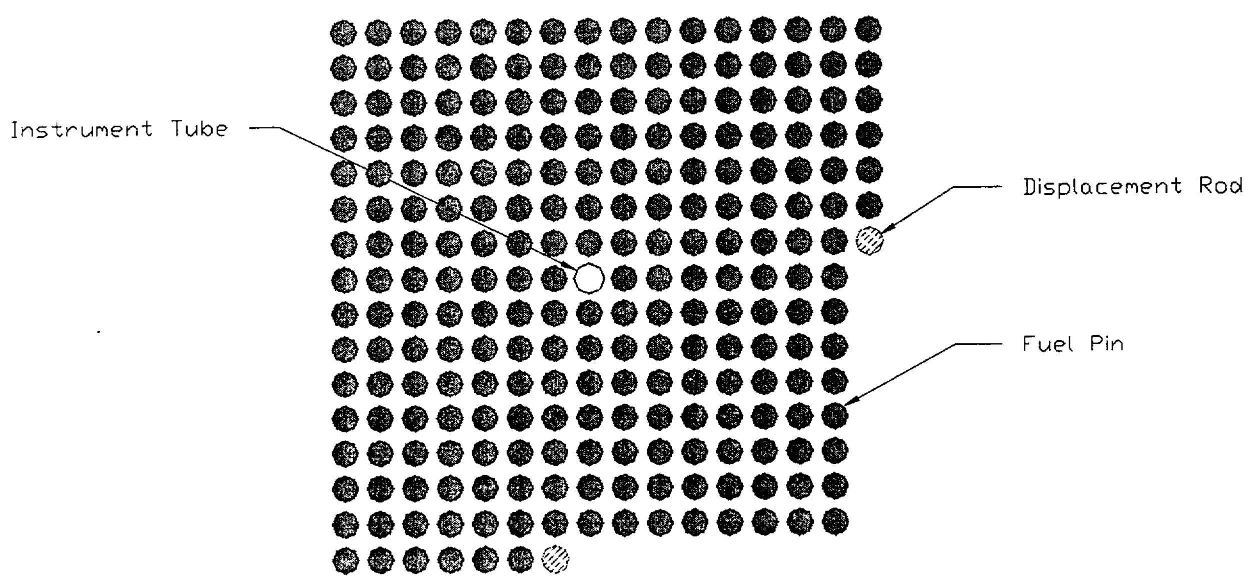


Table 6.2-1 Yankee Class Fuel Assembly Parameters

Parameter	CE Type A	CE Type B	Exxon Type A	Exxon Type B	Exxon Type A	Exxon Type B	West. Type A	West. Type B	United Nuclear Type A	United Nuclear Type B
Assembly Configuration	-	-	-	-	-	-	-	-	-	-
Assembly Array	16 x 16	16 x 16	16 x 16	16 x 16	16 x 16	16 x 16	18 x 18	18 x 18	16 x 16	16 x 16
Max. Enrichment (wt % ^{235}U)	3.90	3.90	4.00	4.00	3.70	3.70	4.94	4.94	4.00	4.00
Max. MTU*	0.2394	0.2384	0.2394	0.2384	0.2394	0.2384	0.2869	0.2860	0.2456	0.2446
Fuel Rod Configuration	-	-	-	-	-	-	-	-	-	-
Fuel Rod Pitch (cm)	1.1989	1.1989	1.1989	1.1989	1.1989	1.1989	1.0719	1.0719	1.1887	1.1887
Active Fuel Length (cm)	231.1400	231.1400	231.1400	231.1400	231.1400	231.1400	233.9975	233.9975	231.1400	231.1400
Rod OD (cm)	0.9271	0.9271	0.9271	0.9271	0.9271	0.9271	0.8636	0.8636	0.9271	0.9271
Clad ID (cm)	0.8052	0.8052	0.8052	0.8052	0.8052	0.8052	0.7569	0.7569	0.8052	0.8052
Pellet OD (cm)	0.7887	0.7887	0.7887	0.7887	0.7887	0.7887	0.7468	0.7468	0.7887	0.7887
Diametral Gap (cm)	0.0165	0.0165	0.0165	0.0165	0.0165	0.0165	0.0102	0.0102	0.0165	0.0165
Rods per Assembly	231	230	231	230	231	230	305	304	237	236
Fuel Material	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2	UO_2
Clad Material	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	SS 348	SS 348	Zircaloy	Zircaloy
Displacement Rod Configuration	-	-	-	-	-	-	-	-	-	-
Displacement Rod Material	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Zircaloy - 4	Zircaloy - 4
Displacement Rod Diameter (cm)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.9271	0.9271
Number Per Assembly	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2	2
Guide Bar Configuration	-	-	-	-	-	-	-	-	-	-
Guide Bar Material	Zircaloy - 4	Zircaloy - 4	SS 304L	SS 304L	Zircaloy	Zircaloy	N/A	N/A	N/A	N/A
Guide Bar Width (cm)	1.0973	1.0973	1.0566	1.0566	1.0566	1.0566	N/A	N/A	N/A	N/A
Guide Bar Shape (cm)	Square	Square	Square	Square	Square	Square	N/A	N/A	N/A	N/A
Number Per Assembly	8	8	8	8	8	8	N/A	N/A	N/A	N/A
Instrument Tube Configuration	-	-	-	-	-	-	-	-	-	-
Instrument Tube ID (cm)	0.9970	0.9970	0.9970	0.9970	0.9970	0.9970	0.9995	0.9995	0.9995	0.9995
Instrument Tube OD (cm)	1.1481	1.1481	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884	1.0884
Number Per Assembly	1	1	1	1	1	1	1	1	1	1
Instrument Tube Material	Zircaloy - 4	Zircaloy - 4	SS 304	SS 304	Zircaloy	Zircaloy	SS 304	SS 304	SS 304	SS 304

*Maximum MTU based on 95% of UO_2 theoretical density for the fuel pellet stack density.

Table 6.2-2 Yankee Class Reconfigured Fuel Assembly Parameters

Parameter	CE Type A/B	Exxon Type A/B	Exxon Type A/B	West. Type A/B	United Nuclear Type A/B
ASSEMBLY CONFIGURATION					
Assembly Array	8x8	8x8	8x8	8x8	8x8
Max. Enrichment (wt % ^{235}U)	3.90	4.00	3.70	4.94	4.00
Max. kgU*	66.33	66.33	66.33	60.21	66.33
FUEL ROD CONFIGURATION (EACH ROD PLACED WITHIN ENCAPSULATING ROD)					
Rod Pitch (cm)	1.905	1.905	1.905	1.905	1.905
Active Fuel Length (cm)	231.1400	231.1400	231.1400	233.9975	231.1400
Rod OD (cm)	0.9271	0.9271	0.9271	0.8636	0.9271
Clad ID (cm)	0.8052	0.8052	0.8052	0.7569	0.8052
Pellet OD (cm)	0.7887	0.7887	0.7887	0.7468	0.7887
Diametrical Gap (cm)	0.0165	0.0165	0.0165	0.0102	0.0165
Max Rods per Assembly	64	64	64	64	64
Fuel Material	UO_2	UO_2	UO_2	UO_2	UO_2
Clad Material	Zircaloy	Zircaloy	Zircaloy	SS 348	Zircaloy
ENCAPSULATING ROD					
Rod OD (cm)	1.27	1.27	1.27	1.27	1.27
Rod ID (cm)	1.1278	1.1278	1.1278	1.1278	1.1278
Rod Material	SS 304	SS 304	SS 304	SS 304	SS 304

* Maximum kgU based on 95% of UO_2 theoretical density for the fuel pellet stack density.

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6.3 Criticality Model Specification

This section describes the KENO-Va models used in the criticality evaluation of the NAC-MPC. The geometric representation of the design basis fuel assembly, the NAC-MPC basket and the associated transfer and storage cask shield regions are described. The material densities and nuclide concentrations are also specified.

6.3.1 Description of Calculational Models

Three models are used in the NAC-MPC storage system criticality evaluations: a fuel/basket model, a transfer cask model and a storage cask model. The fuel/basket model is a single NAC-MPC basket cell containing a fuel assembly. This model is used to determine the most reactive fuel assembly type and to evaluate mechanical perturbations of the fuel and basket. The transfer cask model is an explicit representation of the NAC-MPC basket and canister containing 36 design basis fuel assemblies surrounded by the transfer cask radial shields. This model is used to evaluate the transfer cask reactivity during loading, draining and drying operations. The storage cask model is an explicit representation of the NAC-MPC basket and canister containing up to 36 design basis fuel assemblies, surrounded by the storage cask radial shields. This model is used to evaluate the storage cask during normal, off-normal and accident storage situations.

The fuel/basket model comprises a single basket cell with periodic axial and reflective radial boundary conditions. This simulates an infinite array of fuel/basket cells. The model geometry is divided into four vertical layers: an aluminum heat transfer layer; a flux trap water layer; a steel support disk layer; and a top flux trap water layer. In each of these layers, the fuel assembly array, fuel tube, BORAL sheets, flux trap water gap, steel, or aluminum disk web are modeled. Figure 6.3-1 shows a sketch of the NAC-MPC fuel/basket model.

Both of the storage and transfer cask criticality models are derived from a radial slice of the basket at the central (heat transfer) region. This section is the most reactive region, due to the number of steel support disks and aluminum heat transfer disks displacing water in the flux trap gap. Each model is a stack of four slices containing one aluminum disk, two identical water regions and one steel support disk region (stacked aluminum, water, steel, water). The basket is modeled in each slice and contains a design basis fuel assembly in each of 36 basket tubes with

BORAL sheets. Both cask models explicitly arrange the fuel assemblies and basket tubes in the most reactive configuration consistent with the mechanical tolerances specified by the design drawings. In all models, the fuel assemblies, basket tubes, BORAL sheets and water gaps are explicitly represented. There are no homogenizations. Each cask slice includes the cask radial shield regions surrounded by an outer CUBOID. The four slices are stacked into the KENO-Va GLOBAL UNIT.

Periodic boundary conditions are imposed on the top and bottom of the GLOBAL UNIT to simulate infinite axial extent. Reflecting boundary conditions are imposed on the sides of the GLOBAL UNIT simulating an infinite number of casks in the X-Y plane. Moderator density is varied both in the cask cavity regions normally filled with water and in the exterior CUBOID. Figures 6.3-2 and 6.3-3 show the transfer cask and storage cask criticality models, respectively.

6.3.2 Package Regional Densities

The SCALE 4.3 standard composition library (Petrie) default densities and isotopic distributions are used unless otherwise indicated. The densities used in the KENO-Va criticality analyses are:

Material	Density (g/cc)
UO_2 at 95% TD	0.412
Zircaloy	6.56
Type 348 Stainless Steel	7.92 (non-standard, Westinghouse fuel clad)
H_2O	0.9982
Type 304 Stainless Steel	7.92
Lead	11.344
Aluminum	2.702
BORAL (core)	2.623 (non-standard)
NS-4-FR	1.629 (non-standard)
Concrete	2.243 (based on 140 lb/ft^3 design spec. minimum)
Carbon Steel	7.821

6.3.2.1 Fuel Region

Fuel rod densities are:

Material	Element	Density (atoms/barn-cm)
UO_2 (at 3.9 wt %)	^{235}U	9.271×10^{-4}
	^{238}U	2.231×10^{-2}
	O	4.646×10^{-2}
UO_2 (at 4.0 wt %)	^{235}U	9.406×10^{-4}
	^{238}U	2.229×10^{-2}
	O	4.646×10^{-2}
UO_2 (at 4.9 wt %)	^{235}U	1.162×10^{-4}
	^{238}U	2.207×10^{-2}
	O	4.646×10^{-2}
Zircaloy	Zr	4.331×10^{-2}
Stainless Steel 348	Fe	5.529×10^{-2}
	Cr	1.743×10^{-2}
	Ni	1.057×10^{-2}
	C	3.180×10^{-4}
	Mn	1.736×10^{-3}
	Si	1.698×10^{-3}
	P	6.159×10^{-5}
	S	4.463×10^{-5}

6.3.2.2 Cask Material

Cask material densities are:

Material	Element	Density (atoms/barn-cm)
Boral Core	^{10}B	7.098×10^{-3}
	^{11}B	3.925×10^{-2}
	C	1.220×10^{-2}
	Al	3.358×10^{-2}
Aluminum	Al	6.03×10^{-2}
Stainless Steel 304	Cr	1.743×10^{-2}
	Fe	5.936×10^{-2}
	Ni	7.721×10^{-3}
	Mn	1.736×10^{-3}
Lead	Pb	3.297×10^{-2}
NS-4-FR	H	5.841×10^{-2}
	O	2.607×10^{-2}
	C	2.265×10^{-2}
	N	1.401×10^{-3}
	Al	7.781×10^{-3}
	^{11}B	3.565×10^{-4}
	^{10}B	9.798×10^{-5}
Concrete	O	4.494×10^{-2}
	Si	1.621×10^{-2}
	H	1.340×10^{-2}
	Na	1.704×10^{-3}
	Ca	1.483×10^{-3}
	Fe	3.386×10^{-4}
	Al	1.702×10^{-3}
Carbon Steel	Fe	8.350×10^{-2}
	C	3.925×10^{-3}

6.3.2.3 Water Reflector Densities

The material densities for the water inside and outside the storage cask under normal conditions are:

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

Water density is varied using the volume fraction (VF) parameter on the SCALE 4.3 material information processor card. This acts as a simple multiplier on the above densities.

Figure 6.3-1 NAC-MPC KENO-Va Fuel/Basket Model

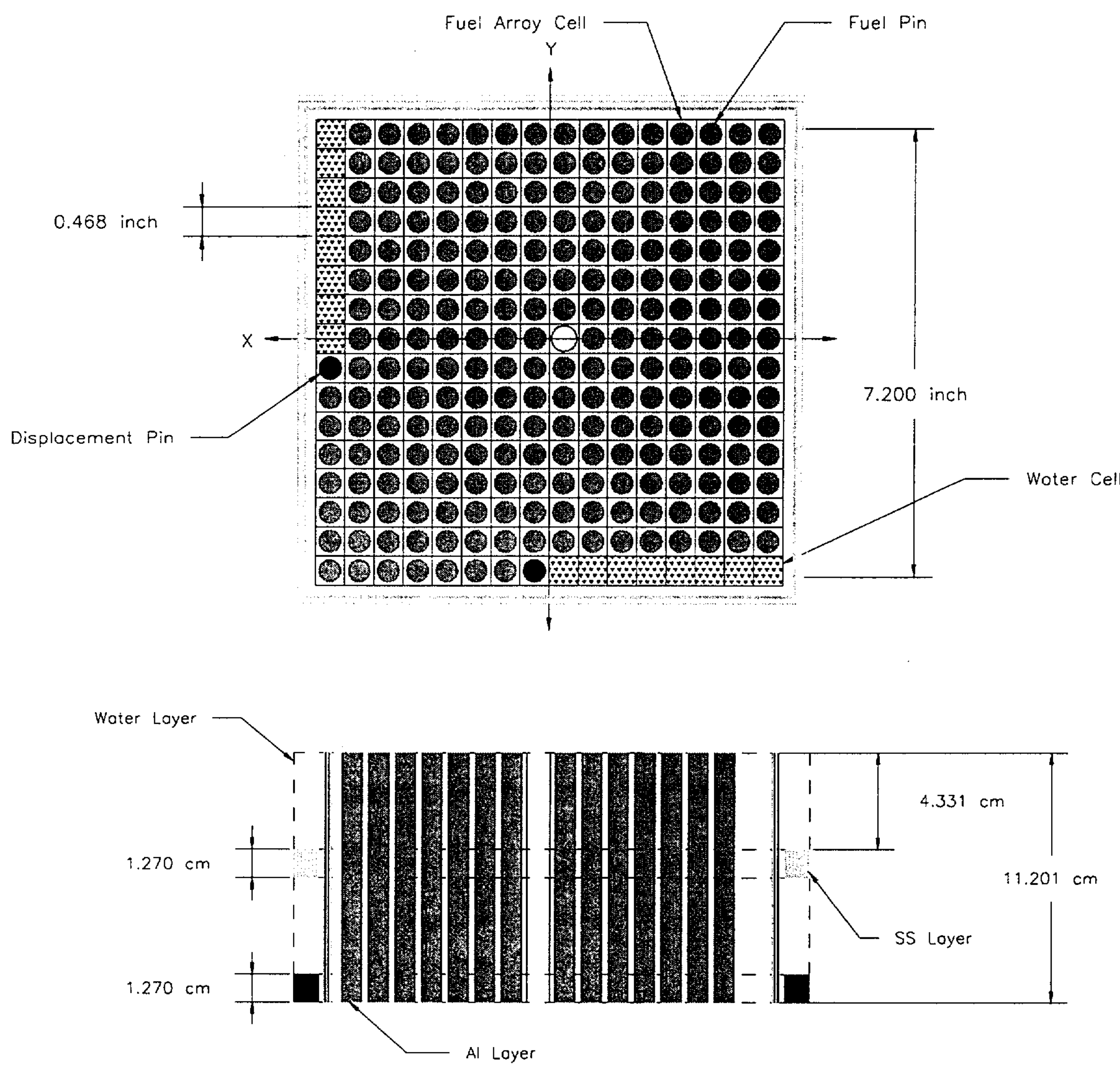
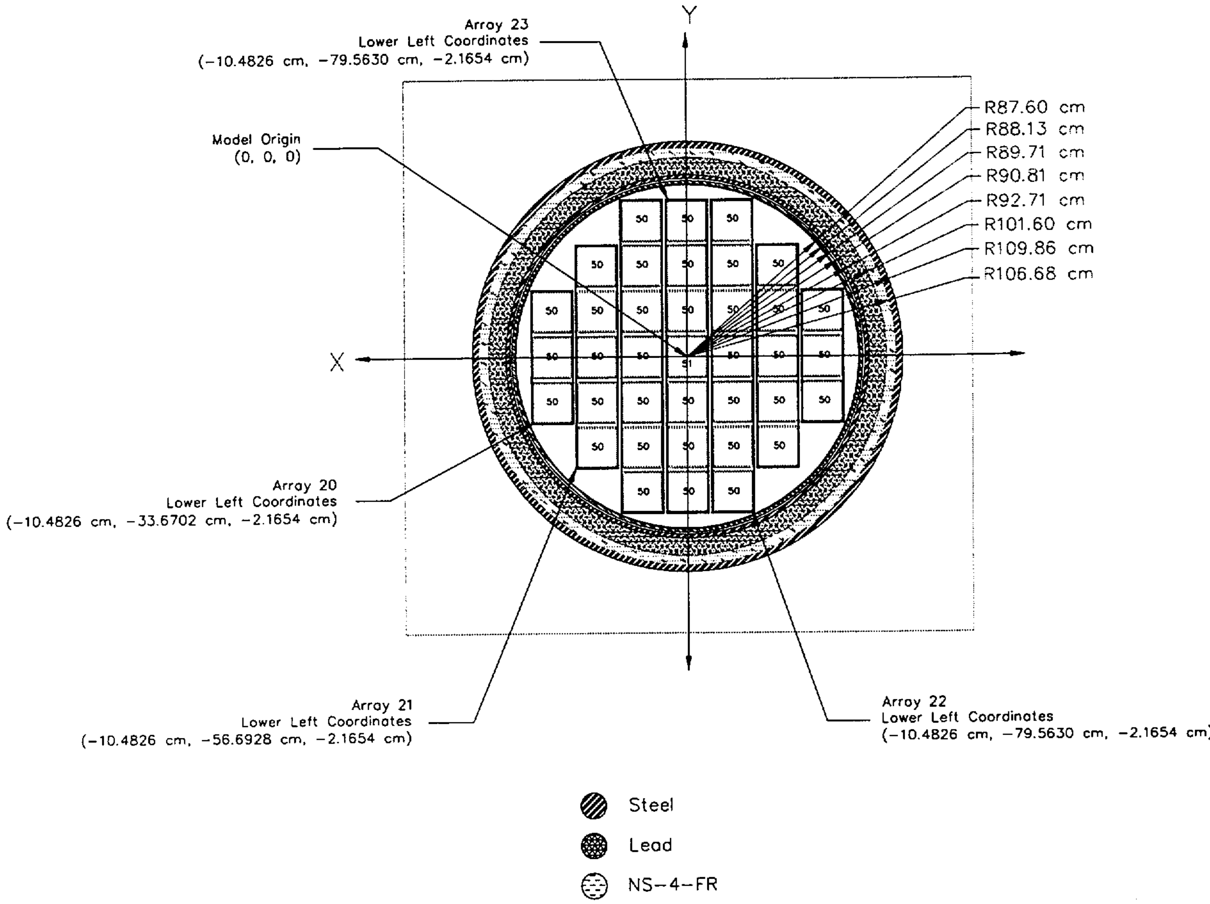
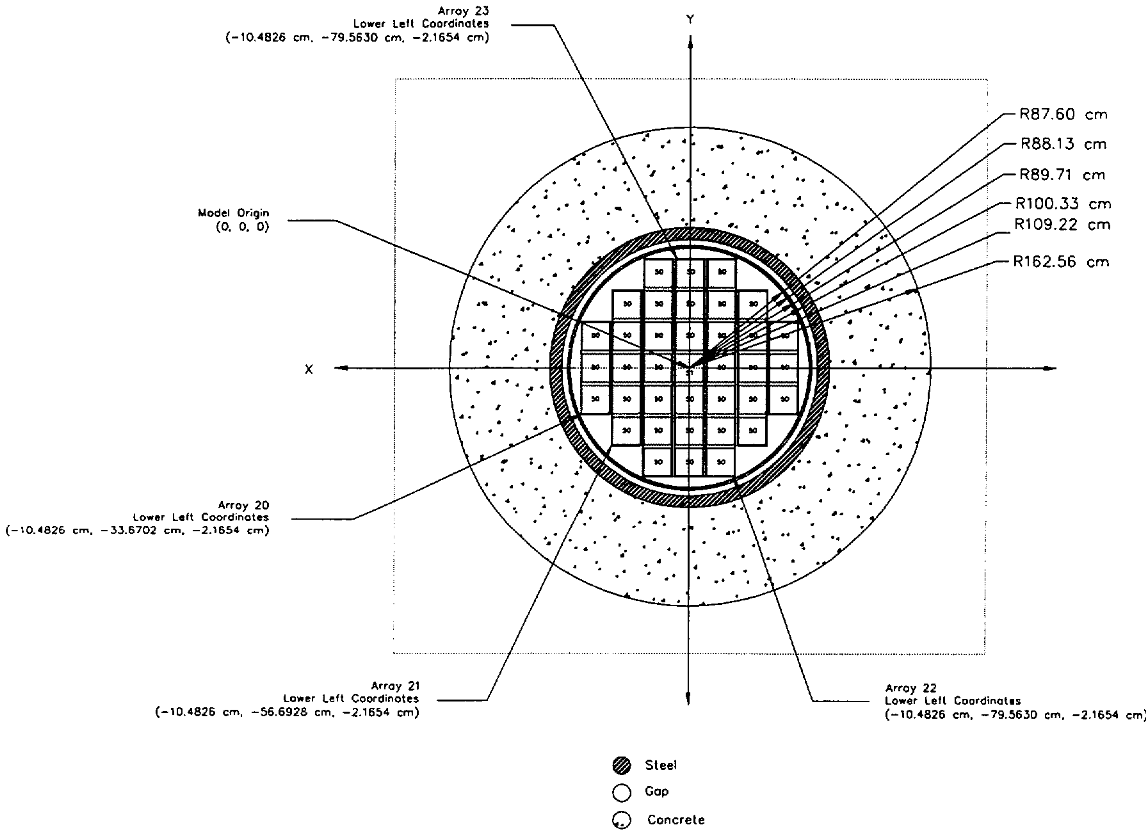


Figure 6.3-2 NAC-MPC KENO-Va Transfer Cask Model



Note: This model represents a slice between a support disk and a heat transfer disk. The center fuel tube position is filled with unit 51. This unit cell describes the vacant fuel tube. As previously stated, the criticality analysis considers 36 Yankee Class fuel assemblies, assuming the center tube is empty.

Figure 6.3-3 NAC-MPC KENO-Va Storage Cask Model



Note: This model represents a slice between a support disk and a heat transfer disk. The center fuel tube position is filled with unit 51. This unit cell describes the vacant fuel tube. As previously stated, the criticality analysis considers 36 Yankee Class fuel assemblies, assuming the center tube is empty.

6.4 Criticality Calculation

This section demonstrates that the criticality analysis of the NAC-MPC is sufficient to satisfy the requirements of 10 CFR 72.124(a), 10 CFR 72.236(c) and Chapter 6 of NUREG 1536. The calculational method is described. Criticality calculations are performed to determine: the most reactive Yankee Class fuel assembly type; the most reactive mechanical configuration in the NAC-MPC basket; and the most reactive moderator density under normal, off-normal and accident conditions.

6.4.1 Calculational Method

The criticality evaluation of the NAC-MPC is performed with the SCALE 4.3 (ORNL) Criticality Safety Analysis Sequence (CSAS) (Landers) for the PC. CSAS includes: the SCALE Material Information Processor (Bucholz), BONAMI (Greene), NITAWL-II (Westfall), and KENO-Va (Petrie). The Material Information Processor generates number densities for standard compositions, prepares geometry data for resonance self-shielding, and creates data input files for the cross section processing codes. The BONAMI and NITAWL-II codes are used to prepare a resonance-corrected cross section library in AMPX working format. The KENO-Va code calculates the model k_{eff} using Monte Carlo techniques. The 27 group ENDF/B-IV neutron cross section library (Jordan) is used in this calculation. The NAC-MPC KENO-Va models are described in further detail below.

6.4.2 Fuel Loading Optimization

The fuel loading is optimized in the NAC-MPC cask criticality models by using: 1) fresh fuel, 2) the most reactive Yankee Class fuel assembly type, 3) the highest possible fuel stack density (95 % of theoretical) and 4) the most reactive basket configuration. The cask models represent fully loaded baskets with 36 design basis fuel assemblies. The models use reflecting boundary conditions on the sides and periodic boundary conditions on the top and bottom. These boundary conditions simulate an infinite array of casks of infinite axial extent.

6.4.3 Criticality Results

This section establishes the most reactive Yankee Class fuel and the most reactive configuration of the fuel within the canister basket. These results are used to calculate the effective neutron multiplication factor for the transfer cask and storage cask assuming full moderation.

6.4.3.1 Most Reactive Assembly

Using the fuel/basket model of the NAC-MPC basket, each of the Yankee Class fuel assembly vendor categories shown in Table 6.2-1 is evaluated. Each particular fuel rod array is explicitly modeled. This includes the Westinghouse 18 x 18 Types A and B at 4.94 wt % ^{235}U, United Nuclear 16 x 16 Types A and B at 4.0 wt % ^{235}U, Exxon 16 x 16 Types A and B with steel guide bars and instrument tube at 4.0 wt % ^{235}U, and CE Type A and B at 3.90 wt % ^{235}U, as well as the reconfigured fuel assembly with the most reactive fuel rods. Note, the Exxon 16 x 16 Types A and B with Zircaloy guide bars and instrument tube is identical to the CE configuration. In order to standardize the comparison, each assembly is evaluated with the fuel UO_2 at 95% theoretical density.

Table 6.4-1 shows the multiplication factor for each Yankee Class fuel type in the NAC-MPC basket. This table shows that either the United Nuclear Type A or Type B has the highest multiplication factor of the Yankee Class fuel assembly vendor categories. Table 6.4-1 also shows that it is difficult to resolve the difference between Type A and Type B fuel assemblies. There is only one fuel rod difference in loading. However, since the United Nuclear Type A has the highest UO_2 mass, this fuel rod array is chosen as the most reactive design basis fuel assembly for the NAC-MPC. This design basis fuel assembly is used in all subsequent transfer and storage cask evaluations.

6.4.3.2 Most Reactive Mechanical Configuration

Using the fuel/basket model with the design basis fuel assembly, an evaluation of the effect of different NAC-MPC basket perturbations is made. This criticality analysis determines the most reactive basket mechanical configuration by altering the nominal fuel/basket model with the design basis assembly and comparing the perturbed k_{eff} to the nominal result. If Δk_{eff} ($k_{perturbed}$ - $k_{nominal}$) is positive, the tolerance causes an increase in reactivity. Conversely, if Δk_{eff} is negative, the tolerance causes a decrease in reactivity. Two sets of perturbations are assessed in this

evaluation of the criticality control: fabrication tolerances and component movement within the basket.

Four major fabrication tolerances are evaluated: the fuel tube opening, the disk opening, the disk thickness and the disk opening placement. Modifications to the nominal fuel/basket model dimensions are made based on the basket and fuel tube tolerances given on the NAC-MPC drawings provided in Chapter 1.0. The tolerance analysis results are shown in Table 6.4-2. Table 6.4-2 shows that the most reactive set of basket tolerances are maximum fuel tube opening, minimum disk opening, maximum disk thickness and minimum (close packed) disk opening placement.

Increasing the fuel tube opening brings more moderator into the gap between the assembly and the tube lowering the efficiency of the BORAL sheets, hence increasing the reactivity of the system. Minimizing the disk opening and maximizing the disk thickness removes water from the flux trap, consequently increasing k_{eff}. Finally, decreasing the web thickness, decreases the flux trap size and also moves assemblies closer together producing an increase in k_{eff}. With respect to fabrication tolerances, this is the most reactive configuration.

Two major component movements within the basket are evaluated: the assembly within the tube and the tube within the basket. Unique to this package is the Yankee Class diagonally symmetric fuel assembly. Consequently, movement toward the three corners must be evaluated as opposed to one corner for a fully symmetric assembly. This assembly produces five movement perturbations: fuel tube movement to the upper right corner, the upper left corner, the lower left corner and side to side. Table 6.4-3 shows the assembly movement analysis results. These results show that the most reactive assembly position is centered within the basket tube. This centering provides the most optimum moderating water gap within the tube.

Similar to the fuel assembly movement analysis, five possible fuel tube movements are evaluated: the upper right corner, the upper left corner, the lower left corner and side to side. Mirror and periodic boundary conditions on the sides of the model are evaluated. Table 6.4-4 shows the tube movement evaluations. These results indicate that the most reactive fuel tube location is shifted to the right side of the tube with mirrored boundary conditions. This result is reasonable given the orientation of the assembly. Shifting the tube to the right side with mirrored boundary conditions moves a complete fuel pin row of two assemblies closer together, hence pushing the largest amount of fuel together and minimizing the flux trap gap between tubes. In

general, these results show that moving the tubes towards each other with the fuel assembly centered in the tube is the most reactive component configuration.

Thus, the following most reactive mechanical configuration is imposed on the NAC-MPC basket model: assemblies centered in the tubes, fuel tubes moved toward the center of the basket, maximum fuel tube opening, minimum disk opening, maximum disk thickness and close packed disk opening locations. The reactivity penalty associated with this configuration versus the nominal configuration is discussed in the transfer cask and storage cask criticality evaluations below.

The fuel/basket model clusters the fuel in groups of four (mirrored boundary), or shifts the fuel to one side of the tube (periodic boundary) and, therefore, does not represent the closest fuel material approach feasible in a model with fuel moved radially inward. To document the maximum reactivity configuration, both tube and assembly movement analyses are repeated in the full cask model. The k_{eff} of these analyses are compared to the nominal cask model. Based on the storage cask and transfer cask reactivity evaluation, the shield configuration of the transport cask does not impact k_{eff} significantly. Therefore, the results of the transport cask analysis, shown below, are applicable to the storage and transfer cask results.

Position	k_{eff}	σ	Δk_{eff}
Nominal	0.8637	0.0007	---
Tubes Moved Toward the Basket Center	0.8689	0.0008	0.0052
Tubes Moved Toward the Basket Shell	0.8596	0.0008	-0.0041
Assemblies Moved Toward the Basket Center	0.8677	0.0007	0.0040
Assemblies Moved Toward the Basket Shell	0.8590	0.0008	-0.0047

Based on the cask analysis, the assembly moved towards the cask center configuration adds a Δk_{eff} of 0.004 to the reactivity of the nominal configuration. The model, documented as worst case mechanical configuration in the fuel/basket evaluation, and employed in optimum moderator studies, is not adjusted from its assembly centered configuration. The Δk_{eff} associated with the assembly movement is accounted for by adding the Δk_{eff} of 0.004 to the KENO-Va neutron multiplication factor (k_{eff}) during k_s calculations.

To verify that the criticality axial models represent the most reactive configuration, the transfer cask accident condition, with full density water, is evaluated assuming that the aluminum heat transfer disk is replaced with water. The results show a decrease in reactivity (Δk_{eff} = - 0.014) for

the water replacement condition. Consequently, the axial model incorporating the aluminum heat transfer disk is conservative.

6.4.3.3 Transfer Cask Criticality Evaluation

Under normal conditions, such as loading in a spent fuel pool, moderator (water) is present in the canister while it is in the transfer cask. Also, during draining and drying operations, moderator is present and its density will vary. Thus, the criticality evaluation of the transfer cask includes an evaluation of the reactivity effects of moderator density variation inside the cask. Off-normal and accident conditions are bounded by assuming the most reactive mechanical basket configuration as well as moderator intrusion into the fuel cladding (100% fuel failure).

Using the transfer cask criticality model, an evaluation of the assumption of 75% of ^{10}B in BORAL, the cumulative effect of worst case mechanical perturbations and the effect of moderator density variation is made. Table 6.4-5 shows transfer cask multiplication factors at various conditions. Table 6.4-5 shows that the assumption of 75% of the BORAL ^{10}B loading results in a 1.5% reactivity penalty and the cumulative effect of the worst case mechanical configuration results in an additional 1% reactivity penalty from the nominal configuration. Table 6.4-5 also shows that reactivity decreases monotonically with decreasing moderator density, and the optimum moderator density is at 1 g/cc. Under normal conditions involving loading, draining and drying, the maximum k_{eff} including bias and uncertainties is 0.8929. The CSAS output file (including an input listing) is shown in Figure 6.7-1. In the off-normal or accident situation involving fuel failure and moderator intrusion, the maximum k_{eff}, including biases and uncertainties, is 0.9021. The CSAS output file (including an output listing) is shown in Figure 6.7-2. Thus, the NAC-MPC transfer cask containing 36 Yankee Class fuel assemblies of the most reactive type in the most reactive configuration is well below the 0.95 NRC criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

6.4.3.4 Storage Cask Criticality Evaluation

Under normal conditions, moderator is not present in the storage cask. However, access to the environment is possible via air inlets and the convective heat transfer annulus between the canister and the storage cask steel liner. This access provides paths for moderator intrusion during a flood. Off-normal conditions evaluate moderator intrusion into the convective heat

transfer annulus. Under accident conditions, it is assumed that the canister confinement fails and moderator intrudes into the canister and fuel cladding (100% failure) is evaluated along with moderator density variation. The accident condition analyses also examine the effect of interior/exterior moderator density variations.

Using the storage cask criticality model, an evaluation is performed of moderator intrusion into the heat transfer annulus under off-normal conditions and into the canister under accident conditions. Table 6.4-6 shows the storage cask multiplication factors at various conditions. Under normal dry conditions, maximum k_{eff}, including biases and uncertainty, is 0.4503, which is well subcritical. The CSAS output file (including an input listing) is shown in Figure 6.7-3. Under off-normal conditions involving flooding of the heat transfer annulus, the k_{eff} of the cask is even less. Under accident conditions involving full moderator intrusion into the canister and fuel clad gap, the maximum k_{eff} of the cask is 0.9018. The CSAS output file (including an input listing) is shown in Figure 6.7-4. Similar to the transfer cask analysis, the storage cask accident condition moderator density study evaluates a monotonic decrease in reactivity with moderator density inside and outside the cask. Thus, the NAC-MPC storage cask containing 36 fuel assemblies of the most reactive Yankee Class type in the most reactive configuration is well below the 0.95 NRC criticality safety limit, including all biases and uncertainties under normal, off-normal and accident conditions.

Based on the results of the criticality analysis for the transfer cask and the storage cask presented in Tables 6.4-5 and 6.4-6, respectively, there is no significant impact on system reactivity when changing reflector dimensions and material composition.

Table 6.4-1 Assembly Type Reactivity Evaluations

Assembly	Initial Enrichment (wt % ^{235}U)	In Basket k_{eff}	σ
Westinghouse Type A	4.94	0.8642	0.00105
Westinghouse Type B	4.94	0.8664	0.00102
United Nuclear Type A	4.00	0.8974	0.00087
United Nuclear Type B	4.00	0.8974	0.00106
Exxon Type A	4.00	0.8870	0.00111
Exxon Type B	4.00	0.8877	0.00111
Combustion Engineering Type A	3.90	0.8943	0.00060
Combustion Engineering Type B	3.90	0.8939	0.00163
Reconfigured Fuel Assembly	4.00	0.6280	0.0007

Table 6.4-2 Basket Tolerance Reactivity Evaluations

Analysis	k_{eff}	σ	Δk_{eff}
Nominal	0.8981	0.0007	-
Fuel Tube Maximum Opening	0.9018	0.0007	0.0037
Fuel Tube Minimum Opening	0.8916	0.0007	-0.0065
Disk Maximum Opening	0.8972	0.0007	-0.0009
Disk Minimum Opening	0.8991	0.0008	0.0010
Disk Maximum Thickness	0.8987	0.0008	0.0006
Disk Minimum Thickness	0.8972	0.0008	-0.0009
Loose Packed Disk Opening	0.8974	0.0008	-0.0007
Close Packed Disk Opening	0.8993	0.0007	0.0012

Table 6.4-3 Fuel Movement Reactivity Evaluations

Assembly Movement	Boundary Conditions	k_{eff}	σ	Δk_{eff}
Nominal	Reflective	0.8981	0.0007	-
Upper Right Corner	Mirrored	0.8954	0.0007	-0.0027
Upper Right Corner	Periodic	0.8943	0.0007	-0.0038
Lower Left Corner	Mirrored	0.8977	0.0007	-0.0004
Lower Left Corner	Periodic	0.8978	0.0008	-0.0003
Upper Left Corner	Mirrored	0.8963	0.0007	-0.0018
Upper Left Corner	Periodic	0.8961	0.0008	-0.0020
Right Side	Mirrored	0.8949	0.0007	-0.0032
Right Side	Periodic	0.8951	0.0007	-0.0030
Left Side	Mirrored	0.8978	0.0007	-0.0003
Left Side	Periodic	0.8972	0.0007	-0.0009

Table 6.4-4 Tube Movement Reactivity Evaluations

Tube Movement	Boundary Conditions	k_{eff}	σ	Δk_{eff}
Nominal	Reflective	0.8981	0.0007	-
Upper Right Corner	Mirrored	0.8999	0.0007	0.0018
Upper Right Corner	Periodic	0.8979	0.0007	-0.0002
Lower Left Corner	Mirrored	0.8984	0.0008	0.0003
Lower Left Corner	Periodic	0.8962	0.0007	-0.0019
Upper Left Corner	Mirrored	0.8991	0.0008	0.0010
Upper Left Corner	Periodic	0.8959	0.0007	-0.0022
Right Side	Mirrored	0.9005	0.0008	0.0024
Right Side	Periodic	0.8966	0.0007	-0.0015
Left Side	Mirrored	0.8968	0.0007	-0.0013
Left Side	Periodic	0.8976	0.0007	-0.0005

Table 6.4-5 Criticality Results for Transfer Cask

Cask Pitch (cm)	Basket Configuration	H_2O Inside (density g/cc)	H_2O Outside (density g/cc)	^{10}B in BORAL	k_{eff}	σ	k_s [1]
319.71	Nominal	1.0	1.0	100%	0.85035	0.00076	0.8684
319.71	Nominal	1.0	1.0	75%	0.86504	0.00070	0.8831
319.71	Worst Case	1.0	1.0	75%	0.87422	0.00076	0.8923
319.71	Worst Case	1.0	0.0001	75%	0.87488	0.00076	0.8929
319.71	Worst Case	0.8	0.0001	75%	0.82355	0.00074	0.8416
319.71	Worst Case	0.6	0.0001	75%	0.76550	0.00069	0.7835
319.71	Worst Case	0.4	0.0001	75%	0.69378	0.00064	0.7118
319.71	Worst Case	0.2	0.0001	75%	0.60267	0.00051	0.6206
319.71	Worst Case	0.1	0.0001	75%	0.55065	0.00042	0.5686
319.71	Worst Case	0.05	0.0001	75%	0.51859	0.00034	0.5365
319.71	Worst Case	0.01	0.0001	75%	0.46634	0.00032	0.4843
319.71	Worst Case + Water in Gap	1.0	1.0	75%	0.88403	0.00074	0.9021

1: Includes a Δk of 0.004 due to radial movement of fuel assembly toward basket center.

Table 6.4-6 Criticality Results for Storage Cask

Cask Pitch (cm)	Basket Configuration	H_2O Inside (density g/cc)	H_2O[1] Outside (density g/cc)	^{10}B	k	σ	k_s [2]
457.2	Nominal	0.0001	0.0001	75%	0.43088	0.00029	0.4488
457.2	Worst Case	0.0001	1.0	75%	0.39800	0.00030	0.4159
457.2	"	0.0001	0.8	75%	0.39906	0.00031	0.4170
457.2	"	0.0001	0.6	75%	0.39869	0.00032	0.4166
457.2	"	0.0001	0.4	75%	0.40071	0.00031	0.4186
457.2	"	0.0001	0.2	75%	0.40963	0.00031	0.4276
457.2	"	0.0001	0.1	75%	0.42134	0.00031	0.4393
457.2	"	0.0001	0.05	75%	0.42924	0.00031	0.4472
457.2	"	0.0001	0.01	75%	0.43241	0.00030	0.4503
457.2	Worst Case + water in gap	1.0	1.0	75%	0.88376	0.00072	0.9018
457.2	"	0.8	0.8	75%	0.83228	0.00072	0.8503
457.2	"	0.6	0.6	75%	0.77378	0.00068	0.7918
457.2	"	0.4	0.4	75%	0.69781	0.00062	0.7158
457.2	"	0.2	0.2	75%	0.59996	0.00053	0.6179
457.2	"	0.1	0.1	75%	0.54264	0.00042	0.5606
457.2	"	0.05	0.05	75%	0.51048	0.00036	0.5284
457.2	"	0.01	0.01	75%	0.46246	0.00031	0.4804

1. Includes heat transfer annulus region.
2. Includes a Δk of 0.004 due to radial movement of fuel assembly toward basket center.

6.5 Critical Benchmark Experiments

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

ANSI/ANS-8.17 prescribes the criteria to establish sub-criticality safety margins. This criteria is as follows:

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

where:

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

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

Δk_s = an allowance for:

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

Δk_c = a margin for uncertainty in k_c, which includes allowance for:

(a) uncertainties in the critical experiments,
(b) statistical or convergence uncertainties, or both, in the computation of k_c,
(c) uncertainties due to extrapolation of k_c outside the range of experimental data, and

(d) uncertainties due to limitations in the geometrical or material representations used in the computational method.

Δk_m = an arbitrary margin to ensure the subcriticality of k_s.

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

The above equation can be rewritten as:

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

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

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

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

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

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

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

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

6.5.1 Benchmark Experiments and Applicability

The criticality safety method is CSAS25 embedded in SCALE version 4.3 for the PC. CSAS25 includes: the SCALE Material Information Processor, BONAMI, NITAWL-II, and KENO-Va. The Material Information Processor generates number densities for standard compositions, prepares geometry data for resonance self-shielding, and creates data input files for the cross section processing codes. The BONAMI and NITAWL-II codes are used to prepare a resonance-corrected cross section library in AMPX working format. The KENO-Va code calculates the model k_{eff} using Monte Carlo techniques. The 27 group ENDF/B-IV neutron cross section library is used in this validation.

6.5.1.1 Description of Experiments

Sixty-three critical experiments were selected; nine Babcox and Wilcox (B&W) 2.46 wt % ^{235}U fuel storage (Baldwin), 10 Pacific Northwest Laboratory (PNL) 4.31 wt % ^{235}U lattice (Bierman, 1980), 21 PNL 2.35 and 4.31 wt % ^{235}U with metal reflectors (Bierman, 1979 & 1981), twelve PNL flux trap (Bierman 1980 and 1988) and 11 Valduc Critical Mass Laboratory (VCML) 4.74 wt % ^{235}U experiments, some involving moderator density variations (Manaranche). These experiments span a range of fuel enrichments, fuel rod pitches, neutron absorber sheet characteristics, shielding materials and geometries that are typical of LWR fuel in a cask.

The experiments are evaluated using three-dimensional models, as close to the actual experiment as possible, to achieve accurate results. Stochastic Monte Carlo error is kept within ±0.1 percent by executing at least 1,000 neutrons/generation for more than 400 generations.

6.5.1.2 Applicability of Experiments

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

For Yankee Class fuel, the majority of the Zircaloy-clad fuel is enriched below 4.0 wt % ^{235}U. For the stainless steel-clad fuel, the enrichment is 4.94 wt % ^{235}U, which is just outside the benchmark experimental range. However, the stainless steel-clad fuel is much less reactive than the Zircaloy clad and is not limiting. Also, in the case of the Yankee Class fuel, the pellet diameter varies from 0.747 to 0.789 cm, the rod outside diameter varies from 0.864 to 0.927 cm and the pitch varies from 1.07 to 1.20 cm, and the resultant H/U volume ratio varies from 1.28 to 1.57. These fuel parameters are all slightly outside of the range of experiments, but given the lack of statistically significant trends as demonstrated in Figures 6.5-2 through 6.5-7, confidence in criticality prediction by extrapolation to the Yankee fuel parameters is high.

Experiments covered the geometry and neutron absorber sheet arrangements typical of NAC basket designs. This included flux trap gap spacings of 3.81 cm such as in the NAC-STC basket and gap spacing as low as 1.91 cm as in the NAC-MPC. The ^{10}B neutron absorber loadings are also typical of NAC basket designs (0.005 to 0.025). The experiments covered the influence of water and metal reflector regions, including steel and lead, which are present in storage and transport cask shielding.

Confidence in predicting criticality, including bias and uncertainty, has been demonstrated for LWR fuel with enrichments up to 4.74 wt % ^{235}U and, based on the lack of significant trend with enrichment, confidence in extrapolating up to 4.94 wt % ^{235}U is high. Confidence in predicting criticality has been demonstrated for storage and transport arrays using flux trap or single neutron absorber sheet or simple spacing criticality control. Confidence in predicting criticality has been demonstrated for LWR fuel storage and transport arrays next to water and metal reflector regions.

6.5.2 Results of Benchmark Calculations

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

The overall average and standard deviation of the sixty-three cases is 0.9948 ± 0.0044. The average Monte Carlo error (statistical convergence) is ±0.0012 for the sixty-three cases. This uncertainty component is statistically subtracted from the uncertainties because it is previously included in the above standard deviation. The KENO-Va models are three-dimensional, fully explicit representations (no homogenization) of the experimental geometry. Therefore, the uncertainty due to limitations of geometrical modeling is taken to be 0.0. The experiments modeled cover the range

of fuel types, enrichments, neutron absorber configurations, neutron absorber ^{10}B loading and metal reflector effects, so there are no extrapolations necessary outside of the range of data, and the uncertainty due to this is also taken to be 0.0. Based on the reported experimental error for the B&W cases, the reported error of the critical size number of rods for the PNL cases and the reported error for the critical height in the VCML cases, the experimental error is conservatively taken to be ± 0.001. Criticality can then be represented as 1.000±0.001. This uncertainty component is statistically added to the sum of the other uncertainties because the bias is the difference between two random variates (i.e., criticality and code prediction and the uncertainty in the difference between two random variates is the statistical sum (rms) of their individual uncertainties).

Thus, the bias or average difference between code calculated and critical is β=1-0.9948 = 0.0052. The uncertainty in the bias, accounting for the statistical convergence (Monte Carlo error) and the uncertainty in criticality is $(0.0044^2 - 0.0012^2 + 0.0010^2)^{1/2} = 0.0043$. For 63 samples of criticality, the 95/95 one side tolerance factor is 2.012 (Owen). This results in a 95/95 one-sided uncertainty in the bias of $\Delta\beta$= 2.012x0.0043=0.0087. Equation 4 now becomes:

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

where Δk_s becomes the uncertainty in k_s due to Monte Carlo error, mechanical and material tolerances and geometric or material representations. If the nominal representation of the system is evaluated for k_s, then the mechanical and material perturbation can be evaluated independently and can be combined statistically as the root sum of squares. If the worst case mechanical and material tolerances are used in the calculations of k_s (e. g., the most reactive positioning of fuel or basket components and 75% of the specified minimum boron loading), then Δk_s becomes 0.0 and the Monte Carlo error, σ_{mc}, can be combined statistically, since it is independent, with the uncertainty in the bias as:

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

6.5.2.1 Trends

Scatter plots of k_{eff} versus wt % ^{235}U, rod pitch, H/U volume ratio, average neutron group causing fission, ^{10}B loading for flux trap cases, and flux trap gap thickness are shown in Figures 6.5-2 through 6.5-7. Included in these scatter plots are linear regression lines with a corresponding correlation coefficient. This statistically indicates any trend or lack thereof. In particular, the correlation coefficient is a measure of the linear relationship between k_{eff} and a critical experiment parameter. If r is +1, a perfect linear relationship with a positive slope is indicated, and if r is -1, a perfect linear relationship with a negative slope is indicated. When r is 0, no linear relationship is indicated. The largest correlation coefficient indicated in the plots is 0.1302 (k_{eff} versus enrichment) and the lowest is 0.0048 (k_{eff} versus ^{10}B loading in flux trap experiments). Based on the correlation coefficients, no statistically significant trends exist over the range of variables studied. Most importantly, no trend is shown with flux trap gap spacing and/or ^{10}B loading. This is the major criticality control feature of the NAC-STC and the NAC-MPC basket.

6.5.3 Comparison of NAC Method to NUREG/CR-6361

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

NAC has performed an extensive LWR critical benchmarking as documented in Sections 6.5.1 and 6.5.2. The method used in NAC benchmarking/validation included the CSAS25 (KENO-Va) criticality analysis sequence, with the 27 group ENDF/B-IV library, contained in SCALE 4.3. Trending in k_{eff} was evaluated for the following independent variables: wt % ^{235}U, rod pitch, H/U

volume ratio, average neutron group causing fission, ^{10}B loading for flux trap cases, and flux trap gap thickness. No statistically significant trends were found, and a constant bias with associated uncertainty was determined for criticality evaluation.

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

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

where:

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

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

Δk_s = allowance for:

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

Δk_c = margin for uncertainty in k_c which includes allowance for:

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

Δk_m= arbitrary administrative margin to ensure subcriticality of k_s

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

Equation 1 can be rewritten as:

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

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

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

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

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

where:

$$USL \equiv 1 - \Delta k_m - \beta - \Delta\beta \qquad (5)$$

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

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

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

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

To this point, both the USL criterion and maximum k_{eff} criterion are equivalent. The effects of trending in the bias or the uncertainty in the bias can be directly incorporated into either Equation 5 or Equation 6. Trending is established by performing a regression analysis of k_{eff} as a function of the principal system variables such as: enrichment, rod pitch, H to U ratio, average group of fission, ^{10}B absorber loading and flux trap gap spacing. Usually, simple linear regression is performed, and the line with the greatest correlation is used to functionalize β. This approach is recommended in NUREG/CR-6361. However, if no strong correlation can be determined, then a constant bias adjustment can be made. This is typically done with a one-side tolerance factor that guarantees 95% confidence in the uncertainty in the bias. This is the approach taken in the NAC-MPC criticality analysis.

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

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

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

The NAC applied USL of 0.9361 bounds the calculated upper safety limits for all enrichment values above 3.0 wt % ^{235}U. Since the maximum reactivities in the NAC-MPC systems are calculated at enrichments well above this level, the existing bias bounds the NUREG calculated USL. The parameters of the most reactive fuel element analysis are presented in Table 6.5-3.

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

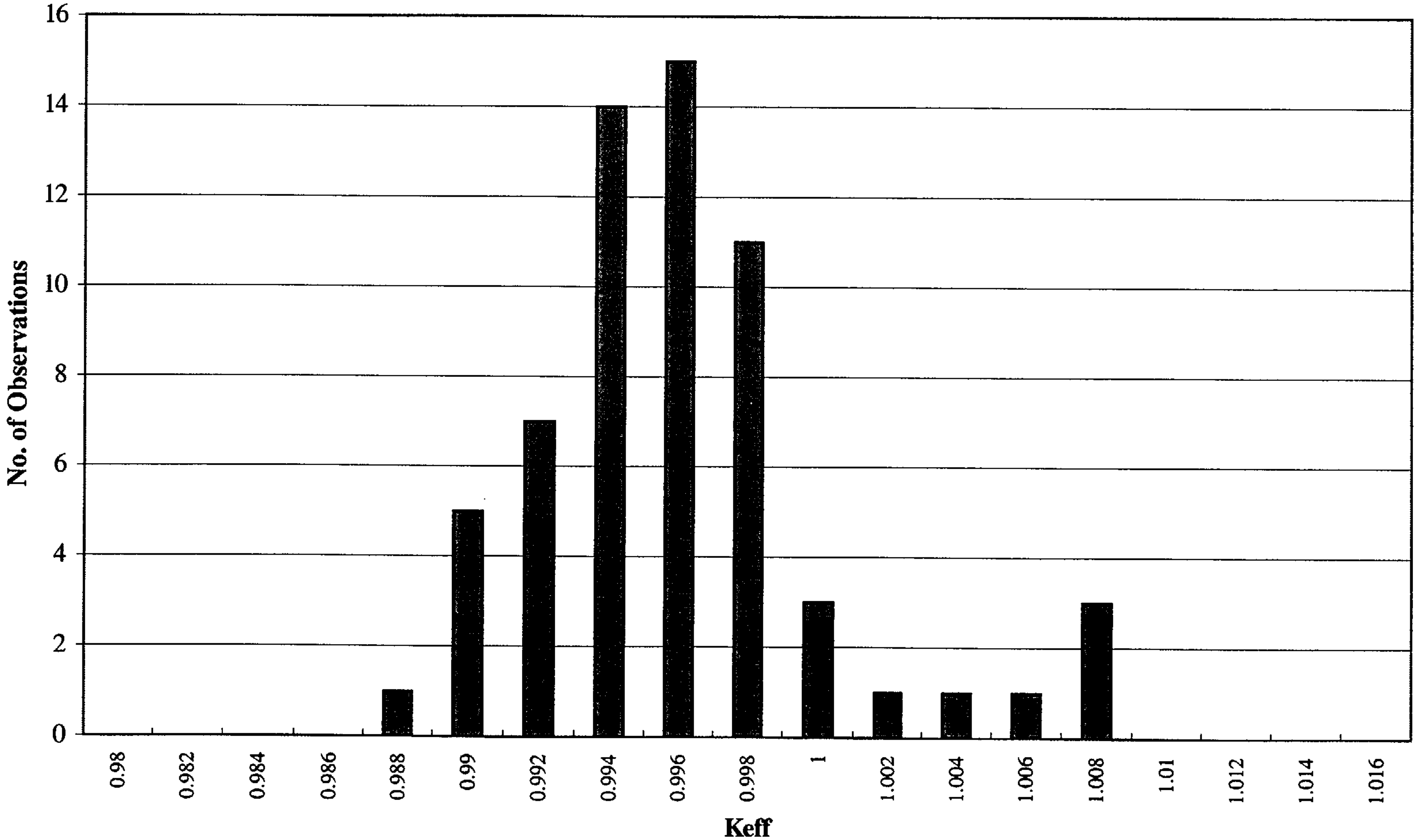


Figure 6.5-2 KENO-Va Validation -27 Group Library K_{eff} Versus Enrichment

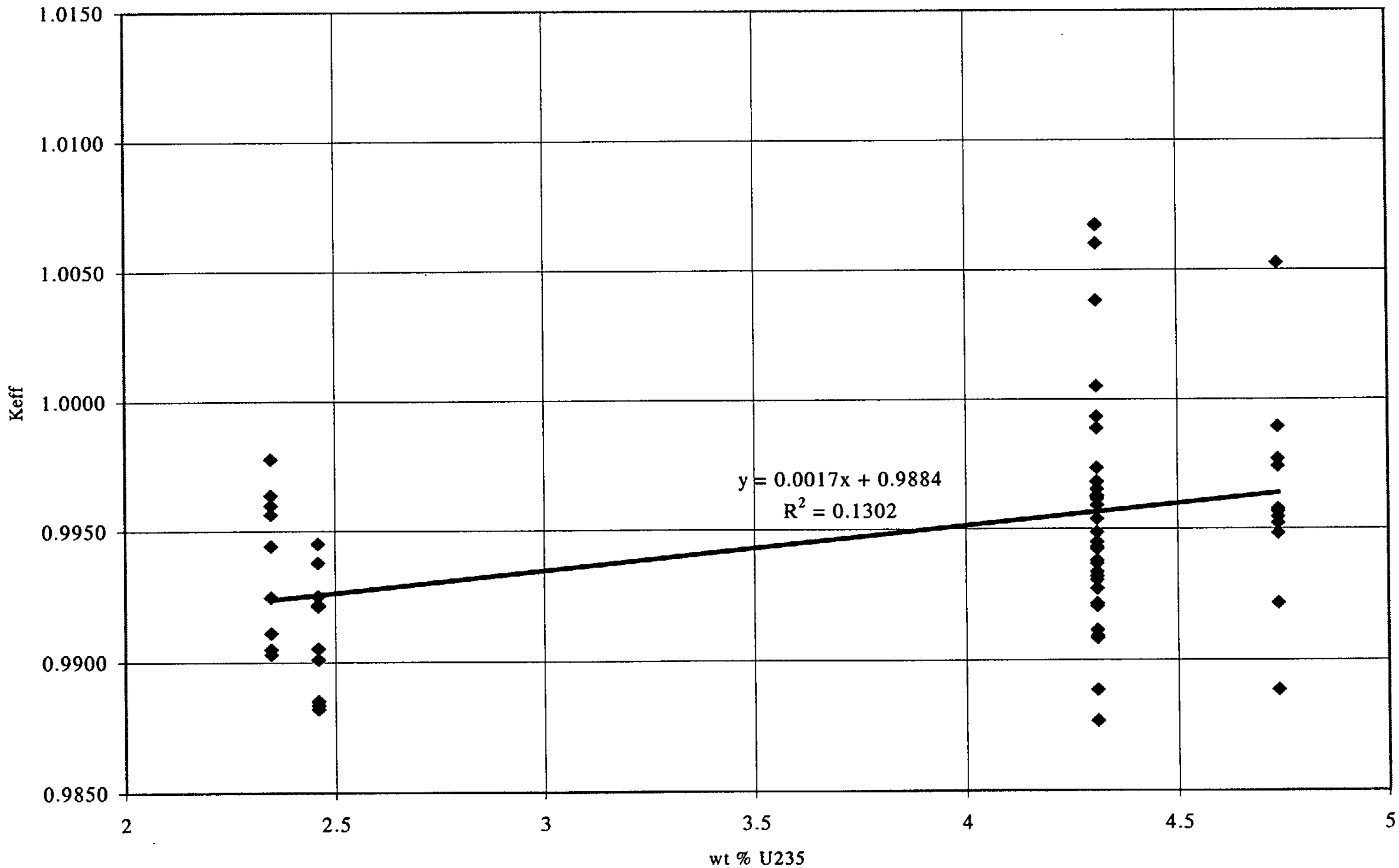


Figure 6.5-3 KENO-Va Validation - 27 Group Library K_{eff} Versus Rod Pitch

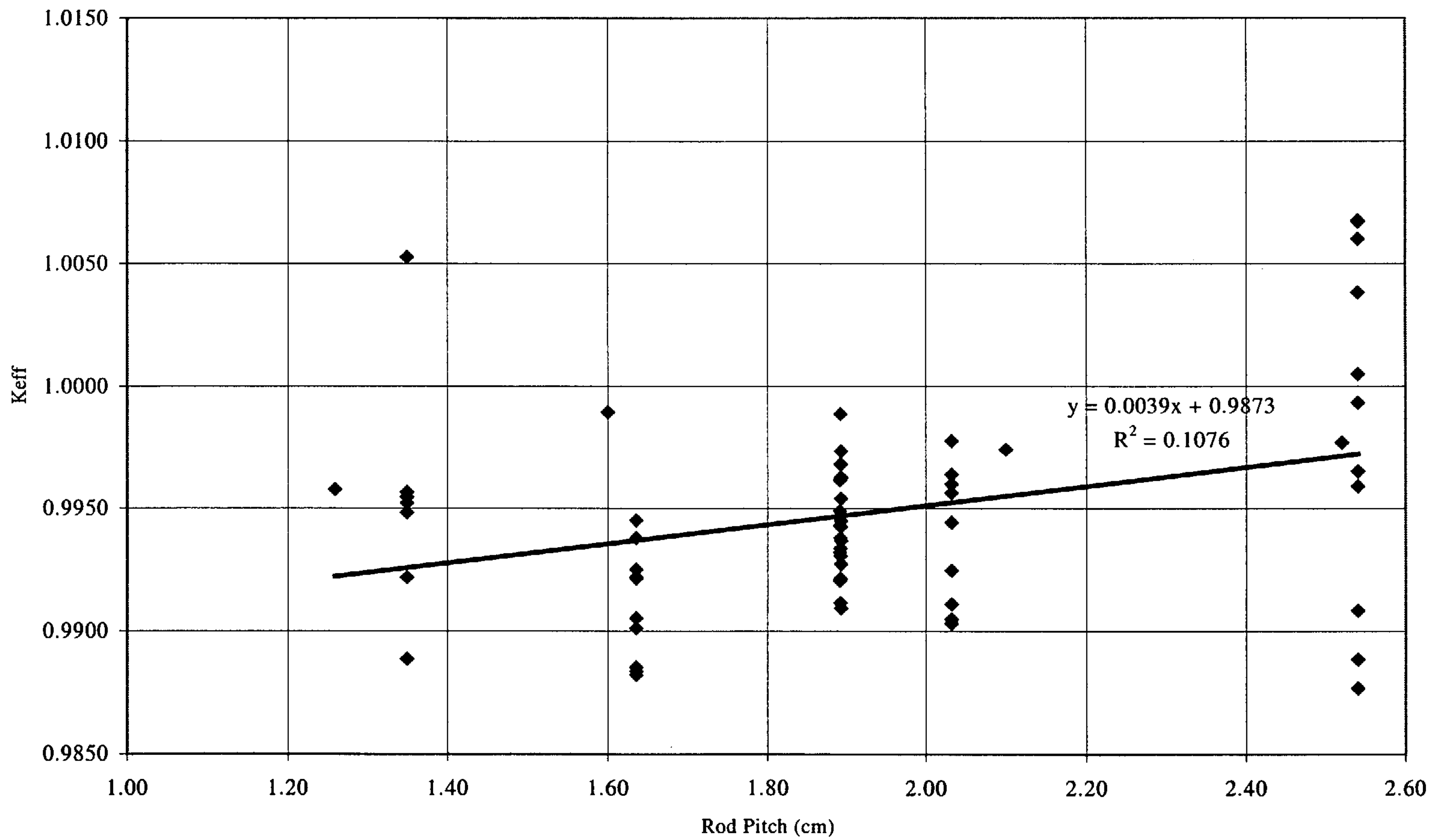


Figure 6.5-4 KENO-Va Validation -27 Group Library K_{eff} Versus H/U Volume Ratio

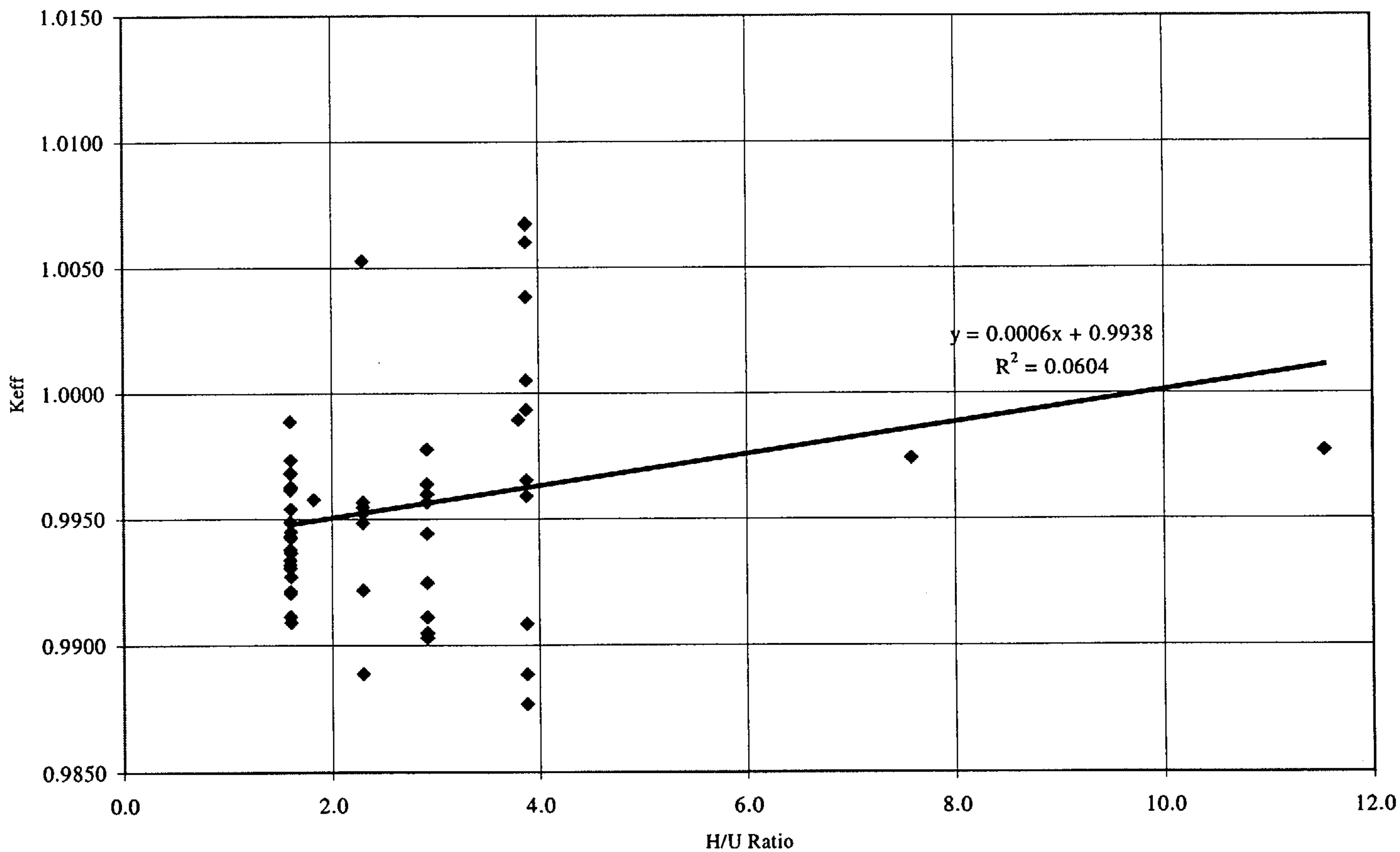


Figure 6.5-5 KENO-Va Validation -27 Group Library K_{eff} Versus Average Group of Fission

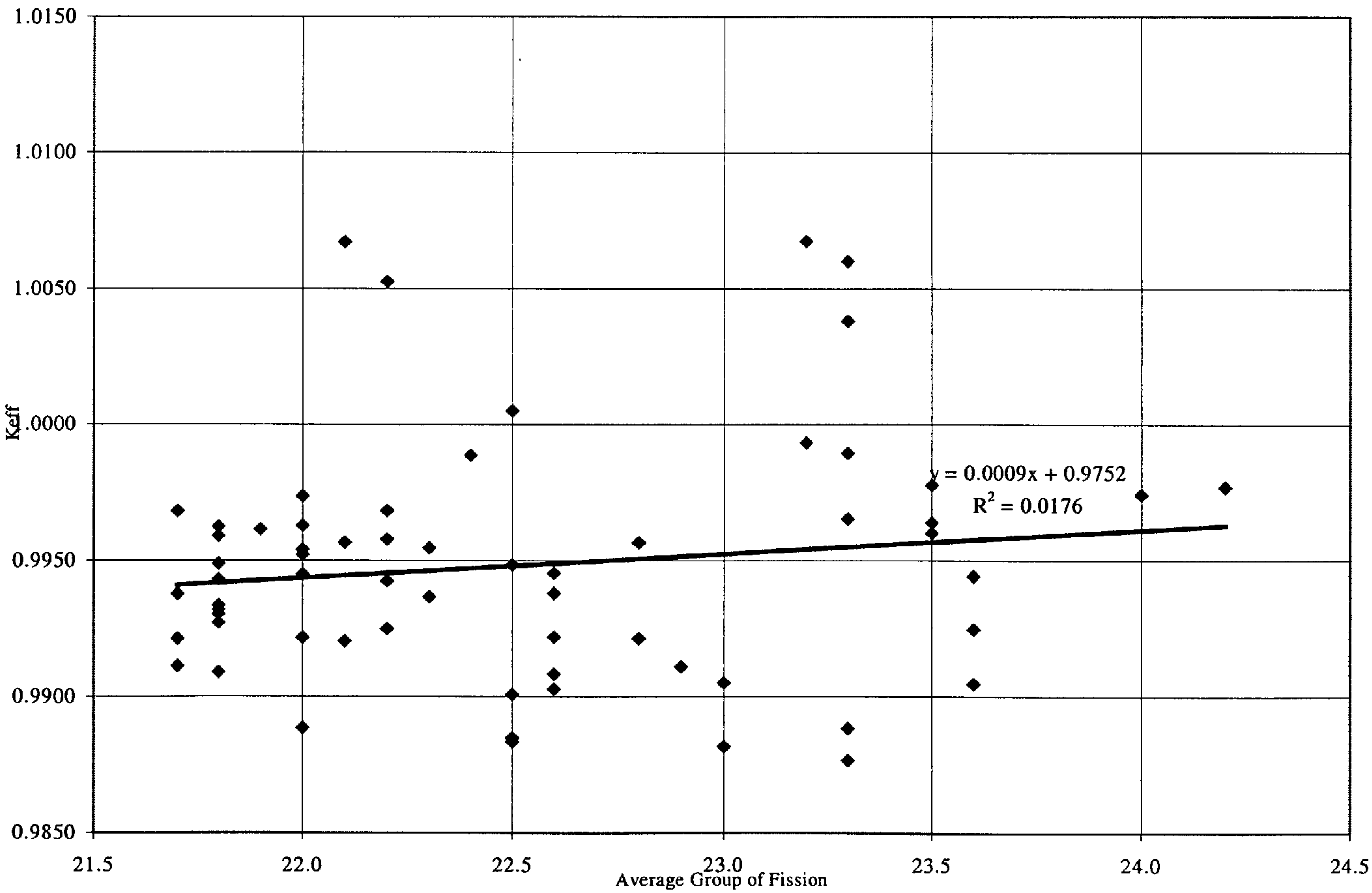


Figure 6.5-6 KENO-Va Validation - 27 Group Library K_{eff} Versus ^{10}B Loading For Flux Trap Criticals

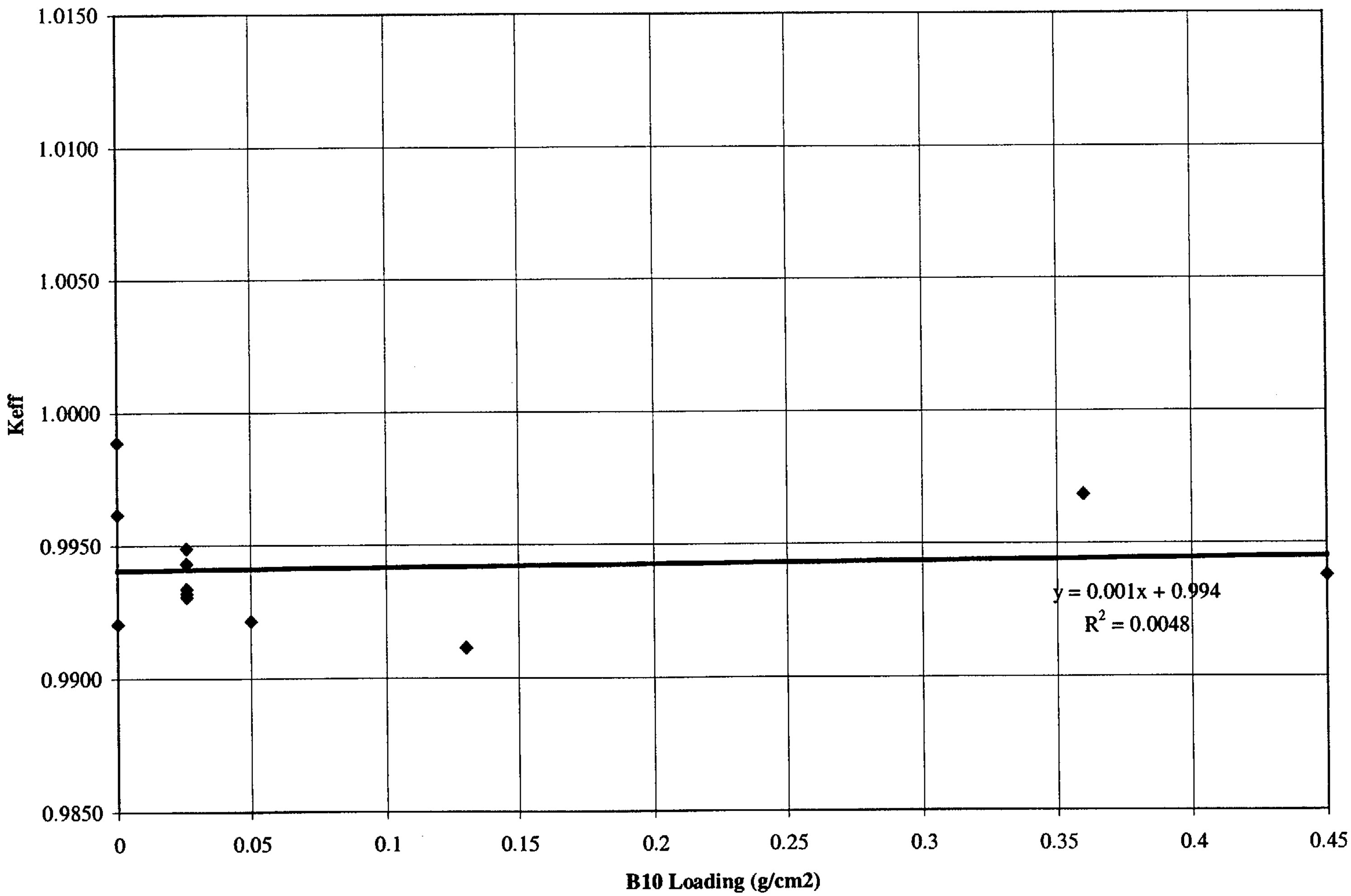


Figure 6.5-7 KENO-Va Validation -27 Group Library Results K_{eff} Versus Flux Trap Critical Gap Thickness

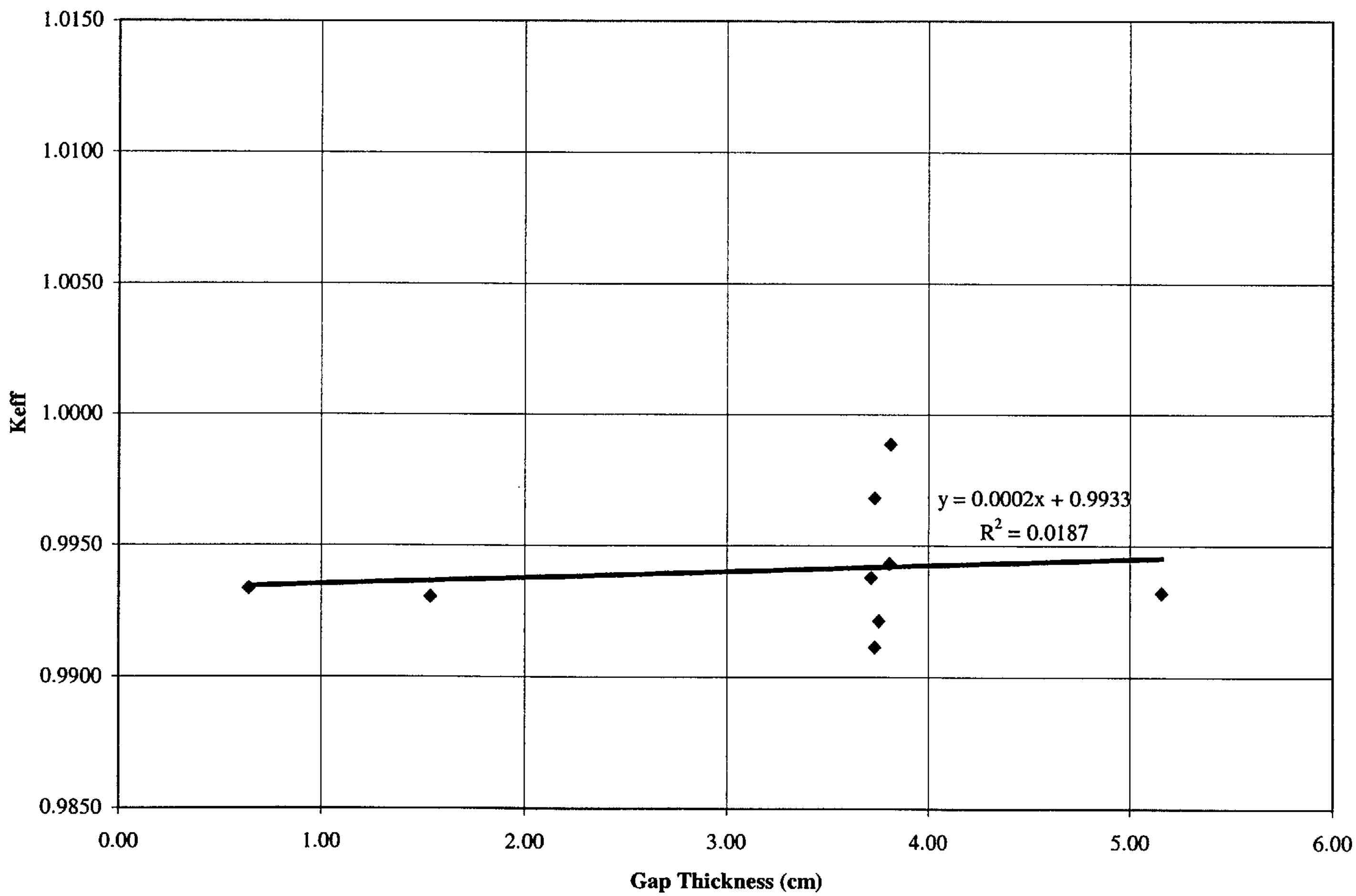


Figure 6.5-8 USLSTATS Output for Fuel Enrichment Study

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

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

Input to statistical treatment from file:EN_KEFF.TXT

Title: 63 LWR CRITICAL EXPERIMENT KEFF VS ENRICHMENT

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

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

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

Output from statistical treatment

63 LWR CRITICAL EXPERIMENT KEFF VS ENRICHMENT

```
Number of data points (n)                        63
Linear regression, k(X)                        0.9884 + ( 1.6748E-03)*X
Confidence on fit (1-gamma) [input]             95.0%
Confidence on proportion (alpha) [input]        95.0%
Proportion of population falling above
lower tolerance interval (rho) [input]          99.5%
Minimum value of X                                 2.3500
Maximum value of X                                 4.7400
Average value of X                                 3.81143
Average value of k                               0.99482
Minimum value of k                               0.98770
Variance of fit, s(k,X)^2                       1.6973E-05
Within variance, s(w)^2                         1.4306E-06
Pooled variance, s(p)^2                         1.8404E-05
Pooled std. deviation, s(p)                     4.2900E-03
C(alpha,rho)*s(p)                               1.5488E-02
```

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

```
student-t @ (n-2,1-gamma)                          1.67078E+00
Confidence band width, W                           7.3606E-03
Minimum margin of subcriticality, C*s(p)-W         8.1273E-03

Upper subcritical limits: (  2.35000 <= X <=    4.74000)
***** *********** *******

USL Method 1 (Confidence Band with
Administrative Margin)             USL1 = 0.9311 + ( 1.6748E-03)*X

USL Method 2 (Single-Sided Uniform
Width Closed Interval Approach)    USL2 = 0.9729 + ( 1.6748E-03)*X


USLs Evaluated Over Range of Parameter X:
**** ********* **** ***** ** ********* **

X:    2.35    2.69    3.03    3.37    3.72    4.06    4.40    4.74
---------------------------------------------------------
USL-1:  0.9350 0.9356 0.9362 0.9367 0.9373 0.9379 0.9384 0.9390
USL-2:  0.9769 0.9775 0.9780 0.9786 0.9792 0.9797 0.9803 0.9809
---------------------------------------------------------

****************************************************************************
Thus spake USLSTATS
Finis.
```

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

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	K_{eff}	σ
Set 1														
B&W-I	Cylindrical	2.46	1.636	1.206	1.03	1.6	0	NA	NA	0		22.8	0.9921	0.0011
B&W-II	3X3-14X14	2.46	1.636	1.206	1.03	1.6	1,037	NA	NA	0		22.2	0.9925	0.0009
B&W-III	3X3-14X14	2.46	1.636	1.206	1.03	1.6	764	NA	NA	1.636		22.6	0.9938	0.0009
B&W-IX	3X3-14X14	2.46	1.636	1.206	1.03	1.6	0	NA	NA	6.543		23	0.9905	0.0010
B&W-X	3X3-14X14	2.46	1.636	1.206	1.03	1.6	143	NA	NA	4.907		23	0.9882	0.0010
B&W-XI	3X3-14X14	2.46	1.636	1.206	1.03	1.6	514	Steel	0	1.636		22.6	0.9945	0.0010
B&W-XIII	3X3-14X14	2.46	1.636	1.206	1.03	1.6	15	B-Al	0.0052	1.636		22.6	0.9922	0.0010
B&W-XIV	3X3-14X14	2.46	1.636	1.206	1.03	1.6	92	B-Al	0.0040	1.636		22.5	0.9885	0.0010
B&W-XVII	3X3-14X14	2.46	1.636	1.206	1.03	1.6	487	B-Al	0.0008	1.636		22.5	0.9884	0.0010
B&W-XIX	3X3-14X14	2.46	1.636	1.206	1.03	1.6	634	B-Al	0.0003	1.636		22.5	0.9901	0.0009
												Average	0.9911	0.0023
Set 2														
PNL-043	17X13 Lattice	4.31	1.892	1.415	1.265	1.6	0	NA	NA	NA	NA	22.0	0.9954	0.0014
PNL-044	16X14 Lattice	4.31	1.892	1.415	1.265	1.6	0	NA	NA	NA	NA	22.0	0.9945	0.0013
PNL-045	14X16 Lattice	4.31	1.892	1.415	1.265	1.6	0	NA	NA	NA	NA	22.0	0.9974	0.0013
PNL-046	12x19 Lattice	4.31	1.892	1.415	1.265	1.6	0	NA	NA	NA	NA	22.0	0.9963	0.0013
PNL-087	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.066	2.83		21.8	0.9927	0.0012
PNL-079	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.030	2.83		21.8	0.9909	0.0012
PNL-093	4 11X14 Arrays	4.31	1.892	1.415	1.265	1.6	0	BORAL	0.026	2.83		21.8	0.9962	0.0012
PNL-115	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Aluminum	0	2.83		22.3	0.9937	0.0013
PNL-064	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Steel (.302)	0	2.83		22.2	0.9942	0.0012
PNL-071	4 9X12 Arrays	4.31	1.892	1.415	1.265	1.6	0	Steel (.485)	0	2.83		22.2	0.9968	0.0012
												Average	0.9948	0.0020

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

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	K_{eff}	σ
Set 3										Cluster	Wall/Cluster			
PNL-STA	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	10.65	0.00	23.5	0.9964	0.0010
PNL-STB	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.20	1.32	23.6	0.9944	0.0010
PNL-STC	3X1 St Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	10.36	2.62	23.6	0.9905	0.0010
PNL-PBA	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.84	0.00	23.5	0.9960	0.0011
PNL-PBB	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.72	0.66	23.5	0.9978	0.0010
PNL_PBC	3X1 Pb Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.25	2.62	23.6	0.9925	0.0010
PNL-DUA	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	11.83	0.00	22.6	0.9903	0.0009
PNL-DUB	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	14.11	1.96	22.8	0.9957	0.0010
PNL-DUC	3X1 DU Refl.	2.35	2.032	1.27	1.1176	2.9	0	NA	NA	13.70	2.62	22.9	0.9911	0.0010
PNL-H20	3X1 H2O Refl	4.31	2.54	1.415	1.265	3.9	0	NA	NA	8.24	inf	23.3	0.9877	0.0023
PNL-ST0	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	12.89	0	23.2	0.9993	0.0012
PNL-ST1	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	14.12	1.32	23.3	1.0060	0.0022
PNL-ST26	3X1 St Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	12.44	2.62	23.3	0.9965	0.0011
PNL-PB0	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	20.62	0	23.2	1.0068	0.0021
PNL-PB13	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	19.04	1.32	23.3	1.0038	0.0012
PNL-PB5	3X1 Pb Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	10.3	5.41	23.3	0.9889	0.0011
PNL-DU0	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	15.38	0	21.8	0.9959	0.0011
PNL-DU13	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	19.04	1.32	22.1	1.0067	0.0010
PNL-DU39	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	18.05	3.91	22.5	1.0005	0.0011
PNL-DU54	3X1 DU Refl.	4.31	2.54	1.415	1.265	3.9	0	NA	NA	13.49	5.41	22.6	0.9908	0.0011
												Average	0.9964	0.0060

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

Criticals	Configuration	wt % ^{235}U	Pitch (cm)	Clad OD (cm)	Pellet OD (cm)	H/U	Sol. B (ppm)	Poison	g $^{10}B/cm^2$	Gap(cm)	Gap Den.	Ave. Gfis	K_{eff}	σ
Set 4														
PNL-229	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	Aluminum	0	3.81	0.9982	22.4	0.9989	0.0012
PNL-230	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.05	3.75	0.9982	21.7	0.9921	0.0012
PNL-228	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.13	3.73	0.9982	21.7	0.9911	0.0012
PNL-214	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.36	3.73	0.9982	21.7	0.9968	0.0013
PNL-231	2x2 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.45	3.71	0.9982	21.7	0.9938	0.0012
PNL-127	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.026	0.64	0.9982	21.8	0.9934	0.0010
PNL-126	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.026	1.54	0.9982	21.8	0.9931	0.0010
PNL-123	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.026	3.80	0.9982	21.8	0.9943	0.0010
PNL-125	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.026	5.16	0.9982	21.8	0.9932	0.0010
PNL-124	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	BORAL	0.026	INF	0.9982	21.8	0.9949	0.0010
PNL-123-S	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	Steel	0	3.80	0.9982	22.1	0.9920	0.0010
PNL-124-S	2x1 Flux Trap	4.31	1.89	1.415	1.265	1.6	0	Steel	0	INF	0.9982	21.9	0.9962	0.0010
												Average	0.9941	0.0022
Set 5														
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0	22.0	0.9922	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.0323	22.0	0.9889	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.2879	22.1	0.9957	0.0013
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	1.90	0.5540	22.2	1.0053	0.0011
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	2.50	0.9982	22.3	0.9955	0.0012
VCML	2x2 Water Gap	4.74	1.35	0.94	0.79	2.3	0	NA	NA	5.00	0.9982	22.5	0.9948	0.0013
VCML	Square Lattice	4.74	1.26	0.94	0.79	1.8	0	NA	NA	NA	NA	22.2	0.9958	0.0012
VCML	Square Lattice	4.74	1.35	0.94	0.79	2.3	0	NA	NA	NA	NA	22.0	0.9952	0.0012
VCML	Square Lattice	4.74	1.60	0.94	0.79	3.8	0	NA	NA	NA	NA	23.3	0.9989	0.0013
VCML	Square Lattice	4.74	2.10	0.94	0.79	7.6	0	NA	NA	NA	NA	24.0	0.9974	0.0012
VCML	Square Lattice	4.74	2.52	0.94	0.79	11.5	0	NA	NA	NA	NA	24.2	0.9977	0.0011
												Average	0.9961	0.0041

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

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

Table 6.5-3 Most Reactive Configuration System Parameters

Parameters	**Value**
Enrichment (wt % ^{235}U)	4.0
Rod pitch (cm)	1.1887
H/U volume ratio	1.52
^{10}B loading (g/cm^2)	0.01
Average group causing fission	21.6
Flux gap thickness (cm)	1.9 to 2.25

6.6 References

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6.7 Supplemental Data

This section contains the CSAS25 input/output for the criticality analysis of the NAC-MPC transfer and storage casks under normal and accident conditions. These summaries include: the input file echo, the CSAS25 and the KENO-Va output sections. BONAMI and NITAWL-II output sections are not included for brevity.

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
  '
  '       File tfn-1000.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE TRANSFER CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '       INTERIOR MODERATOR (MATERIAL  3) VOLUME FRACTION = 1.000
  '       EXTERIOR MODERATOR (MATERIAL 10) VOLUME FRACTION = 0.0001
  '
  27GROUPNDF4 LATTICECELL
  UO2          1             0.95    293.0 92235 4.0 92238 96.0 END
  ZIRCALLOY    2             1.0     293.0                      END
  H2O          3             1.0     293.0                      END
  AL           4             1.0     293.0                      END
  SS304        5             1.0     293.0                      END
  B-10         6  DEN=2.6226 0.0450  293.0                      END
  B-11         6  DEN=2.6226 0.2736  293.0                      END
  C            6  DEN=2.6226 0.0927  293.0                      END
  AL           6  DEN=2.6226 0.5737  293.0                      END
  PB           7             1.0     293.0                      END
  H            8  DEN=1.6291 0.060   293.0                      END
  O            8  DEN=1.6291 0.425   293.0                      END
  C            8  DEN=1.6291 0.277   293.0                      END
  N            8  DEN=1.6291 0.020   293.0                      END
  AL           8  DEN=1.6291 0.214   293.0                      END
  B-10         8  DEN=1.6291 0.001   293.0                      END
  B-11         8  DEN=1.6291 0.004   293.0                      END
  CARBONSTEEL 9              1.0     293.0                      END
  H2O         10             0.0001  293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 0 END
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
  READ PARAM RUN=yes PLT=NO  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER  0 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER  0 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
  CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                                   2P2.1400
CUBOID 5 1 4P10.0661                                  2P2.1400
CUBOID 3 1 4P10.25681                                 2P2.1400
HOLE  14    0.0       10.1615  0.0
HOLE  14    0.0      -10.1615  0.0
HOLE  15    10.1615  0.0       0.0
HOLE  15   -10.1615  0.0       0.0
CUBOID 5 1 4P10.3051                                  2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    0.0       -0.1584       0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    0.0       0.1584        0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    -0.1584   0.0           0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    0.1584    0.0           0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    0.1584    0.1584        0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                                  2P2.1400
HOLE  50    -0.1584   0.1584        0.0
UNIT 57
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
CUBOID 3 1 4P10.4635                             2P2.1400
HOLE  50   0.1584   -0.1584        0.0
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                             2P2.1400
HOLE  50   -0.1584   -0.1584        0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                             2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                              2P0.6604
CUBOID 5 1 4P10.0661                             2P0.6604
CUBOID 3 1 4P10.25681                            2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                             2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   0.0       -0.1584      0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   0.0       0.1584       0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   -0.1584  0.0           0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   0.1584   0.0          0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   0.1584   0.1584       0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   -0.1584   0.1584       0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   0.1584   -0.1584       0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  60   -0.1584   -0.1584       0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                              2P0.6604
CUBOID 5 1 4P10.0661                             2P0.6604
CUBOID 3 1 4P10.25681                            2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                             2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   0.0       -0.1584      0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   0.0       0.1584       0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   -0.1584  0.0           0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   0.1584   0.0          0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   0.1584   0.1584       0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                             2P0.6604
HOLE  70   -0.1584   0.1584       0.0
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                              2P0.6604
HOLE  70   0.1584   -0.1584      0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                              2P0.6604
HOLE  70   -0.1584   -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                              2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN TRANSFER CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253      2P2.1400
HOLE 80      -69.0614 0.0 0.0
HOLE 82      -46.1912 0.0 0.0
HOLE 81       69.0614 0.0 0.0
HOLE 83       46.1912 0.0 0.0
CYLINDER  5 1  89.7128     2P2.1400
CYLINDER  0 1  90.805      2P2.1400
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
CYLINDER  9 1  92.71       2P2.1400
CYLINDER  7 1 101.6        2P2.1400
CYLINDER  8 1 106.68       2P2.1400
CYLINDER  9 1 109.855      2P2.1400
CUBOID   10 1 4P159.855    2P2.1400
UNIT 111
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90     -69.0614 0.0 0.0
HOLE 92     -46.1912 0.0 0.0
HOLE 91      69.0614 0.0 0.0
HOLE 93      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
UNIT 112
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249       2P0.6604
HOLE 100    -69.0614 0.0 0.0
HOLE 102    -46.1912 0.0 0.0
HOLE 101     69.0614 0.0 0.0
HOLE 103     46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -159.855 -159.855 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
53
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
74
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

END DATA
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

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


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


      11              11                   //         11        7777777777777              //    99999999999     666666666666
     111             111                  //         111        777777777777              //    9999999999999   6666666666666
    1111            1111                 //         1111        77        77             //     99         99   66
      11              11                //            11                 77             //      99         99   66
      11              11               //             11                77             //       99         99   66
      11              11              //              11               77             //        9999999999999   666666666666
      11              11             //               11               77            //          999999999999   6666666666666
      11              11            //                11              77            //                     99   66         66
      11              11           //                 11              77           //                      99   66         66
      11              11          //                  11             77           //                       99   66         66
   11111111        11111111      //                11111111          77          //             9999999999999   6666666666666
   11111111        11111111     //                 11111111          77         //              999999999999     66666666666


      11         666666666666                    33333333333    5555555555555                         11         33333333333
     111        6666666666666                   3333333333333   5555555555555                        111        3333333333333
    1111        66                    :::       33         33   55                    :::           1111        33         33
      11        66                    :::                  33   55                    :::             11                   33
      11        66                    :::                  33   55                    :::             11                   33
      11        666666666666                              333   555555555555                          11                  333
      11        6666666666666                             333   5555555555555                         11                  333
      11        66         66         :::                  33              55         :::             11                   33
      11        66         66         :::                  33              55         :::             11                   33
      11        66         66         :::       33         33   55         55         :::             11        33         33
   11111111     6666666666666                   3333333333333   5555555555555                      11111111     3333333333333
   11111111      66666666666                     33333333333     55555555555                       11111111      33333333333
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

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

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                 PROGRAM VERIFICATION INFORMATION                    *****
*****                                                                     *****
*****              CODE SYSTEM:   SCALE-PC VERSION:   4.3                 *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****                    PROGRAM:  CSAS                                   *****
*****                                                                     *****
*****              CREATION DATE:  03-08-96                               *****
*****                                                                     *****
*****                     VOLUME:  ENG                                    *****
*****                                                                     *****
*****                    LIBRARY:  G:\scale43\exe                         *****
*****                                                                     *****
*****                                                                     *****
*****            PRODUCTION CODE:  CSAS                                   *****
*****                                                                     *****
*****                    VERSION:  3.1                                    *****
*****                                                                     *****
*****                    JOBNAME:  SCALE-PC                               *****
*****                                                                     *****
*****          DATE OF EXECUTION:  11/17/96                               *****
*****                                                                     *****
*****          TIME OF EXECUTION:  16:35:13                               *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

    **** PROBLEM PARAMETERS ****

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

    **** PROBLEM COMPOSITION DESCRIPTION ****

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

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

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

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

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

    SC  B-10         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.0450 VOLUME FRACTION
    ROTH      2.6226 SPECIFIED DENSITY
    NEL            1 NO. ELEMENTS
    ICP            1 0/1 MIXTURE/COMPOUND
    TEMP       293.0 DEG KELVIN
                5010       1.00 ATOM/MOLECULE
    END

    SC  B-11         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.2736 VOLUME FRACTION
    ROTH      2.6226 SPECIFIED DENSITY
    NEL            1 NO. ELEMENTS
    ICP            1 0/1 MIXTURE/COMPOUND
    TEMP       293.0 DEG KELVIN
                5011       1.00 ATOM/MOLECULE
    END

    SC  C            STANDARD COMPOSITION
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
MX             6 MIXTURE NO.
VF        0.0927 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012        1.00 ATOM/MOLECULE
END

SC  AL           STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.5737 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027        1.00 ATOM/MOLECULE
END

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

SC  H            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0600 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            1001        1.00 ATOM/MOLECULE
END

SC  O            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.4250 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            8016        1.00 ATOM/MOLECULE
END

SC  C            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2770 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012        1.00 ATOM/MOLECULE
END

SC  N            STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0200 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            7014        1.00 ATOM/MOLECULE
END

SC  AL           STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.2140 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027        1.00 ATOM/MOLECULE
END

SC  B-10         STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0010 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            5010        1.00 ATOM/MOLECULE
END

SC  B-11         STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        0.0040 VOLUME FRACTION
ROTH      1.6291 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
            5011      1.00 ATOM/MOLECULE
END

SC  CARBONSTEEL  STANDARD COMPOSITION
MX             9 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      7.8212 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           26000    99.000 WT%
            6012     1.000 WT%
END

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

**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH  CELL TYPE
PITCH     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 CM GAP OUTER DIAMETER
MGAP           0 MIXTURE NO. OF GAP

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

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

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

********** DATA LIBRARY INFORMATION **********

UNIT                                        VOLUME
NUMBER        DATA SET NAME                 NAME      UNIT FUNCTION
------        -------------                 ----      -------------

  89     G:\scale43\DATALIB\FT89F001                  STANDARD COMPOSITION LIBRARY

  82     G:\scale43\DATALIB\FT82F001                  CROSS SECTION LIBRARY

  11     C:\svv\yankee\wrr5402\tfn-1000\FT11F001      SHORT CROSS SECTION LIBRARY

  90     C:\svv\yankee\wrr5402\tfn-1000\FT90F001      INPUT DATA DIRECT ACCESS


                 STANDARD COMPOSITION LIBRARY DATA
                 ---------------------------------

     UNIT NUMBER   :  89

     DATASET NAME :  G:\scale43\DATALIB\FT89F001

     LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
                     637 STANDARD COMPOSITIONS, 490 NUCLIDES
                     90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.

     CREATION DATE:   6/30/95


                     CROSS SECTION LIBRARY DATA
                     ---------------------------

     UNIT NUMBER   :  82

     DATASET NAME :  G:\scale43\DATALIB\FT82F001

     LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                        BASED ON ENDF-B VERSION 4 DATA
                           COMPILED FOR NRC     1/27/89
                              LAST UPDATED                                08/12/94
                                 L.M.PETRIE   -    ORNL

CONTROL MODULE CSAS25    IS COMPLETE.
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

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

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

     11              11                    //        11         7777777777777              //    99999999999     666666666666
    111             111                   //        111         777777777777              //    9999999999999   6666666666666
   1111            1111                  //        1111         77        77             //     99         99   66
     11              11                 //           11                  77             //      99         99   66
     11              11                //            11                 77             //       99         99   66
     11              11               //             11                77             //        9999999999999   666666666666
     11              11              //              11               77             //          999999999999   6666666666666
     11              11             //               11              77             //                     99   66         66
     11              11            //                11              77            //                      99   66         66
     11              11           //                 11             77            //                       99   66         66
  11111111        11111111       //               11111111          77           //             9999999999999   6666666666666
  11111111        11111111      //                11111111          77          //              999999999999     66666666666

     11          666666666666                 33333333333    5555555555555                      22222222222     99999999999
    111         6666666666666                3333333333333   5555555555555                     2222222222222   9999999999999
   1111         66                 :::       33         33   55                        :::     22         22   99         99
     11         66                 :::                  33   55                        :::                22   99         99
     11         66                 :::                  33   55                        :::                22   99         99
     11         666666666666                           333   555555555555                               22     9999999999999
     11         6666666666666                          333   5555555555555                            22        999999999999
     11         66         66      :::                  33              55             :::          22                    99
     11         66         66      :::                  33              55             :::        22                      99
     11         66         66      :::       33         33   55         55             :::     22                         99
  11111111      6666666666666                3333333333333   5555555555555                     2222222222222   9999999999999
  11111111       66666666666                  33333333333     55555555555                      2222222222222   999999999999
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

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

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                    PROGRAM VERIFICATION INFORMATION                  *****
*****                                                                      *****
*****                 CODE SYSTEM:   SCALE-PC VERSION:   4.3               *****
*****                                                                      *****
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                                                                      *****
*****                PROGRAM:  000009                                      *****
*****                                                                      *****
*****          CREATION DATE:  03-08-96                                    *****
*****                                                                      *****
*****                 VOLUME:  ENG                                         *****
*****                                                                      *****
*****                LIBRARY:  G:\scale43\exe                              *****
*****                                                                      *****
*****                                                                      *****
*****        PRODUCTION CODE:  KENOVA                                      *****
*****                                                                      *****
*****                VERSION:  3.1                                         *****
*****                                                                      *****
*****                JOBNAME:  SCALE-PC                                    *****
*****                                                                      *****
*****      DATE OF EXECUTION:  11/17/96                                    *****
*****                                                                      *****
*****      TIME OF EXECUTION:  16:35:29                                    *****
*****                                                                      *****
*****                                                                      *****
********************************************************************************
********************************************************************************
********************************************************************************
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

****** NUMERIC PARAMETERS ******

TME   MAXIMUM PROBLEM TIME (MIN)              500.00
TBA   TIME PER GENERATION (MIN)                 0.50
GEN   NUMBER OF GENERATIONS                     1003
NPG   NUMBER PER GENERATION                     1000
NSK   NUMBER OF GENERATIONS TO BE SKIPPED          3
BEG   BEGINNING GENERATION NUMBER                  1
RES   GENERATIONS BETWEEN CHECKPOINTS              0
X1D   NUMBER OF EXTRA 1-D CROSS SECTIONS           1
NBK   NEUTRON BANK SIZE                         1025
XNB   EXTRA POSITIONS IN NEUTRON BANK              0
NFB   FISSION BANK SIZE                         1000
XFB   EXTRA POSITIONS IN FISSION BANK              0
WTA   DEFAULT VALUE OF WEIGHT AVERAGE         0.5000
WTH   WEIGHT HIGH FOR SPLITTING               3.0000
WTL   WEIGHT LOW FOR RUSSIAN ROULETTE         0.3333
RND   STARTING RANDOM NUMBER             BB827100001
NB8   NUMBER OF D.A. BLOCKS ON UNIT  8           200
NL8   LENGTH OF D.A. BLOCKS ON UNIT  8           512
ADJ   MODE OF CALCULATION                    FORWARD
      INPUT DATA WRITTEN ON RESTART UNIT          NO
      BINARY DATA INTERFACE                      YES
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
***********************************************************************************************************
***********************************************************************************************************
***                                                                                                     ***
***                  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                                     ***
***********************************************************************************************************
***                         ******     LOGICAL PARAMETERS       ******                                  ***
***                                                                                                     ***
***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA   YES       PLT  PLOT PICTURE MAP(S)                   NO ***
***                                                                                                     ***
***  FLX  COMPUTE FLUX                          NO        FDN  COMPUTE FISSION DENSITIES             NO ***
***                                                                                                     ***
***  SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION  NO        NUB  COMPUTE NU-BAR & AVG FISSION GROUP   YES ***
***                                                                                                     ***
***  MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER   NO        MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION NO ***
***                                                                                                     ***
***  CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER NO        CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION NO ***
***                                                                                                     ***
***  FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER NO        FMP  PRINT FISS PROD MATRIX BY UNIT LOCATION NO ***
***                                                                                                     ***
***  MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER   NO        MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER  NO ***
***                                                                                                     ***
***  CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER NO        CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER NO ***
***                                                                                                     ***
***  FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER NO        FMA  PRINT FISS PROD MATRIX BY ARRAY NUMBER NO ***
***                                                                                                     ***
***  HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL  NO        HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL NO ***
***                                                                                                     ***
***  AMX  PRINT ALL MIXED CROSS SECTIONS        NO        FAR  PRINT FIS. AND ABS. BY REGION         NO ***
***                                                                                                     ***
***  XS1  PRINT 1-D MIXTURE X-SECTIONS          NO        GAS  PRINT FAR BY GROUP                    NO ***
***                                                                                                     ***
***  XS2  PRINT 2-D MIXTURE X-SECTIONS          NO        PAX  PRINT XSEC-ALBEDO CORRELATION TABLES  NO ***
***                                                                                                     ***
***  XAP  PRINT MIXTURE ANGLES & PROBABILITIES  NO        PWT  PRINT WEIGHT AVERAGE ARRAY            NO ***
***                                                                                                     ***
***  PKI  PRINT FISSION SPECTRUM                NO        PGM  PRINT INPUT GEOMETRY                  NO ***
***                                                                                                     ***
***  P1D  PRINT EXTRA 1-D CROSS SECTIONS        NO        BUG  PRINT DEBUG INFORMATION               NO ***
***                                                                                                     ***
***                                                       TRK  PRINT TRACKING INFORMATION            NO ***
***                                                                                                     ***
***                                                                                                     ***
***                                                                                                     ***
***********************************************************************************************************
***********************************************************************************************************
***********************************************************************************************************
                                     PARAMETER INPUT COMPLETED

                      ........    0 IO'S WERE USED READING THE PARAMETER DATA      ........

                      *************** DATA READING COMPLETED ***************
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*****************************************************************************************************************************
***                                                                                                                       ***
***                   TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M***
***                                                                                                                       ***
*****************************************************************************************************************************
*****************************************************************************************************************************
***                                                                                                                       ***
***       UNIT                                                  VOLUME                                                    ***
***      NUMBER                  DATA SET NAME                   NAME       UNIT FUNCTION                                 ***
***      ------                  -------------                   ----       -------------                                 ***
***                                                                                                                       ***
***    XSC  14    C:\svv\yankee\wrr5402\tfn-1000\FT14F001                   MIXED CROSS SECTIONS                          ***
***                                                                                                                       ***
***    ALB  79    G:\scale43\DATALIB\FT79F001                               INPUT ALBEDOS                                 ***
***                                                                                                                       ***
***    WTS  80    G:\scale43\DATALIB\FT80F001                               INPUT WEIGHTS                                 ***
***                                                                                                                       ***
***    SKT  16     UNKNOWN                                                  WRITE SCRATCH DATA                            ***
***                                                                                                                       ***
***    BIN  95    C:\svv\yankee\wrr5402\tfn-1000\FT95F001                   BINARY INPUT DATA                             ***
***                                                                                                                       ***
***    RST  95    C:\svv\yankee\wrr5402\tfn-1000\FT95F001                   READ RESTART DATA                             ***
***                                                                                                                       ***
***    LIB   4    C:\svv\yankee\wrr5402\tfn-1000\FT04F001                   INPUT AMPX WORKING LIBRARY                    ***
***                                                                                                                       ***
***          8    C:\svv\yankee\wrr5402\tfn-1000\FT08F001                   INPUT DATA DIRECT ACCESS                      ***
***                                                                                                                       ***
***          9     UNKNOWN                                                  SUPER GROUPED DIRECT ACCESS                   ***
***                                                                                                                       ***
***         10     UNKNOWN                                                  XSEC MIXING DIRECT ACCESS                     ***
***                                                                                                                       ***
*****************************************************************************************************************************

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

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

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M
                                       MIXING TABLE
                                 NUMBER OF SCATTERING ANGLES =  2
                              CROSS SECTION MESSAGE THRESHOLD =3.0E-05

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

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

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

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

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

MIXTURE =      6           DENSITY(G/CC) =  2.5833
  NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA      AWT             NUCLIDE TITLE
  6005010  7.09799E-03   4.56855E-02    5010    10.0130     B-10 1273 218NGP 042375 P-3 293K                        UPDATED
08/12/94
  6005011  3.92499E-02   2.77771E-01    5011    11.0096      BORON-11         ENDF/B-IV MAT 1160                    UPDATED
08/12/94
  6006012  1.22006E-02   9.41116E-02    6000    12.0001      CARBON-12        ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
  6013027  3.35812E-02   5.82432E-01   13027    26.9818     AL-27 1193 218 GP 040375(5)                             UPDATED
08/12/94

MIXTURE =      7           DENSITY(G/CC) =  11.344
  NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA      AWT             NUCLIDE TITLE
  7082000  3.29690E-02   1.00000E+00   82000   207.2100     PB   1288 218NGP 042375 P-3 293K                        UPDATED
08/12/94

MIXTURE =      8           DENSITY(G/CC) =  1.6307
  NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA      AWT             NUCLIDE TITLE
  8001001  5.84084E-02   5.99323E-02    1001     1.0077      HYDROGEN         ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
  8005010  9.79802E-05   9.99025E-04    5010    10.0130     B-10 1273 218NGP 042375 P-3 293K                        UPDATED
08/12/94
  8005011  3.56450E-04   3.99615E-03    5011    11.0096      BORON-11         ENDF/B-IV MAT 1160                    UPDATED
08/12/94
  8006012  2.26463E-02   2.76729E-01    6000    12.0001      CARBON-12        ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
  8007014  1.40121E-03   1.99805E-02    7014    14.0033      NITROGEN-14      ENDF/B-IV MAT 1275                    UPDATED
08/12/94
  8008016  2.60749E-02   4.24574E-01    8016    15.9904      OXYGEN-16        ENDF/B-IV MAT 1276                    UPDATED
08/12/94
  8013027  7.78110E-03   2.13789E-01   13027    26.9818     AL-27 1193 218 GP 040375(5)                             UPDATED
08/12/94

MIXTURE =      9           DENSITY(G/CC) =  7.8212
  NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA      AWT             NUCLIDE TITLE
  9006012  3.92503E-03   1.00001E-02    6000    12.0001      CARBON-12        ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
  9026000  8.34982E-02   9.90000E-01   26000    55.8447      IRON             ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =     10           DENSITY(G/CC) = 0.99817E-04
  NUCLIDE    ATOM-DENS.    WGT. FRAC.     ZA      AWT             NUCLIDE TITLE
 10001001  6.67692E-06   1.11927E-01    1001     1.0077      HYDROGEN         ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
 10008016  3.33846E-06   8.88074E-01    8016    15.9904      OXYGEN-16        ENDF/B-IV MAT 1276                    UPDATED
08/12/94
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
*******************************************************************************************************
***                                                                                                 ***
***        TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M         ***
***                                                                                                 ***
*******************************************************************************************************
*******************************************************************************************************
***                                                                                                 ***
***                               ****** ADDITIONAL INFORMATION ******                              ***
***                                                                                                 ***
***  NUMBER OF ENERGY GROUPS                 27      USE LATTICE GEOMETRY                      YES  ***
***                                                                                                 ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP  1       GLOBAL ARRAY NUMBER                        60  ***
***                                                                                                 ***
***  NO. OF SCATTERING ANGLES IN XSECS      2      NUMBER OF UNITS IN THE GLOBAL X DIR.        1  ***
***                                                                                                 ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK  33      NUMBER OF UNITS IN THE GLOBAL Y DIR.        1  ***
***                                                                                                 ***
***  ENTRIES/NEUTRON IN THE FISSION BANK  26      NUMBER OF UNITS IN THE GLOBAL Z DIR.        4  ***
***                                                                                                 ***
***  NUMBER OF MIXTURES USED                10      USE A GLOBAL REFLECTOR                    YES  ***
***                                                                                                 ***
***  NUMBER OF BIAS ID'S USED                1      USE NESTED HOLES                          YES  ***
***                                                                                                 ***
***  NUMBER OF DIFFERENTIAL ALBEDOS USED   0      NUMBER OF HOLES                            48  ***
***                                                                                                 ***
***  TOTAL INPUT GEOMETRY REGIONS          133      MAXIMUM HOLE NESTING LEVEL                  3  ***
***                                                                                                 ***
***  NUMBER OF GEOMETRY REGIONS USED       133      USE NESTED ARRAYS                         YES  ***
***                                                                                                 ***
***  LARGEST GEOMETRY UNIT NUMBER          120      NUMBER OF ARRAYS USED                      27  ***
***                                                                                                 ***
***  LARGEST ARRAY NUMBER                   60      MAXIMUM ARRAY NESTING LEVEL                 4  ***
***                                                                                                 ***
***                                                                                                 ***
***  +X BOUNDARY CONDITION             REFLECT      -X BOUNDARY CONDITION                 REFLECT  ***
***                                                                                                 ***
***  +Y BOUNDARY CONDITION             REFLECT      -Y BOUNDARY CONDITION                 REFLECT  ***
***                                                                                                 ***
***  +Z BOUNDARY CONDITION                 PER      -Z BOUNDARY CONDITION                     PER  ***
***                                                                                                 ***
*******************************************************************************************************
```

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	948 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	8.37406E-01	1.12667E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	963 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	8.81055E-01	1.54667E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	948 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	8.74792E-01	1.98667E-01	8.74792E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.50188E-01	2.40833E-01	8.62490E-01	1.23022E-02	0.00000E+00	0.00000E+00
5	8.77478E-01	2.85667E-01	8.67486E-01	8.68389E-03	0.00000E+00	0.00000E+00
6	8.70684E-01	3.29500E-01	8.68285E-01	6.19227E-03	0.00000E+00	0.00000E+00
7	8.43849E-01	3.69000E-01	8.63398E-01	6.84774E-03	0.00000E+00	0.00000E+00
8	8.65031E-01	4.10167E-01	8.63670E-01	5.59777E-03	0.00000E+00	0.00000E+00
9	8.84015E-01	4.50333E-01	8.66577E-01	5.55243E-03	0.00000E+00	0.00000E+00
10	8.94879E-01	4.89833E-01	8.70115E-01	5.96979E-03	0.00000E+00	0.00000E+00
11	8.78442E-01	5.30000E-01	8.71040E-01	5.34555E-03	0.00000E+00	0.00000E+00
12	8.71619E-01	5.70333E-01	8.71098E-01	4.78155E-03	0.00000E+00	0.00000E+00
13	8.55536E-01	6.10667E-01	8.69683E-01	4.55058E-03	0.00000E+00	0.00000E+00
14	8.82806E-01	6.50000E-01	8.70777E-01	4.29561E-03	0.00000E+00	0.00000E+00
15	9.06408E-01	6.89333E-01	8.73518E-01	4.80895E-03	0.00000E+00	0.00000E+00
16	8.76440E-01	7.29667E-01	8.73726E-01	4.45711E-03	0.00000E+00	0.00000E+00
17	8.88423E-01	7.69833E-01	8.74706E-01	4.26345E-03	0.00000E+00	0.00000E+00
18	8.69526E-01	8.08333E-01	8.74382E-01	4.00121E-03	0.00000E+00	0.00000E+00
19	8.96770E-01	8.48667E-01	8.75699E-01	3.98252E-03	0.00000E+00	0.00000E+00
20	9.28071E-01	8.87000E-01	8.78609E-01	4.75012E-03	0.00000E+00	0.00000E+00
21	8.62794E-01	9.27333E-01	8.77776E-01	4.56961E-03	0.00000E+00	0.00000E+00
22	8.55005E-01	9.66667E-01	8.76638E-01	4.48213E-03	0.00000E+00	0.00000E+00
23	9.00226E-01	1.00517E+00	8.77761E-01	4.40885E-03	0.00000E+00	0.00000E+00
24	9.05733E-01	1.04450E+00	8.79033E-01	4.39174E-03	0.00000E+00	0.00000E+00
25	8.73779E-01	1.08667E+00	8.78804E-01	4.20267E-03	0.00000E+00	0.00000E+00
26	8.52265E-01	1.12783E+00	8.77698E-01	4.17293E-03	0.00000E+00	0.00000E+00
27	8.85402E-01	1.16717E+00	8.78006E-01	4.01438E-03	0.00000E+00	0.00000E+00
28	8.91452E-01	1.20750E+00	8.78524E-01	3.89141E-03	0.00000E+00	0.00000E+00
29	9.02320E-01	1.24767E+00	8.79405E-01	3.84683E-03	0.00000E+00	0.00000E+00
30	9.03355E-01	1.28617E+00	8.80260E-01	3.80430E-03	0.00000E+00	0.00000E+00
31	9.06389E-01	1.32550E+00	8.81161E-01	3.77974E-03	0.00000E+00	0.00000E+00
32	8.66698E-01	1.36583E+00	8.80679E-01	3.68326E-03	0.00000E+00	0.00000E+00
33	8.65915E-01	1.40517E+00	8.80203E-01	3.59416E-03	0.00000E+00	0.00000E+00
34	8.79578E-01	1.44550E+00	8.80183E-01	3.48008E-03	0.00000E+00	0.00000E+00
35	8.44839E-01	1.48483E+00	8.79112E-01	3.53894E-03	0.00000E+00	0.00000E+00
36	8.69605E-01	1.52417E+00	8.78833E-01	3.44465E-03	0.00000E+00	0.00000E+00
37	8.92265E-01	1.56267E+00	8.79216E-01	3.36672E-03	0.00000E+00	0.00000E+00
38	8.85513E-01	1.60300E+00	8.79391E-01	3.27654E-03	0.00000E+00	0.00000E+00
39	8.59417E-01	1.64233E+00	8.78852E-01	3.23216E-03	0.00000E+00	0.00000E+00
40	8.59963E-01	1.67983E+00	8.78354E-01	3.18498E-03	0.00000E+00	0.00000E+00
41	8.41635E-01	1.71917E+00	8.77413E-01	3.24197E-03	0.00000E+00	0.00000E+00
42	8.28632E-01	1.75767E+00	8.76193E-01	3.38704E-03	0.00000E+00	0.00000E+00
43	8.76950E-01	1.79617E+00	8.76212E-01	3.30345E-03	0.00000E+00	0.00000E+00
44	8.54718E-01	1.83550E+00	8.75700E-01	3.26420E-03	0.00000E+00	0.00000E+00
45	8.75969E-01	1.87383E+00	8.75706E-01	3.18739E-03	0.00000E+00	0.00000E+00
46	8.51691E-01	1.91417E+00	8.75161E-01	3.16158E-03	0.00000E+00	0.00000E+00
47	8.88452E-01	1.95350E+00	8.75456E-01	3.10461E-03	0.00000E+00	0.00000E+00
48	8.66703E-01	1.99467E+00	8.75266E-01	3.04232E-03	0.00000E+00	0.00000E+00
49	9.09273E-01	2.03417E+00	8.75989E-01	3.06356E-03	0.00000E+00	0.00000E+00
50	9.25346E-01	2.07433E+00	8.77017E-01	3.17043E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	9.12580E-01	3.79325E+01	8.74693E-01	7.88441E-04	0.00000E+00	0.00000E+00
951	8.77250E-01	3.79728E+01	8.74696E-01	7.87614E-04	0.00000E+00	0.00000E+00
952	8.25017E-01	3.80130E+01	8.74643E-01	7.88521E-04	0.00000E+00	0.00000E+00
953	8.91366E-01	3.80523E+01	8.74661E-01	7.87888E-04	0.00000E+00	0.00000E+00
954	8.87194E-01	3.80927E+01	8.74674E-01	7.87170E-04	0.00000E+00	0.00000E+00
955	8.86207E-01	3.81338E+01	8.74686E-01	7.86436E-04	0.00000E+00	0.00000E+00
956	8.45087E-01	3.81750E+01	8.74655E-01	7.86224E-04	0.00000E+00	0.00000E+00
957	8.91207E-01	3.82145E+01	8.74673E-01	7.85591E-04	0.00000E+00	0.00000E+00
958	8.60877E-01	3.82547E+01	8.74658E-01	7.84902E-04	0.00000E+00	0.00000E+00
959	8.46833E-01	3.82958E+01	8.74629E-01	7.84620E-04	0.00000E+00	0.00000E+00
960	8.96081E-01	3.83380E+01	8.74652E-01	7.84121E-04	0.00000E+00	0.00000E+00
961	8.93618E-01	3.83792E+01	8.74671E-01	7.83552E-04	0.00000E+00	0.00000E+00
962	8.75231E-01	3.84195E+01	8.74672E-01	7.82736E-04	0.00000E+00	0.00000E+00
963	8.82148E-01	3.84588E+01	8.74680E-01	7.81960E-04	0.00000E+00	0.00000E+00
964	8.83276E-01	3.84992E+01	8.74689E-01	7.81197E-04	0.00000E+00	0.00000E+00
965	9.39025E-01	3.85403E+01	8.74755E-01	7.83240E-04	0.00000E+00	0.00000E+00
966	8.54465E-01	3.85807E+01	8.74734E-01	7.82710E-04	0.00000E+00	0.00000E+00
967	8.62119E-01	3.86208E+01	8.74721E-01	7.82008E-04	0.00000E+00	0.00000E+00
968	9.00442E-01	3.86620E+01	8.74748E-01	7.81652E-04	0.00000E+00	0.00000E+00
969	9.06123E-01	3.87023E+01	8.74780E-01	7.81517E-04	0.00000E+00	0.00000E+00
970	8.80081E-01	3.87427E+01	8.74786E-01	7.80728E-04	0.00000E+00	0.00000E+00
971	8.84026E-01	3.87828E+01	8.74795E-01	7.79980E-04	0.00000E+00	0.00000E+00
972	8.94924E-01	3.88232E+01	8.74816E-01	7.79452E-04	0.00000E+00	0.00000E+00
973	8.85826E-01	3.88625E+01	8.74827E-01	7.78732E-04	0.00000E+00	0.00000E+00
974	8.68249E-01	3.89020E+01	8.74821E-01	7.77959E-04	0.00000E+00	0.00000E+00
975	8.54260E-01	3.89432E+01	8.74800E-01	7.77447E-04	0.00000E+00	0.00000E+00
976	8.57751E-01	3.89843E+01	8.74782E-01	7.76845E-04	0.00000E+00	0.00000E+00
977	8.82894E-01	3.90237E+01	8.74790E-01	7.76093E-04	0.00000E+00	0.00000E+00
978	8.72030E-01	3.90630E+01	8.74788E-01	7.75302E-04	0.00000E+00	0.00000E+00
979	8.78149E-01	3.91033E+01	8.74791E-01	7.74516E-04	0.00000E+00	0.00000E+00
980	8.44656E-01	3.91427E+01	8.74760E-01	7.74337E-04	0.00000E+00	0.00000E+00
981	8.61601E-01	3.91820E+01	8.74747E-01	7.73662E-04	0.00000E+00	0.00000E+00
982	8.43346E-01	3.92213E+01	8.74715E-01	7.73536E-04	0.00000E+00	0.00000E+00
983	8.84908E-01	3.92617E+01	8.74725E-01	7.72817E-04	0.00000E+00	0.00000E+00
984	9.07479E-01	3.93010E+01	8.74758E-01	7.72750E-04	0.00000E+00	0.00000E+00
985	8.60259E-01	3.93385E+01	8.74744E-01	7.72105E-04	0.00000E+00	0.00000E+00

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

986	8.88639E-01	3.93788E+01	8.74758E-01	7.71449E-04	0.00000E+00	0.00000E+00
987	8.55669E-01	3.94182E+01	8.74738E-01	7.70909E-04	0.00000E+00	0.00000E+00
988	8.79341E-01	3.94575E+01	8.74743E-01	7.70141E-04	0.00000E+00	0.00000E+00
989	8.67160E-01	3.94970E+01	8.74735E-01	7.69398E-04	0.00000E+00	0.00000E+00
990	9.00607E-01	3.95353E+01	8.74762E-01	7.69065E-04	0.00000E+00	0.00000E+00
991	9.00635E-01	3.95757E+01	8.74788E-01	7.68732E-04	0.00000E+00	0.00000E+00
992	8.65557E-01	3.96160E+01	8.74778E-01	7.68012E-04	0.00000E+00	0.00000E+00
993	8.94843E-01	3.96553E+01	8.74799E-01	7.67504E-04	0.00000E+00	0.00000E+00
994	8.91900E-01	3.96947E+01	8.74816E-01	7.66924E-04	0.00000E+00	0.00000E+00
995	8.95329E-01	3.97340E+01	8.74837E-01	7.66429E-04	0.00000E+00	0.00000E+00
996	8.69236E-01	3.97725E+01	8.74831E-01	7.65679E-04	0.00000E+00	0.00000E+00
997	8.88701E-01	3.98128E+01	8.74845E-01	7.65036E-04	0.00000E+00	0.00000E+00
998	8.67711E-01	3.98522E+01	8.74838E-01	7.64301E-04	0.00000E+00	0.00000E+00
999	8.86853E-01	3.98905E+01	8.74850E-01	7.63629E-04	0.00000E+00	0.00000E+00
1000	9.24879E-01	3.99300E+01	8.74900E-01	7.64509E-04	0.00000E+00	0.00000E+00
1001	9.02462E-01	3.99683E+01	8.74928E-01	7.64241E-04	0.00000E+00	0.00000E+00
1002	8.44655E-01	4.00068E+01	8.74897E-01	7.64076E-04	0.00000E+00	0.00000E+00
1003	8.62537E-01	4.00462E+01	8.74885E-01	7.63413E-04	0.00000E+00	0.00000E+00

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

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

LIFETIME = 3.47632E-05 + OR - 7.31644E-08 GENERATION TIME = 2.46340E-05 + OR - 3.61676E-08
NU BAR = 2.44326E+00 + OR - 6.80982E-05 AVERAGE FISSION GROUP = 2.15520E+01 + OR - 3.93530E-03
ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 3.17412E-01 + OR - 9.89744E-04

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.87488	+ OR - 0.00076	0.87412 TO 0.87565	0.87336 TO 0.87641	0.87259 TO 0.87718	1000000
4	0.87491	+ OR - 0.00076	0.87415 TO 0.87567	0.87338 TO 0.87644	0.87262 TO 0.87720	999000
5	0.87491	+ OR - 0.00077	0.87414 TO 0.87567	0.87338 TO 0.87644	0.87261 TO 0.87720	998000
6	0.87491	+ OR - 0.00077	0.87415 TO 0.87568	0.87338 TO 0.87644	0.87261 TO 0.87721	997000
7	0.87494	+ OR - 0.00077	0.87418 TO 0.87571	0.87341 TO 0.87647	0.87264 TO 0.87724	996000
8	0.87495	+ OR - 0.00077	0.87419 TO 0.87572	0.87342 TO 0.87649	0.87265 TO 0.87725	995000
9	0.87494	+ OR - 0.00077	0.87418 TO 0.87571	0.87341 TO 0.87648	0.87264 TO 0.87725	994000
10	0.87492	+ OR - 0.00077	0.87416 TO 0.87569	0.87339 TO 0.87646	0.87262 TO 0.87723	993000
11	0.87492	+ OR - 0.00077	0.87415 TO 0.87569	0.87338 TO 0.87646	0.87261 TO 0.87723	992000
12	0.87492	+ OR - 0.00077	0.87415 TO 0.87569	0.87338 TO 0.87646	0.87261 TO 0.87723	991000
17	0.87489	+ OR - 0.00077	0.87412 TO 0.87566	0.87334 TO 0.87643	0.87257 TO 0.87721	986000
22	0.87485	+ OR - 0.00077	0.87408 TO 0.87562	0.87330 TO 0.87640	0.87253 TO 0.87717	981000
27	0.87480	+ OR - 0.00078	0.87403 TO 0.87558	0.87325 TO 0.87636	0.87248 TO 0.87713	976000
32	0.87471	+ OR - 0.00078	0.87393 TO 0.87548	0.87315 TO 0.87626	0.87237 TO 0.87704	971000
37	0.87473	+ OR - 0.00078	0.87395 TO 0.87551	0.87317 TO 0.87629	0.87238 TO 0.87707	966000
42	0.87483	+ OR - 0.00078	0.87405 TO 0.87561	0.87326 TO 0.87640	0.87248 TO 0.87718	961000
47	0.87486	+ OR - 0.00079	0.87407 TO 0.87564	0.87329 TO 0.87643	0.87250 TO 0.87722	956000
52	0.87474	+ OR - 0.00079	0.87396 TO 0.87553	0.87317 TO 0.87632	0.87238 TO 0.87710	951000
57	0.87470	+ OR - 0.00079	0.87391 TO 0.87549	0.87312 TO 0.87628	0.87233 TO 0.87707	946000
62	0.87473	+ OR - 0.00079	0.87393 TO 0.87552	0.87314 TO 0.87631	0.87235 TO 0.87710	941000
67	0.87464	+ OR - 0.00079	0.87384 TO 0.87543	0.87305 TO 0.87623	0.87226 TO 0.87702	936000
72	0.87462	+ OR - 0.00080	0.87383 TO 0.87542	0.87303 TO 0.87622	0.87223 TO 0.87701	931000
77	0.87463	+ OR - 0.00080	0.87383 TO 0.87543	0.87303 TO 0.87623	0.87223 TO 0.87703	926000
82	0.87460	+ OR - 0.00080	0.87380 TO 0.87541	0.87300 TO 0.87621	0.87220 TO 0.87701	921000
87	0.87460	+ OR - 0.00081	0.87379 TO 0.87540	0.87299 TO 0.87621	0.87218 TO 0.87701	916000
92	0.87462	+ OR - 0.00081	0.87381 TO 0.87542	0.87300 TO 0.87623	0.87220 TO 0.87704	911000

Figure 6.7-1 CSAS Input/Output Summary for Transfer Cask - Normal Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - EXT MOD = 0.0001, INT M

                               FREQUENCY FOR GENERATIONS    4 TO 1003
0.7909 TO 0.7949     *
0.7949 TO 0.7990     *
0.7990 TO 0.8030
0.8030 TO 0.8070     *
0.8070 TO 0.8111
0.8111 TO 0.8151     *
0.8151 TO 0.8192     **
0.8192 TO 0.8232     *****
0.8232 TO 0.8273     ***********
0.8273 TO 0.8313     ***************
0.8313 TO 0.8354     **********
0.8354 TO 0.8394     *********************
0.8394 TO 0.8435     *********************************
0.8435 TO 0.8475     ************************************
0.8475 TO 0.8516     ************************************
0.8516 TO 0.8556     *****************************************
0.8556 TO 0.8597     **************************************
0.8597 TO 0.8637     **************************************************************
0.8637 TO 0.8678     *****************************************************************
0.8678 TO 0.8718     ******************************************************************************
0.8718 TO 0.8759     *******************************************************************
0.8759 TO 0.8799     ***************************************************************
0.8799 TO 0.8840     *************************************************************
0.8840 TO 0.8880     ****************************************************************
0.8880 TO 0.8921     ******************************************************
0.8921 TO 0.8961     **********************************************
0.8961 TO 0.9001     **************************************
0.9001 TO 0.9042     *****************************************
0.9042 TO 0.9082     *****************************
0.9082 TO 0.9123     ***********************
0.9123 TO 0.9163     *****************
0.9163 TO 0.9204     **********
0.9204 TO 0.9244     ********
0.9244 TO 0.9285     ********
0.9285 TO 0.9325     ***
0.9325 TO 0.9366     ***
0.9366 TO 0.9406     **
0.9406 TO 0.9447     ***
0.9447 TO 0.9487
0.9487 TO 0.9528
0.9528 TO 0.9568     **
0.9568 TO 0.9609
0.9609 TO 0.9649
0.9649 TO 0.9690     *
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - water in fuel clad gap
  '
  '       File tf-mr-wg.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE TRANSFER CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '                       WITH WATER IN THE FUEL CLAD GAP
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '       INTERIOR MODERATOR (MATERIAL  3) VOLUME FRACTION = 1.0
  '       EXTERIOR MODERATOR (MATERIAL 10) VOLUME FRACTION = 1.0
  '      WATER GAP MODERATOR (MATERIAL 11) VOLUME FRACTION = 1.0
  '
  27GROUPNDF4 LATTICECELL
  UO2          1             0.95    293.0 92235 4.0 92238 96.0 END
  ZIRCALLOY    2             1.0     293.0                      END
  H2O          3             1.0     293.0                      END
  AL           4             1.0     293.0                      END
  SS304        5             1.0     293.0                      END
  B-10         6  DEN=2.6226 0.0450  293.0                      END
  B-11         6  DEN=2.6226 0.2736  293.0                      END
  C            6  DEN=2.6226 0.0927  293.0                      END
  AL           6  DEN=2.6226 0.5737  293.0                      END
  PB           7             1.0     293.0                      END
  H            8  DEN=1.6291 0.060   293.0                      END
  O            8  DEN=1.6291 0.425   293.0                      END
  C            8  DEN=1.6291 0.277   293.0                      END
  N            8  DEN=1.6291 0.020   293.0                      END
  AL           8  DEN=1.6291 0.214   293.0                      END
  B-10         8  DEN=1.6291 0.001   293.0                      END
  B-11         8  DEN=1.6291 0.004   293.0                      END
  CARBONSTEEL 9              1.0     293.0                      END
  H2O         10             1.0     293.0                      END
  H2O         11             1.0     293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 11 END
  TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - water in fuel clad gap
  READ PARAM RUN=yes PLT=NO  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER 11 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.6604
  CYLINDER 11 1  0.4026   2P0.6604
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.6604
  CYLINDER  5 1  0.5442   2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                          2P2.1400
CUBOID 5 1 4P10.0661                         2P2.1400
CUBOID 3 1 4P10.25681                        2P2.1400
HOLE  14    0.0       10.1615  0.0
HOLE  14    0.0      -10.1615  0.0
HOLE  15    10.1615  0.0       0.0
HOLE  15    -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                         2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    0.0       -0.1584       0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    0.0       0.1584        0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    -0.1584   0.0            0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    0.1584    0.0           0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    0.1584    0.1584        0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                         2P2.1400
HOLE  50    -0.1584   0.1584         0.0
UNIT 57
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                               2P2.1400
HOLE  50   0.1584   -0.1584        0.0
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                               2P2.1400
HOLE  50   -0.1584   -0.1584        0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                               2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                2P0.6604
CUBOID 5 1 4P10.0661                               2P0.6604
CUBOID 3 1 4P10.25681                              2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0      -10.1615  0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                               2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   0.0       -0.1584       0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   0.0       0.1584        0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   -0.1584   0.0           0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   0.1584   0.0           0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   0.1584   0.1584        0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   -0.1584   0.1584        0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   0.1584   -0.1584        0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  60   -0.1584   -0.1584        0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                2P0.6604
CUBOID 5 1 4P10.0661                               2P0.6604
CUBOID 3 1 4P10.25681                              2P0.6604
HOLE  16   0.0       10.1615  0.0
HOLE  16   0.0      -10.1615  0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                               2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  70   0.0       -0.1584       0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  70   0.0       0.1584        0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  70   -0.1584   0.0           0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  70   0.1584   0.0           0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                               2P0.6604
HOLE  70   0.1584   0.1584        0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                               2P0.6604
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
HOLE  70    -0.1584   0.1584       0.0
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                           2P0.6604
HOLE  70    0.1584   -0.1584       0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                           2P0.6604
HOLE  70    -0.1584   -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                           2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN TRANSFER CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253     2P2.1400
HOLE 80     -69.0614 0.0 0.0
HOLE 82     -46.1912 0.0 0.0
HOLE 81      69.0614 0.0 0.0
HOLE 83      46.1912 0.0 0.0
CYLINDER  5 1  89.7128    2P2.1400
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
CYLINDER  0 1  90.805      2P2.1400
CYLINDER  9 1  92.71       2P2.1400
CYLINDER  7 1 101.6        2P2.1400
CYLINDER  8 1 106.68       2P2.1400
CYLINDER  9 1 109.855      2P2.1400
CUBOID   10 1 4P159.855    2P2.1400
UNIT 111
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
HOLE 93       46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
UNIT 112
COM='BASKET ARRAY IN TRANSFER CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249       2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  0 1  90.805      2P0.6604
CYLINDER  9 1  92.71       2P0.6604
CYLINDER  7 1 101.6        2P0.6604
CYLINDER  8 1 106.68       2P0.6604
CYLINDER  9 1 109.855      2P0.6604
CUBOID   10 1 4P159.855    2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -159.855 -159.855 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
53
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
FILL
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
74
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

END DATA
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

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

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

     11              11                    //        11         7777777777777              //    99999999999     666666666666
    111             111                   //        111         777777777777              //    9999999999999   6666666666666
   1111            1111                  //        1111         77         77            //     99         99   66
     11              11                 //           11                   77            //      99         99   66
     11              11                //            11                  77            //       99         99   66
     11              11               //             11                 77            //        9999999999999   666666666666
     11              11              //              11                 77           //          999999999999   6666666666666
     11              11             //               11                77           //                     99   66         66
     11              11            //                11                77          //                      99   66         66
     11              11           //                 11               77          //                       99   66         66
  11111111        11111111       //               11111111            77         //             9999999999999   6666666666666
  11111111        11111111      //                11111111            77        //              999999999999     66666666666

     11         5555555555555                   5555555555555    22222222222                         11          33333333333
    111         5555555555555                   5555555555555   2222222222222                       111         3333333333333
   1111         55                   :::        55              22         22        :::           1111         33         33
     11         55                   :::        55                         22        :::             11                    33
     11         55                   :::        55                         22        :::             11                    33
     11         555555555555                    555555555555             22                          11                   333
     11         5555555555555                   5555555555555          22                            11                   333
     11                    55        :::                   55        22              :::             11                    33
     11                    55        :::                   55      22                :::             11                    33
     11         55         55        :::        55         55    22                  :::             11         33         33
  11111111      5555555555555                   5555555555555   2222222222222                     11111111      3333333333333
  11111111       55555555555                     55555555555    2222222222222                     11111111       33333333333
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

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

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                    PROGRAM VERIFICATION INFORMATION                  *****
*****                                                                      *****
*****                  CODE SYSTEM:   SCALE-PC VERSION:  4.3               *****
*****                                                                      *****
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                                                                      *****
*****                PROGRAM:  CSAS                                        *****
*****                                                                      *****
*****          CREATION DATE:  03-08-96                                    *****
*****                                                                      *****
*****                VOLUME:   ENG                                         *****
*****                                                                      *****
*****               LIBRARY:   G:\scale43\exe                              *****
*****                                                                      *****
*****                                                                      *****
*****        PRODUCTION DOCE:  CSAS                                        *****
*****                                                                      *****
*****                VERSION:  3.1                                         *****
*****                                                                      *****
*****                JOBNAME:  SCALE-PC                                    *****
*****                                                                      *****
*****      DATE OF EXECUTION:  11/17/96                                    *****
*****                                                                      *****
*****      TIME OF EXECUTION:  15:52:13                                    *****
*****                                                                      *****
*****                                                                      *****
********************************************************************************
********************************************************************************
********************************************************************************
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

    **** PROBLEM PARAMETERS ****

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

    **** PROBLEM COMPOSITION DESCRIPTION ****

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

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

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

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

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

    SC  B-10          STANDARD COMPOSITION
    MX              6 MIXTURE NO.
    VF         0.0450 VOLUME FRACTION
    ROTH       2.6226 SPECIFIED DENSITY
    NEL             1 NO. ELEMENTS
    ICP             1 0/1 MIXTURE/COMPOUND
    TEMP        293.0 DEG KELVIN
                 5010       1.00 ATOM/MOLECULE
    END

    SC  B-11          STANDARD COMPOSITION
    MX              6 MIXTURE NO.
    VF         0.2736 VOLUME FRACTION
    ROTH       2.6226 SPECIFIED DENSITY
    NEL             1 NO. ELEMENTS
    ICP             1 0/1 MIXTURE/COMPOUND
    TEMP        293.0 DEG KELVIN
                 5011       1.00 ATOM/MOLECULE
    END

    SC  C             STANDARD COMPOSITION
    MX              6 MIXTURE NO.
    VF         0.0927 VOLUME FRACTION
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
ROTH         2.6226 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               6012      1.00 ATOM/MOLECULE
END

SC  AL              STANDARD COMPOSITION
MX                6 MIXTURE NO.
VF           0.5737 VOLUME FRACTION
ROTH         2.6226 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
              13027      1.00 ATOM/MOLECULE
END

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

SC  H               STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.0600 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               1001      1.00 ATOM/MOLECULE
END

SC  O               STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.4250 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               8016      1.00 ATOM/MOLECULE
END

SC  C               STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.2770 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               6012      1.00 ATOM/MOLECULE
END

SC  N               STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.0200 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               7014      1.00 ATOM/MOLECULE
END

SC  AL              STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.2140 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
              13027      1.00 ATOM/MOLECULE
END

SC  B-10            STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.0010 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               5010      1.00 ATOM/MOLECULE
END

SC  B-11            STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           0.0040 VOLUME FRACTION
ROTH         1.6291 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               5011      1.00 ATOM/MOLECULE
END
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
SC  CARBONSTEEL  STANDARD COMPOSITION
MX             9 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      7.8212 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           26000     99.000 WT%
            6012      1.000 WT%
END

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

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

**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH  CELL TYPE
PITCH     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 CM GAP OUTER DIAMETER
MGAP          11 MIXTURE NO. OF GAP

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

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

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*************************************************************************************************
***                                                                                           ***
***                    TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                           ***
*************************************************************************************************
*************************************************************************************************
***                                                                                           ***
***                      ********** DATA LIBRARY INFORMATION **********                       ***
***                                                                                           ***
***        UNIT                                         VOLUME                                ***
***       NUMBER            DATA SET NAME                NAME        UNIT FUNCTION            ***
***       ------            -------------                ----        -------------            ***
***                                                                                           ***
***         89      G:\scale43\DATALIB\FT89F001                      STANDARD COMPOSITION LIBRARY ***
***                                                                                           ***
***         82      G:\scale43\DATALIB\FT82F001                      CROSS SECTION LIBRARY    ***
***                                                                                           ***
***         11      C:\svv\yankee\wrr5402\tf-mr-wg\FT11F001          SHORT CROSS SECTION LIBRARY ***
***                                                                                           ***
***         90      C:\svv\yankee\wrr5402\tf-mr-wg\FT90F001          INPUT DATA DIRECT ACCESS ***
***                                                                                           ***
*************************************************************************************************
*************************************************************************************************
***                                                                                           ***
***                                                                                           ***
***                          STANDARD COMPOSITION LIBRARY DATA                                ***
***                          ---------------------------------                                ***
***                                                                                           ***
***          UNIT NUMBER  :  89                                                               ***
***                                                                                           ***
***          DATASET NAME :  G:\scale43\DATALIB\FT89F001                                      ***
***                                                                                           ***
***          LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY                             ***
***                          637 STANDARD COMPOSITIONS, 490 NUCLIDES                          ***
***                          90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.                 ***
***                                                                                           ***
***          CREATION DATE:   6/30/95                                                         ***
***                                                                                           ***
***                                                                                           ***
***                                                                                           ***
***                              CROSS SECTION LIBRARY DATA                                   ***
***                             ---------------------------                                   ***
***                                                                                           ***
***          UNIT NUMBER  :  82                                                               ***
***                                                                                           ***
***          DATASET NAME :  G:\scale43\DATALIB\FT82F001                                      ***
***                                                                                           ***
***          LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY                       ***
***                             BASED ON ENDF-B VERSION 4 DATA                                ***
***                                COMPILED FOR NRC     1/27/89                               ***
***                                   LAST UPDATED                                   08/12/94 ***
***                                      L.M.PETRIE   -   ORNL                                ***
***                                                                                           ***
***                                                                                           ***
***                                                                                           ***
***                                                                                           ***
*************************************************************************************************
*************************************************************************************************

CONTROL MODULE CSAS25   IS COMPLETE.
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

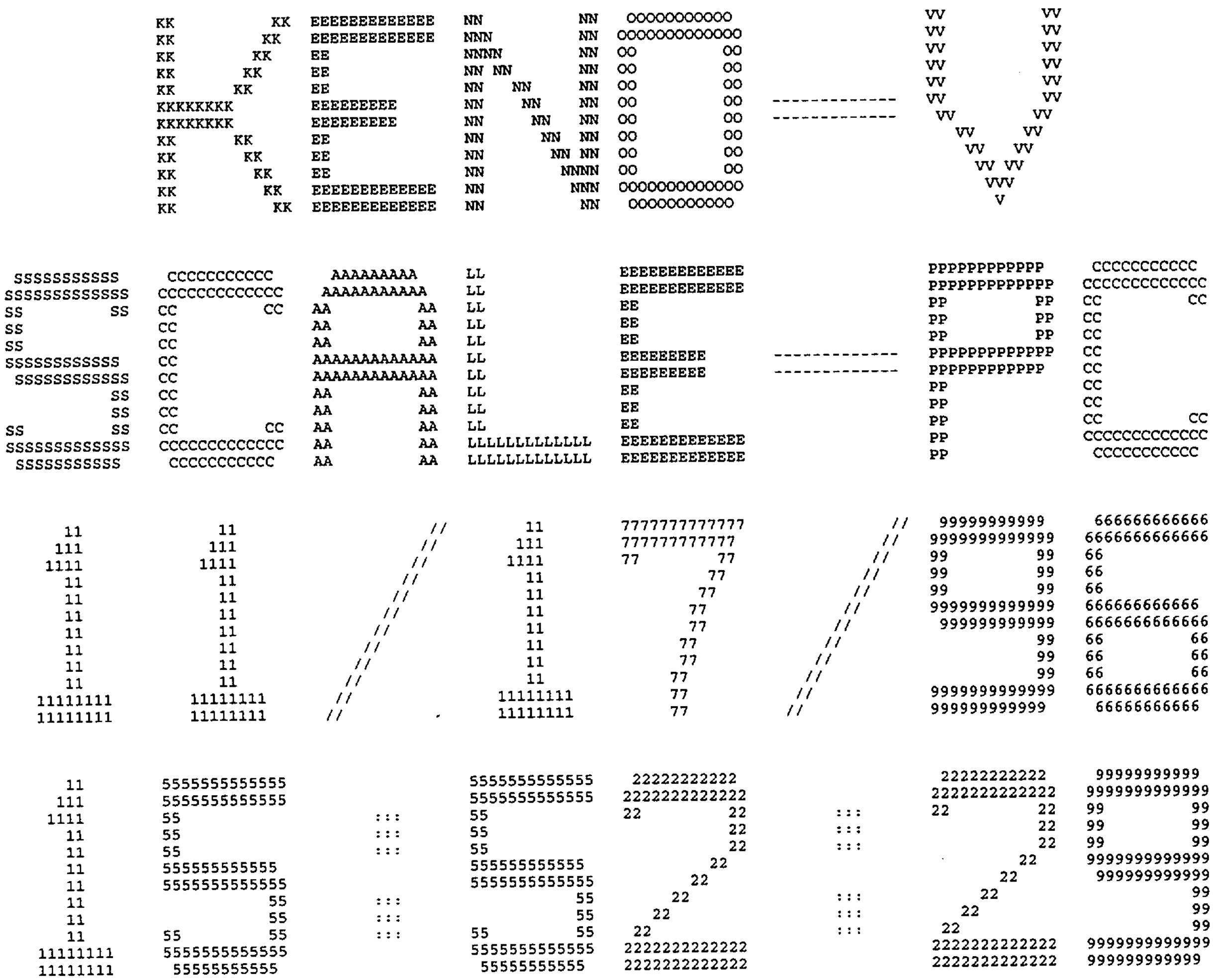

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

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

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                     PROGRAM VERIFICATION INFORMATION                *****
*****                                                                     *****
*****                  CODE SYSTEM:  SCALE-PC VERSION:  4.3               *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****                 PROGRAM:  000009                                    *****
*****                                                                     *****
*****           CREATION DATE:  03-08-96                                  *****
*****                                                                     *****
*****                  VOLUME:  ENG                                       *****
*****                                                                     *****
*****                 LIBRARY:  G:\scale43\exe                            *****
*****                                                                     *****
*****                                                                     *****
*****         PRODUCTION CODE:   KENOVA                                   *****
*****                                                                     *****
*****                 VERSION:   3.1                                      *****
*****                                                                     *****
*****                 JOBNAME:  SCALE-PC                                  *****
*****                                                                     *****
*****       DATE OF EXECUTION:  11/17/96                                  *****
*****                                                                     *****
*****       TIME OF EXECUTION:  15:52:29                                  *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
***************************************************************************************************
***                                                                                             ***
***                TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                             ***
***************************************************************************************************
***                     ******      NUMERIC PARAMETERS      ******                              ***
***                                                                                             ***
***        TME      MAXIMUM PROBLEM TIME (MIN)                      500.00                      ***
***        TBA      TIME PER GENERATION (MIN)                         0.50                      ***
***        GEN      NUMBER OF GENERATIONS                             1003                      ***
***        NPG      NUMBER PER GENERATION                             1000                      ***
***        NSK      NUMBER OF GENERATIONS TO BE SKIPPED                  3                      ***
***        BEG      BEGINNING GENERATION NUMBER                          1                      ***
***        RES      GENERATIONS BETWEEN CHECKPOINTS                      0                      ***
***        X1D      NUMBER OF EXTRA 1-D CROSS SECTIONS                   1                      ***
***        NBK      NEUTRON BANK SIZE                                 1025                      ***
***        XNB      EXTRA POSITIONS IN NEUTRON BANK                      0                      ***
***        NFB      FISSION BANK SIZE                                 1000                      ***
***        XFB      EXTRA POSITIONS IN FISSION BANK                      0                      ***
***        WTA      DEFAULT VALUE OF WEIGHT AVERAGE                 0.5000                      ***
***        WTH      WEIGHT HIGH FOR SPLITTING                       3.0000                      ***
***        WTL      WEIGHT LOW FOR RUSSIAN ROULETTE                 0.3333                      ***
***        RND      STARTING RANDOM NUMBER                     BB827100001                      ***
***        NB8      NUMBER OF D.A. BLOCKS ON UNIT  8                   200                      ***
***        NL8      LENGTH OF D.A. BLOCKS ON UNIT  8                   512                      ***
***        ADJ      MODE OF CALCULATION                            FORWARD                      ***
***                 INPUT DATA WRITTEN ON RESTART UNIT                  NO                      ***
***                 BINARY DATA INTERFACE                              YES                      ***
***                                                                                             ***
***************************************************************************************************
***************************************************************************************************
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*********************************************************************************************************************
*********************************************************************************************************************
***                                                                                                              ***
***                               TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                                              ***
*********************************************************************************************************************
***                               ******      LOGICAL PARAMETERS        ******                                   ***
***                                                                                                              ***
***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA    YES          PLT  PLOT PICTURE MAP(S)                       NO ***
***                                                                                                              ***
***  FLX  COMPUTE FLUX                            NO          FDN  COMPUTE FISSION DENSITIES                 NO ***
***                                                                                                              ***
***  SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION    NO          NUB  COMPUTE NU-BAR & AVG FISSION GROUP       YES ***
***                                                                                                              ***
***  MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER     NO          MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION     NO ***
***                                                                                                              ***
***  CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER   NO          CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION   NO ***
***                                                                                                              ***
***  FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER   NO          FMP  PRINT FISS PROD MATRIX BY UNIT LOCATION   NO ***
***                                                                                                              ***
***  MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER     NO          MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER      NO ***
***                                                                                                              ***
***  CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER   NO          CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER    NO ***
***                                                                                                              ***
***  FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER   NO          FMA  PRINT FISS PROD MATRIX BY ARRAY NUMBER    NO ***
***                                                                                                              ***
***  HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL    NO          HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL     NO ***
***                                                                                                              ***
***  AMX  PRINT ALL MIXED CROSS SECTIONS          NO          FAR  PRINT FIS. AND ABS. BY REGION             NO ***
***                                                                                                              ***
***  XS1  PRINT 1-D MIXTURE X-SECTIONS            NO          GAS  PRINT FAR BY GROUP                        NO ***
***                                                                                                              ***
***  XS2  PRINT 2-D MIXTURE X-SECTIONS            NO          PAX  PRINT XSEC-ALBEDO CORRELATION TABLES      NO ***
***                                                                                                              ***
***  XAP  PRINT MIXTURE ANGLES & PROBABILITIES    NO          PWT  PRINT WEIGHT AVERAGE ARRAY                NO ***
***                                                                                                              ***
***  PKI  PRINT FISSION SPECTRUM                  NO          PGM  PRINT INPUT GEOMETRY                      NO ***
***                                                                                                              ***
***  P1D  PRINT EXTRA 1-D CROSS SECTIONS          NO          BUG  PRINT DEBUG INFORMATION                   NO ***
***                                                                                                              ***
***                                                           TRK  PRINT TRACKING INFORMATION                NO ***
***                                                                                                              ***
***                                                                                                              ***
*********************************************************************************************************************
*********************************************************************************************************************
*********************************************************************************************************************
                                       PARAMETER INPUT COMPLETED

                     ........   0 IO'S WERE USED READING THE PARAMETER DATA      ........

                    *************** DATA READING COMPLETED ***************
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
*******************************************************************************************************
***                                                                                                 ***
***                       TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP ***
***                                                                                                 ***
*******************************************************************************************************
*******************************************************************************************************
***                                                                                                 ***
***      UNIT                                                 VOLUME                                ***
***     NUMBER                 DATA SET NAME                   NAME      UNIT FUNCTION              ***
***     ------                 -------------                   ----      -------------              ***
***                                                                                                 ***
***   XSC  14   C:\svv\yankee\wrr5402\tf-mr-wg\FT14F001                  MIXED CROSS SECTIONS       ***
***                                                                                                 ***
***   ALB  79   G:\scale43\DATALIB\FT79F001                              INPUT ALBEDOS              ***
***                                                                                                 ***
***   WTS  80   G:\scale43\DATALIB\FT80F001                              INPUT WEIGHTS              ***
***                                                                                                 ***
***   SKT  16    UNKNOWN                                                 WRITE SCRATCH DATA         ***
***                                                                                                 ***
***   BIN  95   C:\svv\yankee\wrr5402\tf-mr-wg\FT95F001                  BINARY INPUT DATA          ***
***                                                                                                 ***
***   RST  95   C:\svv\yankee\wrr5402\tf-mr-wg\FT95F001                  READ RESTART DATA          ***
***                                                                                                 ***
***   LIB   4   C:\svv\yankee\wrr5402\tf-mr-wg\FT04F001                  INPUT AMPX WORKING LIBRARY ***
***                                                                                                 ***
***         8   C:\svv\yankee\wrr5402\tf-mr-wg\FT08F001                  INPUT DATA DIRECT ACCESS   ***
***                                                                                                 ***
***         9    UNKNOWN                                                 SUPER GROUPED DIRECT ACCESS ***
***                                                                                                 ***
***        10    UNKNOWN                                                 XSEC MIXING DIRECT ACCESS  ***
***                                                                                                 ***
*******************************************************************************************************

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

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

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
                         TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP
                                    MIXING TABLE
                          NUMBER OF SCATTERING ANGLES =  2
                        CROSS SECTION MESSAGE THRESHOLD =3.0E-05

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

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

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

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

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

MIXTURE =     6          DENSITY(G/CC) =  2.5833
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
   6005010 7.09799E-03  4.56855E-02   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                      UPDATED
08/12/94
   6005011 3.92499E-02  2.77771E-01   5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   6006012 1.22006E-02  9.41116E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   6013027 3.35812E-02  5.82432E-01   13027   26.9818    AL-27 1193 218 GP 040375(5)                           UPDATED
08/12/94

MIXTURE =     7          DENSITY(G/CC) =  11.344
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
   7082000 3.29690E-02  1.00000E+00   82000   207.2100   PB   1288 218NGP 042375 P-3 293K                      UPDATED
08/12/94

MIXTURE =     8          DENSITY(G/CC) =  1.6307
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
   8001001 5.84084E-02  5.99323E-02   1001    1.0077      HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
   8005010 9.79802E-05  9.99025E-04   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                      UPDATED
08/12/94
   8005011 3.56450E-04  3.99615E-03   5011    11.0096     BORON-11       ENDF/B-IV MAT 1160                    UPDATED
08/12/94
   8006012 2.26463E-02  2.76729E-01   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   8007014 1.40121E-03  1.99805E-02   7014    14.0033     NITROGEN-14    ENDF/B-IV MAT 1275                    UPDATED
08/12/94
   8008016 2.60749E-02  4.24574E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
   8013027 7.78110E-03  2.13789E-01   13027   26.9818    AL-27 1193 218 GP 040375(5)                           UPDATED
08/12/94

MIXTURE =     9          DENSITY(G/CC) =  7.8212
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
   9006012 3.92503E-03  1.00001E-02   6000    12.0001     CARBON-12      ENDF/B-IV MAT 1274/THRM1065           UPDATED
08/12/94
   9026000 8.34982E-02  9.90000E-01   26000   55.8447     IRON           ENDF/B-IV MAT 1192                    UPDATED
08/12/94

MIXTURE =    10          DENSITY(G/CC) = 0.99817
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
  10001001 6.67692E-02  1.11927E-01   1001    1.0077      HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
  10008016 3.33846E-02  8.88074E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94

MIXTURE =    11          DENSITY(G/CC) = 0.99817
   NUCLIDE  ATOM-DENS.   WGT. FRAC.    ZA      AWT               NUCLIDE TITLE
  11001001 6.67692E-02  1.11927E-01   1001    1.0077      HYDROGEN       ENDF/B-IV MAT 1269/THRM1002           UPDATED
08/12/94
  11008016 3.33846E-02  8.88074E-01   8016    15.9904     OXYGEN-16      ENDF/B-IV MAT 1276                    UPDATED
08/12/94
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

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*************************************************************************************************
***                                                                                           ***
***        TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP    ***
***                                                                                           ***
*************************************************************************************************
*************************************************************************************************
***                                                                                           ***
***                         ****** ADDITIONAL INFORMATION ******                              ***
***                                                                                           ***
***  NUMBER OF ENERGY GROUPS               27        USE LATTICE GEOMETRY                 YES ***
***                                                                                           ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP   1        GLOBAL ARRAY NUMBER                   60 ***
***                                                                                           ***
***  NO. OF SCATTERING ANGLES IN XSECS      2        NUMBER OF UNITS IN THE GLOBAL X DIR.   1 ***
***                                                                                           ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK   33        NUMBER OF UNITS IN THE GLOBAL Y DIR.   1 ***
***                                                                                           ***
***  ENTRIES/NEUTRON IN THE FISSION BANK   26        NUMBER OF UNITS IN THE GLOBAL Z DIR.   4 ***
***                                                                                           ***
***  NUMBER OF MIXTURES USED               11        USE A GLOBAL REFLECTOR               YES ***
***                                                                                           ***
***  NUMBER OF BIAS ID'S USED               1        USE NESTED HOLES                     YES ***
***                                                                                           ***
***  NUMBER OF DIFFERENTIAL ALBEDOS USED    0        NUMBER OF HOLES                       48 ***
***                                                                                           ***
***  TOTAL INPUT GEOMETRY REGIONS         133        MAXIMUM HOLE NESTING LEVEL             3 ***
***                                                                                           ***
***  NUMBER OF GEOMETRY REGIONS USED      133        USE NESTED ARRAYS                    YES ***
***                                                                                           ***
***  LARGEST GEOMETRY UNIT NUMBER         120        NUMBER OF ARRAYS USED                 27 ***
***                                                                                           ***
***  LARGEST ARRAY NUMBER                  60        MAXIMUM ARRAY NESTING LEVEL            4 ***
***                                                                                           ***
***                                                                                           ***
***  +X BOUNDARY CONDITION            REFLECT        -X BOUNDARY CONDITION            REFLECT ***
***                                                                                           ***
***  +Y BOUNDARY CONDITION            REFLECT        -Y BOUNDARY CONDITION            REFLECT ***
***                                                                                           ***
***  +Z BOUNDARY CONDITION                PER        -Z BOUNDARY CONDITION                PER ***
***                                                                                           ***
*************************************************************************************************
```

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER	K5-132	WARNING....ONLY	960 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	8.38679E-01	1.08833E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
2	9.42980E-01	1.48167E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER	K5-132	WARNING....ONLY	932 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	8.79994E-01	1.86667E-01	8.79994E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.82794E-01	2.27000E-01	8.81394E-01	1.40035E-03	0.00000E+00	0.00000E+00
5	8.34080E-01	2.66333E-01	8.65623E-01	1.57920E-02	0.00000E+00	0.00000E+00
6	8.72462E-01	3.07500E-01	8.67333E-01	1.12968E-02	0.00000E+00	0.00000E+00
7	8.52487E-01	3.56000E-01	8.64363E-01	9.24043E-03	0.00000E+00	0.00000E+00
8	8.86952E-01	4.00000E-01	8.68128E-01	8.43192E-03	0.00000E+00	0.00000E+00
9	9.00160E-01	4.40333E-01	8.72704E-01	8.46893E-03	0.00000E+00	0.00000E+00
10	9.27940E-01	4.77833E-01	8.79609E-01	1.00729E-02	0.00000E+00	0.00000E+00
11	8.82204E-01	5.19000E-01	8.79897E-01	8.88814E-03	0.00000E+00	0.00000E+00
12	9.06370E-01	5.60167E-01	8.82544E-01	8.37898E-03	0.00000E+00	0.00000E+00
13	9.02590E-01	5.99500E-01	8.84367E-01	7.79507E-03	0.00000E+00	0.00000E+00
14	8.60403E-01	6.38833E-01	8.82370E-01	7.39080E-03	0.00000E+00	0.00000E+00
15	8.63454E-01	6.82833E-01	8.80914E-01	6.95252E-03	0.00000E+00	0.00000E+00
16	8.77766E-01	7.22167E-01	8.80690E-01	6.44070E-03	0.00000E+00	0.00000E+00
17	8.84876E-01	7.62500E-01	8.80969E-01	6.00246E-03	0.00000E+00	0.00000E+00
18	8.73653E-01	8.01833E-01	8.80511E-01	5.63338E-03	0.00000E+00	0.00000E+00
19	8.76214E-01	8.40333E-01	8.80259E-01	5.29767E-03	0.00000E+00	0.00000E+00
20	8.83080E-01	8.78667E-01	8.80415E-01	4.99715E-03	0.00000E+00	0.00000E+00
21	8.86274E-01	9.18167E-01	8.80724E-01	4.73688E-03	0.00000E+00	0.00000E+00
22	8.81537E-01	9.56500E-01	8.80764E-01	4.49398E-03	0.00000E+00	0.00000E+00
23	8.49911E-01	9.97667E-01	8.79295E-01	4.52007E-03	0.00000E+00	0.00000E+00
24	8.97669E-01	1.03617E+00	8.80130E-01	4.38990E-03	0.00000E+00	0.00000E+00
25	8.52765E-01	1.07550E+00	8.78941E-01	4.36017E-03	0.00000E+00	0.00000E+00
26	9.06153E-01	1.11500E+00	8.80074E-01	4.32579E-03	0.00000E+00	0.00000E+00
27	8.73814E-01	1.15433E+00	8.79824E-01	4.15670E-03	0.00000E+00	0.00000E+00
28	8.85887E-01	1.19367E+00	8.80057E-01	4.00044E-03	0.00000E+00	0.00000E+00
29	8.88861E-01	1.23300E+00	8.80383E-01	3.86321E-03	0.00000E+00	0.00000E+00
30	9.03642E-01	1.27233E+00	8.81214E-01	3.81423E-03	0.00000E+00	0.00000E+00
31	9.16851E-01	1.31267E+00	8.82443E-01	3.88009E-03	0.00000E+00	0.00000E+00
32	8.58351E-01	1.35300E+00	8.81640E-01	3.83358E-03	0.00000E+00	0.00000E+00
33	8.87792E-01	1.39133E+00	8.81838E-01	3.71316E-03	0.00000E+00	0.00000E+00
34	8.76488E-01	1.43067E+00	8.81671E-01	3.59914E-03	0.00000E+00	0.00000E+00
35	8.81292E-01	1.46917E+00	8.81660E-01	3.48839E-03	0.00000E+00	0.00000E+00
36	8.48341E-01	1.50850E+00	8.80680E-01	3.52326E-03	0.00000E+00	0.00000E+00
37	8.68676E-01	1.54783E+00	8.80337E-01	3.43826E-03	0.00000E+00	0.00000E+00
38	8.83753E-01	1.58733E+00	8.80431E-01	3.34274E-03	0.00000E+00	0.00000E+00
39	8.71009E-01	1.62667E+00	8.80177E-01	3.26110E-03	0.00000E+00	0.00000E+00
40	8.74951E-01	1.66600E+00	8.80039E-01	3.17710E-03	0.00000E+00	0.00000E+00
41	8.93585E-01	1.70450E+00	8.80387E-01	3.11399E-03	0.00000E+00	0.00000E+00
42	8.90604E-01	1.74383E+00	8.80642E-01	3.04587E-03	0.00000E+00	0.00000E+00
43	8.84406E-01	1.78967E+00	8.80734E-01	2.97207E-03	0.00000E+00	0.00000E+00
44	9.19408E-01	1.82900E+00	8.81655E-01	3.04310E-03	0.00000E+00	0.00000E+00
45	8.67636E-01	1.87200E+00	8.81329E-01	2.98932E-03	0.00000E+00	0.00000E+00
46	8.64888E-01	1.91583E+00	8.80955E-01	2.94440E-03	0.00000E+00	0.00000E+00
47	8.74001E-01	1.95533E+00	8.80800E-01	2.88237E-03	0.00000E+00	0.00000E+00
48	8.70232E-01	1.99467E+00	8.80571E-01	2.82836E-03	0.00000E+00	0.00000E+00
49	9.08330E-01	2.03500E+00	8.81161E-01	2.82985E-03	0.00000E+00	0.00000E+00
50	8.93306E-01	2.07433E+00	8.81414E-01	2.78180E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	8.61184E-01	3.76597E+01	8.83707E-01	7.49771E-04	0.00000E+00	0.00000E+00
951	9.38198E-01	3.76998E+01	8.83765E-01	7.51178E-04	0.00000E+00	0.00000E+00
952	8.70550E-01	3.77402E+01	8.83751E-01	7.50516E-04	0.00000E+00	0.00000E+00
953	8.62074E-01	3.77805E+01	8.83728E-01	7.50073E-04	0.00000E+00	0.00000E+00
954	8.87262E-01	3.78198E+01	8.83732E-01	7.49294E-04	0.00000E+00	0.00000E+00
955	8.75056E-01	3.78592E+01	8.83723E-01	7.48562E-04	0.00000E+00	0.00000E+00
956	8.85677E-01	3.79003E+01	8.83725E-01	7.47780E-04	0.00000E+00	0.00000E+00
957	8.60378E-01	3.79397E+01	8.83700E-01	7.47396E-04	0.00000E+00	0.00000E+00
958	9.04548E-01	3.79790E+01	8.83722E-01	7.46933E-04	0.00000E+00	0.00000E+00
959	9.11408E-01	3.80193E+01	8.83751E-01	7.46712E-04	0.00000E+00	0.00000E+00
960	8.77433E-01	3.80597E+01	8.83745E-01	7.45962E-04	0.00000E+00	0.00000E+00
961	9.30274E-01	3.80982E+01	8.83793E-01	7.46761E-04	0.00000E+00	0.00000E+00
962	8.70589E-01	3.81383E+01	8.83779E-01	7.46110E-04	0.00000E+00	0.00000E+00
963	8.76762E-01	3.81787E+01	8.83772E-01	7.45369E-04	0.00000E+00	0.00000E+00
964	9.30255E-01	3.82190E+01	8.83820E-01	7.46160E-04	0.00000E+00	0.00000E+00
965	8.86082E-01	3.82602E+01	8.83823E-01	7.45388E-04	0.00000E+00	0.00000E+00
966	8.37636E-01	3.83003E+01	8.83775E-01	7.46154E-04	0.00000E+00	0.00000E+00
967	9.13884E-01	3.83398E+01	8.83806E-01	7.46033E-04	0.00000E+00	0.00000E+00
968	9.01212E-01	3.83782E+01	8.83824E-01	7.45479E-04	0.00000E+00	0.00000E+00
969	8.98383E-01	3.84185E+01	8.83839E-01	7.44859E-04	0.00000E+00	0.00000E+00
970	9.02978E-01	3.84578E+01	8.83859E-01	7.44352E-04	0.00000E+00	0.00000E+00
971	9.18267E-01	3.84982E+01	8.83894E-01	7.44431E-04	0.00000E+00	0.00000E+00
972	8.78049E-01	3.85375E+01	8.83888E-01	7.43688E-04	0.00000E+00	0.00000E+00
973	8.52884E-01	3.85797E+01	8.83856E-01	7.43607E-04	0.00000E+00	0.00000E+00
974	8.45918E-01	3.86190E+01	8.83817E-01	7.43866E-04	0.00000E+00	0.00000E+00
975	8.58468E-01	3.86583E+01	8.83791E-01	7.43558E-04	0.00000E+00	0.00000E+00
976	9.44680E-01	3.86968E+01	8.83854E-01	7.45420E-04	0.00000E+00	0.00000E+00
977	9.16211E-01	3.87362E+01	8.83887E-01	7.45394E-04	0.00000E+00	0.00000E+00
978	8.71239E-01	3.87755E+01	8.83874E-01	7.44743E-04	0.00000E+00	0.00000E+00
979	8.98959E-01	3.88167E+01	8.83889E-01	7.44141E-04	0.00000E+00	0.00000E+00
980	9.29580E-01	3.88578E+01	8.83936E-01	7.44846E-04	0.00000E+00	0.00000E+00
981	8.87870E-01	3.88973E+01	8.83940E-01	7.44096E-04	0.00000E+00	0.00000E+00
982	9.04001E-01	3.89367E+01	8.83961E-01	7.43618E-04	0.00000E+00	0.00000E+00
983	8.56109E-01	3.89768E+01	8.83932E-01	7.43402E-04	0.00000E+00	0.00000E+00
984	8.79591E-01	3.90163E+01	8.83928E-01	7.42657E-04	0.00000E+00	0.00000E+00
985	9.29226E-01	3.90557E+01	8.83974E-01	7.43331E-04	0.00000E+00	0.00000E+00
986	8.77684E-01	3.90950E+01	8.83968E-01	7.42603E-04	0.00000E+00	0.00000E+00

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

987	8.91019E-01	3.91353E+01	8.83975E-01	7.41883E-04	0.00000E+00	0.00000E+00
988	8.83327E-01	3.91747E+01	8.83974E-01	7.41131E-04	0.00000E+00	0.00000E+00
989	8.90881E-01	3.92130E+01	8.83981E-01	7.40412E-04	0.00000E+00	0.00000E+00
990	8.95827E-01	3.92533E+01	8.83993E-01	7.39760E-04	0.00000E+00	0.00000E+00
991	8.83975E-01	3.92937E+01	8.83993E-01	7.39012E-04	0.00000E+00	0.00000E+00
992	8.88243E-01	3.93338E+01	8.83997E-01	7.38277E-04	0.00000E+00	0.00000E+00
993	8.61167E-01	3.93742E+01	8.83974E-01	7.37891E-04	0.00000E+00	0.00000E+00
994	8.94656E-01	3.94145E+01	8.83985E-01	7.37226E-04	0.00000E+00	0.00000E+00
995	8.47387E-01	3.94547E+01	8.83948E-01	7.37405E-04	0.00000E+00	0.00000E+00
996	9.31154E-01	3.94950E+01	8.83996E-01	7.38192E-04	0.00000E+00	0.00000E+00
997	8.82171E-01	3.95343E+01	8.83994E-01	7.37452E-04	0.00000E+00	0.00000E+00
998	8.57257E-01	3.95755E+01	8.83967E-01	7.37200E-04	0.00000E+00	0.00000E+00
999	8.41131E-01	3.96150E+01	8.83924E-01	7.37712E-04	0.00000E+00	0.00000E+00
1000	9.17187E-01	3.96552E+01	8.83957E-01	7.37726E-04	0.00000E+00	0.00000E+00
1001	9.33352E-01	3.96937E+01	8.84007E-01	7.38644E-04	0.00000E+00	0.00000E+00
1002	8.90597E-01	3.97358E+01	8.84013E-01	7.37934E-04	0.00000E+00	0.00000E+00
1003	8.92086E-01	3.97742E+01	8.84021E-01	7.37241E-04	0.00000E+00	0.00000E+00

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

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
                                        TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

LIFETIME =  3.45256E-05 + OR -  6.86456E-08          GENERATION TIME =  2.47901E-05 + OR -  3.68122E-08
NU BAR   =  2.44276E+00 + OR -  6.93264E-05     AVERAGE FISSION GROUP =  2.16172E+01 + OR -  3.98797E-03
                     ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION =  3.02159E-01 + OR -  9.59208E-04
```

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.88403	+ OR - 0.00074	0.88329 TO 0.88476	0.88255 TO 0.88550	0.88181 TO 0.88624	1000000
4	0.88403	+ OR - 0.00074	0.88329 TO 0.88477	0.88255 TO 0.88550	0.88181 TO 0.88624	999000
5	0.88408	+ OR - 0.00074	0.88334 TO 0.88481	0.88260 TO 0.88555	0.88186 TO 0.88629	998000
6	0.88409	+ OR - 0.00074	0.88335 TO 0.88483	0.88261 TO 0.88557	0.88187 TO 0.88630	997000
7	0.88412	+ OR - 0.00074	0.88338 TO 0.88486	0.88264 TO 0.88560	0.88190 TO 0.88634	996000
8	0.88412	+ OR - 0.00074	0.88338 TO 0.88486	0.88264 TO 0.88560	0.88190 TO 0.88633	995000
9	0.88410	+ OR - 0.00074	0.88336 TO 0.88484	0.88262 TO 0.88558	0.88188 TO 0.88632	994000
10	0.88406	+ OR - 0.00074	0.88332 TO 0.88480	0.88258 TO 0.88554	0.88184 TO 0.88627	993000
11	0.88406	+ OR - 0.00074	0.88332 TO 0.88480	0.88258 TO 0.88554	0.88184 TO 0.88628	992000
12	0.88404	+ OR - 0.00074	0.88330 TO 0.88478	0.88256 TO 0.88552	0.88182 TO 0.88626	991000
17	0.88407	+ OR - 0.00074	0.88332 TO 0.88481	0.88258 TO 0.88555	0.88184 TO 0.88630	986000
22	0.88409	+ OR - 0.00075	0.88334 TO 0.88483	0.88259 TO 0.88558	0.88185 TO 0.88633	981000
27	0.88413	+ OR - 0.00075	0.88338 TO 0.88488	0.88263 TO 0.88563	0.88188 TO 0.88637	976000
32	0.88410	+ OR - 0.00075	0.88334 TO 0.88485	0.88259 TO 0.88560	0.88184 TO 0.88635	971000
37	0.88415	+ OR - 0.00075	0.88340 TO 0.88491	0.88265 TO 0.88566	0.88189 TO 0.88642	966000
42	0.88416	+ OR - 0.00076	0.88340 TO 0.88492	0.88265 TO 0.88568	0.88189 TO 0.88643	961000
47	0.88417	+ OR - 0.00076	0.88341 TO 0.88493	0.88265 TO 0.88569	0.88189 TO 0.88645	956000
52	0.88411	+ OR - 0.00076	0.88334 TO 0.88487	0.88258 TO 0.88563	0.88182 TO 0.88639	951000
57	0.88413	+ OR - 0.00076	0.88336 TO 0.88489	0.88260 TO 0.88565	0.88183 TO 0.88642	946000
62	0.88417	+ OR - 0.00077	0.88341 TO 0.88494	0.88264 TO 0.88571	0.88187 TO 0.88647	941000
67	0.88417	+ OR - 0.00077	0.88341 TO 0.88494	0.88264 TO 0.88571	0.88187 TO 0.88647	936000
72	0.88421	+ OR - 0.00077	0.88344 TO 0.88498	0.88267 TO 0.88575	0.88190 TO 0.88652	931000
77	0.88422	+ OR - 0.00077	0.88345 TO 0.88499	0.88267 TO 0.88577	0.88190 TO 0.88654	926000
82	0.88424	+ OR - 0.00077	0.88346 TO 0.88501	0.88269 TO 0.88578	0.88191 TO 0.88656	921000
87	0.88421	+ OR - 0.00078	0.88343 TO 0.88499	0.88265 TO 0.88576	0.88188 TO 0.88654	916000
92	0.88414	+ OR - 0.00078	0.88336 TO 0.88492	0.88258 TO 0.88570	0.88179 TO 0.88648	911000

Figure 6.7-2 CSAS Input/Output Summary for Transfer Cask - Accident Conditions (Continued)

```
TRANSFER CASK CRITICALITY: MOST REACTIVE CONFIGURATION - WATER IN FUEL CLAD GAP

                              FREQUENCY FOR GENERATIONS     4 TO 1003
0.8068 TO 0.8099    *
0.8099 TO 0.8130
0.8130 TO 0.8160
0.8160 TO 0.8191    **
0.8191 TO 0.8222    *
0.8222 TO 0.8253    *
0.8253 TO 0.8283    ***
0.8283 TO 0.8314    ***
0.8314 TO 0.8345    *******
0.8345 TO 0.8376    ***
0.8376 TO 0.8406    ***********
0.8406 TO 0.8437    *********
0.8437 TO 0.8468    ************
0.8468 TO 0.8499    *****************
0.8499 TO 0.8529    *********************
0.8529 TO 0.8560    ***********************
0.8560 TO 0.8591    ****************************
0.8591 TO 0.8621    *********************************
0.8621 TO 0.8652    **************************************
0.8652 TO 0.8683    *************************************
0.8683 TO 0.8714    ****************************************************
0.8714 TO 0.8744    *******************************************
0.8744 TO 0.8775    ***************************************************
0.8775 TO 0.8806    *********************************************
0.8806 TO 0.8837    ************************************************
0.8837 TO 0.8867    ***************************************************************
0.8867 TO 0.8898    ********************************************
0.8898 TO 0.8929    *********************************************************
0.8929 TO 0.8960    ***********************************************
0.8960 TO 0.8990    ********************************************
0.8990 TO 0.9021    **************************************
0.9021 TO 0.9052    *******************************
0.9052 TO 0.9082    ********************************
0.9082 TO 0.9113    *****************************
0.9113 TO 0.9144    ****************************
0.9144 TO 0.9175    ****************************
0.9175 TO 0.9205    *******************
0.9205 TO 0.9236    **********
0.9236 TO 0.9267    ******
0.9267 TO 0.9298    *******
0.9298 TO 0.9328    ******
0.9328 TO 0.9359    *******
0.9359 TO 0.9390    *****
0.9390 TO 0.9421    **
0.9421 TO 0.9451    ****
0.9451 TO 0.9482
0.9482 TO 0.9513
0.9513 TO 0.9543    ***
0.9543 TO 0.9574
0.9574 TO 0.9605    *
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
  WRR EC455-5302 YANKEE Storage CASK KENO-Va MODEL Base Case
  '
  '   File: storage.in
  '
  '   THIS IS A BASE CASE MODEL OF THE NAC-MPC BASKET
  '   LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '           INSERTED INTO THE STORAGE CASK
  '
  '   The normal condition is dry (0.0001) everywhere
  '
  '
  '        material     volume
  '         number     fraction
  '        --------    --------
  '            3        0.0001     inside canister
  '            7        0.0001     canister/VCC gap
  '           10        0.0001     external to VCC
  '
  '
  '             PRODUCED FOR THE YANKEE ROWE
  '                STC LICENSE AMENDMENT
  '
  27GROUPNDF4 LATTICECELL
  UO2          1              0.95    293.0 92235 4.0 92238 96.0 END
  ZIRCALLOY    2              1.0     293.0                      END
  H2O          3              0.0001  293.0                      END
  AL           4              1.0     293.0                      END
  SS304        5              1.0     293.0                      END
  B-10         6   DEN=2.6226 0.0450  293.0                      END
  B-11         6   DEN=2.6226 0.2736  293.0                      END
  C            6   DEN=2.6226 0.0927  293.0                      END
  AL           6   DEN=2.6226 0.5737  293.0                      END
  H2O          7              0.0001  293.0                      END
  CARBONSTEEL  8              1.0     293.0                      END
  REG-CONCRETE 9   DEN=2.243  1.0     293.0                      END
  H2O         10              0.0001  293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 0 END
  WRR EC455-5302 YANKEE Storage CASK KENO-Va MODEL Base Case
  READ PARAM RUN=yes PLT=YES GEN=1003 NPG=1000 tme=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1654
  CYLINDER  0 1  0.4026    2P2.1654
  CYLINDER  2 1  0.4635    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1654
  CYLINDER  5 1  0.5442    2P2.1654
  CUBOID    3 1  4P0.5944  2P2.1654
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943   2P0.635
  CYLINDER  0 1  0.4026   2P0.635
  CYLINDER  2 1  0.4635   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998   2P0.635
  CYLINDER  5 1  0.5442   2P0.635
  CUBOID    3 1  4P0.5944 2P0.635
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1654
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1654
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P0.0318 2P9.144 2P2.1654
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
CUBOID 4 1 2P0.0953 2P9.144 2P2.1654
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.635
CUBOID 4 1 2P9.144 2P0.0953 2P0.635
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.635
CUBOID 4 1 2P0.0953 2P9.144 2P0.635
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4826 2P0.9525 2P2.1654
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4826 2P1.0287 2P2.1654
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4826 2P1.1112 2P2.1654
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1112 2P79.5630 2P2.1654
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4826 2P0.9525 2P0.635
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4826 2P1.0287 2P0.635
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4826 2P1.1112 2P0.635
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1112 2P79.5630 2P0.635
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4445 2P0.9906 2P0.635
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4445 2P1.0668 2P0.635
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4445 2P1.1493 2P0.635
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1493 2P79.5249 2P0.635
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='WATER LEVEL ASSEMBLY CELL'
ARRAY  1  -9.5104 -9.5104 -2.1654
CUBOID 3 1 4P9.906                          2P2.1654
CUBOID 5 1 4P10.028                         2P2.1654
CUBOID 3 1 4P10.2187                        2P2.1654
HOLE  14   0.0       10.1234  0.0
HOLE  14   0.0      -10.1234  0.0
HOLE  15   10.1234  0.0       0.0
HOLE  15   -10.1234 0.0       0.0
CUBOID 5 1 4P10.267                         2P2.1654
CUBOID 3 1 4P10.4826                        2P2.1654
UNIT 51
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4826                        2P2.1654

'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='SUPPORT DISK ASSEMBLY CELL'
ARRAY  2  -9.5104 -9.5104 -0.635
CUBOID 3 1 4P9.906                          2P0.635
CUBOID 5 1 4P10.028                         2P0.635
CUBOID 3 1 4P10.2187                        2P0.635
HOLE  16   0.0       10.1234  0.0
HOLE  16   0.0      -10.1234  0.0
HOLE  17   10.1234  0.0       0.0
HOLE  17   -10.1234 0.0       0.0
CUBOID 5 1 4P10.267                         2P0.635
CUBOID 3 1 4P10.4826                        2P0.635
UNIT 61
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4826                        2P0.635
'
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='HEAT TRANSFER ASSEMBLY CELL'
ARRAY  2  -9.5104 -9.5104 -0.635
CUBOID 3 1 4P9.906                          2P0.635
CUBOID 5 1 4P10.028                         2P0.635
CUBOID 3 1 4P10.2187                        2P0.635
HOLE  16   0.0       10.1234  0.0
HOLE  16   0.0      -10.1234 0.0
HOLE  17   10.1234  0.0      0.0
HOLE  17   -10.1234 0.0      0.0
CUBOID 5 1 4P10.267                         2P0.635
CUBOID 3 1 4P10.4445                        2P0.635
UNIT 71
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4445                        2P0.635

'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY)'
ARRAY 20 -10.4826 -33.6702 -2.1654
UNIT 81
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 21 -10.4826 -56.6928 -2.1654
UNIT 82
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY)'
ARRAY 22 -10.4826 -79.5630 -2.1654
UNIT 83
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 23 -10.4826 -79.5630 -2.1654
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY)'
ARRAY 30 -10.4826 -33.6702 -0.635
UNIT 91
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 31 -10.4826 -56.6928 -0.635
UNIT 92
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY)'
ARRAY 32 -10.4826 -79.5630 -0.635
UNIT 93
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 33 -10.4826 -79.5630 -0.635
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY)'
ARRAY 40 -10.4445 -33.6321 -0.635
UNIT 101
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY)'
ARRAY 41 -10.4445 -56.6547 -0.635
UNIT 102
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY)'
ARRAY 42 -10.4445 -79.5249 -0.635
UNIT 103
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 43 -10.4445 -79.5249 -0.635
'
'  BASKET ARRAY IN STORAGE CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6702 -79.5630 -2.1654
CYLINDER 3 1 88.1253      2P2.1654
HOLE 80      -69.0804 0.0 0.0
HOLE 81      -46.2102 0.0 0.0
HOLE 80       69.0804 0.0 0.0
HOLE 81       46.2102 0.0 0.0
CYLINDER  5 1  89.7128     2P2.1654
CYLINDER  7 1 100.33       2P2.1654
CYLINDER  8 1 109.22       2P2.1654
CYLINDER  9 1 162.56       2P2.1654
CUBOID   10 1 4P228.60     2P2.1654
UNIT 111
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6702 -79.5630 -0.635
CYLINDER 5 1 87.6046      2P0.635
HOLE 90      -69.0804 0.0 0.0
HOLE 91      -46.2102 0.0 0.0
HOLE 90       69.0804 0.0 0.0
HOLE 91       46.2102 0.0 0.0
CYLINDER  3 1  88.1253     2P0.635
CYLINDER  5 1  89.7128     2P0.635
CYLINDER  7 1 100.33       2P0.635
CYLINDER  8 1 109.22       2P0.635
CYLINDER  9 1 162.56       2P0.635
CUBOID   10 1 4P228.60     2P0.635
UNIT 112
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6321 -79.5249 -0.635
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
CYLINDER 4 1 87.249      2P0.635
HOLE 100    -69.0804 0.0 0.0
HOLE 101    -46.2102 0.0 0.0
HOLE 100     69.0804 0.0 0.0
HOLE 101     46.2102 0.0 0.0
CYLINDER  3 1  88.1253    2P0.635
CYLINDER  5 1  89.7128    2P0.635
CYLINDER  7 1 100.33      2P0.635
CYLINDER  8 1 109.22      2P0.635
CYLINDER  9 1 162.56      2P0.635
CUBOID   10 1 4P228.60    2P0.635
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -228.60  -228.60  0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
50
22
50
22
50
END FILL
ARA=21  NUX=1 NUY=9 NUZ=1
FILL
50
21
50
22
50
22
50
21
50
END FILL
ARA=22  NUX=1 NUY=13 NUZ=1
FILL
50
20
50
21
50
22
50
22
50
21
50
20
50
END FILL
ARA=23  NUX=1 NUY=13 NUZ=1
FILL
50
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
20
50
21
50
22
51
22
50
21
50
20
50
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
60
32
60
32
60
END FILL
ARA=31  NUX=1 NUY=9 NUZ=1
FILL
60
31
60
32
60
32
60
31
60
END FILL
ARA=32  NUX=1 NUY=13 NUZ=1
FILL
60
30
60
31
60
32
60
32
60
31
60
30
60
END FILL
ARA=33  NUX=1 NUY=13 NUZ=1
FILL
60
30
60
31
60
32
61
32
60
31
60
30
60
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
70
42
70
42
70
END FILL
ARA=41  NUX=1 NUY=9 NUZ=1
FILL
70
41
70
42
70
42
70
41
70
END FILL
ARA=42  NUX=1 NUY=13 NUZ=1
FILL
70
40
70
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
41
70
42
70
42
70
41
70
40
70
END FILL
ARA=43  NUX=1 NUY=13 NUZ=1
FILL
70
40
70
41
70
42
71
42
70
41
70
40
70
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
82 23 83 23 82
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
92 33 93 33 92
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
102 43 103 43 102
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY

READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS

READ PLOT
SCR=YES PIC=MAT LPI=10
clr=0 255 255 255
    1   0   0   0
    2   0 238   0
    3 135 206 250
    4 205 205   0
    5 238   0   0
    6 160  32 240
    7 238 118  33
    8 255 165   0
    9 150 150 150
   10  60 179 113  end color
'
' WHOLE BASKET HORIZONTAL SLICES
'
TTL='BASKET X-Y CROSS SECTION AT Z= 0.635 HEAT TRANSFER DISK LEVEL'
XUL=  -175 YUL=  175  ZUL= 0.635
XLR=   175 YLR= -175  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 3.44 WATER LEVEL'
XUL=  -175 YUL=  175  ZUL= 3.44
XLR=   175 YLR= -175  ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y CROSS SECTION AT Z= 6.236 SS DISK LEVEL'
XUL=  -175 YUL=  175  ZUL= 6.236
XLR=   175 YLR= -175  ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' HEAT TRANSFER DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANTD I HEAT TRANSFER DISK'
XUL=   0.   YUL= 80      ZUL= 0.635
XLR=  80.0  YLR=  0.0    ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II HEAT TRANSFER DISK'
XUL=   0.0 YUL= -0.0   ZUL= 0.635
XLR=  80   YLR= -80     ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III HEAT TRANSFER DISK'
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
XUL= -80.0  YUL=  -0.0  ZUL= 0.635
XLR=  -0.0  YLR= -80.0  ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV HEAT TRANSFER DISK'
XUL= -80.0  YUL= 80.0   ZUL= 0.635
XLR=  -0.0  YLR=  0.0   ZLR= 0.635
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' WATER LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=   0.   YUL=  80     ZUL= 3.44
XLR=  80.0  YLR=   0.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=   0.0  YUL=  -0.0   ZUL= 3.44
XLR=  80    YLR= -80     ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0  YUL=  -0.0   ZUL= 3.44
XLR=  -0.0  YLR= -80.0   ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0  YUL= 80.0    ZUL= 3.44
XLR=  -0.0  YLR=  0.0    ZLR= 3.44
UAX=1.0 VDN=-1.0 NAX=1500 END
'
' SUPPORT DISK LEVEL BASKET QUADRANTS
'
TTL='BASKET X-Y QUADRANT I WATER LEVEL'
XUL=   0.   YUL=  80     ZUL= 6.236
XLR=  80.0  YLR=   0.0   ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT II WATER LEVEL'
XUL=   0.0  YUL=  -0.0   ZUL= 6.236
XLR=  80    YLR= -80     ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT III WATER LEVEL'
XUL= -80.0  YUL=  -0.0   ZUL= 6.236
XLR=  -0.0  YLR= -80.0   ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
TTL='BASKET X-Y QUADRANT IV WATER LEVEL'
XUL= -80.0  YUL= 80.0    ZUL= 6.236
XLR=  -0.0  YLR=  0.0    ZLR= 6.236
UAX=1.0 VDN=-1.0 NAX=1500 END
'
'  VERTICAL SLICES
'
TTL='BASKET X-Z CROSS SECTION ALUMINUM LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 1.27
XLR=  90  YLR=0.4   ZLR= -.1
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION WATER LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 4.318
XLR=  90  YLR=0.4   ZLR= 1.27
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION SS LEVEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 6.858
XLR=  90  YLR=0.4   ZLR= 5.588
UAX=1.0 WDN=-1.0 NAX=1500 END
TTL='BASKET X-Z CROSS SECTION ENTIRE MODEL (MIDDLE OF FUEL PIN)'
XUL= -90  YUL=0.4   ZUL= 12
XLR=  90  YLR=0.4   ZLR= 0
UAX=1.0 WDN=-1.0 NAX=1500 END
END PLOT
END DATA
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
 ccccccccccc     sssssssssss      AAAAAAAAA      sssssssssss     22222222222    5555555555555
ccccccccccccc   sssssssssssss    AAAAAAAAAAA    sssssssssssss   2222222222222   5555555555555
cc         cc   ss         ss   AA         AA   ss         ss   22         22   55
cc              ss              AA         AA   ss                         22   55
cc              ss              AA         AA   ss                         22   55
cc              ssssssssssss    AAAAAAAAAAAAA   ssssssssssss             22     555555555555
cc               ssssssssssss   AAAAAAAAAAAAA    ssssssssssss          22       5555555555555
cc                         ss   AA         AA              ss        22                    55
cc                         ss   AA         AA              ss      22                      55
cc         cc   ss         ss   AA         AA   ss         ss    22             55         55
ccccccccccccc   sssssssssssss   AA         AA   sssssssssssss   2222222222222   5555555555555
 ccccccccccc     sssssssssss    AA         AA    sssssssssss    2222222222222    55555555555

 sssssssssss     ccccccccccc      AAAAAAAAA     LL              EEEEEEEEEEEEE                   PPPPPPPPPPPP     ccccccccccc
sssssssssssss   ccccccccccccc    AAAAAAAAAAA    LL              EEEEEEEEEEEEE                   PPPPPPPPPPPPP   ccccccccccccc
ss         ss   cc         cc   AA         AA   LL              EE                              PP         PP   cc         cc
ss              cc              AA         AA   LL              EE                              PP         PP   cc
ss              cc              AA         AA   LL              EE                              PP         PP   cc
ssssssssssss    cc              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPPP   cc
 ssssssssssss   cc              AAAAAAAAAAAAA   LL              EEEEEEEEE       -------------   PPPPPPPPPPPP    cc
           ss   cc              AA         AA   LL              EE                              PP              cc
           ss   cc              AA         AA   LL              EE                              PP              cc
ss         ss   cc         cc   AA         AA   LL              EE                              PP              cc         cc
sssssssssssss   ccccccccccccc   AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP              ccccccccccccc
 sssssssssss     ccccccccccc    AA         AA   LLLLLLLLLLLLL   EEEEEEEEEEEEE                   PP               ccccccccccc

      11         22222222222              //      0000000       7777777777777              //    99999999999     666666666666
     111        2222222222222            //      000000000      777777777777              //    9999999999999   6666666666666
    1111        22         22           //      00       00     77         77            //     99         99   66
      11                   22          //      00         00             77             //      99         99   66
      11                   22         //       00         00            77             //       99         99   66
      11                 22          //        00         00           77             //        9999999999999   666666666666
      11               22           //         00         00           77            //          999999999999   6666666666666
      11             22            //          00         00          77            //                     99   66         66
      11           22             //           00         00          77           //                      99   66         66
      11         22              //             00       00          77           //                       99   66         66
    11111111    2222222222222   //               000000000           77          //         9999999999999   6666666666666
    11111111    2222222222222  //                 0000000            77         //          999999999999     66666666666

   0000000       666666666666                          11          88888888888                   5555555555555     0000000
  000000000     6666666666666                         111         8888888888888                  5555555555555    000000000
 00       00    66                   :::             1111         88         88      :::         55              00       00
00         00   66                   :::               11         88         88      :::         55             00         00
00         00   66                   :::               11         88         88      :::         55             00         00
00         00   666666666666                           11          88888888888                   555555555555   00         00
00         00   6666666666666                          11          88888888888                   5555555555555  00         00
00         00   66         66        :::               11         88         88      :::                   55   00         00
00         00   66         66        :::               11         88         88      :::                   55   00         00
 00       00    66         66        :::               11         88         88      :::         55        55    00       00
  000000000     6666666666666                       11111111      8888888888888                  5555555555555    000000000
   0000000       66666666666                        11111111       88888888888                    55555555555      0000000
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

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

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                     PROGRAM VERIFICATION INFORMATION                 *****
*****                                                                      *****
*****                   CODE SYSTEM:   SCALE-PC VERSION:   4.3             *****
*****                                                                      *****
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                                                                      *****
*****                 PROGRAM:  CSAS                                       *****
*****                                                                      *****
*****           CREATION DATE:  03-08-96                                   *****
*****                                                                      *****
*****                  VOLUME:  ENG                                        *****
*****                                                                      *****
*****                 LIBRARY:  G:\scale43\exe                             *****
*****                                                                      *****
*****                                                                      *****
*****         PRODUCTION CODE:  CSAS                                       *****
*****                                                                      *****
*****                 VERSION:  3.1                                        *****
*****                                                                      *****
*****                 JOBNAME:  SCALE-PC                                   *****
*****                                                                      *****
*****       DATE OF EXECUTION:  12/07/96                                   *****
*****                                                                      *****
*****       TIME OF EXECUTION:  06:18:50                                   *****
*****                                                                      *****
*****                                                                      *****
********************************************************************************
********************************************************************************
********************************************************************************
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

    **** PROBLEM PARAMETERS ****

    LIB 27GROUPNDF4  LIBRARY
    MXX           10 MIXTURES
    MSC           13 COMPOSITION SPECIFICATIONS
    IZM            4 MATERIAL ZONES
    GE  LATTICECELL  GEOMETRY
    MORE           0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
    MSLN           0 FUEL SOLUTIONS

    **** PROBLEM COMPOSITION DESCRIPTION ****

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

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

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

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

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

    SC  B-10         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.0450 VOLUME FRACTION
    ROTH      2.6226 SPECIFIED DENSITY
    NEL            1 NO. ELEMENTS
    ICP            1 0/1 MIXTURE/COMPOUND
    TEMP       293.0 DEG KELVIN
                5010      1.00 ATOM/MOLECULE
    END

    SC  B-11         STANDARD COMPOSITION
    MX             6 MIXTURE NO.
    VF        0.2736 VOLUME FRACTION
    ROTH      2.6226 SPECIFIED DENSITY
    NEL            1 NO. ELEMENTS
    ICP            1 0/1 MIXTURE/COMPOUND
    TEMP       293.0 DEG KELVIN
                5011      1.00 ATOM/MOLECULE
    END

    SC  C            STANDARD COMPOSITION
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
MX             6 MIXTURE NO.
VF        0.0927 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            6012        1.00 ATOM/MOLECULE
END

SC  AL           STANDARD COMPOSITION
MX             6 MIXTURE NO.
VF        0.5737 VOLUME FRACTION
ROTH      2.6226 SPECIFIED DENSITY
NEL            1 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           13027        1.00 ATOM/MOLECULE
END

SC  H2O          STANDARD COMPOSITION
MX             7 MIXTURE NO.
VF        0.0001 VOLUME FRACTION
ROTH      0.9982 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            1 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
            1001        2.00 ATOMS/MOLECULE
            8016        1.00 ATOM/MOLECULE
END

SC  CARBONSTEEL  STANDARD COMPOSITION
MX             8 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      7.8212 THEORETICAL DENSITY
NEL            2 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           26000      99.000 WT%
            6012       1.000 WT%
END

SC  REG-CONCRETE STANDARD COMPOSITION
MX             9 MIXTURE NO.
VF        1.0000 VOLUME FRACTION
ROTH      2.2430 SPECIFIED DENSITY
NEL            7 NO. ELEMENTS
ICP            0 0/1 MIXTURE/COMPOUND
TEMP       293.0 DEG KELVIN
           26000       1.400 WT%
            1001       1.000 WT%
           13027       3.400 WT%
           20000       4.400 WT%
            8016      53.200 WT%
           14000      33.700 WT%
           11023       2.900 WT%
END

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

**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH  CELL TYPE
PITCH     1.1887 CM CENTER TO CENTER SPACING
FUELOD    0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL          1 MIXTURE NO. OF FUEL
MMOD           3 MIXTURE NO. OF MODERATOR
CLADOD    0.9271 CM CLAD OUTER DIAMETER
MCLAD          2 MIXTURE NO. OF CLAD
GAPOD     0.8052 CM GAP OUTER DIAMETER
MGAP           0 MIXTURE NO. OF GAP

ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

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

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
***************************************************************************************************
***                                                                                             ***
***                      WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE             ***
***                                                                                             ***
***************************************************************************************************
***************************************************************************************************
***                                                                                             ***
***                        ********** DATA LIBRARY INFORMATION **********                       ***
***                                                                                             ***
***      UNIT                                                VOLUME                             ***
***     NUMBER              DATA SET NAME                     NAME      UNIT FUNCTION           ***
***     ------              -------------                     ----      -------------           ***
***                                                                                             ***
***       89      G:\scale43\DATALIB\FT89F001                           STANDARD COMPOSITION LIBRARY ***
***                                                                                             ***
***       82      G:\scale43\DATALIB\FT82F001                           CROSS SECTION LIBRARY   ***
***                                                                                             ***
***       11      C:\svv\wrr5302\storage\FT11F001                       SHORT CROSS SECTION LIBRARY ***
***                                                                                             ***
***       90      C:\svv\wrr5302\storage\FT90F001                       INPUT DATA DIRECT ACCESS ***
***                                                                                             ***
***************************************************************************************************
***************************************************************************************************
***                                                                                             ***
***                                                                                             ***
***                              STANDARD COMPOSITION LIBRARY DATA                              ***
***                              ---------------------------------                              ***
***                                                                                             ***
***        UNIT NUMBER  :  89                                                                   ***
***                                                                                             ***
***        DATASET NAME :  G:\scale43\DATALIB\FT89F001                                          ***
***                                                                                             ***
***        LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY                                 ***
***                        637 STANDARD COMPOSITIONS, 490 NUCLIDES                              ***
***                        90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.                     ***
***                                                                                             ***
***        CREATION DATE:   6/30/95                                                             ***
***                                                                                             ***
***                                                                                             ***
***                                                                                             ***
***                                 CROSS SECTION LIBRARY DATA                                  ***
***                                 --------------------------                                  ***
***                                                                                             ***
***        UNIT NUMBER  :  82                                                                   ***
***                                                                                             ***
***        DATASET NAME :  G:\scale43\DATALIB\FT82F001                                          ***
***                                                                                             ***
***        LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY                           ***
***                           BASED ON ENDF-B VERSION 4 DATA                                    ***
***                              COMPILED FOR NRC     1/27/89                                   ***
***                                 LAST UPDATED                                     08/12/94   ***
***                                    L.M.PETRIE   -    ORNL                                   ***
***                                                                                             ***
***                                                                                             ***
***                                                                                             ***
***                                                                                             ***
***************************************************************************************************
***************************************************************************************************

CONTROL MODULE CSAS25    IS COMPLETE.
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

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

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

      11         22222222222              //     0000000     7777777777777             //   99999999999    666666666666
     111        2222222222222            //     000000000    777777777777             //   9999999999999  6666666666666
    1111        22        22            //     00       00   77        77            //    99        99   66
      11                  22           //      00        00           77            //     99        99   66
      11                  22          //       00        00          77            //      99        99   66
      11                22           //        00        00         77            //       9999999999999  666666666666
      11              22            //         00        00         77           //         999999999999  6666666666666
      11            22             //          00        00        77           //                    99  66        66
      11          22              //           00        00        77          //                     99  66        66
      11        22               //             00      00        77          //                      99  66        66
   11111111     2222222222222   //              000000000         77         //            9999999999999  6666666666666
   11111111     2222222222222  //                0000000          77        //             999999999999    66666666666

     0000000     666666666666                      11           99999999999                   0000000     7777777777777
    000000000   6666666666666                     111          9999999999999                 000000000    777777777777
   00       00  66                 :::           1111          99        99       :::       00       00   77        77
  00         00 66                 :::             11          99        99       :::      00         00           77
  00         00 66                 :::             11          99        99       :::      00         00          77
  00         00 666666666666                       11          9999999999999               00         00         77
  00         00 6666666666666                      11           999999999999               00         00         77
  00         00 66        66       :::             11                     99      :::      00         00        77
  00         00 66        66       :::             11                     99      :::      00         00        77
   00       00  66        66       :::             11                     99      :::       00       00        77
    000000000   6666666666666                   11111111       9999999999999                 000000000         77
     0000000     66666666666                    11111111       999999999999                   0000000          77
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

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

```
*******************************************************************************
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                  PROGRAM VERIFICATION INFORMATION                   *****
*****                                                                     *****
*****                CODE SYSTEM:  SCALE-PC VERSION:  4.3                 *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*****                                                                     *****
*****                                                                     *****
*****               PROGRAM:  000009                                      *****
*****                                                                     *****
*****         CREATION DATE:  03-08-96                                    *****
*****                                                                     *****
*****                VOLUME:  ENG                                         *****
*****                                                                     *****
*****               LIBRARY:  G:\scale43\exe                              *****
*****                                                                     *****
*****                                                                     *****
*****       PRODUCTION CODE:  KENOVA                                      *****
*****                                                                     *****
*****               VERSION:  3.1                                         *****
*****                                                                     *****
*****               JOBNAME:  SCALE-PC                                    *****
*****                                                                     *****
*****     DATE OF EXECUTION:  12/07/96                                    *****
*****                                                                     *****
*****     TIME OF EXECUTION:  06:19:07                                    *****
*****                                                                     *****
*****                                                                     *****
*******************************************************************************
*******************************************************************************
*******************************************************************************
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

****** NUMERIC PARAMETERS ******

TME    MAXIMUM PROBLEM TIME (MIN)                 500.00
TBA    TIME PER GENERATION (MIN)                    0.50
GEN    NUMBER OF GENERATIONS                        1003
NPG    NUMBER PER GENERATION                        1000
NSK    NUMBER OF GENERATIONS TO BE SKIPPED             3
BEG    BEGINNING GENERATION NUMBER                     1
RES    GENERATIONS BETWEEN CHECKPOINTS                 0
X1D    NUMBER OF EXTRA 1-D CROSS SECTIONS              1
NBK    NEUTRON BANK SIZE                            1025
XNB    EXTRA POSITIONS IN NEUTRON BANK                 0
NFB    FISSION BANK SIZE                            1000
XFB    EXTRA POSITIONS IN FISSION BANK                 0
WTA    DEFAULT VALUE OF WEIGHT AVERAGE            0.5000
WTH    WEIGHT HIGH FOR SPLITTING                  3.0000
WTL    WEIGHT LOW FOR RUSSIAN ROULETTE            0.3333
RND    STARTING RANDOM NUMBER                BB827100001
NB8    NUMBER OF D.A. BLOCKS ON UNIT  8              200
NL8    LENGTH OF D.A. BLOCKS ON UNIT  8              512
ADJ    MODE OF CALCULATION                       FORWARD
       INPUT DATA WRITTEN ON RESTART UNIT             NO
       BINARY DATA INTERFACE                         YES
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                     WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE                ***
***                                                                                               ***
*****************************************************************************************************
***                       ******     LOGICAL PARAMETERS     ******                                ***
***                                                                                               ***
*** RUN  EXECUTE PROBLEM AFTER CHECKING DATA     YES    PLT  PLOT PICTURE MAP(S)                  YES ***
***                                                                                               ***
*** FLX  COMPUTE FLUX                            NO     FDN  COMPUTE FISSION DENSITIES            NO  ***
***                                                                                               ***
*** SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION    NO     NUB  COMPUTE NU-BAR & AVG FISSION GROUP   YES ***
***                                                                                               ***
*** MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER     NO     MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION NO ***
***                                                                                               ***
*** CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER   NO     CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION NO ***
***                                                                                               ***
*** FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER   NO     FMP  PRINT FISS PROD MATRIX BY UNIT LOCATION NO ***
***                                                                                               ***
*** MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER     NO     MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER NO  ***
***                                                                                               ***
*** CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER   NO     CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER NO ***
***                                                                                               ***
*** FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER   NO     FMA  PRINT FISS PROD MATRIX BY ARRAY NUMBER NO ***
***                                                                                               ***
*** HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL    NO     HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL NO ***
***                                                                                               ***
*** AMX  PRINT ALL MIXED CROSS SECTIONS          NO     FAR  PRINT FIS. AND ABS. BY REGION        NO  ***
***                                                                                               ***
*** XS1  PRINT 1-D MIXTURE X-SECTIONS            NO     GAS  PRINT FAR BY GROUP                   NO  ***
***                                                                                               ***
*** XS2  PRINT 2-D MIXTURE X-SECTIONS            NO     PAX  PRINT XSEC-ALBEDO CORRELATION TABLES NO  ***
***                                                                                               ***
*** XAP  PRINT MIXTURE ANGLES & PROBABILITIES    NO     PWT  PRINT WEIGHT AVERAGE ARRAY           NO  ***
***                                                                                               ***
*** PKI  PRINT FISSION SPECTRUM                  NO     PGM  PRINT INPUT GEOMETRY                 NO  ***
***                                                                                               ***
*** P1D  PRINT EXTRA 1-D CROSS SECTIONS          NO     BUG  PRINT DEBUG INFORMATION              NO  ***
***                                                                                               ***
***                                                     TRK  PRINT TRACKING INFORMATION           NO  ***
***                                                                                               ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
*****************************************************************************************************
                              PARAMETER INPUT COMPLETED

               ........   0 IO'S WERE USED READING THE PARAMETER DATA    ........

               *************** DATA READING COMPLETED ***************
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***                       WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE              ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***      UNIT                                            VOLUME                                   ***
***     NUMBER            DATA SET NAME                   NAME        UNIT FUNCTION               ***
***     ------            -------------                   ----        -------------               ***
***                                                                                               ***
***   XSC  14    C:\svv\wrr5302\storage\FT14F001                      MIXED CROSS SECTIONS        ***
***                                                                                               ***
***   ALB  79    G:\scale43\DATALIB\FT79F001                          INPUT ALBEDOS               ***
***                                                                                               ***
***   WTS  80    G:\scale43\DATALIB\FT80F001                          INPUT WEIGHTS               ***
***                                                                                               ***
***   SKT  16     UNKNOWN                                             WRITE SCRATCH DATA          ***
***                                                                                               ***
***   BIN  95    C:\svv\wrr5302\storage\FT95F001                      BINARY INPUT DATA           ***
***                                                                                               ***
***   RST  95    C:\svv\wrr5302\storage\FT95F001                      READ RESTART DATA           ***
***                                                                                               ***
***   LIB   4    C:\svv\wrr5302\storage\FT04F001                      INPUT AMPX WORKING LIBRARY  ***
***                                                                                               ***
***         8    C:\svv\wrr5302\storage\FT08F001                      INPUT DATA DIRECT ACCESS    ***
***                                                                                               ***
***         9     UNKNOWN                                             SUPER GROUPED DIRECT ACCESS ***
***                                                                                               ***
***        10     UNKNOWN                                             XSEC MIXING DIRECT ACCESS   ***
***                                                                                               ***
*****************************************************************************************************

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

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

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
                    WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

                                          MIXING TABLE

                                NUMBER OF SCATTERING ANGLES =  2
                             CROSS SECTION MESSAGE THRESHOLD =3.0E-05


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

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

MIXTURE =     3           DENSITY(G/CC) = 0.99817E-04
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
   3001001  6.67692E-06  1.11927E-01    1001     1.0077       HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
   3008016  3.33846E-06  8.88074E-01    8016    15.9904       OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94

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

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

MIXTURE =     6           DENSITY(G/CC) =  2.5833
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
   6005010  7.09799E-03  4.56855E-02    5010    10.0130      B-10 1273 218NGP 042375 P-3 293K                           UPDATED
08/12/94
   6005011  3.92499E-02  2.77771E-01    5011    11.0096       BORON-11        ENDF/B-IV MAT 1160                        UPDATED
08/12/94
   6006012  1.22006E-02  9.41116E-02    6000    12.0001       CARBON-12       ENDF/B-IV MAT 1274/THRM1065               UPDATED
08/12/94
   6013027  3.35812E-02  5.82432E-01   13027    26.9818      AL-27 1193 218 GP 040375(5)                                UPDATED
08/12/94

MIXTURE =     7           DENSITY(G/CC) = 0.99817E-04
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
   7001001  6.67692E-06  1.11927E-01    1001     1.0077       HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
   7008016  3.33846E-06  8.88074E-01    8016    15.9904       OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94

MIXTURE =     8           DENSITY(G/CC) =  7.8212
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
   8006012  3.92503E-03  1.00001E-02    6000    12.0001       CARBON-12       ENDF/B-IV MAT 1274/THRM1065               UPDATED
08/12/94
   8026000  8.34982E-02  9.90000E-01   26000    55.8447       IRON            ENDF/B-IV MAT 1192                        UPDATED
08/12/94

MIXTURE =     9           DENSITY(G/CC) =  2.2430
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
   9001001  1.34031E-02  9.99867E-03    1001     1.0077       HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
   9008016  4.49394E-02  5.31997E-01    8016    15.9904       OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94
   9011023  1.70392E-03  2.90003E-02   11023    22.9895       SODIUM-23       ENDF/B-IV MAT 1156                        UPDATED
08/12/94
   9013027  1.70211E-03  3.40003E-02   13027    26.9818      AL-27 1193 218 GP 040375(5)                                UPDATED
08/12/94
   9014000  1.62080E-02  3.37003E-01   14000    28.0853       SILICON         ENDF/B-IV MAT 1194                        UPDATED
08/12/94
   9020000  1.48287E-03  4.40004E-02   20000    40.0803      CALCIUM ENDF/B-IV MAT 1195                                 UPDATED
08/12/94
   9026000  3.38630E-04  1.40001E-02   26000    55.8447       IRON            ENDF/B-IV MAT 1192                        UPDATED
08/12/94

MIXTURE =    10           DENSITY(G/CC) = 0.99817E-04
   NUCLIDE   ATOM-DENS.   WGT. FRAC.     ZA       AWT                 NUCLIDE TITLE
  10001001  6.67692E-06  1.11927E-01    1001     1.0077       HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
  10008016  3.33846E-06  8.88074E-01    8016    15.9904       OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
*****************************************************************************************************
***                                                                                               ***
***           WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE                          ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                           ****** ADDITIONAL INFORMATION ******                                ***
***                                                                                               ***
***  NUMBER OF ENERGY GROUPS                27       USE LATTICE GEOMETRY                   YES   ***
***                                                                                               ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP  1        GLOBAL ARRAY NUMBER                     60   ***
***                                                                                               ***
***  NO. OF SCATTERING ANGLES IN XSECS      2        NUMBER OF UNITS IN THE GLOBAL X DIR.     1   ***
***                                                                                               ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK   32        NUMBER OF UNITS IN THE GLOBAL Y DIR.     1   ***
***                                                                                               ***
***  ENTRIES/NEUTRON IN THE FISSION BANK   25        NUMBER OF UNITS IN THE GLOBAL Z DIR.     4   ***
***                                                                                               ***
***  NUMBER OF MIXTURES USED               10        USE A GLOBAL REFLECTOR                 YES   ***
***                                                                                               ***
***  NUMBER OF BIAS ID'S USED               1        USE NESTED HOLES                       YES   ***
***                                                                                               ***
***  NUMBER OF DIFFERENTIAL ALBEDOS USED    0        NUMBER OF HOLES                         24   ***
***                                                                                               ***
***  TOTAL INPUT GEOMETRY REGIONS          97        MAXIMUM HOLE NESTING LEVEL               2   ***
***                                                                                               ***
***  NUMBER OF GEOMETRY REGIONS USED       97        USE NESTED ARRAYS                      YES   ***
***                                                                                               ***
***  LARGEST GEOMETRY UNIT NUMBER         120        NUMBER OF ARRAYS USED                   18   ***
***                                                                                               ***
***  LARGEST ARRAY NUMBER                  60        MAXIMUM ARRAY NESTING LEVEL              4   ***
***                                                                                               ***
***                                                                                               ***
***  +X BOUNDARY CONDITION            REFLECT        -X BOUNDARY CONDITION              REFLECT   ***
***                                                                                               ***
***  +Y BOUNDARY CONDITION            REFLECT        -Y BOUNDARY CONDITION              REFLECT   ***
***                                                                                               ***
***  +Z BOUNDARY CONDITION                PER        -Z BOUNDARY CONDITION                  PER   ***
***                                                                                               ***
*****************************************************************************************************
```

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	475 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	4.11868E-01	6.25517E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	477 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	4.19477E-01	6.55817E+00	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	511 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	4.40874E-01	6.86483E+00	4.40874E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	4.31155E-01	7.17333E+00	4.36014E-01	4.85970E-03	0.00000E+00	0.00000E+00
5	4.38865E-01	7.49550E+00	4.36965E-01	2.96232E-03	0.00000E+00	0.00000E+00
6	4.17054E-01	7.80133E+00	4.31987E-01	5.40036E-03	0.00000E+00	0.00000E+00
7	4.24368E-01	8.11900E+00	4.30463E-01	4.45201E-03	0.00000E+00	0.00000E+00
8	4.17726E-01	8.43017E+00	4.28340E-01	4.20951E-03	0.00000E+00	0.00000E+00
9	4.26347E-01	8.74600E+00	4.28056E-01	3.56907E-03	0.00000E+00	0.00000E+00
10	4.31943E-01	9.06183E+00	4.28542E-01	3.12887E-03	0.00000E+00	0.00000E+00
11	4.34519E-01	9.37583E+00	4.29206E-01	2.83822E-03	0.00000E+00	0.00000E+00
12	4.34790E-01	9.69900E+00	4.29764E-01	2.59928E-03	0.00000E+00	0.00000E+00
13	4.36472E-01	1.00185E+01	4.30374E-01	2.42892E-03	0.00000E+00	0.00000E+00
14	4.35529E-01	1.03362E+01	4.30804E-01	2.25852E-03	0.00000E+00	0.00000E+00
15	4.38165E-01	1.06510E+01	4.31370E-01	2.15332E-03	0.00000E+00	0.00000E+00
16	4.41168E-01	1.09660E+01	4.32070E-01	2.11286E-03	0.00000E+00	0.00000E+00
17	4.50614E-01	1.12882E+01	4.33306E-01	2.32321E-03	0.00000E+00	0.00000E+00
18	4.42851E-01	1.16077E+01	4.33903E-01	2.25356E-03	0.00000E+00	0.00000E+00
19	4.31047E-01	1.19188E+01	4.33735E-01	2.12351E-03	0.00000E+00	0.00000E+00
20	4.43283E-01	1.22375E+01	4.34265E-01	2.07115E-03	0.00000E+00	0.00000E+00
21	4.31275E-01	1.25487E+01	4.34108E-01	1.96543E-03	0.00000E+00	0.00000E+00
22	4.22313E-01	1.28553E+01	4.33518E-01	1.95561E-03	0.00000E+00	0.00000E+00
23	4.16142E-01	1.31638E+01	4.32690E-01	2.03588E-03	0.00000E+00	0.00000E+00
24	4.38541E-01	1.34760E+01	4.32956E-01	1.95927E-03	0.00000E+00	0.00000E+00
25	4.22596E-01	1.37863E+01	4.32506E-01	1.92557E-03	0.00000E+00	0.00000E+00
26	4.43309E-01	1.40985E+01	4.32956E-01	1.89775E-03	0.00000E+00	0.00000E+00
27	4.29567E-01	1.44117E+01	4.32821E-01	1.82530E-03	0.00000E+00	0.00000E+00
28	4.32907E-01	1.47247E+01	4.32824E-01	1.75369E-03	0.00000E+00	0.00000E+00
29	4.30161E-01	1.50332E+01	4.32725E-01	1.69037E-03	0.00000E+00	0.00000E+00
30	4.45822E-01	1.53545E+01	4.33193E-01	1.69471E-03	0.00000E+00	0.00000E+00
31	4.58676E-01	1.56703E+01	4.34072E-01	1.85638E-03	0.00000E+00	0.00000E+00
32	4.43808E-01	1.59733E+01	4.34396E-01	1.82256E-03	0.00000E+00	0.00000E+00
33	4.41420E-01	1.62827E+01	4.34623E-01	1.77729E-03	0.00000E+00	0.00000E+00
34	4.38101E-01	1.65940E+01	4.34732E-01	1.72428E-03	0.00000E+00	0.00000E+00
35	4.20226E-01	1.68997E+01	4.34292E-01	1.72806E-03	0.00000E+00	0.00000E+00
36	4.30418E-01	1.72110E+01	4.34178E-01	1.68033E-03	0.00000E+00	0.00000E+00
37	4.40334E-01	1.75222E+01	4.34354E-01	1.64107E-03	0.00000E+00	0.00000E+00
38	4.29066E-01	1.78343E+01	4.34207E-01	1.60158E-03	0.00000E+00	0.00000E+00
39	4.26009E-01	1.81373E+01	4.33985E-01	1.57337E-03	0.00000E+00	0.00000E+00
40	4.30454E-01	1.84458E+01	4.33893E-01	1.53423E-03	0.00000E+00	0.00000E+00
41	4.28514E-01	1.87580E+01	4.33755E-01	1.50072E-03	0.00000E+00	0.00000E+00
42	4.34513E-01	1.90683E+01	4.33774E-01	1.46284E-03	0.00000E+00	0.00000E+00
43	4.30687E-01	1.93823E+01	4.33698E-01	1.42870E-03	0.00000E+00	0.00000E+00
44	4.14305E-01	1.96882E+01	4.33237E-01	1.46874E-03	0.00000E+00	0.00000E+00
45	4.18237E-01	2.00003E+01	4.32888E-01	1.47599E-03	0.00000E+00	0.00000E+00
46	4.29721E-01	2.03215E+01	4.32816E-01	1.44385E-03	0.00000E+00	0.00000E+00
47	4.32701E-01	2.06292E+01	4.32813E-01	1.41140E-03	0.00000E+00	0.00000E+00
48	4.18180E-01	2.09312E+01	4.32495E-01	1.41656E-03	0.00000E+00	0.00000E+00
49	4.33377E-01	2.12488E+01	4.32514E-01	1.38622E-03	0.00000E+00	0.00000E+00
50	4.35003E-01	2.15565E+01	4.32566E-01	1.35802E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	4.23082E-01	3.02703E+02	4.30921E-01	3.02884E-04	0.00000E+00	0.00000E+00
951	4.23632E-01	3.03085E+02	4.30913E-01	3.02662E-04	0.00000E+00	0.00000E+00
952	4.39814E-01	3.03453E+02	4.30922E-01	3.02489E-04	0.00000E+00	0.00000E+00
953	4.33060E-01	3.03762E+02	4.30925E-01	3.02179E-04	0.00000E+00	0.00000E+00
954	4.38819E-01	3.04109E+02	4.30933E-01	3.01975E-04	0.00000E+00	0.00000E+00
955	4.25373E-01	3.04472E+02	4.30927E-01	3.01715E-04	0.00000E+00	0.00000E+00
956	4.39266E-01	3.04828E+02	4.30936E-01	3.01525E-04	0.00000E+00	0.00000E+00
957	4.32237E-01	3.05156E+02	4.30937E-01	3.01212E-04	0.00000E+00	0.00000E+00
958	4.11043E-01	3.05477E+02	4.30916E-01	3.01616E-04	0.00000E+00	0.00000E+00
959	4.11484E-01	3.05803E+02	4.30896E-01	3.01984E-04	0.00000E+00	0.00000E+00
960	4.43532E-01	3.06125E+02	4.30909E-01	3.01957E-04	0.00000E+00	0.00000E+00
961	4.28865E-01	3.06449E+02	4.30907E-01	3.01649E-04	0.00000E+00	0.00000E+00
962	4.37268E-01	3.06771E+02	4.30914E-01	3.01408E-04	0.00000E+00	0.00000E+00
963	4.30274E-01	3.07099E+02	4.30913E-01	3.01094E-04	0.00000E+00	0.00000E+00
964	4.24956E-01	3.07414E+02	4.30907E-01	3.00845E-04	0.00000E+00	0.00000E+00
965	4.26253E-01	3.07715E+02	4.30902E-01	3.00571E-04	0.00000E+00	0.00000E+00
966	4.48713E-01	3.08029E+02	4.30921E-01	3.00827E-04	0.00000E+00	0.00000E+00
967	4.26241E-01	3.08331E+02	4.30916E-01	3.00554E-04	0.00000E+00	0.00000E+00
968	4.21349E-01	3.08625E+02	4.30906E-01	3.00406E-04	0.00000E+00	0.00000E+00
969	4.23477E-01	3.08963E+02	4.30898E-01	3.00194E-04	0.00000E+00	0.00000E+00
970	4.22261E-01	3.09289E+02	4.30889E-01	3.00016E-04	0.00000E+00	0.00000E+00
971	4.21615E-01	3.09630E+02	4.30880E-01	2.99859E-04	0.00000E+00	0.00000E+00
972	4.34719E-01	3.10055E+02	4.30884E-01	2.99576E-04	0.00000E+00	0.00000E+00
973	4.34609E-01	3.10379E+02	4.30888E-01	2.99292E-04	0.00000E+00	0.00000E+00
974	4.15198E-01	3.10694E+02	4.30871E-01	2.99419E-04	0.00000E+00	0.00000E+00
975	4.30697E-01	3.11024E+02	4.30871E-01	2.99112E-04	0.00000E+00	0.00000E+00
976	4.40992E-01	3.11341E+02	4.30882E-01	2.98985E-04	0.00000E+00	0.00000E+00
977	4.26609E-01	3.11709E+02	4.30877E-01	2.98710E-04	0.00000E+00	0.00000E+00
978	4.40731E-01	3.12052E+02	4.30887E-01	2.98575E-04	0.00000E+00	0.00000E+00
979	4.29475E-01	3.12365E+02	4.30886E-01	2.98273E-04	0.00000E+00	0.00000E+00
980	4.21792E-01	3.12669E+02	4.30877E-01	2.98113E-04	0.00000E+00	0.00000E+00
981	4.38641E-01	3.13015E+02	4.30884E-01	2.97913E-04	0.00000E+00	0.00000E+00
982	4.24572E-01	3.13313E+02	4.30878E-01	2.97679E-04	0.00000E+00	0.00000E+00
983	4.47810E-01	3.13628E+02	4.30895E-01	2.97876E-04	0.00000E+00	0.00000E+00
984	4.39955E-01	3.13948E+02	4.30905E-01	2.97715E-04	0.00000E+00	0.00000E+00
985	4.32729E-01	3.14266E+02	4.30906E-01	2.97418E-04	0.00000E+00	0.00000E+00

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

986	4.12678E-01	3.14578E+02	4.30888E-01	2.97693E-04	0.00000E+00	0.00000E+00
987	4.42827E-01	3.14927E+02	4.30900E-01	2.97637E-04	0.00000E+00	0.00000E+00
988	4.33477E-01	3.15251E+02	4.30903E-01	2.97347E-04	0.00000E+00	0.00000E+00
989	4.31513E-01	3.15611E+02	4.30903E-01	2.97046E-04	0.00000E+00	0.00000E+00
990	4.18927E-01	3.15916E+02	4.30891E-01	2.96993E-04	0.00000E+00	0.00000E+00
991	4.26421E-01	3.16219E+02	4.30887E-01	2.96727E-04	0.00000E+00	0.00000E+00
992	4.31255E-01	3.16526E+02	4.30887E-01	2.96427E-04	0.00000E+00	0.00000E+00
993	4.50152E-01	3.16845E+02	4.30906E-01	2.96765E-04	0.00000E+00	0.00000E+00
994	4.31645E-01	3.17155E+02	4.30907E-01	2.96467E-04	0.00000E+00	0.00000E+00
995	4.26160E-01	3.17469E+02	4.30902E-01	2.96206E-04	0.00000E+00	0.00000E+00
996	4.22311E-01	3.17781E+02	4.30894E-01	2.96035E-04	0.00000E+00	0.00000E+00
997	4.19499E-01	3.18098E+02	4.30882E-01	2.95959E-04	0.00000E+00	0.00000E+00
998	4.37252E-01	3.18400E+02	4.30889E-01	2.95730E-04	0.00000E+00	0.00000E+00
999	4.24955E-01	3.18710E+02	4.30883E-01	2.95494E-04	0.00000E+00	0.00000E+00
1000	4.26402E-01	3.19030E+02	4.30878E-01	2.95231E-04	0.00000E+00	0.00000E+00
1001	4.37645E-01	3.19351E+02	4.30885E-01	2.95014E-04	0.00000E+00	0.00000E+00
1002	4.38846E-01	3.19670E+02	4.30893E-01	2.94826E-04	0.00000E+00	0.00000E+00
1003	4.31258E-01	3.19986E+02	4.30893E-01	2.94531E-04	0.00000E+00	0.00000E+00

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

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

```
LIFETIME = 2.46949E-04 + OR -  1.25870E-06            GENERATION TIME = 1.80874E-06 + OR -  7.97475E-09
NU BAR   = 2.55392E+00 + OR -  2.02013E-04        AVERAGE FISSION GROUP = 6.60224E+00 + OR -  2.87354E-03
                    ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION = 8.67901E+04 + OR -  2.67219E+02
```

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.43088	+ OR - 0.00029	0.43059 TO 0.43118	0.43029 TO 0.43147	0.43000 TO 0.43177	1000000
4	0.43088	+ OR - 0.00029	0.43059 TO 0.43118	0.43029 TO 0.43147	0.43000 TO 0.43177	999000
5	0.43088	+ OR - 0.00030	0.43058 TO 0.43117	0.43028 TO 0.43147	0.42999 TO 0.43176	998000
6	0.43089	+ OR - 0.00030	0.43059 TO 0.43118	0.43030 TO 0.43148	0.43000 TO 0.43177	997000
7	0.43090	+ OR - 0.00030	0.43060 TO 0.43119	0.43030 TO 0.43149	0.43001 TO 0.43178	996000
8	0.43091	+ OR - 0.00030	0.43061 TO 0.43120	0.43032 TO 0.43150	0.43002 TO 0.43179	995000
9	0.43091	+ OR - 0.00030	0.43062 TO 0.43121	0.43032 TO 0.43150	0.43003 TO 0.43180	994000
10	0.43091	+ OR - 0.00030	0.43062 TO 0.43121	0.43032 TO 0.43150	0.43002 TO 0.43180	993000
11	0.43091	+ OR - 0.00030	0.43061 TO 0.43120	0.43032 TO 0.43150	0.43002 TO 0.43180	992000
12	0.43090	+ OR - 0.00030	0.43061 TO 0.43120	0.43031 TO 0.43150	0.43002 TO 0.43179	991000
17	0.43086	+ OR - 0.00030	0.43056 TO 0.43115	0.43026 TO 0.43145	0.42997 TO 0.43175	986000
22	0.43084	+ OR - 0.00030	0.43054 TO 0.43114	0.43024 TO 0.43144	0.42995 TO 0.43173	981000
27	0.43084	+ OR - 0.00030	0.43055 TO 0.43114	0.43025 TO 0.43144	0.42995 TO 0.43174	976000
32	0.43079	+ OR - 0.00030	0.43049 TO 0.43108	0.43019 TO 0.43138	0.42989 TO 0.43168	971000
37	0.43077	+ OR - 0.00030	0.43047 TO 0.43107	0.43017 TO 0.43137	0.42987 TO 0.43166	966000
42	0.43077	+ OR - 0.00030	0.43047 TO 0.43107	0.43017 TO 0.43137	0.42987 TO 0.43167	961000
47	0.43080	+ OR - 0.00030	0.43050 TO 0.43110	0.43020 TO 0.43140	0.42990 TO 0.43171	956000
52	0.43081	+ OR - 0.00030	0.43051 TO 0.43111	0.43020 TO 0.43141	0.42990 TO 0.43171	951000
57	0.43083	+ OR - 0.00030	0.43053 TO 0.43114	0.43023 TO 0.43144	0.42993 TO 0.43174	946000
62	0.43084	+ OR - 0.00030	0.43053 TO 0.43114	0.43023 TO 0.43145	0.42992 TO 0.43175	941000
67	0.43085	+ OR - 0.00031	0.43055 TO 0.43116	0.43024 TO 0.43146	0.42994 TO 0.43177	936000
72	0.43088	+ OR - 0.00031	0.43058 TO 0.43119	0.43027 TO 0.43150	0.42996 TO 0.43180	931000
77	0.43087	+ OR - 0.00031	0.43056 TO 0.43118	0.43025 TO 0.43148	0.42994 TO 0.43179	926000
82	0.43088	+ OR - 0.00031	0.43057 TO 0.43119	0.43026 TO 0.43150	0.42995 TO 0.43181	921000
87	0.43090	+ OR - 0.00031	0.43059 TO 0.43122	0.43028 TO 0.43153	0.42997 TO 0.43184	916000
92	0.43096	+ OR - 0.00031	0.43065 TO 0.43127	0.43034 TO 0.43158	0.43003 TO 0.43189	911000

Figure 6.7-3 CSAS Input/Output Summary for Storage Cask - Normal Conditions (Continued)

```
WRR EC455-5302 YANKEE STORAGE CASK KENO-VA MODEL BASE CASE

                               FREQUENCY FOR GENERATIONS    4 TO 1003
0.3976 TO 0.3985     *
0.3985 TO 0.3994
0.3994 TO 0.4003
0.4003 TO 0.4013
0.4013 TO 0.4022
0.4022 TO 0.4031
0.4031 TO 0.4040
0.4040 TO 0.4050
0.4050 TO 0.4059
0.4059 TO 0.4068     *
0.4068 TO 0.4077     ***
0.4077 TO 0.4087     *
0.4087 TO 0.4096     *
0.4096 TO 0.4105     *
0.4105 TO 0.4115     *****
0.4115 TO 0.4124     ******
0.4124 TO 0.4133     ******
0.4133 TO 0.4142     *****
0.4142 TO 0.4152     ***********
0.4152 TO 0.4161     ***********
0.4161 TO 0.4170     ************
0.4170 TO 0.4179     **********************
0.4179 TO 0.4189     ******************
0.4189 TO 0.4198     **************
0.4198 TO 0.4207     ***********************
0.4207 TO 0.4216     ****************************
0.4216 TO 0.4226     *****************************
0.4226 TO 0.4235     *************************************
0.4235 TO 0.4244     **************************
0.4244 TO 0.4253     ******************
0.4253 TO 0.4263     ************************************
0.4263 TO 0.4272     **********************************
0.4272 TO 0.4281     ****************************************
0.4281 TO 0.4290     ******************************
0.4290 TO 0.4300     ************************************
0.4300 TO 0.4309     *********************************************
0.4309 TO 0.4318     ************************************
0.4318 TO 0.4327     ****************************************
0.4327 TO 0.4337     *************************************************
0.4337 TO 0.4346     ***********************************
0.4346 TO 0.4355     ******************************
0.4355 TO 0.4364     ****************************
0.4364 TO 0.4374     *****************************
0.4374 TO 0.4383     ***********************************
0.4383 TO 0.4392     *************************
0.4392 TO 0.4401     *******************************
0.4401 TO 0.4411     **************************
0.4411 TO 0.4420     *************************
0.4420 TO 0.4429     *****************
0.4429 TO 0.4438     *************
0.4438 TO 0.4448     *********
0.4448 TO 0.4457     *******************
0.4457 TO 0.4466     ****
0.4466 TO 0.4475     *****
0.4475 TO 0.4485     *********
0.4485 TO 0.4494     *********
0.4494 TO 0.4503     *******
0.4503 TO 0.4513     *****
0.4513 TO 0.4522     *
0.4522 TO 0.4531     *****
0.4531 TO 0.4540     ***
0.4540 TO 0.4550
0.4550 TO 0.4559     *
0.4559 TO 0.4568     *
0.4568 TO 0.4577     *
0.4577 TO 0.4587     *
0.4587 TO 0.4596     *
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions

```
      PRIMARY MODULE ACCESS AND INPUT RECORD ( SCALE DRIVER - 95/03/29 - 09:06:37 )
MODULE CSAS25   WILL BE CALLED
 WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
  '
  '       File st-mr-wg.in
  '
  '       THIS IS A MODEL OF THE YNPS NAC-MPC BASKET IN THE STORAGE CASK
  '               LOADED WITH 36 UNITED NUCLEAR TYPE A ASSEMBLIES
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  '        material     volume
  '         number      fraction
  '        --------     --------
  '            3         1.0000     inside canister
  '            7         1.0000     canister/VCC gap
  '           10         1.0000     external to VCC
  '           11         1.0000     fuel/clad gap
  '
  '
  '            PRODUCED FOR THE YANKEE ROWE
  '               STC LICENSE AMENDMENT
  '
  27GROUPNDF4 LATTICECELL
  UO2          1               0.95    293.0 92235 4.0 92238 96.0 END
  ZIRCALLOY    2               1.0     293.0                      END
  H2O          3               1.0     293.0                      END
  AL           4               1.0     293.0                      END
  SS304        5               1.0     293.0                      END
  B-10         6  DEN=2.6226 0.0450   293.0                      END
  B-11         6  DEN=2.6226 0.2736   293.0                      END
  C            6  DEN=2.6226 0.0927   293.0                      END
  AL           6  DEN=2.6226 0.5737   293.0                      END
  H2O          7               1.0     293.0                      END
  CARBONSTEEL  8               1.0     293.0                      END
  REG-CONCRETE 9  DEN=2.243    1.0     293.0                      END
  H2O         10               1.0     293.0                      END
  H2O         11               1.0     293.0                      END
  END COMP
  SQUAREPITCH  1.1887 0.7887 1 3 0.9271 2 0.8052 11 END
  WRR EC455-5302 STORAGE CASK CRITICALITY: water in fuel/clad gap
  READ PARAM RUN=yes PLT=no  GEN=1003 NPG=1000 TME=500 END PARAM
  READ GEOM
  '
  '  WATER LEVEL UNIT CELLS
  '
  UNIT  1
  COM='FUEL PIN CELL - BETWEEN DISKS'
  CYLINDER  1 1  0.3943    2P2.1400
  CYLINDER 11 1  0.4026    2P2.1400
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  2
  COM='WATER CELL - BETWEEN DISKS'
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  3
  COM='DISPLACEMENT CELL - BETWEEN DISKS'
  CYLINDER  2 1  0.4635    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  UNIT  4
  COM='INSTRUMENT TUBE CELL - BETWEEN DISKS'
  CYLINDER  3 1  0.4998    2P2.1400
  CYLINDER  5 1  0.5442    2P2.1400
  CUBOID    3 1  4P0.5944  2P2.1400
  '
  '  DISK LEVEL UNIT CELLS (BOTH SS AND AL)
  '
  UNIT  5
  COM='FUEL PIN CELL - WITH SS DISK'
  CYLINDER  1 1  0.3943    2P0.6604
  CYLINDER 11 1  0.4026    2P0.6604
  CYLINDER  2 1  0.4635    2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  6
  COM='WATER CELL - WITH SS DISK'
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  7
  COM='DISPLACEMENT CELL - WITH SS DISK'
  CYLINDER  2 1  0.4635    2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  UNIT  8
  COM='INSTRUMENT TUBE CELL - WITH SS DISK'
  CYLINDER  3 1  0.4998    2P0.6604
  CYLINDER  5 1  0.5442    2P0.6604
  CUBOID    3 1  4P0.5944 2P0.6604
  '
  '  WATER LEVEL BORAL SHEETS
  '
  UNIT 14
  COM='X-X BORAL SHEET BETWEEN DISKS'
  CUBOID 6 1 2P9.144 2P0.0318 2P2.1400
  CUBOID 4 1 2P9.144 2P0.0953 2P2.1400
  UNIT 15
  COM='Y-Y BORAL SHEET BETWEEN DISKS'
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
CUBOID 6 1 2P0.0318 2P9.144 2P2.1400
CUBOID 4 1 2P0.0953 2P9.144 2P2.1400
'
'  DISK LEVEL BORAL SHEETS (AL AND SS)
'
UNIT 16
COM='X-X BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P9.144 2P0.0318 2P0.6604
CUBOID 4 1 2P9.144 2P0.0953 2P0.6604
UNIT 17
COM='Y-Y BORAL SHEET WITH SS DISK'
CUBOID 6 1 2P0.0318 2P9.144 2P0.6604
CUBOID 4 1 2P0.0953 2P9.144 2P0.6604
'
' WATER LEVEL WEB MATERIAL
'
UNIT 20
COM='WATER LEVEL WEB MATERIAL (SMALL) X-X'
CUBOID    3 1 2P10.4635 2P0.9716 2P2.1400
UNIT 21
COM='WATER LEVEL WEB MATERIAL (MEDIUM) X-X'
CUBOID    3 1 2P10.4635 2P1.0478 2P2.1400
UNIT 22
COM='WATER LEVEL WEB MATERIAL (LARGE) X-X'
CUBOID    3 1 2P10.4635 2P1.1208 2P2.1400
UNIT 23
COM='WATER LEVEL WEB MATERIAL (LONG) Y-Y'
CUBOID    3 1 2P1.1208 2P79.5249 2P2.1400
'
'  SUPPORT DISK WEB MATERIAL
'
UNIT 30
COM='SUPPORT DISK WEB MATERIAL (SMALL) X-X'
CUBOID    5 1 2P10.4635 2P0.9716 2P0.6604
UNIT 31
COM='SUPPORT DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    5 1 2P10.4635 2P1.0478 2P0.6604
UNIT 32
COM='SUPPORT DISK WEB MATERIAL (LARGE) X-X'
CUBOID    5 1 2P10.4635 2P1.1208 2P0.6604
UNIT 33
COM='SUPPORT DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    5 1 2P1.1208 2P79.5249 2P0.6604
'
'  HEAT TRANSFER DISK WEB MATERIAL
'
UNIT 40
COM='HEAT TRANSFER DISK WEB MATERIAL (SMALL) X-X'
CUBOID    4 1 2P10.4635 2P0.9716 2P0.6604
UNIT 41
COM='HEAT TRANSFER DISK WEB MATERIAL (MEDIUM) X-X'
CUBOID    4 1 2P10.4635 2P1.0478 2P0.6604
UNIT 42
COM='HEAT TRANSFER DISK WEB MATERIAL (LARGE) X-X'
CUBOID    4 1 2P10.4635 2P1.1208 2P0.6604
UNIT 43
COM='HEAT TRANSFER DISK WEB MATERIAL (LONG) Y-Y'
CUBOID    4 1 2P1.1208 2P79.5249 2P0.6604
'
'  WATER LEVEL ASSEMBLY ARRAYS
'
UNIT 50
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL'
ARRAY  1  -9.5104 -9.5104 -2.1400
CUBOID 3 1 4P9.9441                             2P2.1400
CUBOID 5 1 4P10.0661                            2P2.1400
CUBOID 3 1 4P10.25681                           2P2.1400
HOLE  14   0.0       10.1615  0.0
HOLE  14   0.0      -10.1615 0.0
HOLE  15   10.1615  0.0       0.0
HOLE  15   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                            2P2.1400
UNIT 51
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -Y'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   0.0      -0.1584      0.0
UNIT 52
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +Y'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   0.0       0.1584      0.0
UNIT 53
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   -0.1584  0.0           0.0
UNIT 54
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   0.1584   0.0          0.0
UNIT 55
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X +Y'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   0.1584   0.1584       0.0
UNIT 56
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X +Y'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   -0.1584  0.1584        0.0
UNIT 57
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL +X -Y'
CUBOID 3 1 4P10.4635                            2P2.1400
HOLE  50   0.1584   -0.1584       0.0
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
UNIT 58
COM='FUEL TUBE AND ASSEMBLY - WATER LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                    2P2.1400
HOLE  50   -0.1584   -0.1584        0.0
UNIT 59
COM='WATER LEVEL CENTRAL HOLE'
CUBOID 3 1 4P10.4636                                    2P2.1400
'
'   SUPPORT DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 60
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                     2P0.6604
CUBOID 5 1 4P10.0661                                    2P0.6604
CUBOID 3 1 4P10.25681                                   2P0.6604
HOLE  16   0.0        10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                    2P0.6604
UNIT 61
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   0.0       -0.1584        0.0
UNIT 62
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   0.0       0.1584         0.0
UNIT 63
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   -0.1584   0.0            0.0
UNIT 64
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   0.1584   0.0             0.0
UNIT 65
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   0.1584   0.1584          0.0
UNIT 66
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X +Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   -0.1584   0.1584         0.0
UNIT 67
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   0.1584   -0.1584         0.0
UNIT 68
COM='FUEL TUBE AND ASSEMBLY - SUPPORT DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  60   -0.1584   -0.1584        0.0
UNIT 69
COM='SUPPORT DISK CENTRAL HOLE'
CUBOID 3 1 4P10.4636   2P0.6604
'
'   HEAT TRANSFER DISK LEVEL ASSEMBLY ARRAYS
'
UNIT 70
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL'
ARRAY  2  -9.5104 -9.5104 -0.6604
CUBOID 3 1 4P9.9441                                     2P0.6604
CUBOID 5 1 4P10.0661                                    2P0.6604
CUBOID 3 1 4P10.25681                                   2P0.6604
HOLE  16   0.0        10.1615  0.0
HOLE  16   0.0       -10.1615 0.0
HOLE  17   10.1615  0.0       0.0
HOLE  17   -10.1615 0.0       0.0
CUBOID 5 1 4P10.3051                                    2P0.6604
UNIT 71
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   0.0       -0.1584        0.0
UNIT 72
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   0.0       0.1584         0.0
UNIT 73
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   -0.1584   0.0            0.0
UNIT 74
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   0.1584   0.0             0.0
UNIT 75
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X +Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   0.1584   0.1584          0.0
UNIT 76
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   -0.1584   0.1584         0.0
UNIT 77
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL +X -Y'
CUBOID 3 1 4P10.4635                                    2P0.6604
HOLE  70   0.1584   -0.1584         0.0
UNIT 78
COM='FUEL TUBE AND ASSEMBLY - HEAT TRANSFER DISK LEVEL -X -Y'
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
CUBOID 3 1 4P10.4635                         2P0.6604
HOLE  70    -0.1584    -0.1584      0.0
UNIT 79
COM='HEAT TRANSFER CENTRAL HOLE'
CUBOID 3 1 4P10.4636                         2P0.6604
'
'  WATER LEVEL BASKET ARRAYS
'
UNIT 80
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 20 -10.4636 -33.6323 -2.1400
UNIT 81
COM='5X1 WATER LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 21 -10.4636 -33.6323 -2.1400
UNIT 82
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 22 -10.4636 -56.6549 -2.1400
UNIT 83
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 23 -10.4636 -56.6549 -2.1400
UNIT 84
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 24 -10.4636 -79.5251 -2.1400
UNIT 85
COM='13X1 WATER LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 25 -10.4636 -79.5251 -2.1400
UNIT 86
COM='13X1 WATER LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 26 -10.4636 -79.5251 -2.1400
'
'  SUPPORT DISK LEVEL BASKET ARRAYS
'
UNIT 90
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 30 -10.4636 -33.6323 -0.6604
UNIT 91
COM='5X1 SUPPORT DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 31 -10.4636 -33.6323 -0.6604
UNIT 92
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 32 -10.4636 -56.6549 -0.6604
UNIT 93
COM='9X1 WATER LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 33 -10.4636 -56.6549 -0.6604
UNIT 94
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 34 -10.4636 -79.5251 -0.6604
UNIT 95
COM='13X1 SUPPORT DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 35 -10.4636 -79.5251 -0.6604
UNIT 96
COM='13X1 SUPPORT DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 36 -10.4636 -79.5251 -0.6604
'
'  HEAT TRANSFER DISK LEVEL BASKET ARRAYS
'
UNIT 100
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY -X)'
ARRAY 40 -10.4636 -33.6323 -0.6604
UNIT 101
COM='5X1 HEAT TRANSFER DISK LEVEL ARRAY (SMALL ARRAY +X)'
ARRAY 41 -10.4636 -33.6323 -0.6604
UNIT 102
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY -X)'
ARRAY 42 -10.4636 -56.6549 -0.6604
UNIT 103
COM='9X1 HEAT TRANSFER DISK LEVEL ARRAY (MEDIUM ARRAY +X)'
ARRAY 43 -10.4636 -56.6549 -0.6604
UNIT 104
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY -X)'
ARRAY 44 -10.4636 -79.5251 -0.6604
UNIT 105
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (MIDDLE LARGE ARRAY)'
ARRAY 45 -10.4636 -79.5251 -0.6604
UNIT 106
COM='13X1 HEAT TRANSFER DISK LEVEL ARRAY (LARGE ARRAY +X)'
ARRAY 46 -10.4636 -79.5251 -0.6604
'
'  BASKET ARRAY IN STORAGE CASK OVERPACK (LEVEL CONSTRUCTION)
'
UNIT 110
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - WATER LEVEL'
ARRAY 50 -33.6323 -79.5251 -2.1400
CYLINDER 3 1 88.1253      2P2.1400
HOLE 80      -69.0614 0.0 0.0
HOLE 82      -46.1912 0.0 0.0
HOLE 81       69.0614 0.0 0.0
HOLE 83       46.1912 0.0 0.0
CYLINDER  5 1  89.7128     2P2.1400
CYLINDER  7 1 100.33       2P2.1400
CYLINDER  8 1 109.22       2P2.1400
CYLINDER  9 1 162.56       2P2.1400
CUBOID   10 1 4P228.60     2P2.1400
UNIT 111
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - SUPPORT DISK LEVEL'
ARRAY 51 -33.6323 -79.5251 -0.6604
CYLINDER 5 1 87.6046      2P0.6604
HOLE 90      -69.0614 0.0 0.0
HOLE 92      -46.1912 0.0 0.0
HOLE 91       69.0614 0.0 0.0
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
HOLE 93       46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  7 1 100.33       2P0.6604
CYLINDER  8 1 109.22       2P0.6604
CYLINDER  9 1 162.56       2P0.6604
CUBOID   10 1 4P228.60     2P0.6604
UNIT 112
COM='BASKET ARRAY IN STORAGE CASK OVERPACK - HEAT TRANSFER DISK LEVEL'
ARRAY 52 -33.6323 -79.5251 -0.6604
CYLINDER 4 1 87.249       2P0.6604
HOLE 100     -69.0614 0.0 0.0
HOLE 102     -46.1912 0.0 0.0
HOLE 101      69.0614 0.0 0.0
HOLE 103      46.1912 0.0 0.0
CYLINDER  3 1  88.1253     2P0.6604
CYLINDER  5 1  89.7128     2P0.6604
CYLINDER  7 1 100.33       2P0.6604
CYLINDER  8 1 109.22       2P0.6604
CYLINDER  9 1 162.56       2P0.6604
CUBOID   10 1 4P228.60     2P0.6604
'
'  GLOBAL UNIT
'
GLOBAL UNIT 120
ARRAY 60 -228.60 -228.60 0.0
END GEOM
READ ARRAY
ARA=1 NUX=16 NUY=16 NUZ=1  FILL
1 1 1 1 1 1 1 3 2 2 2 2 2 2 2 2
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 4 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
END FILL
ARA=2 NUX=16 NUY=16 NUZ=1  FILL
5 5 5 5 5 5 5 7 6 6 6 6 6 6 6 6
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
7 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 8 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
6 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
END FILL
'
'  WATER LEVEL ARRAYS
'
ARA=20  NUX=1 NUY=5 NUZ=1
FILL
55
22
54
22
57
END FILL
ARA=21  NUX=1 NUY=5 NUZ=1
FILL
56
22
53
22
58
END FILL
ARA=22  NUX=1 NUY=9 NUZ=1
FILL
55
21
55
22
54
22
57
21
57
END FILL
ARA=23  NUX=1 NUY=9 NUZ=1
FILL
56
21
56
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
22
53
22
58
21
58
END FILL
ARA=24  NUX=1 NUY=13 NUZ=1
FILL
55
20
55
21
55
22
54
22
57
21
57
20
57
END FILL
ARA=25  NUX=1 NUY=13 NUZ=1
FILL
52
20
52
21
52
22
59
22
51
21
51
20
51
END FILL
ARA=26  NUX=1 NUY=13 NUZ=1
FILL
56
20
56
21
56
22
53
22
58
21
58
20
58
END FILL
'
'  SUPPOR DISK LEVEL ARRAYS
'
ARA=30  NUX=1 NUY=5 NUZ=1
FILL
65
32
64
32
67
END FILL .
ARA=31  NUX=1 NUY=5 NUZ=1
FILL
66
32
63
32
68
END FILL
ARA=32  NUX=1 NUY=9 NUZ=1
FILL
65
31
65
32
64
32
67
31
67
END FILL
ARA=33  NUX=1 NUY=9 NUZ=1
FILL
66
31
66
32
63
32
68
31
68
END FILL
ARA=34  NUX=1 NUY=13 NUZ=1
FILL
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
65
30
65
31
65
32
64
32
67
31
67
30
67
END FILL
ARA=35  NUX=1 NUY=13 NUZ=1
FILL
62
30
62
31
62
32
69
32
61
31
61
30
61
END FILL
ARA=36  NUX=1 NUY=13 NUZ=1
FILL
66
30
66
31
66
32
63
32
68
31
68
30
68
END FILL
'
'  HEAT TRANSFER DISK LEVEL ARRAYS
'
ARA=40  NUX=1 NUY=5 NUZ=1
FILL
75
42
74
42
77
END FILL
ARA=41  NUX=1 NUY=5 NUZ=1
FILL
76
42
73
42
78
END FILL
ARA=42  NUX=1 NUY=9 NUZ=1
FILL
75
41
75
42
74
42
77
41
77
END FILL
ARA=43  NUX=1 NUY=9 NUZ=1
FILL
76
41
76
42
73
42
78
41
78
END FILL
ARA=44  NUX=1 NUY=13 NUZ=1
FILL
75
40
75
41
75
42
74
42
77
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
41
77
40
77
END FILL
ARA=45  NUX=1 NUY=13 NUZ=1
FILL
72
40
72
41
72
42
79
42
71
41
71
40
71
END FILL
ARA=46  NUX=1 NUY=13 NUZ=1
FILL
76
40
76
41
76
42
73
42
78
41
78
40
78
END FILL
'
'  MAJOR ARRAYS
'
ARA=50 NUX=5 NUY=1 NUZ=1
FILL
84 23 85 23 86
END FILL
ARA=51 NUX=5 NUY=1 NUZ=1
FILL
94 33 95 33 96
END FILL
ARA=52 NUX=5 NUY=1 NUZ=1
FILL
104 43 105 43 106
END FILL
'
'  GLOBAL ARRAY
'
ARA=60 NUX=1 NUY=1 NUZ=4
FILL
112
110
111
110
END FILL
END ARRAY
READ BOUNDS ZFC=PER YXF=REFLECT END BOUNDS
END DATA
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
 ccccccccccc      sssssssssss        AAAAAAAAA       sssssssssss      22222222222    5555555555555
ccccccccccccc    sssssssssssss      AAAAAAAAAAA     sssssssssssss    2222222222222   5555555555555
cc         cc    ss         ss     AA         AA    ss         ss    22         22   55
cc               ss                AA         AA    ss                          22   55
cc               ss                AA         AA    ss                          22   55
cc               ssssssssssss      AAAAAAAAAAAAA    ssssssssssss               22    555555555555
cc                ssssssssssss     AAAAAAAAAAAAA     ssssssssssss            22      5555555555555
cc                          ss     AA         AA               ss          22                   55
cc                          ss     AA         AA               ss        22                     55
cc         cc    ss         ss     AA         AA    ss         ss      22            55         55
ccccccccccccc    sssssssssssss     AA         AA    sssssssssssss    2222222222222   5555555555555
 ccccccccccc      sssssssssss      AA         AA     sssssssssss     2222222222222    55555555555

 sssssssssss      ccccccccccc        AAAAAAAAA      LL               EEEEEEEEEEEEE                    PPPPPPPPPPPP      ccccccccccc
sssssssssssss    ccccccccccccc      AAAAAAAAAAA     LL               EEEEEEEEEEEEE                    PPPPPPPPPPPPP    ccccccccccccc
ss         ss    cc         cc     AA         AA    LL               EE                               PP         PP    cc         cc
ss               cc                AA         AA    LL               EE                               PP         PP    cc
ss               cc                AA         AA    LL               EE                               PP         PP    cc
ssssssssssss     cc                AAAAAAAAAAAAA    LL               EEEEEEEEE        -------------   PPPPPPPPPPPPP    cc
 ssssssssssss    cc                AAAAAAAAAAAAA    LL               EEEEEEEEE        -------------   PPPPPPPPPPPP     cc
           ss    cc                AA         AA    LL               EE                               PP               cc
           ss    cc                AA         AA    LL               EE                               PP               cc
ss         ss    cc         cc     AA         AA    LL               EE                               PP               cc         cc
sssssssssssss    ccccccccccccc     AA         AA    LLLLLLLLLLLLL    EEEEEEEEEEEEE                    PP               ccccccccccccc
 sssssssssss      ccccccccccc      AA         AA    LLLLLLLLLLLLL    EEEEEEEEEEEEE                    PP                ccccccccccc

     11           22222222222              //        0000000        99999999999               //     99999999999      666666666666
    111          2222222222222            //        000000000      9999999999999             //     9999999999999    6666666666666
   1111          22         22           //        00       00     99         99            //      99         99    66
     11                     22          //         00       00     99         99           //       99         99    66
     11                     22         //          00       00     99         99          //        99         99    66
     11                    22         //           00       00     9999999999999         //         9999999999999    666666666666
     11                  22          //            00       00      999999999999        //           999999999999    6666666666666
     11                22           //             00       00                99       //                      99    66         66
     11              22            //              00       00                99      //                       99    66         66
     11            22             //               00       00                99     //                        99    66         66
   11111111      2222222222222   //                 000000000      9999999999999    //          9999999999999    6666666666666
   11111111      2222222222222  //                   0000000       999999999999    //           999999999999      66666666666

   0000000       7777777777777                           11         33333333333                    22222222222       0000000
  000000000      777777777777                           111        3333333333333                  2222222222222     000000000
 00       00     77        77          :::             1111        33         33        :::       22         22    00       00
00         00             77           :::               11                   33        :::                  22   00         00
00         00            77            :::               11                   33        :::                  22   00         00
00         00           77                               11                  333                            22    00         00
00         00           77                               11                  333                          22      00         00
00         00          77              :::               11                   33        :::             22        00         00
00         00          77              :::               11                   33        :::           22          00         00
 00       00          77               :::               11        33         33        :::         22             00       00
  000000000           77                             11111111      3333333333333                  2222222222222     000000000
   0000000            77                             11111111       33333333333                   2222222222222      0000000
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

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

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                  PROGRAM VERIFICATION INFORMATION                    *****
*****                                                                      *****
*****                CODE SYSTEM:   SCALE-PC VERSION:   4.3                *****
*****                                                                      *****
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                                                                      *****
*****                  PROGRAM:  CSAS                                      *****
*****                                                                      *****
*****            CREATION DATE:  03-08-96                                  *****
*****                                                                      *****
*****                   VOLUME:  ENG                                       *****
*****                                                                      *****
*****                  LIBRARY:  G:\scale43\exe                            *****
*****                                                                      *****
*****                                                                      *****
*****          PRODUCTION CODE:  CSAS                                      *****
*****                                                                      *****
*****                  VERSION:  3.1                                       *****
*****                                                                      *****
*****                  JOBNAME:  SCALE-PC                                  *****
*****                                                                      *****
*****        DATE OF EXECUTION:  12/09/96                                  *****
*****                                                                      *****
*****        TIME OF EXECUTION:  07:13:20                                  *****
*****                                                                      *****
*****                                                                      *****
********************************************************************************
********************************************************************************
********************************************************************************
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
**** PROBLEM PARAMETERS ****

LIB 27GROUPNDF4  LIBRARY
MXX             11 MIXTURES
MSC             14 COMPOSITION SPECIFICATIONS
IZM              4 MATERIAL ZONES
GE  LATTICECELL   GEOMETRY
MORE             0 0/1 DO NOT READ/READ OPTIONAL PARAMETER DATA
MSLN             0 FUEL SOLUTIONS


**** PROBLEM COMPOSITION DESCRIPTION ****

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

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

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

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

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

SC  B-10           STANDARD COMPOSITION
MX               6 MIXTURE NO.
VF          0.0450 VOLUME FRACTION
ROTH        2.6226 SPECIFIED DENSITY
NEL              1 NO. ELEMENTS
ICP              1 0/1 MIXTURE/COMPOUND
TEMP         293.0 DEG KELVIN
              5010        1.00 ATOM/MOLECULE
END

SC  B-11           STANDARD COMPOSITION
MX               6 MIXTURE NO.
VF          0.2736 VOLUME FRACTION
ROTH        2.6226 SPECIFIED DENSITY
NEL              1 NO. ELEMENTS
ICP              1 0/1 MIXTURE/COMPOUND
TEMP         293.0 DEG KELVIN
              5011        1.00 ATOM/MOLECULE
END

SC  C              STANDARD COMPOSITION
MX               6 MIXTURE NO.
VF          0.0927 VOLUME FRACTION
ROTH        2.6226 SPECIFIED DENSITY
NEL              1 NO. ELEMENTS
ICP              1 0/1 MIXTURE/COMPOUND
TEMP         293.0 DEG KELVIN
              6012        1.00 ATOM/MOLECULE
END
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
SC  AL              STANDARD COMPOSITION
MX                6 MIXTURE NO.
VF           0.5737 VOLUME FRACTION
ROTH         2.6226 SPECIFIED DENSITY
NEL               1 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
              13027      1.00 ATOM/MOLECULE
END

SC  H2O             STANDARD COMPOSITION
MX                7 MIXTURE NO.
VF           1.0000 VOLUME FRACTION
ROTH         0.9982 THEORETICAL DENSITY
NEL               2 NO. ELEMENTS
ICP               1 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
               1001      2.00 ATOMS/MOLECULE
               8016      1.00 ATOM/MOLECULE
END

SC  CARBONSTEEL  STANDARD COMPOSITION
MX                8 MIXTURE NO.
VF           1.0000 VOLUME FRACTION
ROTH         7.8212 THEORETICAL DENSITY
NEL               2 NO. ELEMENTS
ICP               0 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
              26000    99.000 WT%
               6012     1.000 WT%
END

SC  REG-CONCRETE STANDARD COMPOSITION
MX                9 MIXTURE NO.
VF           1.0000 VOLUME FRACTION
ROTH         2.2430 SPECIFIED DENSITY
NEL               7 NO. ELEMENTS
ICP               0 0/1 MIXTURE/COMPOUND
TEMP          293.0 DEG KELVIN
              26000     1.400 WT%
               1001     1.000 WT%
              13027     3.400 WT%
              20000     4.400 WT%
               8016    53.200 WT%
              14000    33.700 WT%
              11023     2.900 WT%
END

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

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


**** PROBLEM GEOMETRY ****

CTP SQUAREPITCH  CELL TYPE
PITCH       1.1887 CM CENTER TO CENTER SPACING
FUELOD      0.7887 CM FUEL DIAMETER OR SLAB THICKNESS
MFUEL            1 MIXTURE NO. OF FUEL
MMOD             3 MIXTURE NO. OF MODERATOR
CLADOD      0.9271 CM CLAD OUTER DIAMETER
MCLAD            2 MIXTURE NO. OF CLAD
GAPOD       0.8052 CM GAP OUTER DIAMETER
MGAP            11 MIXTURE NO. OF GAP


ZONE SPECIFICATIONS FOR LATTICECELL GEOMETRY

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

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

********** DATA LIBRARY INFORMATION **********

  UNIT                                              VOLUME
 NUMBER          DATA SET NAME                       NAME     UNIT FUNCTION
 ------          -------------                       ----     -------------

   89    G:\scale43\DATALIB\FT89F001                          STANDARD COMPOSITION LIBRARY

   82    G:\scale43\DATALIB\FT82F001                          CROSS SECTION LIBRARY

   11    C:\svv\st-mr-wg\FT11F001                             SHORT CROSS SECTION LIBRARY

   90    C:\svv\st-mr-wg\FT90F001                             INPUT DATA DIRECT ACCESS


                  STANDARD COMPOSITION LIBRARY DATA
                  ---------------------------------

    UNIT NUMBER  :  89

    DATASET NAME :  G:\scale43\DATALIB\FT89F001

    LIBRARY TITLE:  SCALE-4 STANDARD COMPOSITION LIBRARY
                    637 STANDARD COMPOSITIONS, 490 NUCLIDES
                    90 ELEMENTS WITH VARIABLE ISOTOPIC DISTRBUTIONS.

    CREATION DATE:   6/30/95


                      CROSS SECTION LIBRARY DATA
                      ---------------------------

    UNIT NUMBER  :  82

    DATASET NAME :  G:\scale43\DATALIB\FT82F001

    LIBRARY TITLE:  SCALE 4.2 - 27 GROUP NEUTRON GROUP LIBRARY
                       BASED ON ENDF-B VERSION 4 DATA
                          COMPILED FOR NRC      1/27/89
                             LAST UPDATED                              08/12/94
                                L.M.PETRIE   -    ORNL

CONTROL MODULE CSAS25    IS COMPLETE.
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

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

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

      11         22222222222               //      0000000        99999999999               //    99999999999     666666666666
     111        2222222222222             //      000000000     9999999999999             //    9999999999999   6666666666666
    1111        22         22            //       00       00    99         99            //     99         99   66
      11                   22           //      00         00   99         99           //      99         99   66
      11                   22          //       00         00   99         99          //       99         99   66
      11                 22           //        00         00   9999999999999         //        9999999999999   666666666666
      11               22            //         00         00    999999999999        //          999999999999   6666666666666
      11             22             //          00         00              99       //                     99   66         66
      11           22              //           00         00              99      //                      99   66         66
      11        22                //             00       00               99     //                       99   66         66
   11111111     2222222222222    //               000000000     9999999999999    //             9999999999999   6666666666666
   11111111     2222222222222   //                 0000000      999999999999    //              999999999999     66666666666

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

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

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

```
********************************************************************************
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                  PROGRAM VERIFICATION INFORMATION                    *****
*****                                                                      *****
*****              CODE SYSTEM:   SCALE-PC VERSION:  4.3                   *****
*****                                                                      *****
********************************************************************************
********************************************************************************
*****                                                                      *****
*****                                                                      *****
*****                PROGRAM:  000009                                      *****
*****                                                                      *****
*****          CREATION DATE:  03-08-96                                    *****
*****                                                                      *****
*****                 VOLUME:  ENG                                         *****
*****                                                                      *****
*****                LIBRARY:  G:\scale43\exe                              *****
*****                                                                      *****
*****                                                                      *****
*****        PRODUCTION CODE:  KENOVA                                      *****
*****                                                                      *****
*****                VERSION:  3.1                                         *****
*****                                                                      *****
*****                JOBNAME:  SCALE-PC                                    *****
*****                                                                      *****
*****      DATE OF EXECUTION:  12/09/96                                    *****
*****                                                                      *****
*****      TIME OF EXECUTION:  07:13:37                                    *****
*****                                                                      *****
*****                                                                      *****
********************************************************************************
********************************************************************************
********************************************************************************
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

****** NUMERIC PARAMETERS ******

TME   MAXIMUM PROBLEM TIME (MIN)              500.00
TBA   TIME PER GENERATION (MIN)                 0.50
GEN   NUMBER OF GENERATIONS                     1003
NPG   NUMBER PER GENERATION                     1000
NSK   NUMBER OF GENERATIONS TO BE SKIPPED          3
BEG   BEGINNING GENERATION NUMBER                  1
RES   GENERATIONS BETWEEN CHECKPOINTS              0
X1D   NUMBER OF EXTRA 1-D CROSS SECTIONS           1
NBK   NEUTRON BANK SIZE                         1025
XNB   EXTRA POSITIONS IN NEUTRON BANK              0
NFB   FISSION BANK SIZE                         1000
XFB   EXTRA POSITIONS IN FISSION BANK              0
WTA   DEFAULT VALUE OF WEIGHT AVERAGE         0.5000
WTH   WEIGHT HIGH FOR SPLITTING               3.0000
WTL   WEIGHT LOW FOR RUSSIAN ROULETTE         0.3333
RND   STARTING RANDOM NUMBER            BB827100001
NB8   NUMBER OF D.A. BLOCKS ON UNIT  8           200
NL8   LENGTH OF D.A. BLOCKS ON UNIT  8           512
ADJ   MODE OF CALCULATION                    FORWARD
      INPUT DATA WRITTEN ON RESTART UNIT          NO
      BINARY DATA INTERFACE                      YES
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
***********************************************************************************************************************
***********************************************************************************************************************
***                                                                                                                 ***
***                        WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP                          ***
***                                                                                                                 ***
***********************************************************************************************************************
***                          ******      LOGICAL PARAMETERS      ******                                             ***
***                                                                                                                 ***
***  RUN  EXECUTE PROBLEM AFTER CHECKING DATA     YES        PLT  PLOT PICTURE MAP(S)                          NO ***
***                                                                                                                 ***
***  FLX  COMPUTE FLUX                             NO        FDN  COMPUTE FISSION DENSITIES                    NO ***
***                                                                                                                 ***
***  SMU  COMPUTE AVG UNIT SELF-MULTIPLICATION     NO        NUB  COMPUTE NU-BAR & AVG FISSION GROUP          YES ***
***                                                                                                                 ***
***  MKU  COMPUTE MATRIX K-EFF BY UNIT NUMBER      NO        MKP  COMPUTE MATRIX K-EFF BY UNIT LOCATION        NO ***
***                                                                                                                 ***
***  CKU  COMPUTE COFACTOR K-EFF BY UNIT NUMBER    NO        CKP  COMPUTE COFACTOR K-EFF BY UNIT LOCATION      NO ***
***                                                                                                                 ***
***  FMU  PRINT FISS PROD MATRIX BY UNIT NUMBER    NO        FMP  PRINT FISS PROD MATRIX BY UNIT LOCATION      NO ***
***                                                                                                                 ***
***  MKH  COMPUTE MATRIX K-EFF BY HOLE NUMBER      NO        MKA  COMPUTE MATRIX K-EFF BY ARRAY NUMBER         NO ***
***                                                                                                                 ***
***  CKH  COMPUTE COFACTOR K-EFF BY HOLE NUMBER    NO        CKA  COMPUTE COFACTOR K-EFF BY ARRAY NUMBER       NO ***
***                                                                                                                 ***
***  FMH  PRINT FISS PROD MATRIX BY HOLE NUMBER    NO        FMA  PRINT FISS PROD MATRIX BY ARRAY NUMBER       NO ***
***                                                                                                                 ***
***  HHL  COLLECT MATRIX BY HIGHEST HOLE LEVEL     NO        HAL  COLLECT MATRIX BY HIGHEST ARRAY LEVEL        NO ***
***                                                                                                                 ***
***  AMX  PRINT ALL MIXED CROSS SECTIONS           NO        FAR  PRINT FIS. AND ABS. BY REGION                NO ***
***                                                                                                                 ***
***  XS1  PRINT 1-D MIXTURE X-SECTIONS             NO        GAS  PRINT FAR BY GROUP                           NO ***
***                                                                                                                 ***
***  XS2  PRINT 2-D MIXTURE X-SECTIONS             NO        PAX  PRINT XSEC-ALBEDO CORRELATION TABLES         NO ***
***                                                                                                                 ***
***  XAP  PRINT MIXTURE ANGLES & PROBABILITIES     NO        PWT  PRINT WEIGHT AVERAGE ARRAY                   NO ***
***                                                                                                                 ***
***  PKI  PRINT FISSION SPECTRUM                   NO        PGM  PRINT INPUT GEOMETRY                         NO ***
***                                                                                                                 ***
***  P1D  PRINT EXTRA 1-D CROSS SECTIONS           NO        BUG  PRINT DEBUG INFORMATION                      NO ***
***                                                                                                                 ***
***                                                          TRK  PRINT TRACKING INFORMATION                   NO ***
***                                                                                                                 ***
***                                                                                                                 ***
***********************************************************************************************************************
***********************************************************************************************************************
***********************************************************************************************************************
                                           PARAMETER INPUT COMPLETED

                          ........    0 IO'S WERE USED READING THE PARAMETER DATA      ........

                         *************** DATA READING COMPLETED ***************
```

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
*********************************************************************************************************************
***                                                                                                               ***
***                              WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP                  ***
***                                                                                                               ***
*********************************************************************************************************************
*********************************************************************************************************************
***                                                                                                               ***
***          UNIT                                                  VOLUME                                         ***
***         NUMBER            DATA SET NAME                         NAME        UNIT FUNCTION                     ***
***         ------            -------------                         ----        -------------                     ***
***                                                                                                               ***
***     XSC  14      C:\svv\st-mr-wg\FT14F001                                   MIXED CROSS SECTIONS              ***
***                                                                                                               ***
***     ALB  79      G:\scale43\DATALIB\FT79F001                                INPUT ALBEDOS                     ***
***                                                                                                               ***
***     WTS  80      G:\scale43\DATALIB\FT80F001                                INPUT WEIGHTS                     ***
***                                                                                                               ***
***     SKT  16       UNKNOWN                                                   WRITE SCRATCH DATA                ***
***                                                                                                               ***
***     BIN  95      C:\svv\st-mr-wg\FT95F001                                   BINARY INPUT DATA                 ***
***                                                                                                               ***
***     RST  95      C:\svv\st-mr-wg\FT95F001                                   READ RESTART DATA                 ***
***                                                                                                               ***
***     LIB   4      C:\svv\st-mr-wg\FT04F001                                   INPUT AMPX WORKING LIBRARY        ***
***                                                                                                               ***
***           8      C:\svv\st-mr-wg\FT08F001                                   INPUT DATA DIRECT ACCESS          ***
***                                                                                                               ***
***           9       UNKNOWN                                                   SUPER GROUPED DIRECT ACCESS       ***
***                                                                                                               ***
***          10       UNKNOWN                                                   XSEC MIXING DIRECT ACCESS         ***
***                                                                                                               ***
*********************************************************************************************************************

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

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

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

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                         WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP
                                                 MIXING TABLE
                                          NUMBER OF SCATTERING ANGLES =  2
                                      CROSS SECTION MESSAGE THRESHOLD =3.0E-05

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

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

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

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

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

MIXTURE =      6          DENSITY(G/CC) =  2.5833
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
   6005010  7.09799E-03 4.56855E-02   5010    10.0130    B-10 1273 218NGP 042375 P-3 293K                           UPDATED
08/12/94
   6005011  3.92499E-02 2.77771E-01   5011    11.0096     BORON-11        ENDF/B-IV MAT 1160                        UPDATED
08/12/94
   6006012  1.22006E-02 9.41116E-02   6000    12.0001     CARBON-12       ENDF/B-IV MAT 1274/THRM1065               UPDATED
08/12/94
   6013027  3.35812E-02 5.82432E-01   13027   26.9818    AL-27 1193 218 GP 040375(5)                                UPDATED
08/12/94

MIXTURE =      7          DENSITY(G/CC) = 0.99817
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
   7001001  6.67692E-02 1.11927E-01   1001     1.0077     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
   7008016  3.33846E-02 8.88074E-01   8016    15.9904     OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94

MIXTURE =      8          DENSITY(G/CC) =  7.8212
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
   8006012  3.92503E-03 1.00001E-02   6000    12.0001     CARBON-12       ENDF/B-IV MAT 1274/THRM1065               UPDATED
08/12/94
   8026000  8.34982E-02 9.90000E-01   26000   55.8447     IRON            ENDF/B-IV MAT 1192                        UPDATED
08/12/94

MIXTURE =      9          DENSITY(G/CC) =  2.2430
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
   9001001  1.34031E-02 9.99867E-03   1001     1.0077     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
   9008016  4.49394E-02 5.31997E-01   8016    15.9904     OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94
   9011023  1.70392E-03 2.90003E-02   11023   22.9895     SODIUM-23       ENDF/B-IV MAT 1156                        UPDATED
08/12/94
   9013027  1.70211E-03 3.40003E-02   13027   26.9818    AL-27 1193 218 GP 040375(5)                                UPDATED
08/12/94
   9014000  1.62080E-02 3.37003E-01   14000   28.0853     SILICON         ENDF/B-IV MAT 1194                        UPDATED
08/12/94
   9020000  1.48287E-03 4.40004E-02   20000   40.0803    CALCIUM ENDF/B-IV MAT 1195                                 UPDATED
08/12/94
   9026000  3.38630E-04 1.40001E-02   26000   55.8447     IRON            ENDF/B-IV MAT 1192                        UPDATED
08/12/94

MIXTURE =     10          DENSITY(G/CC) = 0.99817
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
  10001001  6.67692E-02 1.11927E-01   1001     1.0077     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
  10008016  3.33846E-02 8.88074E-01   8016    15.9904     OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94

MIXTURE =     11          DENSITY(G/CC) = 0.99817
   NUCLIDE  ATOM-DENS.  WGT. FRAC.     ZA      AWT                NUCLIDE TITLE
  11001001  6.67692E-02 1.11927E-01   1001     1.0077     HYDROGEN        ENDF/B-IV MAT 1269/THRM1002               UPDATED
08/12/94
  11008016  3.33846E-02 8.88074E-01   8016    15.9904     OXYGEN-16       ENDF/B-IV MAT 1276                        UPDATED
08/12/94
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Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

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*****************************************************************************************************
***                                                                                               ***
***          WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP                      ***
***                                                                                               ***
*****************************************************************************************************
*****************************************************************************************************
***                                                                                               ***
***                                ****** ADDITIONAL INFORMATION ******                           ***
***                                                                                               ***
***  NUMBER OF ENERGY GROUPS                 27        USE LATTICE GEOMETRY                  YES  ***
***                                                                                               ***
***  NO. OF FISSION SPECTRUM SOURCE GROUP   1         GLOBAL ARRAY NUMBER                    60  ***
***                                                                                               ***
***  NO. OF SCATTERING ANGLES IN XSECS       2        NUMBER OF UNITS IN THE GLOBAL X DIR.     1  ***
***                                                                                               ***
***  ENTRIES/NEUTRON IN THE NEUTRON BANK    33        NUMBER OF UNITS IN THE GLOBAL Y DIR.     1  ***
***                                                                                               ***
***  ENTRIES/NEUTRON IN THE FISSION BANK    26        NUMBER OF UNITS IN THE GLOBAL Z DIR.     4  ***
***                                                                                               ***
***  NUMBER OF MIXTURES USED                11        USE A GLOBAL REFLECTOR                 YES  ***
***                                                                                               ***
***  NUMBER OF BIAS ID'S USED                1        USE NESTED HOLES                       YES  ***
***                                                                                               ***
***  NUMBER OF DIFFERENTIAL ALBEDOS USED     0        NUMBER OF HOLES                         48  ***
***                                                                                               ***
***  TOTAL INPUT GEOMETRY REGIONS          127        MAXIMUM HOLE NESTING LEVEL               3  ***
***                                                                                               ***
***  NUMBER OF GEOMETRY REGIONS USED       127        USE NESTED ARRAYS                      YES  ***
***                                                                                               ***
***  LARGEST GEOMETRY UNIT NUMBER          120        NUMBER OF ARRAYS USED                   27  ***
***                                                                                               ***
***  LARGEST ARRAY NUMBER                   60        MAXIMUM ARRAY NESTING LEVEL              4  ***
***                                                                                               ***
***                                                                                               ***
***  +X BOUNDARY CONDITION             REFLECT        -X BOUNDARY CONDITION              REFLECT  ***
***                                                                                               ***
***  +Y BOUNDARY CONDITION             REFLECT        -Y BOUNDARY CONDITION              REFLECT  ***
***                                                                                               ***
***  +Z BOUNDARY CONDITION                 PER        -Z BOUNDARY CONDITION                  PER  ***
***                                                                                               ***
*****************************************************************************************************
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Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

GENERATION	GENERATION K-EFFECTIVE	ELAPSED TIME MINUTES	AVERAGE K-EFFECTIVE	AVG K-EFF DEVIATION	MATRIX K-EFFECTIVE	MATRIX K-EFF DEVIATION
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	945 INDEPENDENT	FISSION POINTS WERE	GENERATED	
1	8.75112E-01	1.52000E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	946 INDEPENDENT	FISSION POINTS WERE	GENERATED	
2	8.62201E-01	1.90333E-01	1.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KENO MESSAGE NUMBER K5-132		WARNING....ONLY	940 INDEPENDENT	FISSION POINTS WERE	GENERATED	
3	8.50943E-01	2.29667E-01	8.50943E-01	0.00000E+00	0.00000E+00	0.00000E+00
4	8.68023E-01	2.69167E-01	8.59483E-01	8.53997E-03	0.00000E+00	0.00000E+00
5	8.80813E-01	3.08500E-01	8.66593E-01	8.65244E-03	0.00000E+00	0.00000E+00
6	8.93980E-01	3.48667E-01	8.73440E-01	9.18214E-03	0.00000E+00	0.00000E+00
7	8.98812E-01	3.88167E-01	8.78514E-01	8.73714E-03	0.00000E+00	0.00000E+00
8	8.47197E-01	4.27500E-01	8.73295E-01	8.83944E-03	0.00000E+00	0.00000E+00
9	8.54501E-01	4.66833E-01	8.70610E-01	7.93847E-03	0.00000E+00	0.00000E+00
10	9.10492E-01	5.05333E-01	8.75595E-01	8.49217E-03	0.00000E+00	0.00000E+00
11	8.71962E-01	5.44667E-01	8.75191E-01	7.50026E-03	0.00000E+00	0.00000E+00
12	8.74146E-01	5.82167E-01	8.75087E-01	6.70925E-03	0.00000E+00	0.00000E+00
13	8.90500E-01	6.22500E-01	8.76488E-01	6.22840E-03	0.00000E+00	0.00000E+00
14	9.06346E-01	6.61833E-01	8.78976E-01	6.20632E-03	0.00000E+00	0.00000E+00
15	8.56646E-01	7.01167E-01	8.77258E-01	5.96178E-03	0.00000E+00	0.00000E+00
16	8.87238E-01	7.40500E-01	8.77971E-01	5.56538E-03	0.00000E+00	0.00000E+00
17	8.59775E-01	7.79000E-01	8.76758E-01	5.32121E-03	0.00000E+00	0.00000E+00
18	8.72739E-01	8.18333E-01	8.76507E-01	4.98387E-03	0.00000E+00	0.00000E+00
19	9.20344E-01	8.58667E-01	8.79086E-01	5.34473E-03	0.00000E+00	0.00000E+00
20	8.86820E-01	8.98000E-01	8.79515E-01	5.05735E-03	0.00000E+00	0.00000E+00
21	8.94988E-01	9.37333E-01	8.80330E-01	4.85259E-03	0.00000E+00	0.00000E+00
22	8.22904E-01	9.78500E-01	8.77458E-01	5.42559E-03	0.00000E+00	0.00000E+00
23	8.95033E-01	1.01783E+00	8.78295E-01	5.22818E-03	0.00000E+00	0.00000E+00
24	8.61764E-01	1.05733E+00	8.77544E-01	5.04120E-03	0.00000E+00	0.00000E+00
25	8.54758E-01	1.09667E+00	8.76553E-01	4.91785E-03	0.00000E+00	0.00000E+00
26	8.56199E-01	1.13600E+00	8.75705E-01	4.78425E-03	0.00000E+00	0.00000E+00
27	9.04067E-01	1.17533E+00	8.76840E-01	4.72705E-03	0.00000E+00	0.00000E+00
28	8.47527E-01	1.21283E+00	8.75712E-01	4.67944E-03	0.00000E+00	0.00000E+00
29	8.77057E-01	1.25133E+00	8.75762E-01	4.50307E-03	0.00000E+00	0.00000E+00
30	8.71278E-01	1.29067E+00	8.75602E-01	4.34222E-03	0.00000E+00	0.00000E+00
31	8.89074E-01	1.33000E+00	8.76066E-01	4.21549E-03	0.00000E+00	0.00000E+00
32	8.82954E-01	1.36850E+00	8.76296E-01	4.07902E-03	0.00000E+00	0.00000E+00
33	8.89828E-01	1.40783E+00	8.76733E-01	3.96932E-03	0.00000E+00	0.00000E+00
34	8.42340E-01	1.44717E+00	8.75658E-01	3.99072E-03	0.00000E+00	0.00000E+00
35	9.05755E-01	1.48667E+00	8.76570E-01	3.97397E-03	0.00000E+00	0.00000E+00
36	8.49054E-01	1.52600E+00	8.75760E-01	3.93935E-03	0.00000E+00	0.00000E+00
37	9.04573E-01	1.56533E+00	8.76584E-01	3.91272E-03	0.00000E+00	0.00000E+00
38	8.49513E-01	1.60467E+00	8.75832E-01	3.87612E-03	0.00000E+00	0.00000E+00
39	8.83531E-01	1.64317E+00	8.76040E-01	3.77564E-03	0.00000E+00	0.00000E+00
40	8.74548E-01	1.68067E+00	8.76001E-01	3.67515E-03	0.00000E+00	0.00000E+00
41	9.01435E-01	1.71917E+00	8.76653E-01	3.63860E-03	0.00000E+00	0.00000E+00
42	8.52901E-01	1.75750E+00	8.76059E-01	3.59583E-03	0.00000E+00	0.00000E+00
43	8.85406E-01	1.79700E+00	8.76287E-01	3.51443E-03	0.00000E+00	0.00000E+00
44	8.89607E-01	1.83450E+00	8.76604E-01	3.44437E-03	0.00000E+00	0.00000E+00
45	9.31113E-01	1.87383E+00	8.77872E-01	3.59427E-03	0.00000E+00	0.00000E+00
46	9.03644E-01	1.91133E+00	8.78457E-01	3.56015E-03	0.00000E+00	0.00000E+00
47	9.05612E-01	1.94883E+00	8.79061E-01	3.53207E-03	0.00000E+00	0.00000E+00
48	8.97927E-01	1.98733E+00	8.79471E-01	3.47869E-03	0.00000E+00	0.00000E+00
49	9.02912E-01	2.02583E+00	8.79970E-01	3.44022E-03	0.00000E+00	0.00000E+00
50	8.96326E-01	2.06417E+00	8.80311E-01	3.38498E-03	0.00000E+00	0.00000E+00
.						
.						
.						
950	8.70416E-01	3.74143E+01	8.83893E-01	7.43957E-04	0.00000E+00	0.00000E+00
951	9.05133E-01	3.74527E+01	8.83915E-01	7.43510E-04	0.00000E+00	0.00000E+00
952	8.63683E-01	3.74930E+01	8.83894E-01	7.43032E-04	0.00000E+00	0.00000E+00
953	8.91555E-01	3.75315E+01	8.83902E-01	7.42294E-04	0.00000E+00	0.00000E+00
954	8.66491E-01	3.75698E+01	8.83884E-01	7.41739E-04	0.00000E+00	0.00000E+00
955	8.72970E-01	3.76093E+01	8.83872E-01	7.41049E-04	0.00000E+00	0.00000E+00
956	8.81615E-01	3.76477E+01	8.83870E-01	7.40276E-04	0.00000E+00	0.00000E+00
957	8.99857E-01	3.76862E+01	8.83887E-01	7.39690E-04	0.00000E+00	0.00000E+00
958	8.25766E-01	3.77247E+01	8.83826E-01	7.41412E-04	0.00000E+00	0.00000E+00
959	9.07246E-01	3.77622E+01	8.83850E-01	7.41041E-04	0.00000E+00	0.00000E+00
960	9.17018E-01	3.78007E+01	8.83885E-01	7.41076E-04	0.00000E+00	0.00000E+00
961	8.82141E-01	3.78390E+01	8.83883E-01	7.40306E-04	0.00000E+00	0.00000E+00
962	8.64857E-01	3.78783E+01	8.83863E-01	7.39799E-04	0.00000E+00	0.00000E+00
963	9.01438E-01	3.79168E+01	8.83882E-01	7.39256E-04	0.00000E+00	0.00000E+00
964	8.81430E-01	3.79553E+01	8.83879E-01	7.38491E-04	0.00000E+00	0.00000E+00
965	8.49840E-01	3.79938E+01	8.83844E-01	7.38570E-04	0.00000E+00	0.00000E+00
966	8.75750E-01	3.80313E+01	8.83835E-01	7.37851E-04	0.00000E+00	0.00000E+00
967	8.99929E-01	3.80697E+01	8.83852E-01	7.37275E-04	0.00000E+00	0.00000E+00
968	9.04655E-01	3.81082E+01	8.83873E-01	7.36826E-04	0.00000E+00	0.00000E+00
969	8.62628E-01	3.81467E+01	8.83851E-01	7.36392E-04	0.00000E+00	0.00000E+00
970	8.59757E-01	3.81850E+01	8.83827E-01	7.36051E-04	0.00000E+00	0.00000E+00
971	8.49649E-01	3.82235E+01	8.83791E-01	7.36137E-04	0.00000E+00	0.00000E+00
972	8.52009E-01	3.82628E+01	8.83759E-01	7.36107E-04	0.00000E+00	0.00000E+00
973	8.89858E-01	3.83023E+01	8.83765E-01	7.35376E-04	0.00000E+00	0.00000E+00
974	8.73960E-01	3.83407E+01	8.83755E-01	7.34688E-04	0.00000E+00	0.00000E+00
975	8.82652E-01	3.83800E+01	8.83754E-01	7.33933E-04	0.00000E+00	0.00000E+00
976	8.85957E-01	3.84195E+01	8.83756E-01	7.33183E-04	0.00000E+00	0.00000E+00
977	8.95017E-01	3.84588E+01	8.83767E-01	7.32521E-04	0.00000E+00	0.00000E+00
978	8.90552E-01	3.84982E+01	8.83774E-01	7.31804E-04	0.00000E+00	0.00000E+00
979	8.91674E-01	3.85367E+01	8.83782E-01	7.31099E-04	0.00000E+00	0.00000E+00
980	8.89774E-01	3.85768E+01	8.83789E-01	7.30377E-04	0.00000E+00	0.00000E+00
981	9.12959E-01	3.86153E+01	8.83818E-01	7.30238E-04	0.00000E+00	0.00000E+00
982	8.94913E-01	3.86528E+01	8.83830E-01	7.29581E-04	0.00000E+00	0.00000E+00
983	8.86619E-01	3.86922E+01	8.83833E-01	7.28842E-04	0.00000E+00	0.00000E+00
984	8.51460E-01	3.87317E+01	8.83800E-01	7.28845E-04	0.00000E+00	0.00000E+00
985	8.76222E-01	3.87710E+01	8.83792E-01	7.28144E-04	0.00000E+00	0.00000E+00

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

986	9.00091E-01	3.88093E+01	8.83808E-01	7.27593E-04	0.00000E+00	0.00000E+00
987	9.10388E-01	3.88478E+01	8.83835E-01	7.27354E-04	0.00000E+00	0.00000E+00
988	8.52857E-01	3.88863E+01	8.83804E-01	7.27295E-04	0.00000E+00	0.00000E+00
989	9.04577E-01	3.89257E+01	8.83825E-01	7.26863E-04	0.00000E+00	0.00000E+00
990	8.96359E-01	3.89650E+01	8.83838E-01	7.26237E-04	0.00000E+00	0.00000E+00
991	8.80578E-01	3.90053E+01	8.83834E-01	7.25510E-04	0.00000E+00	0.00000E+00
992	8.72468E-01	3.90428E+01	8.83823E-01	7.24868E-04	0.00000E+00	0.00000E+00
993	8.68384E-01	3.90822E+01	8.83807E-01	7.24304E-04	0.00000E+00	0.00000E+00
994	8.74362E-01	3.91215E+01	8.83798E-01	7.23636E-04	0.00000E+00	0.00000E+00
995	8.95072E-01	3.91610E+01	8.83809E-01	7.22996E-04	0.00000E+00	0.00000E+00
996	8.46965E-01	3.92012E+01	8.83772E-01	7.23219E-04	0.00000E+00	0.00000E+00
997	8.40963E-01	3.92397E+01	8.83729E-01	7.23771E-04	0.00000E+00	0.00000E+00
998	8.79300E-01	3.92782E+01	8.83725E-01	7.23058E-04	0.00000E+00	0.00000E+00
999	8.98173E-01	3.93165E+01	8.83739E-01	7.22478E-04	0.00000E+00	0.00000E+00
1000	9.04993E-01	3.93550E+01	8.83760E-01	7.22068E-04	0.00000E+00	0.00000E+00
1001	8.72868E-01	3.93935E+01	8.83750E-01	7.21427E-04	0.00000E+00	0.00000E+00
1002	8.84715E-01	3.94318E+01	8.83751E-01	7.20706E-04	0.00000E+00	0.00000E+00
1003	8.57689E-01	3.94712E+01	8.83724E-01	7.20456E-04	0.00000E+00	0.00000E+00

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

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

```
LIFETIME =  3.61325E-05 + OR -  7.57716E-08          GENERATION TIME =  2.47869E-05 + OR -  3.65111E-08
NU BAR   =  2.44283E+00 + OR -  7.03085E-05    AVERAGE FISSION GROUP =  2.16146E+01 + OR -  3.98016E-03
                    ENERGY(EV) OF THE AVERAGE LETHARGY CAUSING FISSION =  3.02918E-01 + OR -  9.69277E-04
```

NO. OF INITIAL GENERATIONS SKIPPED	AVERAGE K-EFFECTIVE	DEVIATION	67 PER CENT CONFIDENCE INTERVAL	95 PER CENT CONFIDENCE INTERVAL	99 PER CENT CONFIDENCE INTERVAL	NUMBER OF HISTORIES
3	0.88376	+ OR - 0.00072	0.88304 TO 0.88448	0.88232 TO 0.88520	0.88160 TO 0.88592	1000000
4	0.88377	+ OR - 0.00072	0.88305 TO 0.88449	0.88233 TO 0.88521	0.88161 TO 0.88594	999000
5	0.88378	+ OR - 0.00072	0.88305 TO 0.88450	0.88233 TO 0.88522	0.88161 TO 0.88594	998000
6	0.88377	+ OR - 0.00072	0.88304 TO 0.88449	0.88232 TO 0.88521	0.88160 TO 0.88593	997000
7	0.88375	+ OR - 0.00072	0.88303 TO 0.88447	0.88230 TO 0.88520	0.88158 TO 0.88592	996000
8	0.88379	+ OR - 0.00072	0.88306 TO 0.88451	0.88234 TO 0.88523	0.88162 TO 0.88596	995000
9	0.88382	+ OR - 0.00072	0.88309 TO 0.88454	0.88237 TO 0.88526	0.88165 TO 0.88599	994000
10	0.88379	+ OR - 0.00072	0.88307 TO 0.88451	0.88234 TO 0.88524	0.88162 TO 0.88596	993000
11	0.88380	+ OR - 0.00072	0.88308 TO 0.88453	0.88235 TO 0.88525	0.88163 TO 0.88597	992000
12	0.88381	+ OR - 0.00072	0.88309 TO 0.88454	0.88236 TO 0.88526	0.88164 TO 0.88598	991000
17	0.88383	+ OR - 0.00073	0.88310 TO 0.88456	0.88238 TO 0.88528	0.88165 TO 0.88601	986000
22	0.88385	+ OR - 0.00073	0.88313 TO 0.88458	0.88240 TO 0.88531	0.88167 TO 0.88603	981000
27	0.88390	+ OR - 0.00073	0.88317 TO 0.88463	0.88244 TO 0.88536	0.88172 TO 0.88609	976000
32	0.88395	+ OR - 0.00073	0.88322 TO 0.88469	0.88249 TO 0.88542	0.88176 TO 0.88615	971000
37	0.88398	+ OR - 0.00073	0.88325 TO 0.88472	0.88252 TO 0.88545	0.88179 TO 0.88618	966000
42	0.88404	+ OR - 0.00073	0.88331 TO 0.88478	0.88258 TO 0.88551	0.88184 TO 0.88625	961000
47	0.88394	+ OR - 0.00074	0.88321 TO 0.88468	0.88247 TO 0.88541	0.88174 TO 0.88615	956000
52	0.88392	+ OR - 0.00074	0.88318 TO 0.88466	0.88244 TO 0.88540	0.88170 TO 0.88613	951000
57	0.88396	+ OR - 0.00074	0.88322 TO 0.88470	0.88248 TO 0.88544	0.88174 TO 0.88618	946000
62	0.88397	+ OR - 0.00074	0.88323 TO 0.88472	0.88249 TO 0.88546	0.88174 TO 0.88620	941000
67	0.88399	+ OR - 0.00075	0.88324 TO 0.88474	0.88250 TO 0.88548	0.88175 TO 0.88623	936000
72	0.88412	+ OR - 0.00075	0.88337 TO 0.88486	0.88262 TO 0.88561	0.88188 TO 0.88635	931000
77	0.88415	+ OR - 0.00075	0.88341 TO 0.88490	0.88266 TO 0.88565	0.88191 TO 0.88640	926000
82	0.88410	+ OR - 0.00075	0.88335 TO 0.88486	0.88260 TO 0.88561	0.88185 TO 0.88636	921000
87	0.88419	+ OR - 0.00075	0.88344 TO 0.88494	0.88269 TO 0.88570	0.88193 TO 0.88645	916000
92	0.88429	+ OR - 0.00076	0.88353 TO 0.88504	0.88278 TO 0.88580	0.88202 TO 0.88656	911000

Figure 6.7-4 CSAS Input/Output Summary for Storage Cask - Accident Conditions (Continued)

```
WRR EC455-5302 STORAGE CASK CRITICALITY: WATER IN FUEL/CLAD GAP

                              FREQUENCY FOR GENERATIONS    4 TO 1003
0.8075 TO 0.8107     *
0.8107 TO 0.8140
0.8140 TO 0.8173     *
0.8173 TO 0.8205
0.8205 TO 0.8238     **
0.8238 TO 0.8271     *
0.8271 TO 0.8303     ******
0.8303 TO 0.8336     *****
0.8336 TO 0.8369     *****
0.8369 TO 0.8401     ******
0.8401 TO 0.8434     ***********
0.8434 TO 0.8467     **********
0.8467 TO 0.8500     *********************
0.8500 TO 0.8532     *******************
0.8532 TO 0.8565     *************************
0.8565 TO 0.8598     *****************************
0.8598 TO 0.8630     ***********************************************
0.8630 TO 0.8663     *****************************************
0.8663 TO 0.8696     ********************************************
0.8696 TO 0.8728     ********************************************
0.8728 TO 0.8761     *********************************************
0.8761 TO 0.8794     ************************************************************
0.8794 TO 0.8826     ******************************************************************
0.8826 TO 0.8859     ***************************************************
0.8859 TO 0.8892     ***********************************************
0.8892 TO 0.8925     ********************************************************
0.8925 TO 0.8957     ***********************************************
0.8957 TO 0.8990     **********************************************
0.8990 TO 0.9023     *****************************************************
0.9023 TO 0.9055     ***************************************
0.9055 TO 0.9088     **************************************
0.9088 TO 0.9121     *************************
0.9121 TO 0.9153     ************************
0.9153 TO 0.9186     *********************
0.9186 TO 0.9219     ********************
0.9219 TO 0.9251     **************
0.9251 TO 0.9284     *********
0.9284 TO 0.9317     ******
0.9317 TO 0.9349     *****
0.9349 TO 0.9382     ****
0.9382 TO 0.9415     *
0.9415 TO 0.9448     **
0.9448 TO 0.9480     *
0.9480 TO 0.9513
0.9513 TO 0.9546
0.9546 TO 0.9578
0.9578 TO 0.9611     *
0.9611 TO 0.9644
0.9644 TO 0.9676
0.9676 TO 0.9709     *
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7.0 CONFINEMENT

The NAC-MPC transportable storage canister (canister) provides confinement for its radioactive contents in long-term storage. The confinement boundary is closed by welding that presents a leaktight barrier to the release of contents in all of the evaluated normal, off-normal and accident conditions.

The NAC-MPC canister contains an inert gas (helium). The confinement boundary retains the helium and also prevents the entry of outside air into the NAC-MPC. The exclusion of air precludes degradation of the fuel rod cladding over time, due to cladding oxidation failures.

The NAC-MPC canister confinement system meets the requirements of 10 CFR 72.24 for protection of the public from release of radioactive material, and 10 CFR 72.122 for protection of the spent fuel contents in long-term storage such that future handling of the contents would not pose an operational safety concern.

The helium purity level of 99.9% specified in Appendix 12A, Section 4.5.2 maintains the quantity of oxidizing contaminant to less than one mole per canister for all loading conditions. Based on the calculations presented in Section 4.4.5, the free gas volume of the empty canister is less than 300 moles. Conservatively assuming that all of the impurities in 99.9% pure helium are oxidents, a maximum of 0.3 moles of oxidants could exist in the NAC-MPC canister during storage. By limiting the amount of oxidants to less than one mole, the recommended limits for preventing cladding degradation found in the Pacific Northwest Laboratory, "Evaluation of Cover Gas Impuritities and Their Effects on the Dry Storage of LWR Spent Fuel," PNL-6365 are satisfied.

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7.1 Confinement Boundary

Confinement of the contents in long-term storage is provided by the transportable storage canister. The welded canister forms the confinement vessel.

The primary confinement boundary of the canister consists of the canister shell, bottom closure plate, shield lid, the two (2) port covers, and the welds that join these components. There are no bolted closures or mechanical seals in the primary confinement boundary. The confinement boundary welds are described in Table 7.1-1.

7.1.1 Confinement Vessel

The NAC-MPC transportable storage canister provides the confinement vessel for the radioactive contents.

7.1.1.1 Confinement Vessel - Canister

The canister consists of three (3) principal components: the canister shell, the shield lid, and the structural lid. The canister shell is a right circular cylinder constructed of 5/8-inch thick rolled Type 304L stainless steel plate. The edges of the rolled plate are joined using full penetration welds. It is closed at the bottom end by a 1-inch thick circular plate joined to the shell by a full penetration weld. The inside and outside diameter of the canister are 69.39 inches and 70.64 inches, respectively. The inside length is 121.5 inches. The overall external length of the canister is 122.5 inches. The canister is fabricated in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, except for the top end weld closures and their nondestructive ultrasonic or progressive dye penetrant examinations. The list of Code exceptions for the NAC-MPC System is provided in Table 12A4-1.

After loading, the canister is closed at the top by a shield lid and a structural lid. The shield lid is a 5-inch-thick Type 304 stainless steel plate. It is joined to the canister shell using a field installed bevel weld. The shield lid contains the drain and fill penetrations and provides gamma radiation protection to the operators during the draining, drying and inerting operations. After the shield lid is welded in place, the canister is pressure tested and leak tested to ensure leaktightness. Following draining, drying and inerting operations, the penetrations are closed with Type 304 stainless steel port covers that are welded in place with bevel welds. The

operating procedures describing the handling steps to close the canister are presented in Chapter 8. The pressure and leak test procedures are described in Chapter 9.

A secondary, or redundant, confinement boundary closure is provided at the top of the canister by a structural lid, which is placed over the shield lid. The structural lid is a 3-inch thick Type 304L stainless steel plate. The structural lid provides the attachment points for lifting the loaded canister. The structural lid is welded to the shell using a field installed bevel weld. The weld specifications and weld inspection and acceptance criteria are presented in Sections 7.1.3.2 and 7.1.3.3, respectively.

The confinement boundaries are shown in Figures 7.1-1 and 7.1-2. As illustrated in Figure 7.1-2, the secondary, or redundant, confinement boundary includes: the structural lid, the upper 3.5 inches of the canister shell and the joining weld. This boundary provides additional assurance of the leaktightness of the canister during its service life.

7.1.1.2 Design Documents, Codes, and Standards

The canister is constructed in accordance with the license drawings presented in Section 1.5. The principal Codes and Standards that apply to the design, fabrication and assembly are described in Sections 7.1.1 and 7.1.3 and are shown on the licensing drawings. Other Codes and Standards are applied as appropriate in the design or specification of the canister.

7.1.1.3 Technical Requirements for the Canister

The canister confines up to 36 intact or reconfigured Yankee Class fuel assemblies. The total number of rods in reconfigured assemblies is limited to 64. Over its 50-year design life, the canister precludes the release of radioactive contents and precludes the entry of air that could potentially damage the cladding of the stored spent fuel. The design of the canister to the requirements of ASME Section III, Subsection NB, ensures that the canister maintains confinement in all of the evaluated normal, off-normal, and accident conditions.

The design of the canister allows the recovery of stored spent fuel, should that become necessary.

The canister has no exposed penetrations, no mechanical closures, and does not employ seals to maintain confinement. There is no requirement for continuous monitoring.

The design basis parameters for the Yankee Class fuel are presented in Section 1.2.3. The design criteria that apply to the canister, as an element of the NAC-MPC dry storage system, are presented in Table 1.2-1.

7.1.1.4 Release Rate

The primary confinement boundary is formed by a stainless steel plate joined by welding. The welds are visually inspected, nondestructively examined, and pressure tested to confirm integrity. Consequently, the confinement boundary is leaktight. There is no maximum allowable leak rate specified for the NAC-MPC canister, as leakage to any degree up to the level of sensitivity of the leak test, is not acceptable. However, to demonstrate leaktightness of the shield lid, a leak test is performed based on the leaktight condition of 1×10^{-7} ref cm^3/sec, as defined by the American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, ANSI N14.5-1997, issued by the American National Standards Institute in December 1997.

Based on a leaktight configuration, the calculation of radionuclide inventories is not required.

7.1.2 Confinement Penetrations

Two penetrations (with quick disconnect fittings) are provided in the canister shield lid for operator use. One penetration is used for draining residual water from the canister. It connects to a drain tube that extends to the bottom of the canister. The other penetration extends only to the underside of the shield lid. It is used to introduce air, or inert gas, into the top of the canister. Once draining is completed, either penetration may be used for vacuum drying and backfilling with helium. Following backfilling, both penetrations are closed with port covers that are welded to the shield lid. When the port covers are in place, the penetrations are not accessible. These port covers are subsequently enclosed and covered by the structural lid, which is also welded in place. The structural lid and the remainder of the canister have no penetrations.

7.1.3 Seals and Welds

This section describes the process used to properly assemble the confinement vessel. Weld processes, examination and acceptance criteria are described in Sections 7.1.3.2 and 7.1.3.3.

There are no elastomer or metallic seals used in the confinement boundary of the canister.

7.1.3.1 Fabrication

All cutting, machining, welding, and forming is in accordance with Section III, Article NB-4000 of the ASME Code, unless otherwise specified in the approved fabrication drawings and specifications consistent with the exception to the code described in Section 7.1.1.1 and in Table 12A4-1 of Appendix 12A in Chapter 12. License drawings are provided in Section 1.5. ASME code stamping of the canister is not required.

7.1.3.2 Welding Specifications

The canister body is assembled using longitudinal and circumferential welded joints in the shell and circumferential welded joints at the bottom plate/shell juncture.

These welds are in accordance with ASME Code Section IX. The full penetration longitudinal weld joining the canister shell is radiographed in accordance with ASME Code Section V, Article 2. The weld joining the bottom plate to the canister shell is ultrasonically inspected in accordance with ASME Code Section V, Article 5. The acceptance criteria for these welds is as specified in ASME Code Section III, NB-5320 and NB-5330, respectively. The finished surface of each weld is liquid penetrant examined in accordance with ASME Code Section V, Article 6, and accepted in accordance with Section III, NB-5350.

After loading, the canister is closed by a shield lid and a structural lid using field installed bevel welds.

After the shield lid is welded in place, the canister is pnuematically (air over water) pressure tested. Following draining, drying and inerting operations, the vent and drain ports are closed with port covers that are welded in place with bevel welds. The shield lid and port cover welds are liquid penetrant examined at the root and final passes in accordance with ASME Section V, Article 6. Acceptance is in accordance with ASME Code Section III, NB-5350. The shield lid to canister shell weld is liquid penetrant examined at the root and final passes in accordance with ASME Code Section V, Article 6, and is pressure and leak tested to ensure leaktightness. The operating procedures describing the handling steps to seal the canister are presented in Chapter 8. The pressure and leak test procedures are described in Chapter 9.

A secondary, or redundant, confinement boundary is provided at the top end of the canister by a structural lid, which is placed over the shield lid. The structural lid is welded to the shell using a field-installed bevel weld. The structural lid to canister shell weld is either: 1) ultrasonically examined (UT) in accordance with ASME Code Section V, Article 5, with the final weld surface liquid penetrant (PT) examined in accordance with ASME Code Section V, Article 6, or 2) progressive liquid penetrant examined in accordance with ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, Subsections NB-5330 (UT) and NB-5350 (PT).

All welding procedures are written and qualified in accordance with Section IX of the ASME Code. Each welder and welding operator must be qualified in accordance with Section IX of the ASME Code.

The results of all weld examinations are recorded.

7.1.3.3 Testing, Inspection, and Examination

The following tests are performed to ensure satisfactory performance of the confinement vessel:

1. All components are visually examined for conformance with the fabrication drawings.
2. All welds that are directly visible are visually examined in accordance with the requirements of ASME Code Section V, Article 9.
3. The acceptance standards for visual examination of the canister welded joints are as specified in ASME Code, Section III, NB-4424 and NB-4427. Unacceptable weld defects are repaired in accordance with ASME Code Section III, Subarticle NB-4450, and visually re-examined.
4. Canister welds designated to be examined by radiographic examination are examined in accordance with the requirements of Section V, Article 2 of the ASME Code. The minimum acceptance standards for radiographic examination are as specified in ASME Code Section III, NB-5320. Welds designated for ultrasonic examination are examined in accordance with the requirements of Section V, Article 5, of the ASME Code. The acceptance standards for ultrasonic examination are as specified in ASME Code Section III, NB-5330. Unacceptable defects in the welds are repaired in accordance with ASME Code Section III, NB-4450, and re-examined.

5. A written report of each weld examination is prepared. At a minimum, the written report includes: identification of part, material, name and level of examiner, NDE procedure used and the findings or dispositions, if any.

6. All personnel performing nondestructive testing are qualified in accordance with American Society of Nondestructive Testing Recommended Practice No. SNT-TC-1A.

7. Individuals qualified for NDT Level I, NDT Level II, or NDT level III may perform nondestructive testing. Only Level II or Level III personnel may interpret the results of examination or make determination of the acceptability of examined parts.

8. The vendor completely assembles the canister prior to shipping. The purpose of assembling the canister is to ensure that all items specified have been supplied and to test the fit of the shield lid assembly including drain tube and the structural lid.

9. A helium leak test is used to verify that the weld joining the shield lid to the canister wall is leaktight. The containment vessel is pressurized to 22 psia through the either the drain port to leak test the shield lid to canister shell weld. The sensitivity of the helium leak test shall be at least 4.0 x 10^{-8} cm^3/sec (helium), so as to demonstrate a leakage rate not greater than 8.0 x 10^{-8} cm^3/sec (helium). Any indication of a leak is an unacceptable condition and must be repaired.

7.1.4 Closure

The primary closure of the transportable storage canister consists of the welded shield lid and the two (2) welded port covers. There are no bolted closures or mechanical seals in the primary closure. A secondary, or redundant, closure is provided at the top end of the canister by the structural lid. The structural lid, when welded to the canister shell, fully encloses the shield lid and the port covers.

Figure 7.1-1 Transportable Storage Canister Primary and Secondary Confinement Boundaries

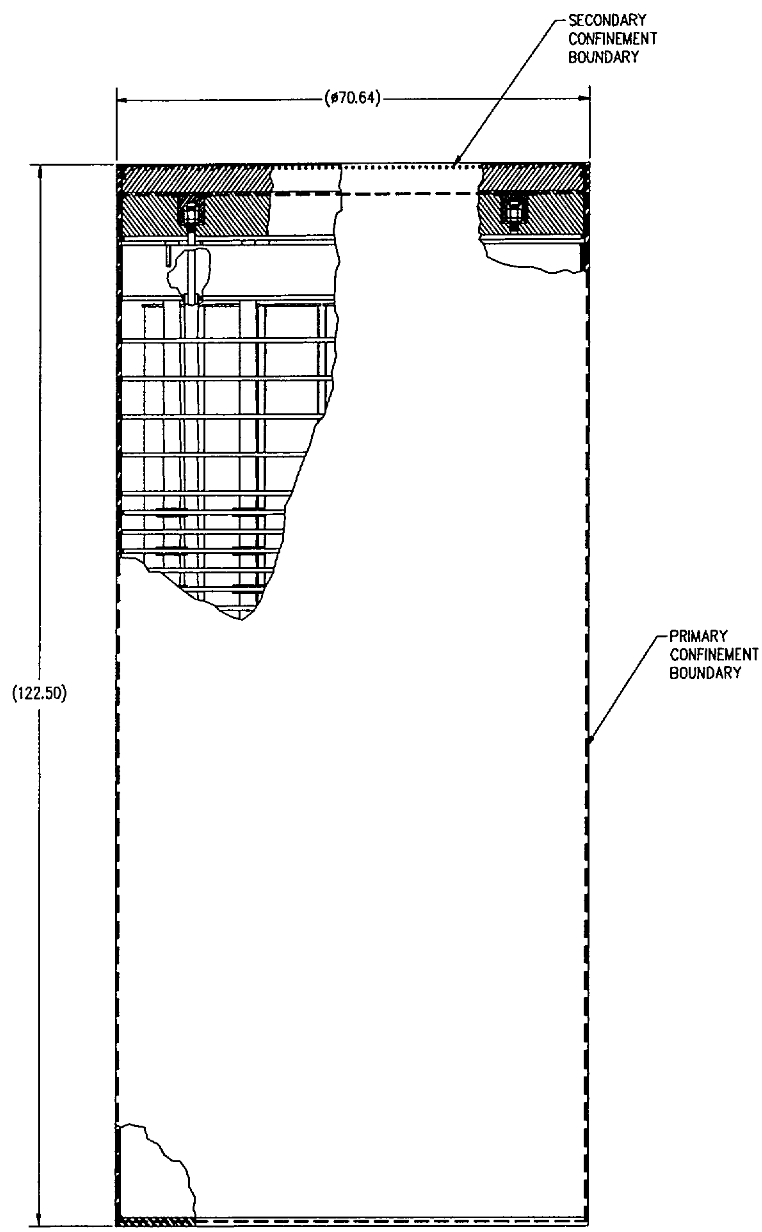

Figure 7.1-2 Confinement Boundary Detail at Shield Lid Penetration

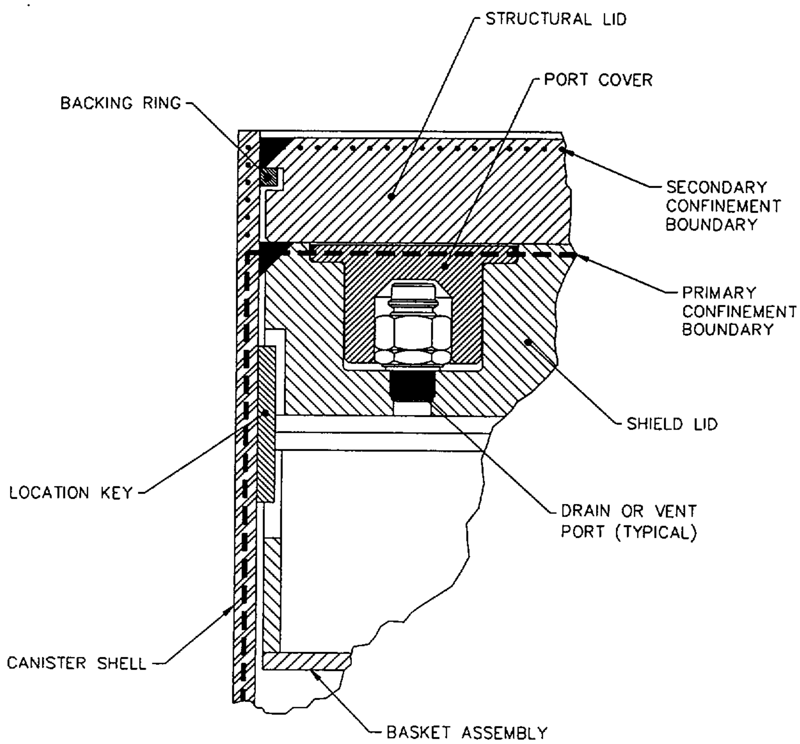

Table 7.1-1 Canister Confinement Boundary Welds

Confinement Boundary Welds		
MPC Weld Location	**Weld Type**	**ASME Code Category (Section III, Subsection NB)**
Shell longitudinal	Full penetration groove (shop weld)	A
Shell circumferential (if used)	Full penetration groove (shop weld)	B
Bottom plate to shell	Full penetration groove (shop weld)	C
Shield lid to shell	Bevel (field weld)	C
Structural lid to shell	Bevel (field weld)	C
Vent and drain port covers to shield lid	Bevel (field weld)	C

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7.2 Requirements for Normal Conditions of Storage

The canister is transferred to a vertical concrete storage cask using a transfer cask. During this transfer, the canister is subject to handling loads. The evaluation of the canister for normal handling loads is provided in Chapter 3.0. The principal design criteria for the NAC-MPC system are provided in Chapter 2.0.

Once the canister is placed inside of the vertical concrete storage cask, it is effectively protected from direct loading due to natural phenomena, such as wind, snow and ice loading. The principal direct loading for normal operating conditions arises from increased internal pressure caused by decay heat, solar insolation, and ambient temperature. The normal operating internal pressure is evaluated in Chapter 3.0, as described in Section 7.2.2.

7.2.1 Release of Radioactive Material

The structural analysis of the canister for normal conditions of storage that is presented in Section 3.4.4 shows that the canister is not breached in any of the normal operating events. Consequently, there is no release of radioactive material during normal conditions of storage.

7.2.2 Pressurization of the Confinement Vessel

The canister is vacuum dried and backfilled with helium at one (1) atmosphere absolute prior to installing and welding the penetration port covers. In service, the internal pressure increases due to an increase in temperature of the helium and due to the postulated failure of fuel rod cladding of 3% of the fuel rods, which releases 30% of the available fission gases in those rods.

The temperature of the helium increases due to the fuel decay heat, high ambient temperature, and the effect of full solar insolation on the concrete cask surface. Fuel cladding failure is assumed to release a fraction of the available fission gas and other radionuclides that are assumed to be releasable and all of the charge gas installed in the fuel rods at the time of manufacture of the rod. The evaluation conservatively adds the releasable inventory of the reconfigured fuel rods classified as failed to the inventory of the intact fuel that is assumed to fail in normal conditions.

The canister, shield lid, fittings, and the canister basket are fabricated from materials that do not react with ordinary or borated spent fuel pool water to generate gases. The aluminum heat transfer disks, fuel tubes, and BORAL plates used for criticality control are protected by an oxide

film that forms shortly after fabrication. This oxide layer effectively precludes further oxidation of the aluminum components or other reaction with water in the canister at temperatures less than 200°F, which is higher than the typical spent fuel pool water temperature. No steels requiring protective coatings or paints are used in the canister, shield lid, fittings, or basket. Therefore, there are no protective coatings or paints present that could interact with water to release gases.

The calculation of the canister pressure based on normal storage conditions is presented in Section 4.4.5 and is 7.9 psig. This pressure is well within the design internal pressure value of 11.5 psig for normal condition of storage. There are no adverse consequences, due to the internal pressure resulting from normal storage conditions.

Since the canister is vacuum dried and backfilled with helium prior to sealing, there are no significant moisture or gases, such as air, that remain in the canister. Consequently, there is no potential that radiolytic decomposition could cause an increase in canister internal pressure or result in a build up of explosive gases in the canister.

7.3 Confinement Requirements for Hypothetical Accident Conditions

The evaluation of the canister for off-normal and accident condition loading is provided in Sections 3.5, 11.1 and 11.2, respectively.

Once the canister is placed inside the vertical concrete storage cask, it is effectively protected from direct loading due to natural phenomena, such as seismic events, flooding and tornado (wind driven) missiles. Accident conditions assume the cladding failure of all the fuel rods stored in the canister. Consequently, there is an increase in canister internal pressure due to the release of a fraction of the fission product and charge gases. The accident conditions internal pressure is 33 psig as calculated in Section 11.2.1.

For evaluation purposes, a class of accidents identified as off-normal is also considered in Section 11.1. This class of accidents is not considered here, since off-normal conditions are bounded by the hypothetical accident conditions.

The structural analysis of the canister for off-normal and accident conditions of storage, which is presented in Chapter 11, shows that the canister is not breached in any of the evaluated events. Consequently, based on a leaktight configuration, there is no release of radioactive material during off-normal or accident conditions of storage.

The resulting site boundary dose due to a hypothetical accident is, therefore, less than the 5 rem whole body or organ (including skin) dose at a 100 meter minimum boundary required by 10 CFR 72.106 (b) for accident exposures.

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8.0 OPERATING PROCEDURES

This chapter provides general guidance for using the NAC-MPC for storage operations. Three operating conditions are addressed. The first is loading the transportable storage canister (canister), installing it in the vertical concrete cask (concrete cask), and transferring it to the storage (ISFSI) pad. The second is the removal of the loaded canister from the concrete cask. The third is opening the canister to remove spent fuel in the unlikely event that this should be necessary.

The operating procedure for transferring a loaded canister from a concrete cask to the NAC-STC transport cask is described in Section 7.2.2 of the NAC-STC SAR.

Users are expected to develop site-specific procedures that incorporate the requirements presented here, consistent with the Operating Controls and Limits presented in Chapter 12. In addition, supplemental shielding may be employed to reduce radiation exposure for certain of the tasks specified by these procedures. Use of supplemental shielding is at the discretion of the user.

Operation of the NAC-MPC system requires the use of ancillary equipment items. The ancillary equipment supplied with the system is shown in Table 8.1-1. The system does not rely on the use of bolted closures, but bolts are used to secure retaining rings and lids. The hoist rings used for lifting the shield lid and canister have threaded fittings. Table 8.1-2 provides the torque values for installed bolts and hoist rings.

The design of the NAC-MPC is such that the potential for spread of contamination during handling and future transport of the canister is minimized. The concrete cask is constructed of new materials. The canister is loaded in the spent fuel pool, but is protected from gross contact with pool water by a jacket of clean water while it is in the transfer cask. Only the top of the open canister is exposed to contaminated pool water. The top of the canister is closed by the structural lid, which is not contaminated when it is installed. Consequently, the canister external surface is expected to be essentially clean.

When used in accordance with these procedures, the user dose is ALARA.

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8.1 Loading the NAC-MPC Storage System

The NAC-MPC storage system consists of three principal components: the transportable storage canister (canister), the transfer cask, and the vertical concrete cask (concrete cask). The transfer cask is used to hold the canister during loading and while the canister is being closed and sealed. The transfer cask is also used to transfer the canister to the concrete cask and to load the canister into the transport cask. The principal handling operations involve closing and sealing the canister by welding and loading it into the concrete cask. The vent and drain port locations are shown in Figure 8.1-1.

This procedure assumes that the canister with an empty basket is installed in the transfer cask, that the transfer cask is positioned in the decontamination area or other suitable work station, and that the concrete cask is positioned on a heavy-haul transporter in the cask receiving area or other suitable staging area. The staging area should be within the handling "footprint" of the cask handling crane.

The operator must ensure that the fuel assemblies selected for loading into the canister conform to the requirements of Table 2.1-1 and the Certificate of Compliance or Site Specific Approval.

8.1.1 Loading and Closing the Transportable Storage Canister

1. Visually inspect the basket fuel tubes to ensure they are unobstructed and free of debris. Ensure that the welding zones on the canister, shield and structural lids, and the port covers are prepared for welding. Ensure transfer cask door lock bolts are installed and secure.
2. Flood the canister with clean water until the water is about 4 inches from the top of the canister.

   Note: Do not fill the canister completely in order to avoid spilling water during the transfer to the spent fuel pool.
3. Attach a clean water line to the transfer cask.
4. If it is not already attached, attach the transfer cask lifting yoke to the cask handling crane, and engage the transfer cask lifting trunnions.

   Note: The minimum temperature of the transfer cask (i.e., external ambient temperature) must be verified to be higher than 0°F prior to lifting. See Appendix 12A, Section 3.1.9.
5. Raise the transfer cask and move it over the pool, following the prescribed travel path.
6. Lower the transfer cask to the pool surface and turn on the clean water line to flood the annulus between the transfer cask and canister.

7. Lower the transfer cask as the annulus fills with clean water until the trunnions are at the surface and hold that position until clean water fills the remainder of the canister and overflows the sides of the transfer cask. Then lower the transfer cask to the bottom of the pool cask loading area.

   Note: If an intermediate shelf is used to avoid wetting the cask handling crane hook, follow the plant procedure for use of the extension piece.
8. Disengage the transfer cask lifting yoke to provide clear access to the canister.
9. Load the previously designated fuel assemblies into the canister.
10. Attach a three-legged sling to the shield lid using the swivel hoist rings.
11. Using the cask handling crane, or auxiliary hook, lower the shield lid until it rests in the top of the canister. Note the time that the shield lid is installed.

    Note: Ensure that the shield lid key slot aligns with the key welded to the canister shell.
12. Raise the transfer cask until its top just clears the pool surface. Hold at that position, and using a suction pump, drain the pool water from above the shield lid. After the water is removed, continue to raise the cask.
13. As the cask is raised, spray the transfer cask outer surface with clean water to wash off any gross contamination.
14. When the cask is clear of the pool surface, but still over the pool, turn off the clean water flow to the annulus and allow the annulus water to drain to the pool. Move the cask to the decontamination area or other suitable work station.

    Note: Access to the top of the transfer cask is required. A suitable work platform may need to be erected.
15. Verify that the shield lid is level. Decontaminate the top of the transfer cask and shield lid as required to allow welding and inspection activities.

    Note: Supplemental shielding may be used for activities around the shield lid.
16. Insert the drain tube through the drain port of the shield lid into the basket drain tube sleeve. Torque the drain tube to 125 ± 5 ft-lbs. Install a mating quick-disconnect fitting in the vent line to open the vent. Remove the hoist rings.
17. Connect the suction pump to the drain port. Verify that the vent port is open. Remove approximately 50 gallons of water from the canister. Disconnect and remove the pump. Note the time the transfer cask is removed from the pool. Operations through Step 25 must be completed in 20 hours.
18. Install the semiautomated welding equipment.

19. Attach the hydrogen gas detector to the vent port. Verify that the concentration of any detectable hydrogen gas is below 2.4%.

    Note: If the concentration exceeds 2.4%, operate the vacuum system to remove gases from the under side of the shield lid and re-verify hydrogen gas concentration.

20. Operate the welding equipment to complete the root weld joining the shield lid to the canister shell following approved procedures.

    Note: Stop welding if the hydrogen detector indicates a hydrogen concentration above 2.4% and clear hydrogen gas buildup.

21. Prepare the weld and perform a liquid penetrant weld examination of the root pass. Record the results of the weld examination.

    Note: The hydrogen detector may be removed from the vent port, if necessary.

22. Complete welding of the shield lid to the canister wall and remove the weld equipment.
23. Prepare the weld and perform a liquid penetrant weld examination of the final pass. Record the results of the weld examination.
24. Remove any lines attached to the drain port. Attach an air pressure line to the vent port. Pressurize the canister to 50 psig and hold the pressure. There must be no loss of pressure for 10 minutes (To be consistent with the specified canister transportation test pressure).
25. Release the pressure and visually inspect the shield lid to canister shell weld for indications of leaks and defects. Record the results of the inspection.
26. Attach the suction pump to the drain line. Ensure that the vent line is open. Using the pump, remove the remaining free water from the canister cavity.

    Note: Steps 26 through 35 must be completed within 16 hours in accordance with LCO 3.1.5.

27. Remove any free water in the drain port cavity. Install the drain port cover.

    Note: If previously removed, reinstall the hydrogen gas detector to the vent port. Operate the detector to verify that the concentration of hydrogen gas is below 2.4%. If not, use the vacuum system to clear hydrogen gas from the cavity and the drain line.

28. Weld the drain port cover to the shield lid.
29. Prepare the weld and perform a liquid penetrant examination of the drain port cover weld root and final passes. Record the results of the weld examination.
30. Attach the vacuum equipment to the vent port line.
31. Operate the vacuum equipment, until a vacuum of 3 mm of mercury exists in the canister, in accordance with the requirements of Technical Specification LCO 3.1.2.
32. Verify that no water remains in the canister by holding the vacuum for 30 minutes. If water is present in the cavity, the pressure will rise as the water vaporizes. Continue the vacuum/hold cycle until there is no indicated rise in pressure after 30 minutes.

33. Backfill the canister cavity with helium having a minimum purity of 99.9%.
34. Restart the vacuum equipment and evacuate the canister to 3 mm of mercury, in accordance with the requirements of Technical Specification LCO 3.1.2.
35. Backfill the canister cavity with helium, pressurizing it to 22 psia (approximately 7.5 psig) in accordance with the requirements of Technical Specification LCO 3.1.3.
36. Using a helium leak detector, verify that there is no leak at the shield lid weld to a sensitivity of 4×10^{-8} cm^3/second (helium) in accordance with the requirements of Technical Specification LCO 3.1.4.

    Note: Steps 36 through Step 12 of the concrete cask loading procedure (Section 8.1.2) must be completed within 26 hours in accordance with LCO 3.1.6.
37. Vent the canister helium pressure to one (1) atmosphere absolute (0 psig).
38. Remove any attachments to the vent port fitting. Dry any residual water that may be present in the vent port cavity.
39. Install the vent port cover and weld the vent port cover to the shield lid.
40. Prepare the weld and perform a liquid penetrant examination of the vent port cover weld root and final passes. Record the results of the weld examination.
41. Remove any supplemental shielding used during shield lid closure activities.
42. Attach a three-legged sling to the structural lid using the swivel hoist rings.

    Note: Verify that the structural lid is stamped, or otherwise marked, to provide traceability of the canister contents. Verify that the structural lid weld backing ring is in place on the structural lid.
43. Using the cask handling or the auxiliary crane, install the structural lid in the top of the canister. Verify that the structural lid does not protrude above the canister shell and is approximately centered in the canister shell. Verify that the gap in the backing ring is not aligned with the shield lid alignment key. Remove the lifting sling and the hoist rings.
44. Install the automated welding equipment on the structural lid.
45. Complete the root weld pass joining the structural lid to the canister shell.
46. Prepare the weld and perform a liquid penetrant examination of the weld root pass and record the results of the weld examination.
47. Complete the remainder of the weld, performing NDE (progressive liquid penetrant or ultrasonic testing) examination. Record the results of each weld examination.
48. Remove the welding equipment.

49. Prepare the weld and perform an ultrasonic inspection of the weld, if required, then perform a liquid penetrant examination of the final weld pass. Record the results of the weld examinations.
50. Perform a smear survey of the accessible area at the top of the canister to ensure that the surface contamination is less than the limits established for the site (typically less than 20 dpm/100 cm^2 alpha, and less than 1,000 dpm/ 100 cm^2 beta-gamma). Smear survey results shall meet the requirements of Technical Specification LCO 3.2.2.
51. Install the transfer cask retaining ring.
52. Decontaminate the external surface of the transfer cask.

8.1.2 Loading the Vertical Concrete Cask

This section of the loading procedure assumes that the vertical concrete cask (concrete cask) is located on the bed of a heavy-haul trailer under the cask handling crane and that the concrete cask shield plug and lid are not in place.

1. Using a suitable crane, place the transfer adapter on the top of the concrete cask.
2. Using the transfer adapter bolt hole pattern, align the adapter to the concrete cask. Bolt the adapter to the cask using four (4) socket head cap screws.
3. Verify that the bottom door connectors on the adapter plate are in the fully extended position.
4. If not already done, attach the transfer cask lifting yoke to the cask handling crane. Verify that the transfer cask retaining ring is installed.
5. Install six (6) swivel hoist rings in the structural lid of the canister. Verify that the hoist ring threads are fully engaged, and attach two (2) three-legged slings. Stack the slings on the top of the canister so they are available for use in lowering the canister into the concrete cask.
6. Engage the transfer cask trunnions with the transfer cask lifting yoke. Ensure that all lines are disconnected from the transfer cask.
7. Raise the transfer cask and move it over the concrete cask. Lower the transfer cask, ensuring that the transfer cask bottom door rails and connector tees align with the adapter plate rails and door connectors. Prior to final set down, remove transfer cask door lock bolts.

   Note: The minimum temperature of the transfer cask must be verified to be higher than 0°F (i.e., external ambient temperature) prior to lifting in accordance with Technical Specification LCO 3.1.9.
8. Ensure that the bottom door connector tees are engaged with the adapter plate door connectors.

9. Disengage the transfer cask yoke from the transfer cask and from the cask handling crane hook.
10. Return the cask handling crane hook to the top of the transfer cask and engage the two (2) three-legged slings attached to the canister by attaching the master links to the crane hook. Lift the canister slightly (about ½ inch) to take the canister weight off of the transfer cask bottom doors.

    Note: A load cell may be used to determine when the canister is supported by the crane. Avoid raising the canister to the point that the structural lid engages the transfer cask retaining ring, as this could result in lifting the transfer cask.

    Caution: The three-legged sling master links must be at least 67 inches above the canister lid. (Refer to Technical Specifications, Appendix 12A, Section 4.5.2).
11. Using the hydraulic system, open the bottom doors to access the concrete cask cavity.
12. Lower the canister into the concrete cask, using a slow crane speed as the canister nears the bottom of the concrete cask.
13. Disconnect the slings from the canister and close the transfer cask bottom doors.
14. Retrieve the transfer cask lifting yoke and attach the yoke to the transfer cask.
15. Lift the transfer cask off the concrete cask and return it to the decontamination area or designated work station.
16. Using the auxiliary crane, remove the adapter plate from the top of the concrete cask.
17. Remove the swivel hoist rings from the structural lid and replace them with bolts.
18. Using the auxiliary crane, retrieve the shield plug and install the shield plug in the top of the concrete cask.
19. Using the auxiliary crane, retrieve the concrete cask lid and install the lid in the top of the concrete cask using six stainless steel bolts.
20. Ensure that there is no foreign material left at the top of the concrete cask. Install the tamper-indicating seal.
21. Verify that the concrete cask surface dose rates are less than those established by the requirements of Technical Specification LCO 3.2.1 (The average surface dose rate shall not exceed 50 mrem per hour on the sides and 35 mrem per hour on the top. The dose rates measured at the inlets and outlets shall be less than 100 mrem per hour measured at a point that is the extension of the external surface.)

8.1.3 Transporting the Vertical Concrete Cask

This section of the procedure assumes that the loaded concrete cask is positioned on a heavy-haul trailer.

1. Using a suitable towing vehicle, tow the heavy-haul trailer to the dry storage pad (ISFSI). Verify that the bed of the trailer is approximately at the same height as the pad surface.
2. Install four (4) hydraulic jacks at the four (4) designated jacking points at the bottom cooling air vents.
3. Raise the concrete cask approximately 3 inches.

   Caution: Do not exceed a maximum lift height of 6 inches, in accordance with the requirements of Technical Specification LCO 3.1.8.
4. Move the air-bearing rig set under the cask.

   Note: A hydraulic skid may also be used to move the concrete cask. The height the concrete cask is raised depends upon the height of the skid or air pad set used, but may not exceed 6 inches.
5. Inflate the air-bearing rig set. Remove the four (4) hydraulic jacks.
6. Using a suitable towing vehicle, move the concrete cask from the bed of the transporter to the designated location on the storage pad.
7. Turn off the air-bearing rig set, allowing it to deflate.
8. Reinstall the four (4) hydraulic jacks and raise the concrete cask approximately 3 inches.

   Caution: Do not exceed a maximum lift height of 6 inches, in accordance with the requirements of Technical Specification LCO 3.1.8.
9. Remove the air-bearing rig set pads. Ensure that the surface of the dry storage pad under the cask is free of foreign objects.
10. Lower the concrete cask to the surface.

    Note: Ensure that the spacing between concrete casks is 15 (+1, -0) feet.
11. Remove the four (4) hydraulic jacks.
12. Install screens in the inlets and outlets.
13. Install/connect the temperature monitoring equipment.
14. Scribe/stamp the concrete cask name plate to indicate loading.

Figure 8.1-1 Vent and Drain Port Locations

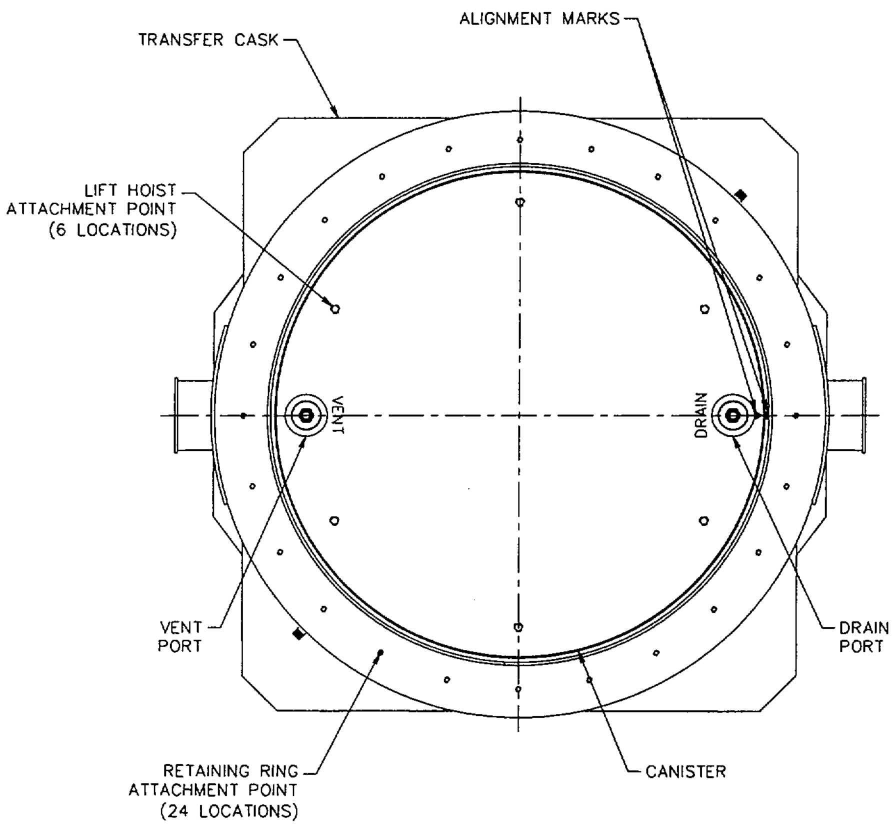


Table 8.1-1 List of Ancillary Equipment

Item	Description
Transfer Cask Lifting Yoke	Required for lifting and moving the transfer cask.
Transport Trailer (Optional)	Heavy-haul (double drop frame) trailer required for moving the loaded and empty concrete cask to and from the ISFSI pad.
Helium Supply System	Supplies helium to the canister for helium backfill and purging operations.
Vacuum Drying System	Used for evacuating the canister. Used to remove residual water, air and initial helium backfill.
Automated Welding System	Used for welding the shield lid and structural lid to the canister shell.
Self-Priming Pump	Used to remove water from the canister.
Shield Lid Sling	A three-legged sling used for lifting the shield lid. It is also used to lift the concrete cask shield plug and lid.
Canister Sling	A set of 2 three-legged slings joined by a master link, used for lifting the structural lid by itself, or for lifting the canister when the structural lid is welded to it. The master link allows the slings to be loaded simultaneously during the lift.
Transfer Adapter	Used to align the transfer cask to the concrete cask or transport cask. Provides the platform for the operation of the transfer cask bottom doors.
Hydraulic Unit	Operates the bottom doors of the transfer cask.
Lift Pump Unit	Jacking system for raising and lowering the concrete cask.
Air Pad Rig Set	Air cushion system used for moving the concrete cask.

Table 8.1-2 Torque Values

Fastener	**Torque Value (ft-lbs)**	**Torque Pattern**
Transfer Adapter Bolts	40 ± 5	None
Transfer Cask Retaining Ring Bolts	100 ±10	None
Concrete Cask Lid Bolts	40 ± 5	None
Lifting Hoist Rings*		
Canister Shield Lid	800 + 80, - 0	None
Canister Structural Lid	800 + 80, - 0	None
Concrete Cask Lid	800 + 80, - 0	None
* Threads must be fully engaged		
Canister and Lid Plug Bolts	Hand Tight	None
Transfer Cask Door Lock Bolts	Hand Tight	None
Canister Drain Line	125 ± 5	None

8.2 Removal of the Transportable Storage Canister from the Vertical Concrete Cask

Removal of the loaded canister from the concrete cask is expected to occur at the time of shipment of the canistered fuel off site. Alternately, removal could be required in the unlikely event of an accident condition that rendered the concrete cask or canister unsuitable for continued long-term storage or for transport. This procedure identifies the general steps to return the loaded canister to the transfer cask and return the transfer cask to the decontamination station, or other designated work area. Since these steps are the reverse of those undertaken to place the canister in the concrete cask, as described in Section 8.1.2, they are summarized here.

At the option of the user, the canister may be removed from the concrete cask and transferred to another concrete cask or to the NAC-STC transport cask at the ISFSI site. This transfer is done using the transfer cask, which provides shielding for the canister contents during the transfer.

1. Using the hydraulic jacking system and the air pad set, move the concrete cask from the ISFSI pad to the heavy-haul trailer. The bed of the trailer must be approximately level with the surface of the pad.

   Caution: Do not exceed a maximum lift height of 6 inches when raising the concrete cask to install the air pad set in accordance with the requirements of Technical Specification LCO 3.1.8.
2. Tow the transporter to the cask receiving area or other designated work station.
3. Remove the concrete cask shield plug and lid. Install the hoist rings in the canister structural lid. Verify that the hoist ring threads are fully engaged and attach the lift slings. Install the transfer adapter.
4. Retrieve the transfer cask and position it on the transfer adapter on the top of the concrete cask.

   Note: The minimum temperature of the transfer cask must be verified to be higher than 0°F (i.e., external ambient temperature) prior to lifting in accordance with Technical Specification LCO 3.1.9.
5. Open the shield doors. Attach the canister lift slings to the cask handling crane hook.

   Caution: The three-legged sling master links must be at least 67 inches above the canister lid. (Refer to Technical Specifications, Appendix 12A, Section 4.5.2).
6. Raise the canister into the transfer cask. Use caution to avoid contacting the transfer cask retaining ring with the canister.

7. Close the shield doors. Lower the canister to rest on the bottom doors. Disconnect the canister slings from the crane hook.
8. Retrieve the transfer cask lifting yoke. Engage the transfer cask trunnions and move the transfer cask to the decontamination area or designated work station.
   Note: Prior to moving transfer cask, install and secure door lock bolts.

After the transfer cask containing the canister is in the decontamination area or other suitable work station, additional operations may be performed on the canister. It may be opened, transferred to another concrete cask, or placed in the NAC-STC transport cask. The length of time that the loaded canister is in the transfer cask and spent fuel cooldown operations must be monitored in accordance with LCO 3.1.7 and LCO 3.1.10.

8.3 Unloading the Transportable Storage Canister

Circumstances could arise that dictate the opening of a previously loaded canister and the removal of the stored spent fuel. This section describes the basic operations needed to open the sealed canister. It is assumed that the canister is positioned in the transfer cask and that the transfer cask is in the decontamination station or other suitable work station. The principal mechanical operations are the cutting of the closure welds, filling with water, and the removal of the spent fuel. Supplemental shielding is used as required. The length of time that the loaded canister is in the transfer cask and spent fuel cooldown operations must be monitored in accordance with LCO 3.1.7 and LCO 3.1.10.

1. Remove the transfer cask retaining ring.
2. Survey the top of the canister to establish the radiation level and contamination level at the structural lid.
3. Set up the weld cutting equipment to cut the structural lid weld (Abrasive grinding, hydrolaser, or similar cutting equipment).
4. Tent the top of the transfer cask as required.
5. Operate the cutting equipment to cut the structural lid weld.
   Note: Monitor for any out-gassing. Wear respiratory protection as required.
6. Remove the cutting equipment and attach a three-legged sling to the structural lid.
7. Using the auxiliary crane, lift the structural lid off of the canister and out of the transfer cask.
8. Survey the top of the shield lid to determine radiation and contamination levels. Use supplemental shielding as necessary. Decontaminate the top of the shield lid, if necessary.
9. Tent the top of the transfer cask, if required. Using an abrasive grinder and wearing suitable respiratory protection, cut the welds joining the vent and drain port covers to the shield lid.
10. Remove the port covers. Monitor for any out-gassing and survey the radiation level at the quick-disconnect fittings. Attach a manually valved line with a vacuum bottle to the vent port quick-disconnect. Open the valve to the vacuum bottle to obtain a gas sample from the vent line. Analyze the gas sample to determine the make up of the canister atmosphere.
    Caution: The canister could be pressurized.
11. Attach a nitrogen gas line to the drain port quick-disconnect and a discharge line from the vent port quick-disconnect to an off-gas handling system. Monitor the vent line, so that the radiation level of the discharge gas and the temperature of the discharge gas are indicated.
    Note: Any significant radiation level in the discharge gas indicates the presence of fission gas products. The temperature of the gas indicates the thermal conditions in the canister.
    Caution: Discharge gas temperature could initially be above 400°F.

12. Continue to flow nitrogen through the line, until there is no evidence of fission gas activity in the discharge line. Continue to monitor the gas discharge temperature. When there is no additional evidence of fission gas, stop the nitrogen flow and disconnect the drain and vent port line connections.

    Caution: The discharge line and fittings may be very hot.

    Note: See Figure 8.3-1 for a typical line diagram of the canister cool down support system.

13. Attach a source of clean water with a minimum temperature of 70°F and a maximum supply pressure of 35 psig to the drain port quick-disconnect. Attach a discharge line to the vent port quick-disconnect. Slowly start the flow of clean water to establish a flow rate of 5 (+ 3, - 0) gpm. Monitor the discharge line pressure gage during canister flooding. Secure filling the canister if at any time the canister vent line discharge pressure exceeds 30 psig. Re-establish flow when canister pressure is reduced below 20 psig. The discharge line will initially discharge hot gas, but after the canister fills, it will discharge hot water. The canister filling is expected to take less than 8 hours (Caution: Relatively cool water may flash steam as it encounters hot surfaces within the canister. If there are grossly failed or ruptured fuel rods within the canister, very high levels of radiation could rapidly appear at the discharge line. The radiation level of the discharge gas or water should be continuously monitored).

    Note: The fuel cooldown procedure must conform to the requirements of Technical Specification LCO 3.1.7.

14. Continue to flow water through the canister until the exit water temperature stabilizes, then stop the flow of water.

15. Connect a suction pump to the drain port and remove approximately 50 gallons of water. Disconnect and remove the pump.

16. Attach a hydrogen gas detector to the vent port. Verify that the concentration of hydrogen gas is less than 2.4%.

17. Set up the weld cutting equipment to cut the shield lid weld (Abrasive grinding, hydrolaser, or similar cutting equipment.). Route the vent line to avoid interference with the weld cutting operation.

18. Operate the cutting equipment to cut the shield lid weld.

    Note: Stop the cutting operation if the hydrogen gas detector indicates a concentration of hydrogen gas above 2.4%. Clear the gas before proceeding with the cutting operation.

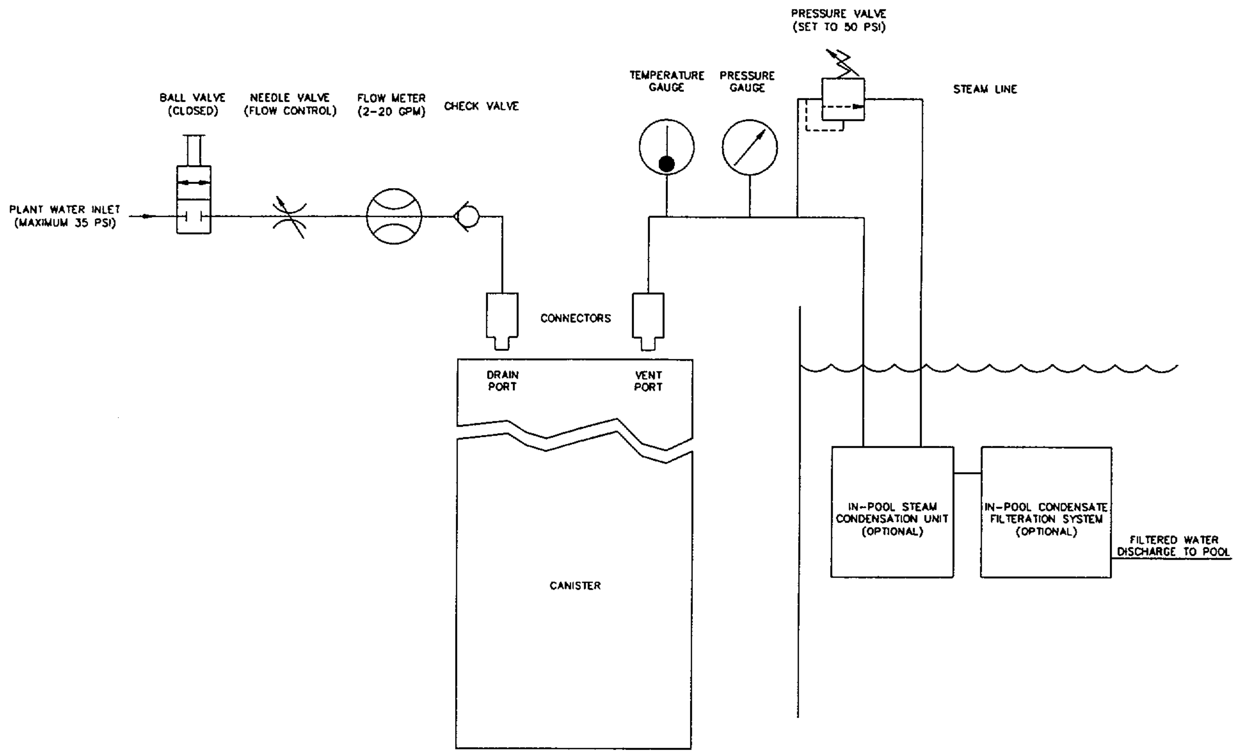
19. Remove the cutting equipment. Install the shield lid lifting hoist rings and attach a three-legged sling. Attach a line to the sling master link to aid in attaching the sling to the crane hook.

20. Attach the clean water line to the transfer cask.
21. Retrieve the transfer cask lifting yoke and engage the transfer cask lifting trunnions.

    Note: The minimum temperature of the transfer cask must be verified to be higher than 0°F (i.e., external ambient temperature) prior to lifting in accordance with Technical Specification LCO 3.1.9.
22. Move the transfer cask over the pool and lower the bottom of the transfer cask to the surface. Start the flow of clean water to the transfer cask annulus. Continue to lower the transfer cask, as the annulus fills with clean water, until the top of the transfer cask is about 4 inches above the pool surface. Hold this position until clean water fills the top of the transfer cask.
23. Lower the transfer cask to the bottom of the cask loading area and remove the lifting yoke.
24. Attach the shield lid lifting sling to the crane hook.
25. Slowly lift the shield lid. Move the shield lid to one side after it is raised clear of the transfer cask (Caution: The drain line tube is suspended from the under side of the shield lid. The lid should be raised as straight as possible until the tube clears the canister basket. Use caution if the shield lid is removed from the pool. The under side of the shield lid and the attached drain line could be highly contaminated.).
26. Visually inspect the fuel for damage.

At this point, the spent fuel could be transferred from the canister to the fuel racks. If the fuel is damaged, special rigging could be required to remove the fuel. In addition, the bottom of the canister could be highly contaminated. Care must be exercised in the handling of the transfer cask when it is removed from the pool. Highly radioactive particles could rest on flat surfaces of the transfer cask resulting in high dose rates.

Figure 8.3-1 Canister Reflood Piping and Controls Schematic



Note: The fuel cooldown procedure must conform to the requirements of Technical Specification LCO 3.1.7.

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9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

This chapter specifies the acceptance criteria and the maintenance program for the NAC-MPC storage system primary components: vertical concrete cask (storage cask), transportable storage canister (canister). The design of the NAC-MPC system requires shop fabrication of the canister shell with the bottom plate, the shield and structural lids for the canister, and the basket that holds the spent fuel. The storage cask consists of reinforced concrete placed around steel components that are integral to the performance of the storage cask. These steel components include: a liner that forms the central cavity of the storage cask, a set of air outlet passage-ways that allow cooling to the stored canister, a shield plug, a steel closure lid, and a steel base. The base includes: the air inlets and associated pathways, provides a pedestal upon which the canister rests, and provides a structural support for raising the storage cask. The steel components are shop fabricated. The reinforcing steel will be bent in the shop and delivered to the storage cask construction site. The storage cask construction will include the erection of the cask liner onto the steel base. The concrete is placed around the liner after the reinforcing steel has been properly erected.

As described in Chapter 8, the storage cask is intended to be lifted by hydraulic jacks and moved using air pads under the base. It does not have lifting trunnions.

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9.1 Acceptance Tests

The acceptance tests ensure that the storage cask and canister are fabricated, assembled, inspected and tested in accordance with the requirements of this SAR and the license drawings.

9.1.1 Visual and Nondestructive Examination Inspections

The acceptance test program establishes a set of visual inspections and nondestructive examination or test requirements for the fabrication and assembly of the storage cask and canister. Satisfactory results for these inspections, examinations and tests demonstrate that the components comply with the requirements of the SAR and the license drawings, and the initial operation of the storage system complies with regulatory requirements.

A fit-up test of the canister and its components is performed during the acceptance inspection. The fit-up test demonstrates that the canister, basket, shield lid and structural lid can be properly assembled during fuel loading and canister closure operations.

A visual inspection is performed on all materials and welds used for storage cask, canister and basket fabrication. The visual inspection applies to finished surfaces of the components. All welds (shop and field installed) are visually inspected for defects prior to the nondestructive examinations that are specified. The welding of the canister is performed in accordance with ASME Code, Section III, Subsection NB-4000, except as described in Section 7.1.3 and Table 12A4-1.

The visual inspections of the canister welds are performed in accordance with the ASME Code Section V, Article 9. Acceptance criteria for the visual examinations of the canister welds are in accordance with ASME Code Section III, Subsection NB-4424 and NB-4427. Required weld repairs on the canister are performed in accordance with ASME Code Section III, NB-4450, and are reexamined in accordance with the original acceptance criteria.

Welding of the storage cask's steel components, including field installed welds, is performed in accordance with either: 1) ANSI/AWS D1.1-96 and is inspected in accordance with ANSI/AWS D1.1, Section 8.15.1; or 2) ASME Code Section VIII, and inspected in accordance with ASME Code Section V, Article 9. Weld procedures and welder qualifications shall be in accordance with ANSI/AWS D1.1, Section 5, or ASME Code Section IX.

Welding of the basket assembly for spent fuel is performed in accordance with ASME Code Section III, NG-4000. Visual examination of the welds is performed per the requirements of ASME Code Section V, Article 9. Acceptance criteria for the visual examination of the basket assembly welds are that of ASME Code Section III, Subsections NB-4424 and NG-4427. Any required weld repairs are performed in accordance with ASME Code Section III, NG-4450 and are re-examined in accordance with the original acceptance criteria.

Qualified personnel perform all visual inspections according to written and approved procedures. The results of all visual weld inspections are recorded.

9.1.1.1 Nondestructive Weld Examination

All of the welds of the canister assembly are nondestructively examined in addition to the visual examination previously discussed. In accordance with the ASME Code Section III, Subsection NB, requirements for confinement vessels, the canister shell welds are volumetrically examined by radiography (RT) in accordance with the ASME Code Section V, Article 2, with acceptance criteria in accordance with ASME Code Section III, NB-5320. The weld that joins the bottom plate to the canister shell is ultrasonically (UT) examined per ASME Code Section V, Article 5, with acceptance criteria in accordance with ASME Code Section III, NB-5330. The finished surface of the canister shell and bottom plate welds are liquid penetrant examined in accordance with ASME Code Section V, Article 6, with acceptance in accordance with ASME Code Section III, NB-5350. The shield lid to canister shell weld and the structural lid to shell weld, as well as the vent and drain port covers to shield lid welds, are field welds that are performed after the canister is loaded. The root and final passes of the shield lid to canister shell weld are liquid penetrant (PT) examined per ASME Code, Section V, Article 6. The acceptance criteria are in accordance with ASME Code, Section III, NB-5350. The canister vent port cover and drain port cover to shield lid welds are liquid penetrant examined, i.e., root and final surfaces, in accordance with ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, NB-5350. The canister structural lid to canister shell weld is either: 1) ultrasonically (UT) examined in accordance with ASME Code Section V, Article 5, with the final weld surface liquid penetrant examined in accordance with ASME Code Section V, Article 6 or 2) progressively liquid penetrant examined in accordance with the ASME Code Section V, Article 6. Acceptance criteria are specified in ASME Code Section III, NB-5330 (ultrasonic) and NB-5350 (liquid penetrant).

The basket assembly welds are liquid penetrant examined in accordance with ASME Code Section V, Article 6. The acceptance criteria are in accordance with ASME Code Section III, NG-5350.

All welding of canister and basket components is performed using procedures and welders qualified in accordance with the ASME Code Section IX. Welding of the fabricated steel components of the concrete cask is performed using procedures and welders qualified in accordance with AWS D1.1 or ASME Code Section IX.

9.1.1.2 Fabrication Inspections

Materials used in the fabrication of the NAC-MPC storage cask and canister are procured with certifications and supporting documentation, as necessary, to assure compliance with procurement specifications. All materials are receipt inspected for appropriate acceptance requirements and for traceability to required material certification.

The canister assembly is fabricated to the requirements of ASME Code Section III, Subsection NB. Specific exceptions to the ASME Code are described in Chapter 2 and 7. The basket assembly is fabricated to ASME Code Section III, Subsection NG. Shop fabricated components of the storage cask are fabricated in accordance with ANSI/AWS D1.1-96 or ASME Code Section VIII.

A complete dimensional inspection of all critical components and a components fit-up test is performed on the canister assembly to ensure proper assembly in the field. Acceptance criteria for dimensions shall conform to the fabrication drawings.

Concrete strength and density shall be field verified to American Concrete Institute (ACI) and American Society for Testing and Materials (ASTM) standards to ensure adequacy. Reinforcing steel is installed per specification requirements based on ACI-318.

On completion of fabrication, the canister, basket, and other shop fabricated components shall be inspected for cleanliness. All components shall be free of any foreign material, oil, grease and solvents. Carbon steel components assembled for the storage cask shall be coated with a corrosion-resistant paint.

9.1.2 Structural and Pressure Test

The canister is pressure tested at the time of use. After loading of the canister basket with spent fuel, the shield lid is welded in place after approximately 50 gallons of water are removed from the canister. Prior to removing the remaining spent fuel pool water from the canister, the canister is pressure tested at 50 psig. This pressure is held for 10 minutes. Any loss of pressure during the test period is unacceptable, and the leak must be located and repaired. The pressure test is described in Section 8.1.

The transfer cask lifting trunnions and bottom shield doors shall be load tested in accordance with the requirements of ANSI N14.6 "Special Lifting Devices for Shipping Containers Weighing 10,000 pounds (4500 kg) or More for Nuclear Materials."

The lifting trunnion load test shall consist of applying a vertical load of 429,039 pounds, which is 300 percent of the maximum service load of 143,013 pounds. The bottom shield door load test shall consist of applying a vertical load of 186,810 pounds, which is 300 percent of the maximum service load (62,270 pounds).

The load tests shall consist of applying vertical loads to the lifting trunnions and bottom shield door components. The load will be held for a minimum of 10 minutes and will be performed in accordance with approved written procedures.

Following completion of the lifting trunnion and bottom shield door load tests, all trunnion and door rail welds and all load bearing surfaces shall be visually inspected for permanent deformation, galling or cracking. Inspections utilizing liquid penetrant examination shall be performed in accordance with the ASME Code Section V, Article 6. Acceptance criteria shall be in accordance with ASME Code Section III, NF-5350.

Any evidence of permanent deformation, cracking, galling of the load bearing surfaces or unacceptable liquid penetrant results shall be cause for rejection of the affected component.

9.1.3 Leak Tests

The canister is leak tested at the time of use. After the pressure test described in Section 9.1.2, the canister is drained of residual water, vacuum dried and backfilled with helium. The canister is pressurized with helium to 22 psia. The shield lid to canister shell weld is helium leak tested. The leak test is performed at a sensitivity of at least 4.0 x 10^{-8} cm^3/sec (helium). Any indication of a leak is unacceptable and repair of the leak is required.

9.1.4 Component Tests

The components of the NAC-MPC do not require any special tests in addition to the material receipt, dimensional, and form and fit tests described above, or as described below.

9.1.4.1 Valves, Rupture Disks and Fluid Transport Devices

The NAC-MPC canister and storage casks do not contain rupture disks or fluid transport devices. There are no valves that are part of the confinement boundary for transport or storage. Quick-disconnect valves are installed in the canister vent and drain ports of the shield lid. These valves are intended to be convenience items for the operator, as they provide a means of quickly connecting (or disconnecting) ancillary drain and vent lines to the canister. The quick-disconnect fittings consist of male and female halves. The male fitting is installed in the canister and the female fitting is used as the connecting piece. The male fitting is automatically closes when the mating fitting is removed; however, no credit is taken for this sealing feature. During storage and transport, these fittings are not accessible, as port covers that are welded in place cover them when the canister is closed. As presented for storage, the canister has no accessible valves or fittings.

9.1.4.2 Gaskets

The NAC-MPC canister and concrete cask have no mechanical seals or gaskets that form an integral part of the package, and there are no mechanical seals or gaskets in the confinement boundary.

9.1.5 Shielding Tests

Based on the conservative design of the NAC-MPC storage cask for shielding criteria and the detailed construction requirements, no shielding tests of the concrete storage cask are required.

9.1.6 Neutron-Absorber Tests

9.1.6.1 General

Neutron absorber material (commercially available as BORAL®) in the form of sheets consisting of boron-carbide evenly dispersed within a matrix of aluminum and clad with aluminum is used in the NAC-MPC transportable storage canister fuel baskets. BORAL® is manufactured by AAR Advanced Structures (AAR) of Livonia, Michigan, under a Quality Assurance/Quality Control program in conformance with the requirements of 10 CFR 50, Appendix B. The computer-aided manufacturing process consists of several steps - the first being the mixing of the aluminum and boron-carbide powders that form the core of the finished material, with the amount of each powder a function of the desired ^{10}B areal density. The methods used to control the weight and blend the powders are patented and proprietary processes of AAR.

After manufacturing, test samples from each batch of BORAL® neutron absorber (poison) sheets shall be tested using wet chemistry and/or neutron absorption techniques to verify the presence, proper distribution, and minimum weight percent of ^{10}B. The tests shall be performed in accordance with approved written procedures.

9.1.6.2 Preparation of Samples

Detailed written procedures to perform wet chemistry and/or neutron absorption tests of each batch of BORAL® sheets shall be established by the manufacturer and approved by NAC. For each batch of BORAL® sheets, a sample shall be taken from each end of randomly selected sheets. The samples shall be indelibly marked and recorded for identification. At least 2 percent of the sheets in a batch shall be fully tested as described, with the remaining sheets to be tested at one location to ensure the presence of boron in those sheets.

9.1.6.3 Wet Chemistry Test Performance

An approved facility with chemical analysis capability shall be selected to perform the wet chemistry tests. The tests will ensure the presence of boron and enable the calculation of the ^{10}B areal density.

The most common method of verifying the acceptability of neutron absorber material is the wet chemistry method—a chemical analysis where the aluminum is separated from a sample with known thickness and volume. The remaining boron-carbide material is weighed and the areal density of ^{10}B is computed. A statistical conclusion about the BORAL® sheet from which the sample was taken and that batch of BORAL® sheets may then be drawn based on the test results and the established manufacturing processes previously noted.

9.1.6.4 Neutron Absorption Test Performance

An approved facility with a neutron source and neutron detection capability shall be selected to perform the described tests. The tests will assure that the neutron absorption capacity of the material tested is equal to, or higher than, the given reference value and will verify the uniformity of boron distribution. The principle of measurement of neutron absorption is that the presence of boron results in a slowing down of neutron flux between the neutron sources, the reflector, and the neutron detector—depending on the material thickness and boron content.

Typical test equipment will consist of a neutron source/neutron detector, a reflector, and a counting instrument. The test equipment is calibrated using approved reference sheet(s), whose ^{10}B content has been checked and verified by an independent method such as chemical analysis. The highest permissible counting rate is determined from the neutron counting rates of the reference sheet(s), which should be ground to the minimum allowable plate thickness. This calibration process shall be repeated daily (every 24 hours) while tests are being performed.

9.1.6.5 Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube drawings.

The neutron absorption test shall be considered acceptable if the neutron count determined for each test specimen is less than or equal to the highest permissible neutron count rate determined from the reference sheet(s), which are based on the ^{10}B areal density specified on the fuel tube drawings.

Any specimen not meeting the acceptance criteria shall be rejected and all of the sheets from that batch shall be similarly rejected.

9.1.7 Thermal Tests

No thermal acceptance testing of the NAC-MPC system is required during construction. Temperature measurements are taken at the air outlets of the storage cask during operation in accordance with Chapter 12.0 as verification of the thermal performance of the storage system.

9.1.8 Cask Identification

A stamped stainless steel nameplate, as shown on Drawing No. 455-856, is permanently attached on the outer surface of the storage cask. The nameplate includes the following information:

Vertical Concrete Cask

Owner:	(Utility Name)
Designer:	NAC International Inc.
Fabricator:	(Vendor Name)
Date of Manufacture:	(mm/dd/yy)
Model Number:	(MPC-YR)
Cask No.:	(XXX)
Date of Loading:	(mm/dd/yy)
Empty Weight:	(Pounds [kilograms])

9.2 Maintenance Program

The NAC-MPC storage system is a passive system. There are no active components or systems incorporated in the design. Consequently, there is a minimal amount of maintenance that is required over its lifetime.

The system has no valves, gaskets, rupture discs or seals, and there are no accessible penetrations. Consequently, there is no maintenance associated with these types of features.

9.2.1 Continuing Maintenance Requirements

Recommended maintenance in normal conditions:

1. Daily surveillance of the storage casks:

   Visual inspection of air vents for detection of blockage.

   Verify that "critter screens" are in place, whole and secure.

   Measure and record the ambient temperature and air outlet temperature for each vertical concrete cask upon placement in service. Thereafter, the temperatures shall be recorded on a daily basis to verify the continuing thermal performance of the system.
   Visual inspection of the ISFSI site for security and safeguards.

2. Annual inspection of the storage cask exterior:

   Visual inspection of surface for chipping, spalling or other surface defects. If found, a defect should be corrected by regrouting the affected area. Refer to Appendix 12A, Section 4.5.3 for surface defect limits and required actions.

   Re-application of corrosion-inhibiting (external) coatings on accessible surfaces.

It is not necessary to inspect the canister during the storage period as long as normal conditions exist.

9.2.2 Required Maintenance of First Storage System Placed in Service

The heat transfer characteristics of the NAC-MPC System will be recorded by temperature measurements of the first NAC-MPC System placed in service with a heat load equal to or greater than 7.5 kW.

A letter report summarizing the results of the measurements shall be submitted to the NRC for each cask subsequently loaded with a higher heat load, up to the 12.5 kW maximum heat load for the NAC-MPC System. The calculation and the measured temperature data shall be reported to the NRC in accordance with 10 CFR 72.4. The calculation and comparison need not be reported to the NRC for Canisters that are subsequently loaded with lesser loads than the latest reported case.

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10.0 RADIATION PROTECTION

10.1 Ensuring That Occupational Radiation Exposures Are As Low As Reasonably Achievable (ALARA)

The NAC-MPC provides radiation protection for all areas and systems that may expose personnel to radiation or radioactive materials. The components of the NAC-MPC system that require operation, maintenance and inspection are designed, fabricated, located, and shielded to minimize radiation exposure to personnel.

10.1.1 Policy Considerations

It is the policy of NAC to ensure that the NAC-MPC system is designed, so operation, inspection, repair and maintenance can be carried out while maintaining occupational exposure as low as reasonably achievable (ALARA).

10.1.2 Design Considerations

The design of the NAC-MPC system complies with the requirement of 10 CFR 72.3 concerning ALARA and meets the requirements of 10 CFR 72.126(a) and 10 CFR 20.1101 with regard to maintaining occupational radiation exposures ALARA. Specific design features that demonstrate the ALARA philosophy are:

- Material selection and surface preparation that facilitate decontamination.
- A basket configuration that allows spent fuel loading using accepted standard practice and current experience.
- Positive clean water flow in the transfer cask/canister annulus to minimize the potential for contamination of the canister surface during in-pool loading.
- Passive confinement, thermal, criticality, and shielding systems that require no maintenance.
- Thick steel and concrete walls to reduce the side surface dose rate to 40 mrem/hr (average).

- Nonplanar cooling air pathways to minimize radiation streaming at the inlets and outlets of the concrete cask.

- Use of remote, automated outlet air temperature measurement to reduce surveillance time.

10.1.3 Operational Considerations

The ALARA philosophy has been incorporated into the procedural steps necessary to operate the NAC-MPC in accordance with its design. The following features or actions, which comprise a baseline radiological controls approach, have been incorporated in the design or procedures to minimize occupational radiation exposure:

- Use of prefabricated, shaped temporary shielding during automated welding equipment set up and removal, manual welding, and weld inspection of the shielding and structural lids and for use during all of the canister closing and sealing operations.

- Use of automatic equipment for welding the shield lid and structural lid to the canister shell.

- Decontamination of the exterior surface of the transfer cask, welding of the shield lid, and pressure testing of the canister while the canister remains filled with water.

- Use of quick disconnect fittings at penetrations to facilitate required service connections.

- Use of remote handling equipment, where practical, to reduce radiation exposure.

The operational procedures at a particular facility will be determined by the user's operational conditions and facilities.

10.2 Radiation Protection Design Features

The description of the radiation shielding design is provided in Chapter 5.0. The design basis radiation exposure rates are summarized in this section and in Chapter 2.0. The principal radiation protection design features are the shielding necessary to meet the design objectives, the placement of penetrations near the edge of the canister shield lid to reduce operator exposure and handling time, and the use of shaped supplemental shielding for work on and around the shield and structural lids. This supplemental shielding reduces operator dose rates during the welding, inspection, draining, drying and backfilling operations that seal the canister.

Radiation exposure rates at various work locations were determined for the principal NAC-MPC operational steps. These exposure rates were determined using a combination of the SAS1 and SKYSHINE III computer codes. The use of SAS1 is described in Chapter 5.0. The SKYSHINE-III code is discussed in Section 10.4. The calculated dose rates decrease with time.

10.2.1 Design Basis for Normal Storage Conditions

The radiation protection design basis for the NAC-MPC storage cask is derived from 10 CFR 72 and the applicable ALARA guidelines. The design basis surface dose rates and the calculated 1 meter dose rates are shown below. The calculated dose rates at these, and at other dose points, are also reported in Chapter 5.0, "Shielding Evaluation."

Concrete Storage Cask	Design Basis Maximum Surface Dose Rate (mrem/hr)	1 Meter Maximum Dose Rate (mrem/hr)
Side wall	50.0	20.0
Air inlet/air outlet	100.0	5.0
Top lid	55.0	15.0

Activities associated with closing the canister, including welding of the shield and structural lids, draining, drying, backfilling and testing, will employ temporary shielding to minimize personnel dose in the performance of those tasks.

10.2.2 Design Basis for Accident Conditions

Damage to the NAC-MPC cask after a design basis accident will not result in a radiation exposure at the controlled area boundary in excess of 5 rem to the whole body or any organ, including skin. The high energy missile impact is estimated to reduce the concrete shielding thickness, locally at the point of impact, by 6 inches. This reduction in shielding results in a calculated dose rate of 120 mrem/hr at one meter. There are no other design basis accident conditions that result in a greater estimated loss of shielding.

Two hypothetical accident events that evaluate storage cask tip over and the rupture of 100% of the fuel rods are considered in Chapter 11. There are no design basis events that result in the tip over of the NAC-MPC storage cask or the release of any radioactive material from the canister.

10.3 Estimated On-Site Collective Dose Assessment

Occupational radiation exposures (person-mrem) resulting from the use of the NAC-MPC storage system are calculated using estimated exposure rates presented in Chapter 5.0 and Section 10.2.1. Exposure was evaluated by identifying the tasks and estimating the duration and number of personnel performing those tasks based on industry experience. The tasks identified were based on the design basis operating procedures, as presented in Chapter 8.0.

Dose rates were initially estimated based on the design basis fuel assembly for shielding, the Combustion Engineering Type A fuel assembly with a burnup of 36,000 MWD/MTU and a cool time of 8 years. Since use of these dose rates over predict the total dose for the use of the NAC-MPC system for a 16 cask storage array, the dose rates are adjusted to account for fuel cooling time representative of an ISFSI. The effect of the adjustment is to reduce the maximum estimated total dose for loading each canister by about 20%. This adjustment is described in Section 10.3.2. It is also applied in the calculation of the ISFSI boundary dose rates.

10.3.1 Estimated Collective Dose for Loading a Single NAC-MPC

This section estimates the collective dose due to the loading, sealing, transfer and placement of a single NAC-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background will vary with site specificity. The number of persons allocated to task completion is generally the minimum number required for the task.

Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Table 10.3-1 summarizes the estimated total exposure, by task, attributable to the loading, transfer, sealing and placement of a design basis NAC-MPC.

Due to the additional cooling of casks in a typical array, the actual loading, transfer and storage dose associated with the 16 storage cask array is significantly lower than that of a cask array consisting of design basis casks. Based on the source term weighting factors presented in Section 10.3.2, the occupational dose is approximately 20% lower for a typical cask array.

10.3.2 Estimated Annual Dose Due to Routine Operations

Once in place, the ISFSI will require limited ongoing maintenance and surveillance throughout its design life. The annual dose evaluation considers the combination of the requirements specified in Chapter 12.0 and tasks that are anticipated to be representative of an operational facility. Typically, no maintenance of the storage system is expected to be required annually. Collective dose due to certain events, such as clearing the blockage of air vents, is accounted for in Chapter 11.0.

Routine operations are expected to include:

- A daily visual inspection of the cask array. This inspection consists of the electronic measurement of air outlet temperatures and inspection for blockage of the inlet and outlet vents. Outlet temperature indicators are located away from the cask array. Temperature surveillance is assumed to be performed by one operator and require 1 minute per cask. Inspection of the vents is assumed to take one operator 2 minutes per cask.

- A daily security inspection of the security fence and equipment surrounding the storage area. This surveillance is assumed to require 5 minutes and 1 security officer.

- Grounds maintenance performed every other week by 1 maintenance technician. Grounds maintenance is assumed to require 0.5 hour.

- Quarterly radiological surveillance. The surveillance consists of a radiological survey comprised of a surface radiation measurement on each cask, the determination and/or verification of general area exposure rates and radiological postings. This surveillance is assumed to require 1 hour and 1 person.

- Annual inspection of the general condition of the storage casks. This inspection is estimated to require 15 minutes per cask and require 2 technicians.

The storage array is conservatively assumed to have a fuel population having cooling times ranging from 8 to 20 years. To account for the different ages of the fuel, weighting factors are applied to the single cask dose rates. The application of these factors permits a more accurate representation of the exposure commitment necessary for the routine operation of the ISFSI. The

weighting factors are based on the decayed spectra of the fuel neutron and fuel gamma components of the source term. Table 10.3-2 presents the weighting factors applied to the individual casks in the array. The arrangement of the array is shown in Figure 10.3-1.

For this evaluation, it is assumed that the storage cask array consists of four casks containing the design basis Combustion Engineering Type A 36,000 MWD/MTU burnup, 8 year cooled fuel, and twelve casks loaded with CE Type A 36,000 MWD/MTU burned fuel with cool times representative of the staggered core discharge. The assumed cool times of the fuel in the cask array are shown in Table 10.3-3. The design basis casks represent not only the design basis CE fuel assembly, but also any of the other Yankee fuel categories at the minimum cool time and maximum burnup limit. As stated in Section 5.4.3 maximum design basis cask surface dose rates were employed to establish the minimum cool time for each of the fuel categories.

Based on these assumptions, the annual operation and surveillance requirements result in an estimated annual collective exposure of 626 person-mrem for the 16 cask ISFSI. The estimated annual exposure, by task, is shown in Table 10.3-4.

10.3.3 Estimated Collective Dose for Unloading a Single NAC-MPC

This section estimates the collective dose due to the transfer, opening and unloading a single NAC-MPC containing design basis fuel. This analysis assumes that the exposure incurred by the operators is independent of background radiation, as background radiation varies with each site. The number of persons allocated to task completion is generally the minimum number required for the task. Working area exposure rates are assigned based on the orientation of the worker with respect to the source and take into account the use of temporary shielding.

Table 10.3-5 summarizes the estimated total exposure, by task, attributable to the transfer, opening and unloading of a design basis NAC-MPC.

Figure 10.3-1 Typical ISFSI 16 Cask Array Layout

FIGURE WITHHELD UNDER 10 CFR 2.390

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Table 10.3-1 Estimated Person-Mrem Exposure for Operation of the NAC-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Load Canister	2	7.5	5.0	75.7
Move to Decon Area	2	1.1	11.5	25.3
Setup, Weld Shield Lid, and Inspect Weld	2	7.9	21.5	339.8
Drain/Dry/Backfill and Leak Test Vacuum Drying	2	0.6	45.1	54.1
Weld and Inspect Port Covers	2	2.5	118.8	594.2
Setup, Weld Structural Lid and Inspect Weld	2	7.7	59.4	915.5
Transfer to Storage Cask	4	2.2	18.3	161.0
Position on ISFSI Pad	2	0.8	17.8	28.4
Total				2,194

Table 10.3-2 Storage Cask Radiation Spectra Weighting Factors

Cask	Neutron Weighting Factor	Gamma Weighting Factor	Cask	Neutron Weighting Factor	Gamma Weighting Factor
A-1	1	1	B-1	.83	.74
A-2	1	1	B-2	.80	.71
A-3	1	1	B-3	.78	.69
A-4	1	1	B-4	.75	.67
A-5	.96	.93	B-5	.72	.65
A-6	.93	.86	B-6	.70	.63
A-7	.90	.82	B-7	.67	.61
A-8	.86	.77	B-8	.65	.59

Table 10.3-3 Assumed Fuel Cooling Time for the Storage Casks in the ISFSI Array

Cask	Cooling Time	Cask	Cooling Time
A-1	8 yr.	B-1	13 yr.
A-2	8 yr.	B-2	14 yr.
A-3	8 yr.	B-3	15 yr.
A-4	8 yr.	B-4	16 yr.
A-5	9 yr.	B-5	17 yr.
A-6	10 yr.	B-6	18 yr.
A-7	11 yr.	B-7	19 yr.
A-8	12 yr.	B-8	20 yr.

Table 10.3-4 Estimate of Annual Exposures for a 16 Cask Array

Activity	Dose Rate Distance (meters)	Frequency	Time (hr)	Dose Rate (mrem/hr)	Personnel Required	Total Exposure (person-mrem)
Visual inspection and temperature readings	10	365	0.8	1.3	1	380
Security surveillance	10	365	0.08	1.3	1	38
Radiological surveillance	5	4	1.0	2.7	1	11
Annual inspection	0.3	1	4.0	20.2	2	162
Grounds maintenance	5	26	0.5	2.7	1	35
Total (person-mrem)						626

Table 10.3-5 Estimated Collective Dose for Unloading a Single NAC-MPC

Activity	Personnel	Duration (hr)	Average Dose Rate (mrem/hr)	Exposure (pers-mrem)
Move Storage Cask to Receiving Area	2	0.8	17.8	28.5
Transfer Canister to Transfer Cask	4	2.2	18.3	161.0
Setup, Cut Structural Lid	2	3.9	59.4	463.3
Cut Port Covers	2	1.3	118.8	308.9
Cool Down and Fill Canister with Water	2	8.0	45.1	721.6
Setup and Cut Shield Lid	2	4.0	21.5	172.0
Move to Pool	2	1.1	11.5	25.3
Unload Canister	2	7.5	5.0	75.0
Total		28.8		1,955.6

10.4 Exposures to the Public

The cask array shown in Figure 10.3-1 is evaluated to determine the minimum distance necessary to achieve a controlled area boundary dose of 25 mrem/year as required by 10 CFR 72.104(a). NAC's version 5.0.0 of the SKYSHINE-III code is used to evaluate the placement of the controlled area boundary for the 16 storage cask array shown in Figure 10.3-1. Given the source geometry, spectra and desired detector locations, SKYSHINE III calculates dose rates using a combination of pre-calculated transmission and reflection data and the Monte Carlo technique to integrate over the source direction and energy variables.

The cask array is explicitly modeled in the code, with the source term from each cask represented as top and side surface sources. Surface source emission fluxes are provided from 1D SAS1 shielding evaluations. The top and side source energy distributions for both neutron and gamma radiation are taken from the design basis cask in Tables 5.4-4 and 5.4-5. As stated in Section 10.2, the associated reference cask source strengths are multiplied by weighting factors to correct for the differences in cooling times.

Version 5.0.0 of SKYSHINE-III, explicitly calculates cask self shielding based on the cask geometry and arrangement of the cask array. A ray tracing technique is utilized. Given the source position on the cask surface and the direction cosines for the source emission, geometric tests are made to see if any adjacent casks are in the path of the emission. If so, the emission history does not contribute to the air scatter dose. Also, given the source position on the cask surface and the direction cosines for the source to detector location, geometric tests are made to see if any adjacent casks are in the source path. If so, the emission position does not contribute to the uncollided dose at the detector location.

The performance of the SKYSHINE-III Code is benchmarked by modeling a set of Kansas State University ^{60}Co skyshine experiments and by modeling two Kansas State University neutron computational benchmarks. The code compared well with these benchmarks for both neutron and gamma doses versus distance.

Annual exposures based on a 2,080 hour work year were determined at distances ranging from 100 to 300 meters surrounding a 2 x 8 cask array (Figure 10.3-1) as shown in Table 10.4-1. The storage

array is assumed to have a fuel population reflective of that of an operating reactor facility and that fuel cool time will range from 8 to 20 years.

Table 10.4-1 presents a summary of the results of the SKYSHINE-III evaluation and Figure 10.4-1 includes a plot of the limiting boundary distances. The results presented in Table 10.4-1 are interpolated for each orientation to determine the minimum distance necessary to achieve an annual dose of 25 mrem. These interpolated results are presented for each orientation in Table 10.4-2 and indicate that a required minimum distance varies around the ISFSI from approximately 150 meters on the longer-cooled 2 cask side to 190 meter on the shorter-cooled 8 cask side. An enveloping boundary 200 meters by 150 meters around the ISFSI will ensure compliance with the requirements of 10 CFR 72.104(a), i.e., a dose rate not exceeding 25 mrem/year.

While these analyses are performed for typical arrays of casks containing design-basis spent fuel assemblies, full compliance with the requirements of 10 CFR 72.104(a) can only be demonstrated on a site-specific basis. Consequently, each ISFSI licensee performs a site-specific dose analysis for the facility to show that the requirements of 10 CFR 72 are met. Site-specific boundary distances may vary significantly based on fuel type, fuel cooling time, exposure duration and number of casks in service.

Figure 10.4-1 Controlled Area Boundary Determination for a 16 Cask Array

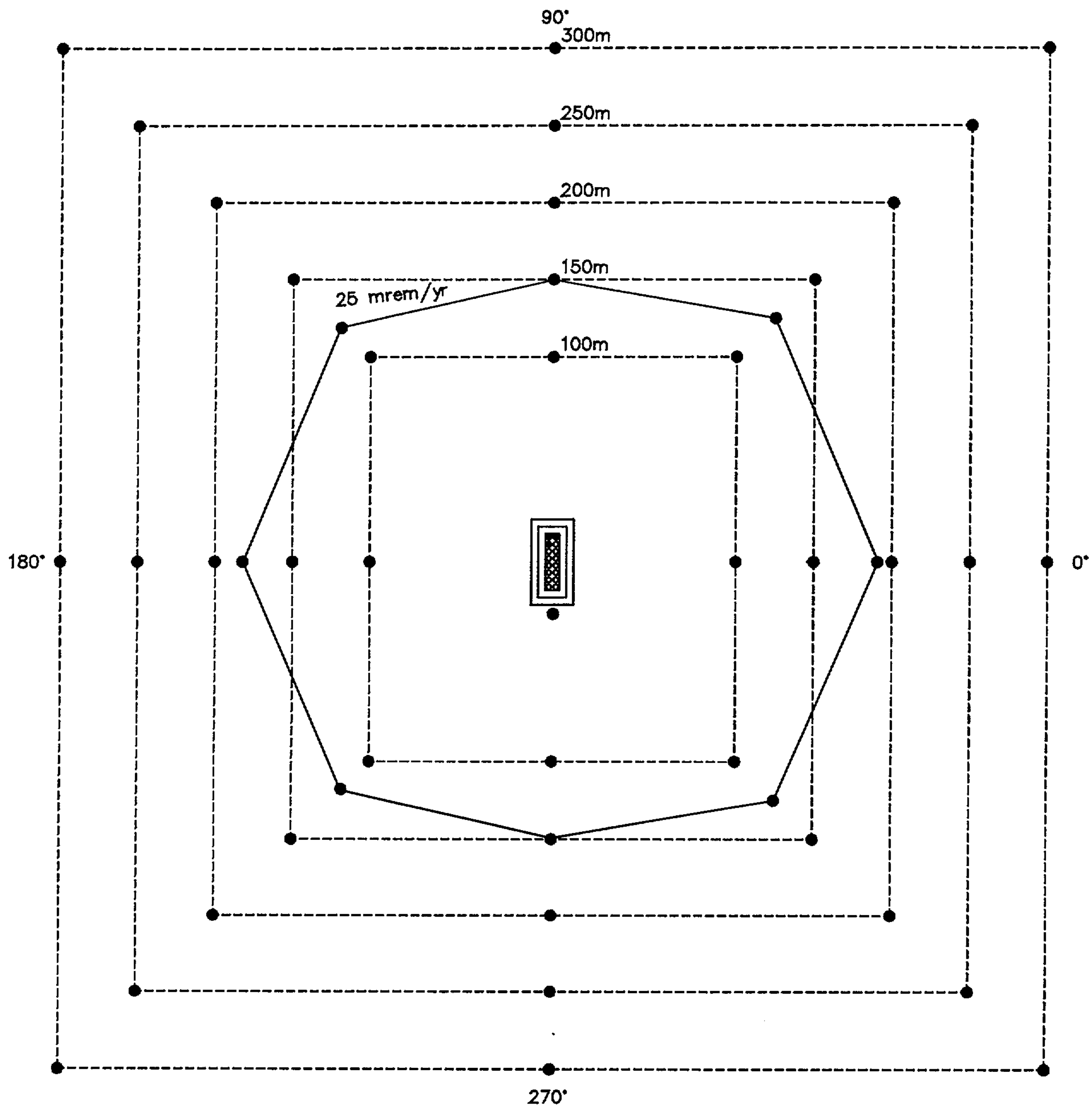

Table 10.4-1 Summary of Annual Exposure Doses at Distances Away from Cask Array

Orientation[1]	Dose at Distance from Cask Array (mrem)[2, 3]				
	100 m	**150 m**	**200 m**	**250 m**	**300 m**
0 degrees	107.69	44.02	20.70	10.55	5.67
45 degrees	36.84	13.27	5.42	2.41	1.13
90 degrees	56.90	25.00	12.16	6.29	3.40
135 degrees	32.88	11.89	4.86	2.15	1.01
180 degrees	92.10	38.03	17.94	9.16	4.92
225 degrees	32.72	11.16	4.58	2.04	0.96
270 degrees	55.96	22.74	11.14	5.79	3.14
315 degrees	37.20	13.37	5.46	2.42	1.14

Notes:

1. Denotes orientation counter-clockwise from X axis shown in Figure 10.3-1.
2. Boundary distance is from security fence. In case of 45, 135, 225, and 315 orientations, boundary distance is diagonally from corner of security fence.
3. Based on 2,080 hours of occupancy.

Table 10.4-2 Controlled Area Boundary for 2 x 8 Cask Array Based on Annual Exposure

Orientation (degrees)[1]	Boundary Distance with Work Year Occupancy (m)[2,3]
0	190.40
45	176.95
90	149.99
135	167.95
180	182.43
225	166.74
270	146.60
315	177.62

Notes:

1. Denotes counter clockwise orientation from X axis shown in Figure 10.3-1.
2. Boundary distance is from security fence. In case of 45, 135, 225, and 315 orientations, boundary distance is diagonally from corner of security fence.
3. Based on 2,080 hours of occupancy.

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11.0 ACCIDENT ANALYSIS

The analyses of the off-normal and accident design events, including those identified by ANSI/ANS 57.9-1992, are presented in this section. Section 11.1 describes the off-normal events that could occur during the use of the NAC-MPC storage system, possibly as often as once per calendar year. Section 11.2 addresses very low probability events that might occur once during the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the surrounding environment. Section 11.3 describes the design basis load conditions for the transportable storage canister. As described in Section 11.3, the canister is analyzed for loads imposed during transportation. These transport condition loads envelope the loads for the storage condition analyzed herein.

This chapter demonstrates that the NAC-MPC satisfies the requirements of 10 CFR 72.24 and 10 CFR 72.122 for off-normal and accident conditions. These analyses are based on conservative assumptions to ensure that the consequences of off-normal conditions and accident events are bounded by the reported results. The actual response of the NAC-MPC system to the postulated events will be much better than that reported, i.e., stresses, temperatures, and radiation doses will be lower than predicted. If required for a site specific application, a more detailed evaluation could be used to extend the limits defined by the events evaluated in this section.

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11.1 Off-Normal Events

This section evaluates postulated events that might occur once during any calendar year of operations. The actual occurrence of any of these events is unlikely.

11.1.1 Blockage of Half of the Air Inlets

This section evaluates the NAC-MPC storage cask for the steady state effects of a blockage of one-half of the air inlets at the normal ambient temperature (75°F).

11.1.1.1 Cause of Event

The likely cause of air inlet blockage is debris deposited in the inlets by wind or by intrusion of a burrowing animal. It is expected that screens over the inlets would preclude such animals and would exclude debris from the inlet channels.

This event would be detected visually by the persons inspecting the air inlets and gathering outlet air temperature data on a daily basis. It could also be detected by security forces, or other operations personnel engaged in other routine activities, such as fence inspection or grounds maintenance.

11.1.1.2 Analysis of the Blockage Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.4.1. Air mass flow and air carried heat are calculated using the airflow model described in Section 4.4.1.1. The maximum component temperatures due to one-half of the air inlets being blocked are compared to the allowable component temperatures for the off-normal event (see Table 4.1-4).

Component	1/2 Inlets Blocked Max Temp. (°F)	Allowable Temp. (°F)
Fuel Cladding	565	806
Support Disks	531	800
Heat Transfer Disks	529	700
Canister Shell	318	800
Concrete	168	350

This evaluation shows that the component temperatures are within the allowable temperature range for the condition of one-half of the inlets blocked.

11.1.1.3 Radiological Consequences

There are no significant radiological consequences for this event. Personnel will be subject to an estimated maximum contact dose rate of 240 mrem/hr when clearing the inlets. If it is assumed that a worker kneeling with his hands on the inlets would require 15 minutes to clear the inlets, the estimated maximum extremity dose is 60 mrem. The whole body dose would be significantly less.

11.1.1.4 NAC-MPC Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are less than the allowable temperatures. The NAC-MPC storage cask continues to perform its function with one-half of the air inlets blocked.

11.1.1.5 Recovery and/or Corrective Actions

The debris blocking the inlets must be manually removed. The nature of the debris may indicate that other actions are required to prevent recurrence of the blockage.

11.1.2 Canister Off-Normal Handling Load

This section evaluates the consequence of loads on the transportable storage canister during the installation of the canister in the storage cask, or removal of the canister from the storage or transfer casks.

11.1.2.1 Cause of Event

Unintended loads could be applied to the canister, due to misalignment or faulty crane operation or inattention of the operators.

Detection of the event is expected to occur by observation of the event or banging or scraping noise associated with movement of the canister. The event is expected to be obvious to the operators at the time of occurrence.

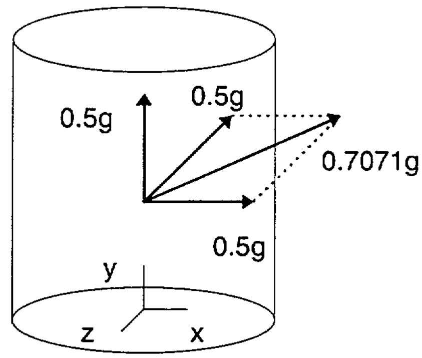
11.1.2.2 Analysis of the Canister Off-Normal Handling Load Event

The canister structural analysis, including lifting loads, was evaluated using an ANSYS finite element model. The model is described in Section 3.4.4-1.

The off-normal handling load condition is assumed to consist of loads of 0.5 g applied in all directions (i.e., in the global x, y, and z directions) in addition to the 1.1 g lifting load (an additional 10 percent load is included as a dynamic load factor during lifts) applied in the finite element model. The stresses resulting from off-normal handling are estimated by combining the normal handling stresses at the design off-normal internal pressure of 18 psig with the stress results from a 20 g side and a 20 g bottom end impact of the canister ratioed to the off-normal 0.5 g-loading.

A design off-normal internal pressure is calculated based on the condition of 10 percent fuel rod failure with 30 percent fission gas release at a conservative gas temperature of 620°F. The calculated off-normal internal pressure is 14.4 psig. A design internal off-normal pressure of 18 psig is conservatively used in the canister finite element model as shown in Figure 3.4.4.1-1.

The 0.5 g acceleration in the vertical direction is additive to the 1.1 g acceleration for normal lifting. The two 0.5 g accelerations in the horizontal directions result in a single horizontal acceleration of 0.7071 g as shown below:



$$\sqrt{(0.5g)^2+(0.5g)^2}=0.7071g$$

The stresses obtained from the 20 g side and 20 g bottom end impacts of the canister were then scaled to obtain the additive off-normal handling stresses for 0.7071g side load ($\sigma_{0.7071g}$) and 0.5g vertical load ($\sigma_{0.5g}$) as follows:

$$\sigma_{0.7071g}=\sigma_{1-ft,side}\left(\frac{0.7071g}{20g}\right)$$

and,

$$\sigma_{0.5g}=\sigma_{1-ft,bottomend}\left(\frac{0.5g}{20g}\right)$$

Where 20 g is the deceleration applied in the canister model analysis.

The off-normal handling stresses for the side and the vertical g-loading were then added to the normal-handling stresses to obtain the total off-normal handling stresses.

The pertinent stress results from the 20 g side impact and 20 g bottom end of the canister are summarized below. These stress results are presented in Section 11.3.1.

Side: S_{pm} = 13,884 psi
S_{pm+pb} = 24,044 psi

Bottom End: S_{pm} = 1,961 psi
S_{pm+pb} = 4,273 psi

The side and bottom end impact stresses scaled to off-normal handling g-loads were calculated as:

Side:

$$\left(S_{pm}\right)_{0.7071g} = \left(S_{pm}\right)_{20g}\left(\frac{0.7071g}{20g}\right) = 13{,}884\text{psi}\left(\frac{0.7071g}{20g}\right) = 491\text{ psi (0.491 ksi)}$$

$$\left(S_{pm+pb}\right)_{0.7071g} = \left(P_{pm+pb}\right)_{20g}\left(\frac{0.7071g}{20g}\right) = 24{,}044\text{psi}\left(\frac{0.7071g}{20g}\right) = 850\text{ psi (0.85 ksi)}$$

Vertical (bottom):

$$\left(S_{pm}\right)_{0.5g} = \left(S_{pm}\right)_{20g}\left(\frac{0.5g}{20g}\right) = 1{,}961\text{psi}\left(\frac{0.5g}{20g}\right) = 49\text{ psi (0.049 ksi)}$$

$$\left(S_{pm+pb}\right)_{0.5g} = \left(S_{pm+pb}\right)_{20g}\left(\frac{0.5g}{20g}\right) = 4{,}273\text{psi}\left(\frac{0.5g}{20g}\right) = 107\text{ psi (0.107 ksi)}$$

The total stresses for a load condition that includes off-normal handling is obtained by adding the off-normal handling stresses to the normal handling stresses at a design off normal internal pressure of 18 psig.

$$\begin{aligned}\left(S_{pm}\right)_{Case\ w/Off-normal} &= \left(S_{pm}\right)_{Normal} + \left(S_{pm}\right)_{0.7071g} + \left(S_{pm}\right)_{0.5g}\\ &= \left(S_{pm}\right)_{Normal} + 0.491\text{ ksi} + 0.049\text{ ksi}\\ &= \left(S_{pm}\right)_{Normal} + 0.54\text{ ksi}\end{aligned}$$

$$\begin{aligned}\left(S_{pm+pb}\right)_{Case\ w/Off-normal} &= \left(S_{pm+pb}\right)_{Normal} + \left(S_{pm+pb}\right)_{0.7071g} + \left(S_{pm+pb}\right)_{0.5g}\\ &= \left(S_{pm+pb}\right)_{Normal} + 0.85\text{ ksi} + 0.107\text{ ksi}\\ &= \left(S_{pm+pb}\right)_{Normal} + 0.96\text{ ksi}\end{aligned}$$

The maximum primary membrane stress (S_{pm}) for normal handling occurs at location 13. The maximum primary membrane plus bending stress (S_{pm+pb}) for normal handling occurs at location 2. These stress locations are shown in Figure 3.4.4.1-4. Allowable stresses are determined at 250°F in accordance with ASME Code Section NB, Service Level C (See Table 2.2-4).

For location 13:

Normal Handling P_m Stress (ksi)	12.07
Additional P_m Stress Due to Off-Normal Handling (ksi)	0.54
Off-Normal Handling P_m Stress (ksi)	12.61
Allowable P_m Stress (ksi)	20.30
Margin of Safety	+0.61

For location 2:

Normal Handling $P_m + P_b$ Stress (ksi)	26.15
Additional $P_m + P_b$ Stress Due to Off-Normal Handling (ksi)	0.96
Off-Normal Handling $P_m + P_b$ Stress (ksi)	27.11
Allowable $P_m + P_b$ Stress (ksi)	30.06
Margin of Safety	+0.11

These results show that the canister maintains a positive margin of safety for the off-normal handling condition.

11.1.2.3 Radiological Consequences

There are no radiological consequences for this off-normal event.

11.1.2.4 NAC-MPC Performance

This evaluation shows that the stress induced in the canister as a consequence of the assumed off-normal handling loading is within the allowable stress for Service Level C loading. There is no deterioration of canister performance.

11.1.2.5 Recovery and/or Corrective Actions

Operations should be halted until the cause of the misalignment, interference or faulty operation is identified and corrected. Since the radiation level of the canister sides and bottom is high, extreme caution should be exercised if inspection of these surfaces is required.

11.1.3 Failure of Instrumentation

The NAC-MPC system uses an electronic temperature sensing system to read and record the outlet air temperature at each of the four air outlets on each storage cask. The temperatures are read and recorded during a daily inspection of the ISFSI.

11.1.3.1 Cause of Accident

Failure of the temperature measuring instrumentation could occur as a result of component failure, or as a result of another accident condition that interrupted power or damaged the sensing or reader terminals.

The failure is expected to be identified by the lack of a reading at the temperature reader terminal. Alternately, a malfunction could result in a disparity between outlet temperatures or between similar storage casks.

11.1.3.2 Analysis of Instrumentation Failure

Since the temperatures of each outlet of each storage cask are recorded daily, there is early opportunity to identify and correct a defect. Because the canister and concrete cask are a large heat sink, and because there are few conditions that could result in a cooling air temperature increase, there is no concern about the temporary loss of remote sensing and monitoring of the outlet air temperature.

The principal condition that could cause an increase in temperature is the blockage of the cooling air inlets or outlets. The purpose of the daily inspection is to ensure that the inlets and outlets are not obstructed, such that the cooling efficiency of the system is reduced. As shown in Section 11.2.8, even if all of the inlets and outlets for a single cask are blocked immediately after the temperature is read, it would take more than 24 hours before any component approached its allowable temperature limit. There would be no consequence, if the affected storage cask continued to operate in normal storage conditions.

11.1.3.3 Radiological Consequences For This Accident

There are no radiological consequences for this event.

11.1.3.4 NAC-MPC Performance

The NAC-MPC canister and storage cask are a large thermal sink. During the period of loss of instrumentation, no significant change in canister temperature will occur under normal conditions.

11.1.3.5 Recovery and Corrective Actions

This event requires that the temperature reporting equipment be either replaced or repaired and calibrated. Prior to repair or replacement, the temperature shall be recorded manually.

11.1.4 Severe Environmental Conditions (100°F and -40°F)

This section evaluates the NAC-MPC for the steady state effects of high and low ambient temperature conditions.

11.1.4.1 Cause of Event

Large geographical areas of the United States are subjected to sustained summer temperatures in the 90°F to 100°F range and winter temperatures that are significantly below zero. To bound the expected steady state temperatures of the canister and storage cask during these severe ambient conditions, analyses were performed to calculate the steady state storage cask, canister, and fuel cladding temperatures for a 100°F ambient temperature and 24-hour average solar loads. Similarly, winter weather analyses were performed for a -40°F ambient temperature with no solar load. The maximum thermal load of 12.5 kW was applied for these analyses. Neither ambient temperature condition is expected to last more than several days.

Detection of off-normal ambient temperatures would occur during the daily measurement of ambient temperature and storage cask outlet air temperature.

11.1.4.2 Analysis of the Off-Normal Ambient Temperature Event

Off-normal temperature conditions are evaluated using the thermal models described in Section 4.4.1. The temperature profile for the concrete cask and for the air flow for the steady state conditions associated with a 100°F ambient condition are shown in Figures 11.1.4-1 and 11.1.4-2, respectively. Similar profiles for the -40°F ambient temperature condition are shown in Figures 11.1.4-3 and 11.1.4-4. The principal component temperatures for each of these ambient temperature conditions are summarized below.

Component	100°F Ambient Max Temp. (°F)	-40°F Ambient Max Temp. (°F)	Allowable Temp. (°F)
Fuel Cladding	587	453	806
Support Disks	554	412	800
Heat Transfer Disks	552	411	700
Canister Shell	347	187	800
Concrete	196	5	350

This evaluation shows that the component temperatures are within the allowable values for the off-normal ambient conditions.

The thermal stress evaluation for these off-normal conditions are bounded by that for the accident condition with 125°F ambient temperature (Section 11.2.10), since the accident condition has the maximum temperature gradient through the storage cask concrete wall.

Stress intensities corresponding to thermal loads in the canister were evaluated using an ANSYS finite element model as described in Section 3.4.4. The thermal stresses occur in the canister as a result of the maximum temperature gradients in the canister. The finite element analysis assumes that the canister contains the maximum heat load of 12.5 kW, as this ensures the largest gradient for either load condition (i.e., if the canister was at a uniform -40°F, no temperature gradient would exist and no thermal stress would be induced in the canister). No other loads are applied, and the thermal stress is classified as secondary. The smallest margin of safety is +2.75, which occurs at location 13, at the center of the bottom plate (Figure 11.2.1-1). The thermal stresses for the support disks and weldments due to these off-normal conditions are bounded in the thermal stress analysis presented in Section 3.4.4.1.

11.1.4.3 Radiological Consequences

There are no radiological consequences for this off-normal event.

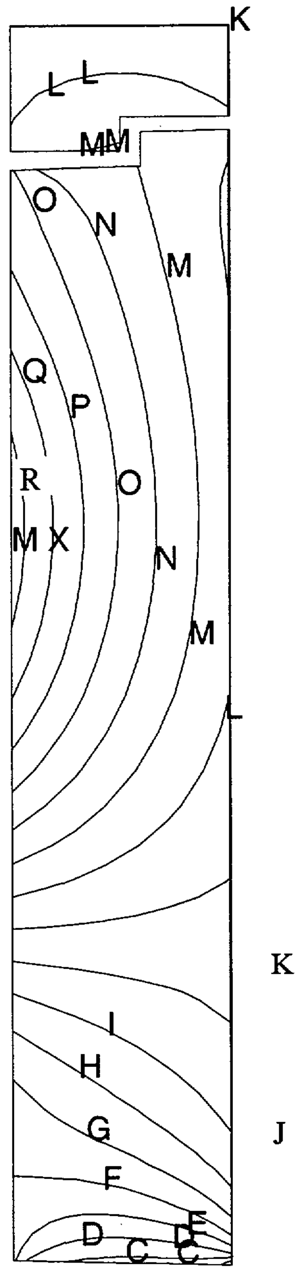
11.1.4.4 NAC-MPC Performance

There are no adverse consequences for this off-normal condition. The maximum component temperatures are within the allowable temperature values. The materials used are not subject to low temperature brittle fracture.

11.1.4.5 Corrective Actions

No corrective actions are required for this off-normal condition.

Figure 11.1.4-1 Temperature Profile of the Concrete Cask in 100°F Ambient Steady State Conditions



	°F
MX=	196
*A=	103
*B=	108
C=	113
D=	119
E=	124
F=	129
G=	134
H=	140
I=	145
J=	150
K=	156
L=	161
M=	166
N=	172
O=	177
P=	182
Q=	188
R=	193

MX = Maximum Temperature

*These temperatures occur over short distances around the inlet vent, but are not shown due to the scale of the figure.

Figure 11.1.4-2 Temperature Profile of the Air Flow Stream in 100°F Ambient Steady State Conditions

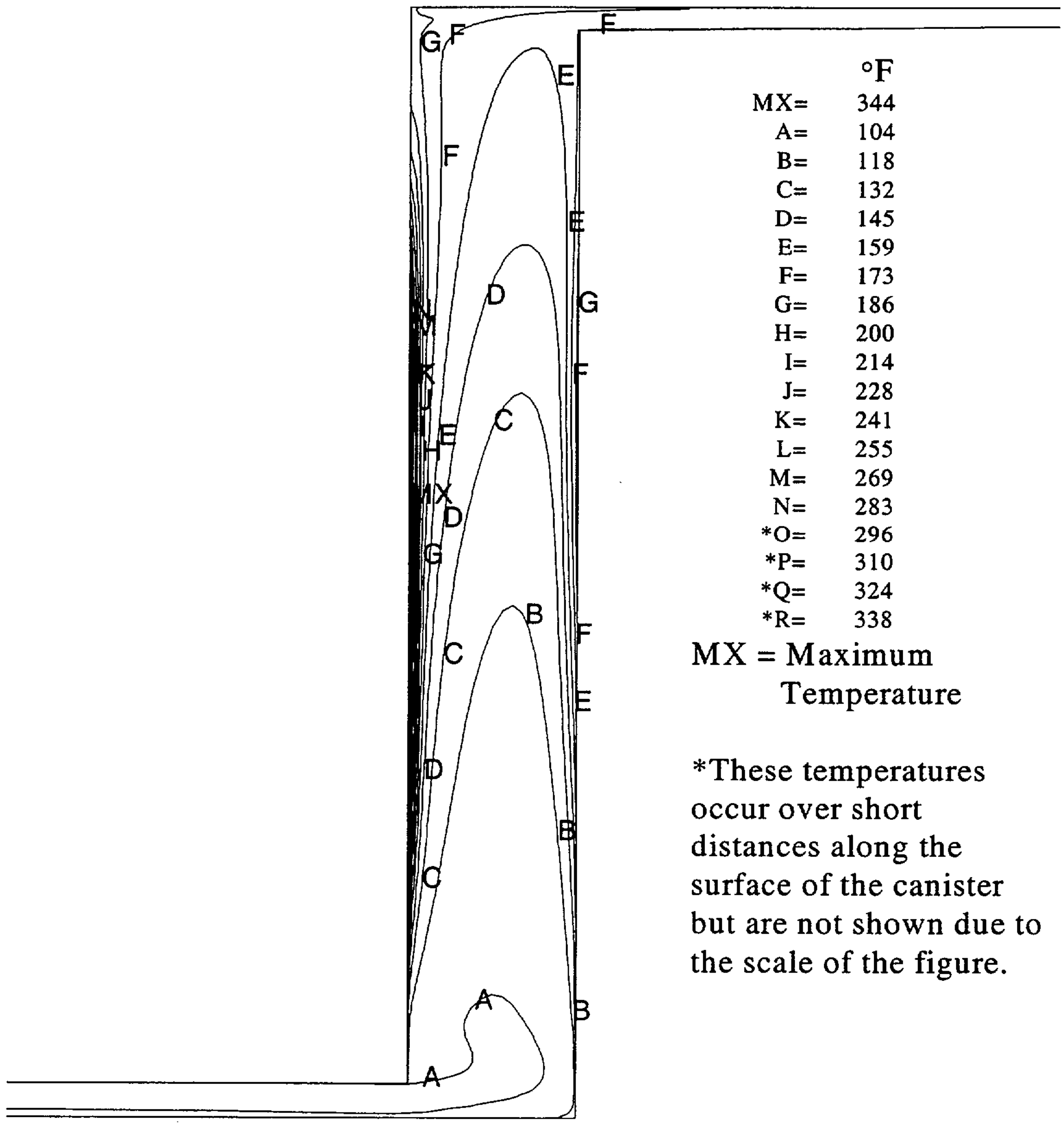


Figure 11.1.4-3 Temperature Profile of the Concrete in -40°F Ambient Steady State Conditions

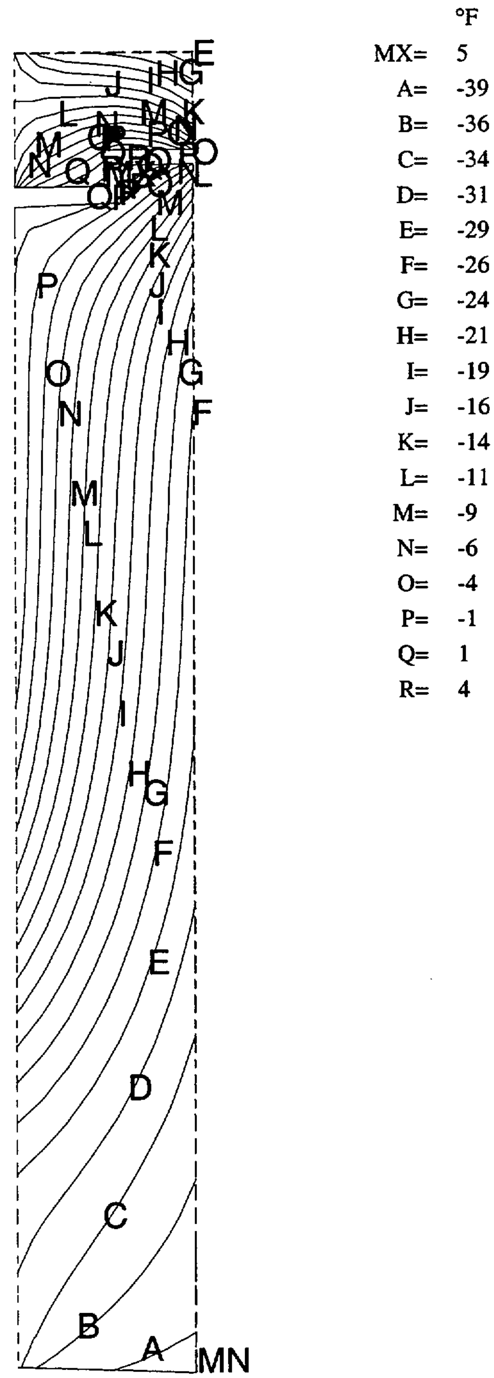
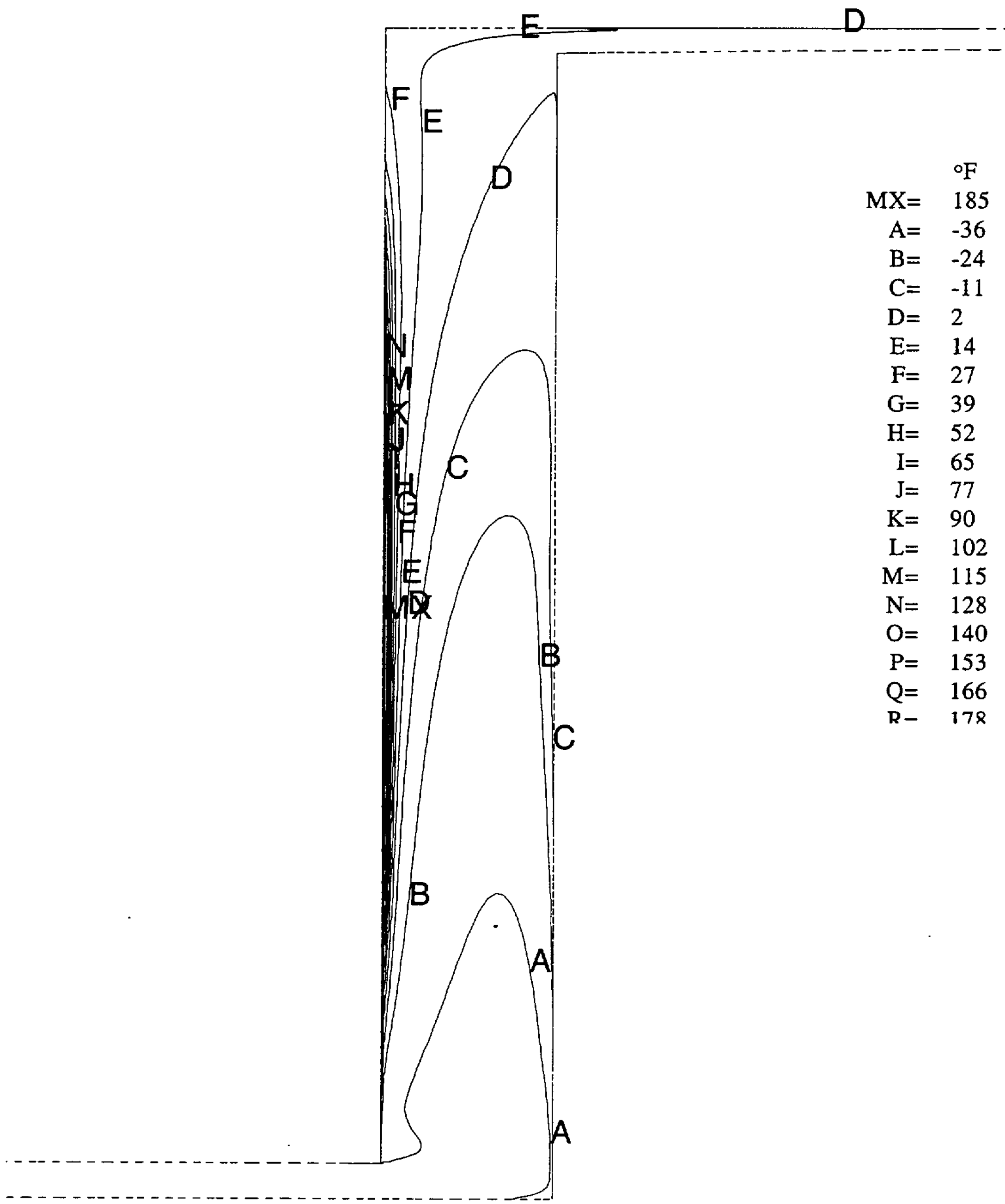


Figure 11.1.4-4 Temperature Profile of the Air Flow Stream in -40°F Ambient Steady State Conditions



11.1.5 Small Release of Radioactive Particulate From the Canister Exterior

The procedures for loading the canister provide for steps to ensure that the canister exterior surface does not come into contact with contaminated spent fuel pool water, and the exterior surface of the canister is surveyed by smear at the top end to verify canister surface conditions. No particulate release from the canister exterior surface is expected to occur in normal use.

11.1.5.1 Cause of Event

In spite of precautions taken to preclude contamination to the external surface of the canister, it is possible that a portion of the canister surface may become slightly contaminated and that the contamination will go undetected. Surface contamination could become airborne and be released as a result of the air flow over the canister surface.

Detection of the release of small amounts of radioactive particles over time would be difficult to ascertain. The release would likely not be at a level that would result in detection by any of the long-term radiation dose monitoring methods (such as TLDs) normally employed. It is possible that a suspected release could be verified by a smear survey of the air outlets.

11.1.5.2 Analysis

A calculation was made to determine the level of surface contamination that results in a dose of one (1) mrem annually at a point 100 meters from the ISFSI site. The calculation shows that at the minimum distance of 100 meters permitted by 10 CFR 72, a residual contamination limit of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α activity, on the surface of each of 16 casks yields a dose of one (1) mrem annually.

The method for determining the residual contamination limit is based on the plume dispersion, calculations presented in U.S. NRC Regulatory Guides 1.109 and 1.145.

11.1.5.3 Radiological Consequences

The projected dose at a boundary located 100 meters from the ISFISI is estimated to be less than one (1) mrem annually due to the postulated surface contamination. This dose is based on a postulated surface contamination of approximately 20,000 dpm/100 cm^2 β-γ and 200 dpm/100 cm^2 α, for each of the 16 storage casks in the design basis ISFSI. This analysis is highly conservative and demonstrates that the potential off-site radiological consequences from the release of surface contamination on the canisters is negligible.

11.1.5.4 NAC-MPC Performance

Procedural steps are employed to ensure that the canister surface is generally free of surface contamination prior to its installation in the storage cask. The surface of the canister is free of traps that could hold contamination. The presence of external surface contamination on the canister is unlikely.

11.1.5.5 Corrective Actions

No corrective action is required, since the radiological consequence is negligible.

11.2 Accidents

This section provides the results of analyses of the design basis and hypothetical accident conditions evaluated for the NAC-MPC system. The analyses presented show that the NAC-MPC system has substantial design margin of safety and provides protection to the public and to occupational personnel. In addition to these design basis accidents, this section addresses very low probability events that might occur over the lifetime of the ISFSI or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the immediate environment.

11.2.1 Accident Pressurization

Accident pressurization is a hypothetical event that assumes the failure of all of the fuel rods contained within the canister at the maximum internal temperature. There are no storage conditions that are expected to lead to the rupture of all of the fuel rods and none that result in the assumed maximum temperature of 650°F.

11.2.1.1 Cause of Pressurization

The hypothetical breach of all of the fuel rods in a canister would release the fission and fill gases to the interior of the canister.

11.2.1.2 Analysis of Accident Pressurization

11.2.1.2.1 Maximum Canister Internal Pressure

The analysis requires the calculation of the free volume of the canister, calculation of the quantity of fill and fission gas in the 36 fuel assemblies, and the subsequent calculation of the pressure in the canister if these gases are added to the helium pressure (initially at 1 atm) already present in the canister (Section 4.4.5). The quantity of fission gases was conservatively estimated assuming that 30% of the total gases present are released from the fuel. The bulk temperature of the helium is conservatively taken to be 650°F. This temperature bounds the calculated bulk temperature of helium for any of the evaluated normal, off-normal, or accident conditions.

The internal pressure is a function of rod-fill, fission and canister backfill gases. All of the gases, except the fission gases, are assumed to be helium. The total pressure for each volume are found by calculating the molar quantity of each gas and summing those directly. The design basis fuel assembly for the internal pressure calculation is the Combustion Engineering Type A assembly. This assembly has the highest fuel rod back-fill pressure (315 psig) and received the highest burnup (36,000 MWD/MTU [Section 2.1.1]).

The number of moles of the backfill gases are calculated using the Ideal Gas Law, PV = NRT. Backfill gases for the canister and cavity are assumed to be initially at 1 atmosphere. The quantity of fission gas is derived from the SAS2H source term evaluation of the CE Type A fuel assembly.

The number of moles of gas in the canister is:

$$N = N_{\text{TSC Back-Fill}} + N_{\text{Rod Back-Fill}} + 0.3\left(N_{\text{Fission Gas}}\right)$$

The number of moles of helium contained in the canister as backfill and the number of moles of gas in the fuel rods (as helium backfill and fission products) were calculated in Section 4.4.5.

The number of moles of gas due to the hypothetical failure of 100% of the fuel rods is:

$$N = \underset{\text{(canister backfill)}}{175.26\,\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(rod backfill)}}{77.95\,\frac{\text{Moles}}{\text{Cask}}} + \underset{\text{(fission gas)}}{0.3\left(423.44\,\frac{\text{Moles}}{\text{Cask}}\right)}$$

$$N = 380.24\,\frac{\text{Moles}}{\text{Cask}}$$

Based on an assumed bounding temperature of 650°F, the maximum pressure in the canister is:

$$P = \frac{\left(380.24\,\frac{\text{Moles}}{\text{Cask}}\right) \times \left(0.0821\,\frac{\text{atm}\,\ell}{\text{mole K}}\right) \times 616.48\text{ K}}{\left(4{,}877.93\,\frac{\ell}{\text{Cask}}\right)} = 3.95\text{ atm} \approx 58.0\text{ psia} \approx 43.3\text{ psig.}$$

11.2.1.2.2 Maximum Canister Stress Due to Internal Pressure

The stresses that result in the canister due to the internal pressure were evaluated using the ANSYS finite element model described in Section 3.4.4. The pressure used for the evaluation is 55 psig, which is conservatively assumed to bound all loading conditions, including canister re-flooding. The results of the analysis are shown in Tables 11.2.1-1 (primary membrane stress) and 11.2.1-2 (primary membrane plus bending stress). The locations of the canister analysis sections are shown in Figure 11.2.1-1.

A uniform pressure of 55 psig is applied to the underside of the canister shield lid and the inner surface of the canister shell. A uniform pressure of 65.61 psig (55 psig + the pressure representing the weight of the contents) is applied to the bottom plate. CONTAC52 elements are used to model the contact between the bottom plate and the supporting surface. An acceleration of 1g is applied in the axial direction of the canister model.

These results show that the minimum margin of safety for primary membrane stress is +1.83 at location 1. The minimum margin of safety for primary membrane plus bending stress is 0.58 at location 2.

11.2.1.3 Radiological Consequences

There are no radiological consequences for this accident.

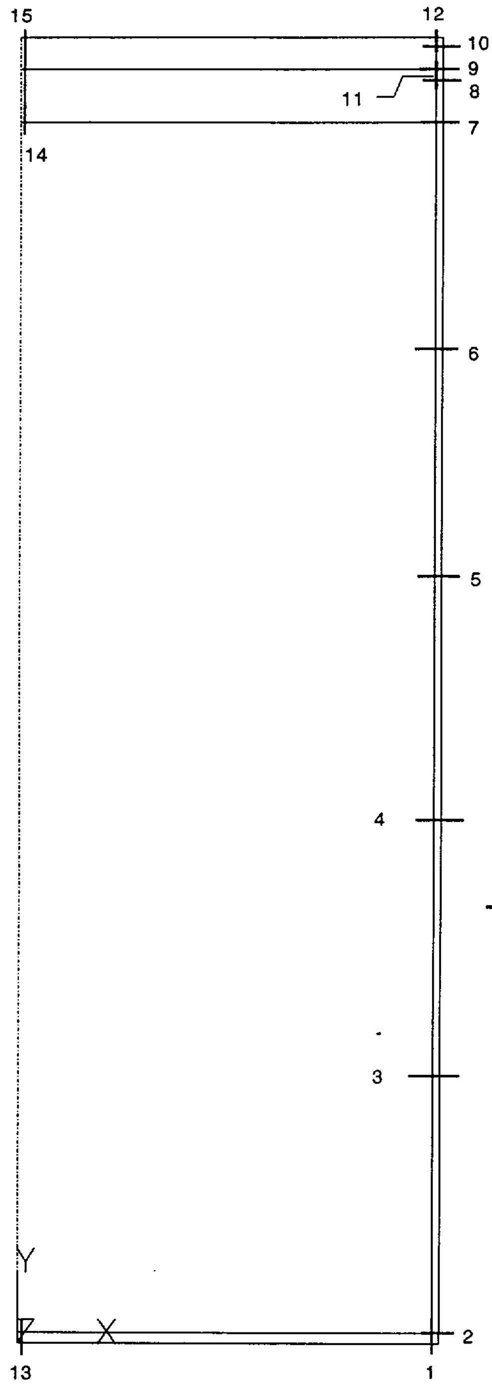
11.2.1.4 NAC-MPC Performance

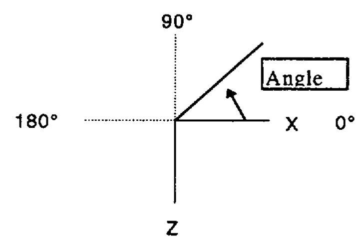
This analysis demonstrates that the canister performance is not significantly affected by the increase in internal pressure that results from the hypothetical rupture of all of the fuel rods contained in the canister. There is a positive margin of safety throughout the canister.

11.2.1.5 Recovery and/or Corrective Actions

There are no recovery or corrective actions required for this hypothetical accident event. The rupture of fuel rods within the canister is unlikely to be detected by any measurements or inspections that could be undertaken from the exterior of the canister or storage cask.

Figure 11.2.1-1 Section Location for Canister Stress Evaluation





Top View of Axis

Location of sections at Z=0 (Note: these sections are repeated at each angular division in the 180° model).

	Node 1		Node 2	
Loc.	X1	Y1	X2	Y2
1	34.695	0.0	34.695	1.0
2	34.695	1.0	35.32	1.0
3	34.695	23.7	35.32	23.7
4	34.695	46.4	35.32	46.4
5	34.695	69.1	35.32	69.1
6	34.695	91.8	35.32	91.8
7	34.695	114.5	35.32	114.5
8	34.695	118.5	35.32	118.5
9	34.695	119.5	35.32	119.5
10	34.695	121.62	35.32	121.62
11	34.695	118.5	34.695	119.5
12	34.695	121.62	34.695	122.5
13	0.01	0.0	0.01	1.0
14	0.01	114.5	0.01	119.5
15	0.01	119.5	0.01	122.5

Table 11.2.1-1 Canister Primary Membrane Stress (ksi) Due to Internal Pressure (55 psig) for the Accident Pressurization Condition

Location	Angle	SX	SY	SZ	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-1.8	9.6	3.3	-2.1	0.9	0.3	12.3	34.8	1.83
2	0	4.7	-3.7	-3.1	-1.8	0.3	-0.5	9.29	34.8	2.74
3	0	0	1.4	2.9	0	0	0.2	3.0	34.8	10.61
4	0	0	1.4	3	0	0	0.2	3.08	34.8	10.31
5	0	0	1.4	3	0	0	0.2	3.08	34.8	10.3
6	0	0	1.4	3	0	0	0.2	3.06	34.8	10.38
7	0	0	1.4	1.4	-0.1	0	0.1	1.47	34.8	22.66
8	0	0.6	1	1	0.4	0	0	0.88	34.8	38.36
9	0	-1.2	0.9	0.7	0	0	0.1	2.04	34.8	16.02
10	0	1.1	-0.3	0.4	0.1	0	0	1.45	34.8	22.98
11	0	-0.2	-1	0.3	0	0	0	1.35	34.8	24.87
12	0	-0.2	1.1	0.3	0.2	0	0	1.3	34.8	25.69
13	63	1.3	-0.1	1.3	0	0	0	1.42	34.8	23.46
14	72	-0.1	0	-0.1	0	0	0	0.13	34.8	270.66
15	0	0.2	0	0.2	0	0	0	0.16	34.8	211.2

A stress of "0" indicates that the stress at the location is positive, but less than 0.1 ksi. Components x, y, and z correspond to the radial, circumferential, and axial directions, respectively.

Table 11.2.1-2 Canister Primary Membrane Plus Bending Stress (ksi) Due to Internal Pressure (55 psig) for the Accident Pressurization Condition

Location	Angle	SX	SY	SZ	SXY	SYZ	SXZ	Stress Intensity	Allowable Stress	Margin of Safety
1	0	-11.7	0.8	1.8	-3.1	1.1	0.6	14.99	52.2	2.48
2	0	2.9	-29.7	-11.6	-2.3	0	-1	32.94	52.2	0.58
3	0	0	1.8	3.1	0	0	0.3	3.17	52.2	15.48
4	0	0	1.4	3.1	0	0	0.2	3.13	52.2	15.7
5	0	0	1.4	3.1	0	0	0.2	3.13	52.2	15.68
6	0	0	1.5	3.1	0	0	0.2	3.11	52.2	15.78
7	0	0.1	1.7	1.5	-0.1	0	0.1	1.61	52.2	31.52
8	0	0.4	0.5	0.8	0.5	0	0	1.05	52.2	48.53
9	0	-0.7	5.6	2.3	0.3	0	0.2	6.27	52.2	7.33
10	0	0.9	-2.3	-0.3	0	0	-0.1	3.21	52.2	15.27
11	0	-1.5	-3.3	-0.6	-0.3	0	0.1	2.7	52.2	18.33
12	0	-1.5	0.6	-0.3	0.2	0	0.1	2.2	52.2	22.73
13	72	1.3	-0.1	1.3	0	0	0	1.46	52.2	34.83
14	0	-3.2	-0.1	-3.2	0	0	0	3.1	52.2	15.84
15	0	0.4	0	0.4	0	0	0	0.37	52.2	138.46

A stress of "0" indicates that the stress at the location is positive, but less than 0.1 ksi.

11.2.2 Earthquake Event

11.2.2.1 Cause of Earthquake

Earthquakes are natural phenomena, which the cask might be subjected at any U.S. site. The design basis seismic event is described and discussed in Section 2.2.3.2. This analysis shows that the concrete storage cask containing the loaded canister does not tip over or slide in the design basis earthquake. The design basis earthquake is one imparting a horizontal acceleration of 0.25g at the top surface of the storage pad. The vertical acceleration is defined as two-thirds of the horizontal acceleration in accordance with ASCE 4-86.

11.2.2.2 Earthquake Analysis

The concrete storage cask is a very stiff structure. Although free-standing, it has been analyzed as a cantilever fixed at the base (Roark). For the purpose of calculating seismic loads, the cask is treated as a rigid body attached to the ground and equivalent static analysis methods were used to calculated loads, stresses, and overturning moments.

The natural frequencies of the empty concrete storage cask and the storage cask and canister are calculated to be 89 cycles per second and 36.1 cycles per second, respectively. The natural frequency of the empty storage cask was calculated using the frequency equation:

$$fn = \left(\frac{Kn}{2\pi}\right)\sqrt{\frac{EIg}{WL^4}}$$ (Roark, Table 36, Case 3)

The natural frequency of the loaded canister is calculated using:

$$\frac{1}{\omega^2} = \frac{1}{\omega^2{}_F} + \frac{1}{\omega^2{}_S}$$ (Blevins, Equation 8 • 30)

where:

$$\omega_F = \frac{\lambda^2}{2\pi L^2}\sqrt{\frac{EI}{M}}$$ and

$$\omega_S = \frac{\lambda}{2\pi L}\sqrt{\frac{KG}{M}}$$

Since the natural frequency is above 33 cycles per second, there is no dynamic amplification and the storage cask and canister are considered to be rigid bodies (NUREG-0800). Static analysis is applied to the evaluation of the earthquake event response.

The following paragraphs present the calculations for acceleration, overturning/restoring forces, and moments for the fully loaded concrete cask.

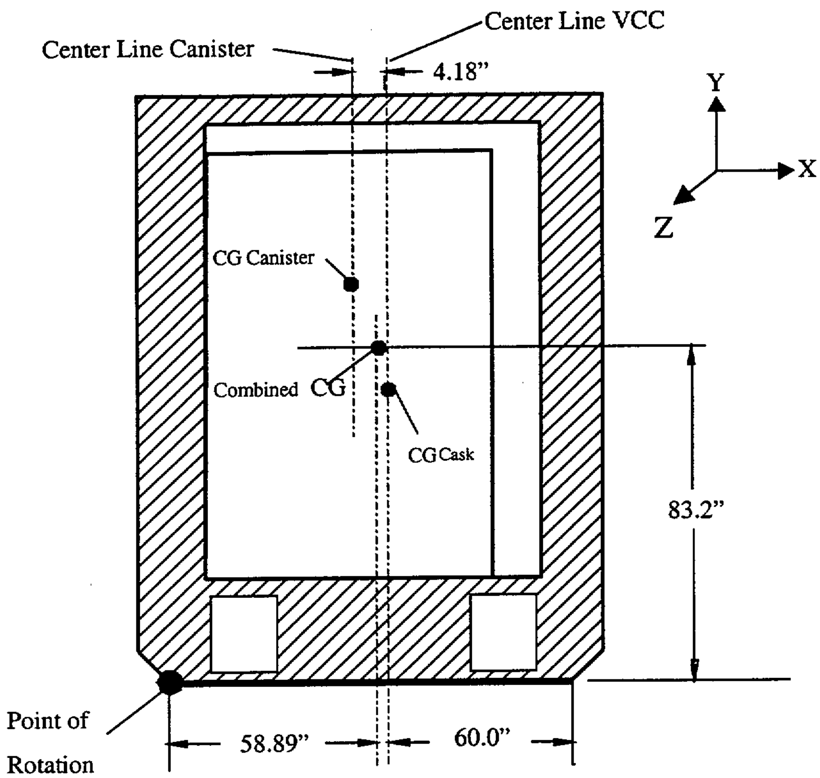
Because the canister is not attached to the concrete cask, the combined center of gravity (CG) for the concrete cask, with the canister in its maximum off-center position, must be calculated. For convenience, a point of rotation (P.O.R.) is established at the outside lower edge of the concrete cask.

The inside diameter of the concrete cask is 79.0" and the outside diameter of the canister is 70.64"; therefore, the maximum eccentricity between the two is $\left(\frac{79.0''-70.64''}{2}\right) = 4.18''$

The horizontal displacement, x, of the combined CG due to eccentric placement of the canister is:

$x = \left(\frac{54730 \times 4.18}{206100}\right) = 1.11''$, therefore, the distance from the postulated point of rotation to the horizontal center of gravity is: (60.0 - 1.11) = 58.89 in.

The vertical location of the CG remains at 83.2". The various moment arms resulting from this calculation are shown in the sketch below.



To maintain the concrete cask in equilibrium, the restoring moment, M_R, must be greater than, or equal to, the overturning moment (i.e., $M_R \geq M_O$). Based on this premise, the following derivation shows that the 0.25g acceleration of the design basis earthquake is well below the acceleration required to tip the concrete cask over.

The combination of horizontal and vertical acceleration components is based on the 100-40-40 approach of ASCE 4-86, which considers that when the maximum response from one component occurs, the responses from the other two components are 40% of the maximum. The vertical component of acceleration is obtained by scaling the corresponding ordinates of the horizontal components by two-thirds.

Let $a_x = a_z = a$ = horizontal acceleration components

$a_y = (2/3)a$ = vertical acceleration component

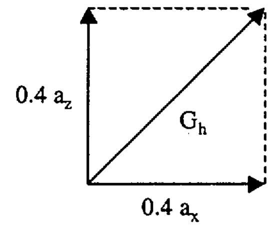
G_h = resultant of two horizontal acceleration components

G_v = vertical acceleration component

There are two combinations that have to be analyzed:

1)

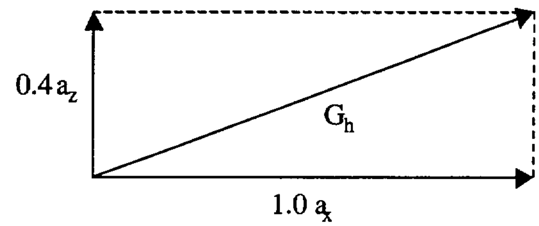
$$G_h = \sqrt{(0.4 \times a_x)^2 + (0.4 \times a_z)^2} = 0.566 \times a$$



$$G_v = 1.0 \times a_y = 0.667 \times a$$

2)

$$G_h = \sqrt{(1.0 \times a_x)^2 + (0.4 \times a_z)^2} = 1.077 \times a$$



$$G_v = 0.4 \times a_y = 0.267 \times a$$

For the cask to resist overturning, the restoring moment, M_R, about the point of rotation, must be greater than or equal to the overturning moment, M_o.

$$M_R \geq M_o \text{, or}$$
$$F_r \times b \geq F_o \times d \Rightarrow (W \times 1 - W \times G_v) \times b \geq (W \times G_h) \times d$$

where:

d = center of gravity measured from the base of the concrete cask (83.2 inch)
b = horizontal distance from the point of rotation to the CG (58.89 inch)
W = the weight of the concrete cask (206,100 lbs)
F_o = overturning force
F_r = restoring force

Substituting for G_h and G_v gives:

1) $$(1 - 0.667a)\frac{b}{d} \geq 0.566 \times a$$

$$a \leq \frac{b/d}{0.566 + 0.667(b/d)}$$

1) $$a \leq \frac{58.89/83.2}{0.566 + 0.667 \times 58.89/83.2}$$

$$a \leq 0.682g$$

2) $$(1 - 0.267a)\ \frac{b}{d} \geq 1.077\ a$$

$$a \leq \frac{b/d}{1.077 + 0.267\,(b/d)}$$

2) $$a \leq \frac{58.89/83.2}{1.077 + 0.267 \times 58.89/83.2}$$

$$a \leq 0.559g$$

Therefore, the minimum acceleration that may cause a tip over of a fully loaded concrete cask is 0.559g. Since the 0.25g design basis earthquake acceleration is less than 0.559g, the concrete cask will not tip over.

The factor of safety is 0.559 / 0.25 = 2.24, which is greater than the factor of safety of 1.1 required by ANSI /ANS-57.9.

To keep the cask from sliding, the force holding the cask (F_s) has to be greater than or equal to the force trying to move the cask. Based on the equation for static friction:

$$F_s = \mu N \geq G_h W$$

$$\mu\,(1-G_v)W \geq G_h W$$

where:
μ = coefficient of friction
N = normal force
W = weight of the concrete cask
G_v = vertical acceleration component
G_h = resultant of horizontal acceleration component

Substituting for G_h and G_v for the two combination conditions:

1) $$\mu(1 - 0.667a) \geq 0.566\,a$$
$$\mu \geq \frac{0.566a}{1 - 0.667a}$$

2) $$\mu(1 - 0.267a) \geq 1.077\,a$$
$$\mu \geq \frac{1.077a}{1 - 0.267a}$$

For a = 0.25g

1) $\mu \geq 0.17$

2) $\mu \geq 0.29$

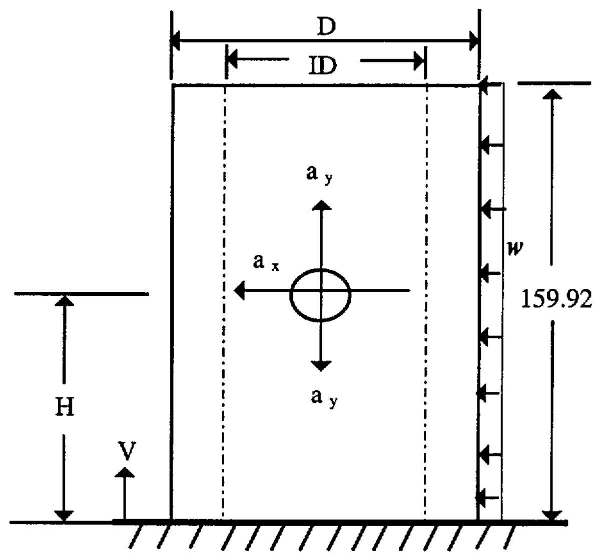
The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.29. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad, 0.35 (Funk), is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis earthquake conditions. The factor of safety is 0.35 / 0.29 =1.21 which is greater than the factor of safety of 1.1 required by ANSI/ANS-57.9.

The stresses in the concrete due to the design basis G-loads are conservatively calculated below. The fully loaded concrete cask is considered to be fixed at its base and subjected to seismic loads equal to 0.25 g in the two orthogonal horizontal directions and the vertical direction.

The accelerations are:

$a_x = (0.25^2 + 0.25^2)^{0.5} = 0.354$ g (horizontal direction)

$a_y = \pm 0.25$ g (vertical direction)



The following parameters are used in the calculation:

H	= 83.2 in. (Location of Center of Gravity)	
W_{vcc}	= 206,100 lb. (VCC weight)	
D	= 128 in. (concrete exterior diameter)	
ID	= 86 in. (concrete interior diameter)	
A	$= \pi (D^2 - ID^2) / 4$	= 7,059.2 in.^{2}
I	$= \pi (D^4 - ID^4) / 64$	$= 10.492 \times 10^6$ in.^{4}
S_{outer}	= 2I /D	= 163,937.5 in.^{3}
S_{inner}	= 2I / (ID)	= 244,000.0 in.^{3}
w	$= a_x W_{vcc} / 159.92$	= 456.22 lb / in.

The maximum bending moment (M) at support is:

$$M = w (159.92)^2 / 2 = 5.834 \times 10^6 \text{ in.-lb}$$

With a_y = - 0.25g, the maximum compressive stress at the outer and inner surfaces of the concrete shell are:

$$\sigma_{v\ outer} = (M\ /\ S_{outer}) + (a_y\ (W_{vcc})\ /\ A) = -35.59 - 7.30 = -42.9 \text{ psi}$$
$$\sigma_{v\ inner} = (M\ /\ S_{inner}) + (a_y\ (W_{vcc})\ /\ A) = -23.91 - 7.30 = -31.2 \text{ psi}$$

The compressive stresses are included in the load combination No. 5 in Table 3.4.4.2-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined stresses for the load combination of dead, live, thermal and earthquake are below the allowable stress.

11.2.2.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.2.4 NAC-MPC Performance

This analysis shows that the Yankee NAC-MPC vertical concrete cask performance is not affected by the design basis earthquake. The vertical concrete cask does not tip over for the design-basis earthquake having ground accelerations of 0.25 g.

11.2.2.5 Recovery and/or Corrective Actions

Inspection of the storage casks is required following an earthquake accident. While the cask does not tip over, there is a potential for movement of a cask relative to other casks and for superficial damage at the bottom edge due to that movement. The temperature monitoring system should be checked for operation as movement of a cask could have disconnected the monitoring system.

11.2.3 Explosion

The flood analysis presented in Section 11.2.6 shows that the NAC-MPC system would not experience adverse effects due to a pressure of 22 psig applied to the canister. The vertical concrete cask will also be unaffected. This pressure is considered to bound any explosions occurring in the vicinity of the ISFSI.

11.2.3.1 Cause of Accident

An explosion is an unlikely event because administrative controls will exclude explosive substances in the vicinity of the ISFSI. No flammable or explosive substances are stored or used at the storage facility; therefore, an explosion affecting the site is extremely unlikely. This evaluation is provided in order to provide a bounding pressure that could be used in the event that the potential of an explosion must be considered at a given site.

11.2.3.2 Evaluation of the Explosion Event

The NAC-MPC canister shell was evaluated in Section 11.2.6 for the effects of a flood having a depth of 50 feet. The water exerts an external hydrostatic pressure of 22 psig on the canister, which results in stress in the canister shell.

The maximum primary membrane stress calculated in the canister is 8.82 ksi. The allowable stress for accident conditions is 40.08 ksi. The margin of safety for primary membrane stress is + 3.54.

The maximum primary membrane plus bending stress calculated in the canister is 19.18 ksi. The allowable primary membrane plus bending stress for accident conditions is 60.12 ksi. The margin of safety for primary membrane plus bending stress is + 2.13.

Consequently, there is no adverse consequence to the canister as a result of the 22 psig external pressure. This pressure conservatively bounds an explosion event.

The concrete cask is a monolithic structure that is not affected by the explosion overpressure.

11.2.3.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.3.4 NAC-MPC Performance

This analysis shows that the NAC-MPC system performance is not affected by explosion over pressure.

11.2.3.5 Recovery and/or Corrective Actions

In the unlikely event of a nearby explosion, inspection of the storage casks is required to ensure that the air inlets and outlets are free of debris and to ensure that the monitoring system is intact. There are no recovery or corrective actions required for this accident event.

11.2.4 Failure of All Fuel Rods With a Subsequent Ground Level Breach of the Canister

This section addresses the potential mechanistic failure of the canister and subsequent release of radioactive gas, volatile and particulate material from the canister.

As described in Chapters 3, 4, and 11, the NAC-MPC is evaluated for normal conditions, and for a series of off-normal and accident events that include cask tip over, cask drop, flooding, fire and explosion, lightning, earthquake, loss of shielding, adiabatic heat up, and tornado generated missiles. The evaluations show that for these design basis events, there is no mechanistic failure of the confinement boundary of the canister, i.e., the canister maintains its structural integrity. As described in Chapter 7 and in Section 8.1.1, the canister is tested to demonstrate that it is leaktight as defined by ANSI N14.5-1997.

Therefore, no further evaluation of this potential accident condition is required.

11.2.5 Fire Accident

This section evaluates the effects of a hypothetical fire accident as a bounding condition. A fire accident is a very unlikely occurrence in the storage cask lifetime.

11.2.5.1 Cause of Accident

There is no probable cause for this accident event. There are no flammable materials in the area of the ISFSI. While it is possible that a transport vehicle could start a fire while transferring a loaded storage cask at the ISFSI, this fire would be confined to the vehicle and would be rapidly extinguished by the persons performing the transfer operations.

Detection of the event would be by observation of fire or smoke.

11.2.5.2 Accident Analysis

The bounding hypothetical fire accident condition is assumed to be an 8-minute fire in which the following conditions are applied:

1) The air inlets are not blocked; air flows into the inlets, upward past the canister shell surface, and out the outlets.

2) A temperature of 1475°F is applied to the boundary of the air along the inlet surfaces, up to an elevation of 10 inches above the base, to force the air to be heated as the air flows through the inlets. Both the top and bottom surfaces of the inlets have the temperature specification of 1475°F applied to them.

3) The fire condition is applied for 8 minutes.

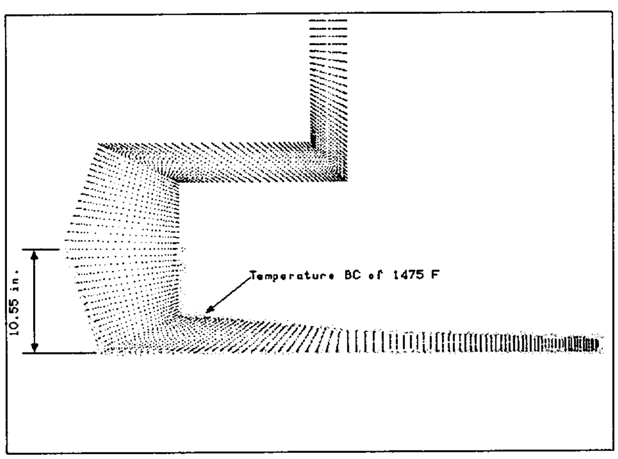
4) After the fire condition, the air inlet temperature is returned to 75°F.

5) Solar insolation is applied during the fire, since the fire condition is applied only to the base of the concrete cask.

6) The initial condition for the fire is the steady state normal operating condition with an ambient temperature of 75°F, a heat input corresponding to a 12.5 kW fuel heat source and solar insolation applied to the top and sides of the Vertical Concrete Cask. During the steady state condition, the air entering the inlet is at a temperature of 75°F.

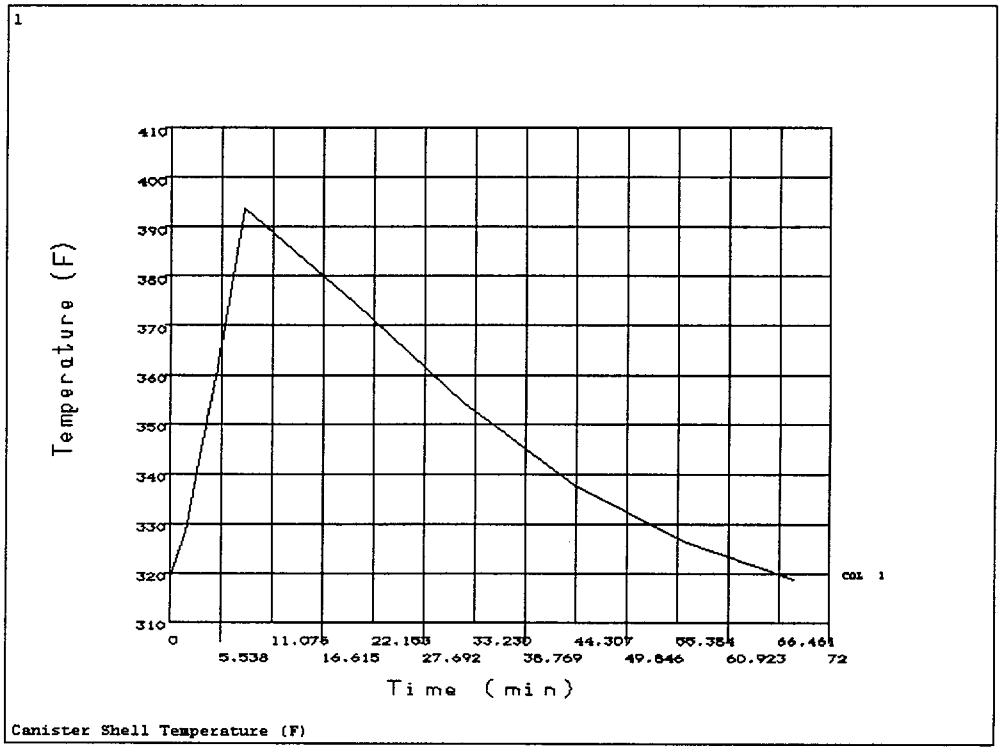
The assumptions used in the hypothetical fire accident are very conservative due to the limited amount of combustible material (less than 50 gallons of diesel fuel) present at the ISFSI. The fuel is assumed to spread over a large combustible area and the fire is assumed to totally engulf the entire base of the cask. Thus, the duration of an associated fire is relatively short (assumed to be 8 minutes). The analysis is further simplified by assuming an instantaneous change of the ambient air temperature from 75°F to 1475°F.

The event is evaluated using the two-dimensional air flow model described in Section 4.4.1.1. The initial phase of the transient solution is to bring the air flow model to steady state conditions using the conditions described in Section 4.4.1.1. The next phase is started with a step change of the temperature to 1475°F, which is applied to the inner surface of the inlets as shown below:



This condition is applied for 8 minutes. After the 8-minute period, the 1475°F boundary condition is removed and the external conditions at the time of normal operating steady state conditions are applied. This initiates the cool down phase, which is analyzed for an additional 60 minutes.

The time history for the canister shell temperature is shown below.



The sharp change in the canister shell temperature near the end of the fire condition results because the canister contents are not modeled. This is considered to be conservative, since the reduced thermal capacitance of the system maximizes the temperature change of the canister surface due to flow of the heated air. The temperature rise of the canister shell due to the fire condition is determined to be 75°F. This change in temperature is added to the component maximum steady state normal condition temperature to compute the maximum component temperatures due to the fire. The bulk concrete temperature experienced a temperature change of 11°F due to the local heating of the concrete. The maximum temperatures for the 8-minute fire/vents not blocked condition are:

Component	Steady State Temperature (°F)	Maximum Temperature as a Result of the Fire (°F)	Allowable Short Term Temperatures (°F)
Canister shell	319	394	800
Heat transfer disk	527	602	700
Support disk	529	604	800
Fuel cladding	563	638	806
Bulk concrete	133	144	350

The component temperatures are shown to be less than the allowable temperatures, which confirms that the thermal response of the NAC-MPC system is acceptable for the fire condition.

11.2.5.3 Radiological Consequences

There are no significant radiological consequences for this accident. There may be local spalling of concrete during the fire event, which could lead to some minor reduction in shielding effectiveness. The principal effect would be local increases in radiation dose rate on the concrete cask surface.

11.2.5.4 NAC-MPC Performance

The peak temperature of the canister shell is 394°F, which is reached 8 minutes after the fire starts. The canister shell temperature cools rapidly following the end of the fire event and is at normal temperature in about 60 minutes. The concrete temperature increases only slightly during the hypothetical event. The peak temperature of the heat transfer disk is 602°F, which is less than the short-term allowable temperature of 700°F. The peak fuel temperature is 638°F, which is much less than the short-term allowable fuel temperature of 806°F. The fuel, canister, and support disk are not significantly affected by the accident.

Even for the severe 10 CFR 71 hypothetical thermal accident (fire), the NAC-MPC meets its storage performance requirements.

11.2.5.5 Recovery and/or Corrective Actions

In the unlikely event of such a severe fire at an ISFSI site, the operator will take appropriate immediate response to suppress and extinguish the fire. Following the fire, the concrete cask should be inspected for general deterioration of the concrete, loss of shielding (spalling of concrete), exposed reinforcing bar, and surface discoloration that could affect heat rejection. This inspection would determine the repair activities necessary to return the concrete storage cask to its design basis configuration.

11.2.6 Flood

This evaluation shows that the NAC-MPC system is not adversely affected by a design basis flood having a depth of water of 50 feet and a flow velocity of 15 feet per second.

11.2.6.1 Causes of Flood

The probability of a flood event is highly dependent on land contour and environmental factors that are specific to each ISFSI site. Most reactor sites are not susceptible to flooding as a result of site selection characteristics. This evaluation considers design basis flood conditions of a 50-foot depth of water having a velocity of 15 feet per second. This flood is fully immersing for the NAC-MPC system.

11.2.6.2 Flood Analysis

The concrete cask is considered to be resting on a flat level concrete pad when subjected to a flood velocity pressure distributed uniformly over the projected area of the concrete cask. Because of the concrete cask geometry, rigidity, and large mass, it is analyzed as a rigid body. Assuming full immersion of the concrete cask and steady-state flow conditions, the drag force, F_D, is calculated using classical fluid mechanics for turbulent flow conditions. A safety factor of 1.1 for stability against overturning and sliding is applied. The coefficient of friction between carbon steel and concrete used in this analysis is 0.35 (Funk).

The buoyancy force, F_b, is calculated from the weight of water (62.4 lb/ft^3) displaced by the fully immersed concrete cask. The displacement volume of the concrete cask containing the loaded canister is 1030 ft^3. The displacement volume is the occupied volume less the free space in the central annular cavity of the concrete cask.

$$F_b = \text{Vol} \times 62.4 \text{ lb/ft}^3$$
$$= 64.27 \text{ kip}$$

Assuming the steady-state flow conditions for a rigid cylinder, the total drag force of the water on the concrete cask is given by the formula:

$$F_D = (C_D)(\rho)(V^2)\left(\frac{A}{2}\right) \quad \text{(Roberson)}$$

$$= 21.72 \text{ kip}$$

where:

C_D = Drag coefficient, which is dependent upon the Reynolds Number (Re). For flow velocities greater than 6 ft/sec, the value of C_D approaches 0.7. (Roberson)

ρ = mass density of water = 1.94 slugs/ft^3

D = VCC outside diameter (128 in. / 12 = 10.67 ft)

V = velocity of water flow (15 ft/sec)

A = projected area of the VCC normal to water flow (10.67 ft × 13.33 ft = 142.2 ft^2)

The drag force required to overturn the concrete cask is determined by summing the moments of the drag force and the submerged weight (weight of the cask less the buoyant force) about a point on the bottom edge of the cask. This method assumes a pinned connection, i.e., the cask will rotate about the point on the edge rather than slide. When these moments are in equilibrium, the cask is at the point of overturning.

$$F_D \times \left(\frac{h}{2}\right) = (W_{VCC} - F_b) \times r$$

and

$$F_D = 113.42 \text{ kip}$$

where:

h = concrete cask overall height (159.92 in., use 160 in. / 12 in./ft = 13.33 ft)

W_{VCC} = concrete weight = 206.1 kips

F_b = buoyant force = 64.27 kips

r = concrete cask radius (64 in. / 12 in./ft = 5.33 ft)

Solving the drag force equation for the velocity, V, that is required to overturn the concrete cask:

$$V = \sqrt{\frac{2F_D}{C_D \rho A}}$$

= 32.68 ft/sec. (including safety factor of 1.1)

To prevent sliding, the minimum coefficient of friction (with a safety factor of 1.1) between the carbon steel bottom plate of the concrete cask and the concrete surface upon which it rests is:

$$\mu_{min} = \frac{(1.1)F_{D15}}{F_y}$$

where:

F_y = the immersed weight of the concrete cask

$$\mu_{min} = \frac{(1.1)21.72\text{kip}}{(206.10 - 64.27)\text{kip}} = 0.17$$

The analysis shows that the minimum coefficient of friction, μ, required to prevent sliding of the concrete cask is 0.17. The coefficient of friction between the steel bottom plate of the concrete cask and the concrete surface of the storage pad (0.35) is greater than the coefficient of friction required to prevent sliding of the concrete cask. Therefore, the concrete cask will not slide under design-basis flood conditions.

The water velocity required to overturn the concrete cask is greater than the design-basis velocity of 15 ft/sec. Therefore, the concrete cask will not be overturned under design basis flood conditions.

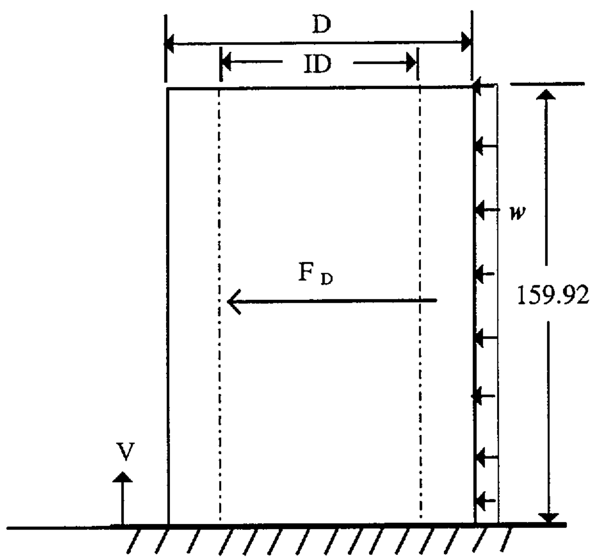
The flood depth of 50 feet exerts a hydrostatic pressure on the canister and the concrete cask. The water exerts a pressure of 22 psig (50 x 62.4/144) on the canister, which results in stresses in the canister shell.

The maximum primary membrane stress in the canister is 8.82 ksi. The allowable stress for accident conditions (2.45 m) is 40.08 ksi. The margin of safety for primary membrane stress is +3.54.

The maximum primary membrane plus bending stress is 19.18 ksi. The allowable primary membrane plus bending stress for accident conditions (3.65m) is 60.12 ksi. The margin of safety is +2.13.

Consequently, there is no adverse consequence to the canister as a result of the hydrostatic pressure due to the flood condition.

The concrete cask is a thick monolithic structure and is not affected by the design basis flood hydrostatic pressure. However, the stresses in the concrete due to the drag force (F_D) are conservatively calculated as shown below. The concrete cask is considered to be fixed at its base.



F_D	= 21,720 lb	
D	= 128 in. (concrete exterior diameter)	
ID	= 86 in. (concrete interior diameter)	

A	$= \pi (D^2 - ID^{2)} / 4$	= 7,059.2 in.^{2}	
I	$= \pi (D^4 - ID^{4)} / 64$	= 10.492 x10^6 in.^{4}	(Moment of Inertia)
S_{outer}	= 2I /D	= 163,937.5 in.^{3}	(Section Modulus for inner surface)
S_{inner}	= 2I / (ID)	= 244,000.0 in.^{3}	(Section Modulus for outer surface)
w	= F_D/ 159.92	= 135.82 lbf / in.	
M	$= w (159.92)^2 / 2$	= 1.737 x 10^6 in.-lb	(Bending Moment at the base)

Maximum stresses at the base surface:

$\sigma_{v\ outer} = M / S_{outer}$ = 10.6 psi (tension or compression)

$\sigma_{v\ inner} = M / S_{inner}$ = 7.1 psi (tension or compression)

The compressive stresses are included in load combination No. 7 in Table 3.4.4.2-1, since they are the governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined stresses for the load combination due to dead, live, thermal and flood loading, are below the allowable stress.

11.2.6.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.6.4 NAC-MPC Performance

This analysis shows that the Yankee NAC-MPC vertical concrete cask system performance is not affected by the design basis flood. The analysis demonstrates that the concrete cask will not slide and will not overturn in the design-basis flood. The hydrostatic pressure exerted by the 50 foot depth of water does not produce significant stress in the canister.

11.2.6.5 Recovery and/or Corrective Actions

Inspection of the storage casks is required following this accident event. While the casks do not tip over or slide, there is a potential for the collection of debris or the accumulation of silt at the base of the cask, which could clog or obstruct the air inlets. Operation of the temperature monitoring system must be verified, as flood conditions may have impaired its operation.

11.2.7 Fresh Fuel Loading in the Canister

This section evaluates the effects of an inadvertent loading of up to 36 fresh, unburned Yankee class fuel assemblies in the canister. This event is not a credible event.

11.2.7.1 Cause of Accident

The cause of this event would be operator and/or procedural error. The design basis criticality condition demonstrates that the canister is designed to accommodate fresh fuel without a resulting criticality event.

This accident is expected to be identified immediately by observation of the condition of the fuel installed in the canister or by a review of the fuel handling records.

11.2.7.2 Analysis of Fresh Fuel Loading in the Canister

The criticality analysis presented in Chapter 6 assumes the loading of up to 36 Yankee class fuel assemblies having no burn up. This analysis shows that the maximum K_{eff} for the canister in the dry normal condition is 0.4503. The maximum K_{eff} in the accident conditions is 0.9021. The accident condition assumes the most reactive configuration of the fuel and full moderator intrusion.

The design of the NAC-MPC is adequate to preclude any effects due to this accident condition.

11.2.7.3 Radiological Consequences For This Accident

There are no radiological consequences for this event.

11.2.7.4 NAC-MPC Performance

The criticality control features of the NAC-MPC canister and basket ensure that the K_{eff} of the fuel is less than 0.95 for all loading conditions of fresh fuel. There is no adverse impact on the NAC-MPC due to this event.

11.2.7.5 Recovery and Corrective Actions

This event requires that the canister be unloaded when the incorrect loading is identified. The controls placed on the movement of fuel assemblies are such that this accident event will not occur.

11.2.8 Full Blockage of Air Inlets and Outlets

This section evaluates the NAC-MPC for the steady state effects of full blockage of the air inlets and outlets at the normal ambient temperature (75°F). It estimates the duration of the event that would result in the concrete reaching its design basis limiting temperature of 350°F.

11.2.8.1 Cause of Event

The likely cause of complete air inlet and outlet blockage is the covering of the cask with earth in a catastrophic event such as greater than design basis earthquake or a land slide. This event is a bounding condition accident that is not credible.

This event would be detected by inspection of general conditions at the site following such an event. It would be detected visually by the persons inspecting the ISFSI site.

11.2.8.2 Analysis of the Blockage Event

The accident temperature conditions are evaluated using the thermal models described in Section 4.4.1. The analysis assumes initial normal storage conditions, with the sudden loss of convective cooling of the canister. Heat is then rejected from the canister to the storage cask liner by radiation and conduction. The loss of convective cooling results in the fairly rapid and sustained heat-up of the canister and the concrete cask. To account for the loss of convective cooling in the ANSYS air flow model (Section 4.4.1.1), the elements in the model were replaced with thermal elements, employing the axis-symmetric option. This option assures that there is no axial temperature difference across the element. This model is used to evaluate the thermal transient resulting from the postulated boundary conditions.

The thermal transient analysis evaluated the concrete temperature conditions for 100 hours. At the end of 24 hours, the concrete temperature is 287°F, an increase of 122°F, compared with the initial (normal conditions) concrete temperature, 165°F. The maximum temperature in the concrete will exceed the thermal design criteria temperature of 350°F at 45.7 hours after the start of the event.

Other conservative assumptions include no internal convection and no heat transfer to the surrounding environment (i.e., the dirt covering the cask in the case of a landslide).

The maximum canister shell temperature is 536°F at 45.7 hours after the start of the event. Considering the maximum temperature difference of 250°F between the canister shell and fuel region (as shown in Table 4.1-4, the ΔT between canister shell and fuel clad is 563 - 319 = 244°F for normal condition of storage), the maximum fuel temperature will reach 786°F (536° + 250°) in the same 45.7-hour period, which is less than the short-term allowable temperature of 806°F.

11.2.8.3 Radiological Consequences

There are no significant radiological consequences for this event, as the NAC-MPC retains its shielding performance. Dose is incurred as a consequence of uncovering the storage cask and vent system. Since the dose rates at the air inlets and outlets are higher than the nominal rate (35 mrem/hr) at the cask wall, personnel will be subject to an estimated maximum dose rate of 100 mrem/hr when clearing the inlets and outlets. If it is assumed that a worker kneeling with his hands on the inlets or outlets would require 15 minutes to clear each inlet or outlet, the estimated extremity dose is 200 mrem for the 8 openings. The whole body dose would be slightly less. In addition, some dose is incurred clearing debris away from the cask body. This dose is estimated at 50 mrem, assuming 2 hours is spent near the cask exterior surface.

11.2.8.4 NAC-MPC Performance

There are no adverse consequences for this accident condition, assuming that debris is cleared within a reasonable time (< 45 hours). The maximum component temperatures are less than the allowable temperatures. The NAC-MPC continues to satisfactorily perform the cooling function with all the inlets and outlets blocked.

11.2.8.5 Recovery and/or Corrective Actions

The debris blocking the vents must be manually removed. In addition, a considerable effort may be involved in clearing the area around the storage casks. No actions are required with regard to the casks proper, provided that the vents are cleared within 45 hours.

11.2.9 Lightning

This analysis demonstrates that the NAC-MPC storage cask does not experience adverse effects due to a lightning strike.

11.2.9.1 Cause of Accident

A lightning strike is a random weather related event. Since the NAC-MPC storage cask is located on an unsheltered pad, the storage cask may be subject to a lightning strike. The probability of a lightning strike is primarily dependent on the geographical location of the ISFSI site, as some geographical regions experience a higher frequency of storms containing lightning than others.

The analysis of the consequence of a lightning strike assumes that the lightning strikes the upper most metal surface and proceeds through the storage cask liner to the ground. The electrical current flow path results in current induced Joulean heating along that path.

A lightning strike on a storage cask may be visually detected at the time of the strike, or by visible surface discoloration at the point of entry or exit of the current flow. Most reactor sites in locations experiencing a frequency of lightning bearing storms have lightning strike detection systems as an aid to ensuring stability of site electric power.

11.2.9.2 Analysis of the Lightning Strike Event

The current path analyzed is from a strike point on the outer radius of the top flange of the storage cask, down through the carbon steel liner and the bottom plate to the ground.

The integrated maximum current for a lightning strike is a peak current of 250 kiloamps over a period of 260 microseconds, and a continuing current of up to 2 kiloamps for 2 seconds in the case of severe lightning discharges (Cianos).

From Joule's Law, the amount of thermal energy developed by the combined currents is given by (Summer):

$$Q = 0.0009478R\left[I_1^2(dt_1) + I_2^2(dt_2)\right]$$
$$= (22.98 \times 10^3)\ R\ \text{Btu}$$

where:

Q = thermal energy (BTU)
I_1 = peak current (amps)
I_2 = continuing current (amps)
dt_1 = duration of peak current (seconds)
dt_2 = duration of continuing current (seconds)
R = resistance (ohms)

The maximum lightning discharge is assumed to attach to the smallest current-carrying component, that is, the top flange connected to the outer lid.

The propagation of the lightning through the carbon steel cask liner, which is both permeable and conductive, is considered to be a transient. For static conditions, the current would be distributed throughout the shell. In a transient condition the current will be near the surface of the conductor. It is assumed that the current is contained in a 90 degree sector of the circular cross section of the steel liner as opposed to the entire cross section. The depth of the current penetration (δ) is estimated as (Fink):

$$\delta = \frac{1}{\sqrt{\pi \mu f \sigma}} \quad \text{(m)}$$

where:

μ = permeability of the conductor = $100\mu_0$ (Summer)
and μ_0 = 4πE-7 Henries/m
σ = electrical conductivity (seimens/meter) = $1/\rho$
= 1/resistivity = 1/9.78E-08 (ohm-m) (Fink)
f = frequency of the field (Hz)

The pulse is represented conservatively as a half sine form, so that the equivalent f = 2 x τ, where τ is the referenced pulse duration. There are two skin depths to be computed, corresponding to different pulse duration. The larger effective frequency will result in a smaller effective area to conduct the current. The effective resistance is computed as (Fink):

$$R = \frac{\rho l}{a}$$

where:

R = resistance (ohms)
ρ = resistivity = 9.78E-08 (ohm-m)
l = length of conductor path
a = area of conductor (m^2)
= $(R_{shell})(\delta)(\pi/4)$
R_{shell} = 35.75 inches = 0.9081 m

Using the current level of the pulse and the duration in conjunction with the carbon steel liner, the resulting energy into the shell is:

	Peak	Continuous	Expression
Time (s) τ	2.60 E-06	2.0	--------------
Peak Current (KA)	250	2	--------------
Frequency (Hz)	2000(conservative)	2.5E-01	$1/(2\tau)$
Skin depth (m) δ	3.52E-04	3.15E-02	$1/\sqrt{\pi\mu f\sigma}$
Conductor length (m) L	4.1	4.1	----------------
Conductor area (m^2) A_c	2.51E-4	2.24E-2	$R_{shell}\,\delta(\pi/4)$
Resistance (ohm) Ω	1.60E-03	1.79E-5	$(L/A)\rho$
Q (Btu)	24.6	.14	$R = \frac{\rho l}{a}$

It is conservatively assumed that this thermal energy dissipation occurs in the localized volume of the carbon steel involved in the current flow path through the flange to the inner liner. Assuming no heat loss or thermal diffusion beyond the current flow boundary, the maximum temperature increase in the flange due to this thermal energy dissipation is calculated as (Black):

$$\Delta T = \frac{Q}{mc}$$

where:

$\Delta T =$ temperature change (°F)
$Q =$ thermal energy (BTU)
$c =$ 0.113 Btu/lb °F
$m =$ mass (lbm)

The ΔT_1 for the peak current (250KA, 260 μsec) for the region of the current is computed based on the mass associated with this region.

$$m = (.284\ \text{lb/in}^3) \times A_c \times L = (.284)(2.51E\text{-}4)(159.92)/C_f = 17.7\ \text{lbm}$$

$$C_f = (.0254^2)\ \ \text{(converts m}^2\text{ to in}^2\text{)}$$

$$\Delta T_1 = 24.6/(17.7 \times .113) = 12.3°F$$

The ΔT_2 for the continuous current (2KA, 2 sec) for the region of the current is computed based on the mass associated with this region.

$$m = (.284\ \text{lb/in}^3) \times A_c \times L = (.284)(2.24E\text{-}2)(159.92)/(.0254^2) = 1577\ \text{lbm}$$

$$\Delta T_2 = .14/(1577 \times .113) = 0.001°F$$

The ΔT_1 would correspond to the increase in the maximum temperature of the steel. For the concrete to experience an increase in temperature, the heat must disperse from the steel liner surface throughout the steel. Using the total thickness of the steel, over the 90 degree sector, the increase in temperature is:

$$m = (.284\ lb/in^3) \times (39.25^2 - 35.75^2)\pi/4 \times L = 9{,}364\ lbm$$

$$\Delta T_1 = (24.6+.14)/(9{,}364 \times .113) = 0.02\ F$$

Therefore the increase in temperature of the concrete is not significant.

11.2.9.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.9.4 NAC-MPC Performance

This analysis shows that the NAC-MPC vertical concrete cask's performance is not affected by a lightning strike. When lightning strikes the cask and travels through the 3.5-inch thick carbon steel storage cask liner, the maximum increases in the steel and concrete temperatures is 12.3°F and 0.0°F, respectively.

11.2.9.5 Recovery and/or Corrective Actions

There are no recovery or corrective actions required for this accident event.

11.2.10 Maximum Anticipated Heat Load (125°F Ambient Temperature)

This analysis evaluates the NAC-MPC response to storage operation with an ambient temperature of 125°F. The NAC-MPC is evaluated at steady state conditions.

11.2.10.1 Cause of Accident

The cause of this condition is a weather event that causes the NAC-MPC to be subject to a 125°F ambient temperature with full solar insolance. A contents heat load of 12.5 kW is assumed.

The condition is analyzed in accordance with the requirements of ANSI/ANS 57.9 to evaluate a credible worse case thermal loading. This condition is considered in the load combinations described in Chapter 2.

Detection of the ambient high temperature condition would occur during the daily measurement of ambient temperature and storage cask outlet air temperature.

11.2.10.2 Analysis of the 125°F Ambient Temperature Event

The severe high temperature condition is evaluated using the thermal models described in Section 4.4.1. The principal component temperatures for this ambient condition are:

Component	125°F Ambient Max Temp. (°F)	Allowable Max Temp. (°F)
Fuel Cladding	607	1058
Support Disks	575	800
Heat Transfer Disks	574	700
Canister Shell	372	800
Concrete	228	350

This evaluation shows that the component temperatures are within the allowable temperature for the severe high ambient temperature conditions.

This event is considered an "accident condition" for the purpose of this evaluation. Consequently, the thermal stress (secondary) occurring in the canister due to this thermal loading is not evaluated.

However, the thermal stresses for the concrete cask are calculated using the same methodology as shown in Section 3.4.4.2 for the stress calculation for normal conditions of storage. The same finite element model is used with the boundary temperatures based on concrete cask thermal analysis results (Section 4.4.4.1). The maximum vertical and circumferential (compressive) stresses at the concrete inside surface are calculated to be 660.1 psi and 127.5 psi, respectively. These stresses are included in the load combination (No. 4) as presented in Table 3.4.4.2-1. The maximum tensile forces in the vertical and hoop reinforcing bars are 19,380 lbs. and 23,196 lbs., respectively. Comparison of these forces and the allowable forces is shown in Table 3.4.4.2-2. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined concrete stress and reinforcing bar force for the load combination of dead (D), live (L) and accident temperature (T_a) are below the allowable stress and force, respectively.

11.2.10.3 Radiological Consequences

There are no radiological consequences for this event.

11.2.10.4 NAC-MPC Performance

There are no adverse consequences for this accident condition. The maximum component temperatures are less than the allowable temperatures for accident conditions and are also less than the temperature limits for normal conditions of storage.

11.2.10.5 Corrective Actions

No corrective actions are required for this accident condition.

11.2.11 Storage Cask 6-Inch Drop

This analysis evaluates a loaded concrete storage cask for a 6-inch drop onto a concrete storage pad. This evaluation shows that neither the concrete storage cask nor the canister experience significant adverse effects due to the 6-inch drop accident.

11.2.11.1 Cause of Accident

The concrete storage cask, containing the loaded canister, must be raised approximately 3-inches in order to install the inflatable air-pads beneath it. The air pads use pressurized air to allow the cask to be moved across the surfaces of the transporter and the ISFSI pad to the designated positions. The cask is raised using hydraulic jacks installed at jack-points in the air inlets.

This accident assumes the failure of one or more of the jacks or of the air pad system, resulting in a drop of the cask. A lift of about 3-inches is required to install and remove the air pads. This analysis conservatively evaluates the consequences of a 6-inch drop.

This accident would be detected by persons jacking or moving the storage cask.

11.2.11.2 Analysis of the 6-Inch Drop Event

A bottom end impact is assumed to occur normal to the concrete pad surface, transmitting the maximum g-load to the concrete storage cask and the canister. The energy absorption is computed as the product of the compressive force acting on the storage cask and its displacement. Conservatively assuming the storage pad is an infinitely rigid surface, exhibiting a uniform isotropic crush strength, the concrete body of the storage cask will crush until the impact energy is absorbed.

A compressive strength of 4,000 psi is used for the storage cask concrete. This is conservative, since it is the minimum specified value and it ignores any energy absorption by the internal friction of the aggregate as crushing proceeds.

The canister rests upon a stand/inlet system, shown in Figure 11.2.11-1, designed to allow cooling of the canister. Following the initial impact, the inlet system will partially collapse, providing an energy absorption mechanism that somewhat reduces the deceleration force on the canister. A detailed evaluation is provided in Section 11.2.11.2.2. The weight of the empty concrete storage cask is 151,364 pounds. The loaded canister weight is 54,730 pounds.

11.2.11.2.1 Evaluation of the Concrete Storage Cask

In the 6-inch bottom drop, the cylindrical portion of the concrete is in contact with the steel bottom baseplate that also supports the stand/inlet system. The baseplate is assumed to be part of an infinitely rigid storage pad. No credit is taken for the crush properties of the storage pad or the underlying soil layer. Therefore, energy absorbed by the crushing of the cylindrical concrete region of the storage cask equals the product of the compressive strength of the concrete, the crush depth of the concrete, and the projected area of the concrete cylinder. Crushing of the concrete continues until the energy absorbed equals the potential energy of the storage cask at the initial drop height. The canister is not rigidly attached to the concrete cask, so it is not considered to contribute to the concrete crushing. The energy balance equation is:

$$w(h+\delta) = P_o A \delta,$$

where:

h = 6 in., the drop height

δ = the crush depth of the concrete cask

P_o = 4000 psi, the compressive strength of the concrete

A = $\pi(R_1^2 - R_2^2)$
= 7,059 in^2, the projected area of the concrete shield wall

w = 151,364 lb × 1.1, the weight of the concrete cask, conservatively multiplied by 1.1 to account for variations in the concrete

It is assumed that the maximum force that can be exerted on the concrete cask is the compressive strength of the concrete multiplied by the area of the concrete being crushed. Therefore, the deceleration of the storage cask is dependent upon the compressive strength of the concrete, the cross-sectional area of the storage cask cylindrical body, and the weight of the empty storage cask with lid. The deceleration due to crush is:

$$a_{vcc} = \frac{P_o A}{w} = 169.6 \quad g\text{'s}.$$

The crush distance computed from the energy balance equation is:

$$\delta = \frac{hw}{P_o A - w} = \frac{(6)(151{,}364 \times 1.1)}{(4000)(7{,}059) - (151{,}364 \times 1.1)} = 0.036 \text{inch}$$

11.2.11.2.2 Evaluation of the Canister for a 6-inch Bottom-End Drop of the Storage Cask

Upon a bottom-end impact of the concrete storage cask on the storage pad, the canister produces a force on the stand/inlet system located near the bottom of the storage cask. It is expected that the steel plate above the air inlet channels will yield. Calculating the flow stress, σ_f, for the material:

$$\sigma_f = \frac{\sigma_y + \sigma_u}{2}$$

$$= 45{,}400 \text{ psi},$$

where:

σ_u = 58,000 psi, A36 carbon steel ultimate strength at 200 °F,

σ_y = 32,800 psi, A36 carbon steel yield strength at 200 °F.

The flow stress results in the deformation of the steel plate above the air inlet vents, and produces a force through the section. The total force is:

$$F = 8(\sigma_f bt),$$

$$= 1.092 \times 10^6 \text{ pounds}$$

where:

b = 1.5 in., the width of the load bearing area

t = 2.0 in., the thickness of the stand

This force results in an acceleration to the loaded canister (weighing w_c = 54,730 pounds) of:

$$g = \frac{F}{w_C} = 19.95$$

The area of contact between the canister bottom and stand is twice as large as the cross-sectional area of the region that yields; therefore, the stand's platform will not be perforated. The expected crush distance, δ, of the crush area is computed by an energy balance equation. The crush distance is:

$$\delta = \frac{hw_c}{P_oA - w_c} = \frac{(6)(54{,}730 \times 1.1)}{(45{,}400)(8)(2)(1.5) - (54{,}730 \times 1.1)} = 0.35\text{in.}$$

which will reduce the height of the air inlet region by only 0.35 inches.

11.2.11.3 Radiological Consequences

There are no radiological consequences for this accident.

11.2.11.4 NAC-MPC Performance

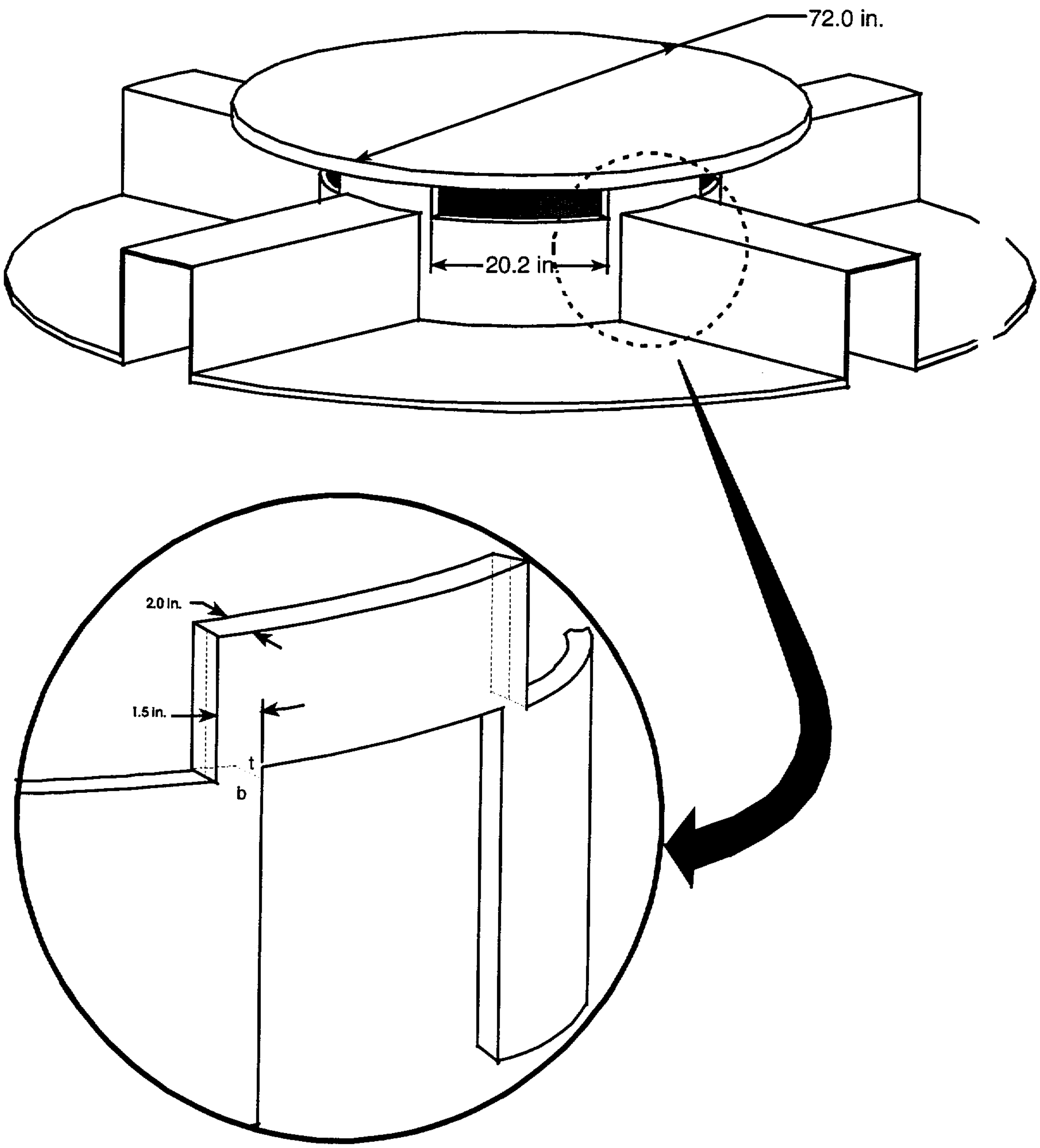
Evaluations of the NAC-MPC concrete storage cask for a 6-inch bottom end drop accident results in a maximum deceleration of 169.6 g for the storage cask, which does not reduce the shielding effectiveness of the cask. The base support, which contains the air inlets, is crushed approximately 0.35 inch. The effect of the reduction of the inlet area by the 6-inch drop is to reduce cooling air flow. The consequences of the loss of one-half of the air inlets is evaluated in Section 11.1.1, which bounds this condition.

The maximum deceleration of 19.95 g for the canister and its internals, as a result of the 6-inch storage cask drop, is bounded by the 56.1 g loading evaluated in Section 11.3, where the adequacy of the canister is demonstrated. The NAC-MPC storage cask system is structurally adequate to withstand a 6-inch drop accident.

11.2.11.5 Recovery and/or Corrective Actions

Even though the storage cask system remains functional and no immediate recovery steps are required, the canister should be moved to a new concrete storage cask as soon as one is available. The damaged storage cask should be inspected for stability, and repaired as required prior to continued use.

Figure 11.2.11-1 Storage Cask Base Plate



11.2.12 Tip Over of the Vertical Concrete Cask

This is a hypothetical accident condition that presents a bounding case for evaluation. There are no design basis accidents that result in the tip over of the vertical concrete cask (concrete cask).

11.2.12.1 Cause of Tip Over

A tip over event is possible in an earthquake that exceeds the design basis described in Section 11.2.2. There are no other events that are expected to result in a tip over of the concrete cask.

A tip over of the concrete storage cask would be observed during a survey of the site following the earthquake or other catastrophic event. The tipped over orientation of the concrete cask would be obvious by inspection.

11.2.12.2 Analysis of the Tip Over Event

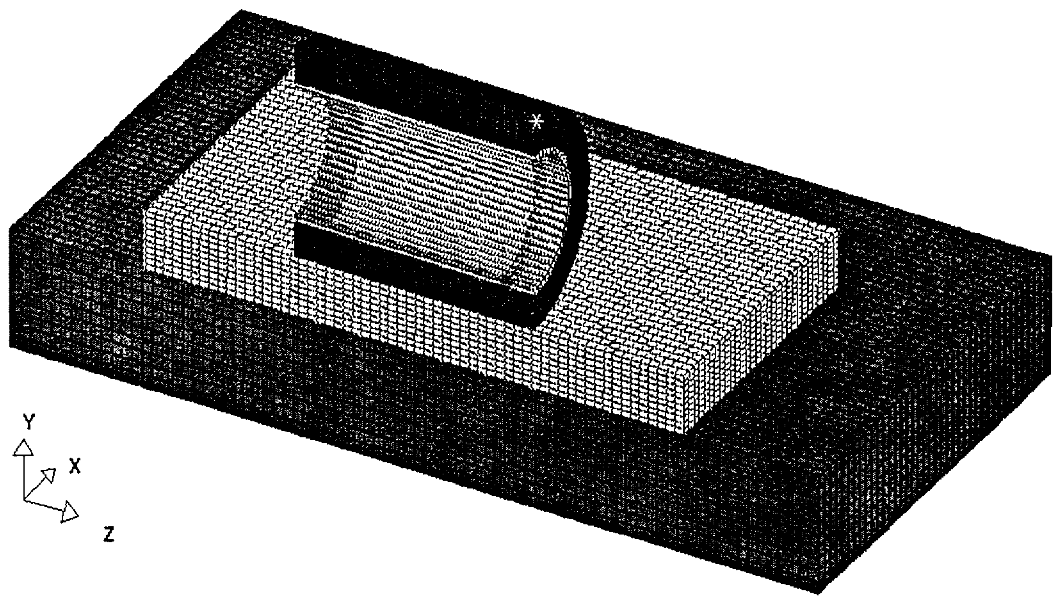
For a tip over event to occur, the center of gravity of the concrete cask and loaded canister must be displaced beyond the outer radius of the concrete cask, i.e., the point of rotation. When the center of gravity passes beyond the point of rotation, the potential energy of the concrete cask and canister will be converted to kinetic energy as the concrete cask and canister rotate toward a horizontal orientation on the ISFSI pad. The subsequent motion of the cask is governed by the structural characteristics of the cask, ISFSI pad, and underlying soil.

The objective of the evaluation of the response of the concrete cask during the tip over event is to determine the maximum acceleration to be used in the structural evaluation of the loaded canister and basket (Section 11.2.12.3). The methodology to determine the concrete cask response follows the methodology contained in NUREG/CR-6608 ("Summary and Evaluation of Low-Velocity Impact Tests of Solid Steel Billet Onto Concrete Pads"). The LS-DYNA program is used in this evaluation.

11.2.12.2.1 Model Description

As shown below, the finite element model includes a half section of the concrete cask, the concrete ISFSI pad and soil subgrade. The concrete pad in the model corresponds to a pad 30-feet by 30-feet square and 3-feet thick, supporting one concrete cask in the center of the pad. The soil under the concrete pad is considered to be 45-feet by 45-feet square and 6-feet thick. As

shown below, only one-half of the concrete cask, pad and soil configuration is modeled due to symmetry.



11.2.12.2.2 Material Properties

The concrete is represented as a homogeneous isotropic material. The concrete cask (outer shell) and the pad are modeled as material Type Number 16 in LS-DYNA. The required input data is:

Compressive strength	= 4,000 psi [1]
Density	= 125 pcf [2]
Poisson's Ratio	= 0.22
Modulus of Elasticity	= 2.917E6 psi
Bulk Modulus	= 1.736E6 psi

Notes:

1. The design strength is 4,000 psi for the concrete cask and ≤ 4,000 psi for the concrete pad. By modeling the compressive strength of the pad to be equal to that of the concrete cask, the evaluation is bounding.
2. The design density for the pad is between 125 pcf and 150 pcf. A density of 125 pcf is used in the model for the pad.

The design density for the soil beneath the ISFSI pad is between 85 lbs/ft^3 and 130 lbs/ft^3.

The material properties used in this model for the soil below the ISFSI pad are:

Density = 100 pcf
Poisson's Ratio (υ) = 0.4
Modulus of Elasticity = $\frac{1-\upsilon^2}{\alpha} k \sqrt{A_{pad}}$ psi (EPRI-TR-108760)

where:

A_{pad} = the area of the concrete pad in square inches
k = the soil stiffness
α = 1.08 for a square area

A soil stiffness of 250 psi/inch is used in this model and analysis. For the 30 x 30 square foot pad, the modulus of elasticity of the soil in this model is calculated as 70,000 psi. Analyses show that there is no significant effect on the calculated impact load using soil stiffness values up to 300 psi/inch.

The concrete cask steel liner has the properties:

Density = 0.284 lb/in^3
Poisson's ratio = 0.31
Modulus of elasticity = 2.9E7 psi

To account for the weight of the shield plug, the loaded canister, and the concrete cask pedestal, effective densities are used for the elements in the first row of the steel liner model adjacent to the impact plane of symmetry. These densities represent the regions (6° in the circumferential direction) of the steel liner subjected to the weight of the shield plug, the loaded canister and the pedestal, during the side impact (tip over) condition. The contact angle (6°) is determined based on the canister/basket analysis for the tip over condition (Section 11.2.12.3). Based on the status of the gap elements at the outer surface of the canister shell (representing the interface between the canister shell and the concrete cask steel liner) in the finite element model used in Section 11.2.12.3, the contact angle between the canister shell and the concrete cask liner is between 4.5° and 9° for the half-symmetry model.

11.2.12.2.3 Boundary Conditions and Initial Conditions

A friction coefficient of 0.25 is used at the interface between the steel liner and the concrete shell, between the concrete cask and the pad, and between the pad and the soil. For all the embedded faces (three side surfaces and the bottom surface) of the soil in the model, the displacements in the direction normal to the surface are restrained. The symmetry boundary conditions are applied for all nodes at the plane of symmetry.

The initial condition corresponds to the concrete cask in a horizontal position with an initial vertical velocity into the concrete pad. The pad and soil are initially at rest.

The initial velocity is simulated by applying an angular velocity (ω) of 1.516 radians/sec to the entire cask. The angular velocity value is computed by considering energy conservation at the cask "center of gravity over corner" tip condition versus the side impact condition.

From energy conservation:

$$mgh = \frac{I\omega^2}{2}$$

where:

mg = total weight of the loaded concrete cask = 206,094 lbs

h = height change of the concrete cask center of gravity (L_{CG}) = $\sqrt{R^2 + \left(\frac{L_{CG}}{2}\right)^2} - R$

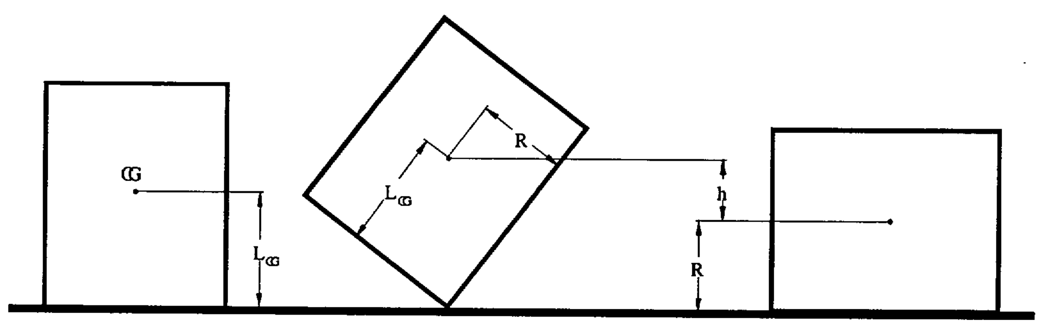
= 40.97 inches

where:

L_{CG} = location of the center of gravity above the pad for the concrete cask = 83.2 inches

R = radius of the concrete cask = 64 inches

I = total mass moment of inertia of the concrete cask about the pivot point = 7,352,751 lb-sec^2-inch



Concrete Cask Tip-Over Height Change

The mass moment of inertia for the concrete shell and the steel liner is calculated using the formula for a hollow right circular cylinder (Blevins).

$$I = \frac{m}{12}(3R_1^2 + 3R_2^2 + 4L^2) + md^2$$

where:

m = mass
R_1 and R_2 = the outer and inner radius of the cylinder
L = height of the cylinder
d = distance between the center of gravity and the pivot point

For the mass of the shield plug, loaded canister and the pedestal, the formula for the moment of inertia for a solid cylinder is used:

$$I = \frac{m}{12}(3R^2 + 4L^2) + md^2$$

where:

m = mass of the cylinder
R = radius of the cylinder
L = height of the cylinder
d = distance between the two pivot axes

The angular velocity is given by $\omega = \sqrt{\frac{2mgh}{I}}$ = 1.516 radians/sec

11.2.12.2.4 Filter Frequency

The accelerations are evaluated at the inner surface of the cask liner, which physically corresponds to the interface of the liner and the loaded canister nearest the plane of impact. Following the methodology contained in NUREG/CR-6608, the Butterworth filter is applied to the nodal accelerations. The filter frequency is based on the fundamental mode of the cask.

The fundamental natural frequency of a beam in transverse vibration due to flexure only is given by Blevins as:

$$f = \frac{\lambda^2}{2\pi}\sqrt{\frac{EI}{\rho AL^4}}$$

where:

$\lambda = 3.92660231$ for a pin-free beam

The frequencies of the concrete (f_c) and the steel liner (f_s) are computed as:

Area of concrete cask = $\pi\ \{(64)^2 - (43)^2\} = 2{,}247\pi\ in^2$

Moment of inertia of concrete cask = $\frac{\pi}{4}\{(64)^4 - (43)^4\} = 3{,}339{,}603.75\pi\ in^4$

$f_c = 31.1\ \lambda^2 = 479.5$ Hz

Area of steel liner = $\pi\ \{(43)^2 - (39.5)^2\} = 288.75\pi\ in^2$

Moment of inertia of steel liner = $\frac{\pi}{4}\{(43)^4 - (39.5)^4\} = 246{,}105.23\pi\ in^4$

$f_s = 36.1\ \lambda^2 = 556.6$ Hz

Since the concrete cask is short compared to its diameter, the contribution of the flexibility due to shear is also incorporated. This is accomplished by using Dunkerley's formula (Blevins). The system frequency is:

$$\frac{1}{f^2} = \frac{1}{f_c^2} + \frac{1}{f_s^2}$$

Thus, the system frequency is: $f = 363.3$ Hz. A cut-off frequency of 375 Hz is conservatively applied to filter the analysis results and measure the peak accelerations.

11.2.12.2.5 Results of the Transient Analysis

The accelerations at key locations of the concrete cask liner, which are required in the evaluation of the loaded canister/basket model (Section 11.2.12.3) are:

Acceleration at Specific Locations at the Concrete Cask Liner

Location on Component	Position Measured from the bottom of the Concrete Cask (inches)	Acceleration (g)
Top support disk	126.2	27.5
Top of the canister structural lid	145.6	31.4

11.2.12.2.6 Validation of the Analysis Methodology

Tip over tests of a steel billet onto a concrete pad were conducted and reported in NUREG/CR-6608. The purpose of the test was to provide data, against which, analysis methodology could be validated. Using the geometry described in the benchmark along with the modeling methodology, these analyses were performed using the soil input data in Section 11.2.12.2.2.

Using the filter frequency reported in the benchmark, the following results are obtained.

Comparison of Accelerations of NUREG/CR-6608 Benchmark

Nodes / Gauge Location	Maximum Experiment (g)	NAC Analysis (g)
16115 / A1	237.5	237.1
17265 / A5	231.5	229.4

11.2.12.3 Analysis of the Canister and Basket

Structural evaluations are performed for the transportable storage canister and fuel basket support disks for tip-over accident conditions. An ANSYS finite element model is used to evaluate this side impact loading condition. Based on the evaluation presented in Section 11.2.12.3.5, the bounding basket drop angle of 45° is used for the evaluation of tip over accident. Thermal conditions are bounded by evaluating the canister and basket using material properties at 75°F and applying the stress allowables for the maximum temperatures at the extreme heat thermal accident condition.

Comparison of maximum stress results to the allowable stress intensities shows that the canister and support disks are structurally adequate for the concrete cask tip over condition and satisfies the stress criteria in accordance with the ASME Code, Section III, Division I, Subsection NB and NG, respectively.

11.2.12.3.1 Canister and Basket Model

A finite element analysis, using the ANSYS program, is performed to evaluate the canister and support disks for the tip over accident condition. Output is in the form of linearized stresses taken across component sections. Additionally, a buckling evaluation is performed on the support disk in accordance with NUREG/CR-6322.

A symmetric one-half (180°) model is used to represent the upper portion of the canister and basket assembly, which is subject to the highest g-load during the tip over accident. As shown in Figure 11.2.12.3-1, the model consists of the upper portion of the canister, the top weldment and the five support disks. The canister is constructed using ANSYS solid (SOLID45) elements. ANSYS SHELL63 elements are used to model the top weldment and the support disks. The model for the canister assembly includes the shield and structural lids. Figure 11.2.12.3-2 shows the basket top weldment and five support disks. A detailed view of the basket support disk showing applied loads is shown in Figure 11.2.12.3-3. For the evaluation of the basket support disk, a basket angle of 45° is considered. This orientation is the most critical during side impact conditions. The weight of the fuel assembly, aluminum heat transfer disks, rods and spacers, and fuel tube (factored by appropriate g-load) are conservatively represented as concentrated forces at mid-span of the ligaments of the support disks.

The canister and basket model use ANSYS CONTAC52 and COMBIN40 elements to simulate contact between adjacent components. Interaction between the basket and canister is modeled using three-dimensional gap elements (CONTAC52) along the periphery of the support disks. Contact between the canister and concrete cask liner is also modeled using CONTAC52 elements. Contact between the canister's structural lid and shield lid is modeled using COMBIN40 combination elements in the axial (UY) degree of freedom. The backing ring is modeled using a ring of COMBIN40 spring gap elements connecting the shield lid and the canister in the axial direction at the lid lower outside radius. In addition, CONTAC52 elements are used to model interaction between the structural lid and canister shell, and the shield lid and canister shell, just below the respective lid weld joints. The size of the CONTAC52 gaps is determined from the nominal dimensions of contacting components. The COMBIN40 elements between the structural and shield lids are assigned a gap size of 0.08 inch, based on the flatness tolerances of the structural and shield lids. A gap of 1E-8 in. is used between the backing ring and shield lid. Note that the gap sizes in the axial direction do not have a significant effect on the side impact analysis results. All gap-spring elements are assigned a stiffness of 1E6 lb/in.

Symmetry boundary conditions are applied at the plane of symmetry of the model, as well as at the cut boundary of the model (canister shell near the 5^{th} support disk). All nodes on the concrete cask side gap elements at the outer surface of the canister shell are fixed in all degrees of freedom (UX, UY, and UZ). In addition, the axial (UY) and in-plane rotational degrees of freedom (ROTX and ROTZ) of the basket nodes are fixed.

Loading of the model includes an internal pressure of 11.5 psig (normal condition of storage) applied to the canister, concentrated loads are applied to all slots (except the central slot where there is no fuel assembly) and the inertial loads.

For the inertial loads, a maximum acceleration of 45 g is conservatively applied to the entire model. The maximum acceleration of the steel liner at the locations of the top support disk and the top of the canister lid during the tip over event is determined to be 27.5 g and 31.4 g, respectively. The main pulse of deceleration lasts for 30 milliseconds. To determine the effect of the rapid application of the inertia loading for the top support disk, a dynamic load factor (DLF) is computed using the mode shapes of a loaded support disk. The mode shapes are extracted using ANSYS for the first four modes. Using the acceleration time history developed

from Section 11.2.12.2, the DLFs for each modal frequency are computed using a single degree of freedom model. The maximum DLF and corresponding frequencies are:

Mode Number	Frequency (Hz)	DLF
1	44	1.61
2	169	1.09
3	234	1.02
4	273	1.03

Applying the maximum DLF to the 27.5g results in a peak acceleration of 44.4g. The canister lid region is significantly stiffer than the basket disk due to its monolithic structure. Applying the DLF of 1.09 to the maximum acceleration time history value of 31.4g results in a maximum of 34.2g. Therefore, applying 45g to the entire canister/basket model is conservative.

A uniform temperature of 75°F is applied to the model to determine material properties during solution. During post processing, temperatures of 575°F and 372°F are conservatively used for the support disks and the canister, respectively, to determine the allowable stresses. These temperatures are the maximum calculated temperatures for the accident (extreme heat) thermal condition (ambient temperature = 125°F).

11.2.12.3.2 Analysis Results for the Canister

The stress results of the canister for the tip over accident condition are summarized in Tables 11.2.12.3-1 and 11.2.12.3-2 for primary membrane and primary membrane plus bending stresses, respectively. The sectional stresses at 14 axial locations are obtained for each angular division of the model (a total of 41 angular locations for each axial location). The locations for the stress sections are shown in Figure 11.2.12.3-4.

The stress evaluation for the canister is performed in accordance with the ASME Code, Section III, Subsection NB, by comparing the linearized stresses of cross sections of the structure against the allowable stresses. Allowable stresses are conservatively taken at a temperature of 372°F (maximum canister temperature is 319°F for normal condition of storage). The allowable stresses for accident conditions are taken from Subsection NB as shown below. S_m and S_u are 16.05 ksi and 59.17 ksi, respectively, for Type 304L stainless steel (canister shell and structural lid). S_m and S_u are 19:06 ksi and 64.85 ksi, respectively, for Type 304 stainless steel (shield lid).

	Accident (Level D) Allowable Stress
P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

During the tip over accident, the canister shell at the structural and shield lids is subjected to the inertial load of the lids, which results in highly localized bearing stresses (Sections 8 through 12 at angular locations of 0 and 4.5 degrees). This stress is predominant because the weights of the structural and shielding lids are transferred to the canister shell through the thickness of the weld (7/8 inch weld for structural lid and 1 inch weld for shield lid). According to ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions. Therefore, the P_m stresses are not presented for the region local to the impact (angular locations of 0 and 4.5 degree) for Sections 8, 9, and 10 in Table 11.2.12.3-1. Stresses are conservatively presented for all locations (including bearing region) for Sections 11.

The inertial load of the shield lid also results in localized bending stresses at the canister shell (at the shield lid weld, i.e., Section 8). This stress state is identified as the case of a cylindrical shell at the junction with a head, as shown in Table NB-3217-1 of the ASME Code, Section III, Subsection NB. The localized bending stress at the structural discontinuity is classified as secondary (Q) stress. In accordance with ASME Section III, Appendix F, secondary stresses are not considered for the stress evaluation for Level D (accident) conditions. Therefore, the P_m+P_b stresses are not presented for the region local to the impact for Section 8 (angular locations of 0 and 4.5 degree) in Table 11.2.12.3-2.

The stress evaluation results for tip-over accident conditions show that the minimum margin of safety in the canister is +0.02 for P_m (Section 12) and +0.10 for P_m+P_b (Section 10).

11.2.12.3.3 Analysis Results for the Support Disk

To evaluate the most critical regions of the support disk, a series of cross sections are considered. To aid in the identification of these sections, Figure 11.2.12.3-5 shows the locations on a support disk. Table 11.2.12.3-3 lists the cross sections versus Point 1 and Point 2, which spans the cross section of the ligament in the plane of the support disk.

The stress evaluation for the support disk is performed according to ASME, Section III, Subsection NG. According to this subsection, linearized stresses of cross sections of the structure are to be compared against the allowable stresses. The allowable stresses for tip over accident conditions are taken from Subsection NG as shown below at the maximum support disk temperature of 575°F (accident-extreme heat). The S_m and S_u are 42.3 ksi and 127.1 ksi, respectively, for 17-4 PH stainless steel.

	Accident (Level D) Allowable Stresses
P_m	Lesser of 0.7 S_u or 2.4 S_m
P_m+P_b	Lesser of 1.0 S_u or 3.6 S_m

The stress evaluation results for the support disks for tip-over impact condition are presented in Tables 11.2.12.3-4 through 11.2.12.3-13. The tables list the 40 highest P_m and P_m+P_b stress intensities for Disks 1 through 5. The minimum margin of safety is +0.21, which occurs in Disk 5 (See Figure 11.2.12.3-4 for identification of support disks). The highest P_m and P_m+P_b stresses occur in Disk 5, with the minimum margin of safety of 1.51 and 0.21, respectively. Locations of the 10 highest P_m and P_m+P_b linearized stresses for Disk 5 are given in Figure 11.2.12.3-6 and 11.2.12.3-7.

11.2.12.3.4 Support Disk Buckling Evaluation

The fuel basket support disks are subjected to compressive and/or inertial loads during impact conditions. For the tip-over accident, the support disks experience in-plane loads. The in-plane loads apply compressive forces and in-plane bending moments on the support disk. Buckling of the support disk is evaluated in accordance with the methods and acceptance criteria of NUREG/CR-6322. Because the ASME Code identifies 17-4PH disk material as ferritic steel, the formulas for non-austenitic steel are used.

The buckling evaluation of the support disk web is based on the Interaction Equations 31 and 32 in NUREG/CR-6322. These two equations adopt the "Limit Analysis Design" approach for structural members subjected to stresses beyond the yield limit of the material, i.e., for members deformed elastically as a result of axial load or bending moment. Other equations applicable to the calculations are noted as they are applied. The maximum forces and moments for the tip-over accident are based on the finite element analysis stress results.

<u>Symbols and Units</u>

P = applied axial compressive loads, kips
M = applied bending moment, kips-inch
P_a = allowable axial compressive load, kips
P_{cr} = critical axial compression load, kips
P_e = Euler buckling loads, kips
P_y = average yield load, equal to profile area times specified minimum yield stress, kips (for normal operating condition)
C_c = column slenderness ratio separating elastic and inelastic buckling
C_m = coefficient applied to bending term in interaction equation
M_m = critical moment that can be resisted by a plastically designed member in the absence of axial load, kip-in.
M_p = plastic moment, kip-in.
F_a = axial compressive stress permitted in the absence of bending moment, ksi
F_e = Euler stress for a prismatic member divided by factor of safety, ksi
k = ratio of effective column length to actual unsupported length
l = unsupported length of member, in.
r = radius of gyration, in.
S_y = yield stress, ksi
A = cross sectional area of member, in^2
Z_x = plastic section modulus, in^3
λ = allowable reduction factor, dimensionless

From NUREG/CR-6322, the following equations are used to evaluate the support disk:

$$\frac{P}{P_{cr}} + \frac{C_m M}{M_m \left[1 - \frac{P}{P_e}\right]} \leq 1.0 \qquad \text{(Equation 31)}$$

$$\frac{P}{P_y} + \frac{M}{1.18\,M_p} \leq 1.0 \qquad \text{(Equation 32)}$$

where:

$$P_{cr} = 1.7 \times A \times F_a$$

$$F_a = \frac{P_a}{A} \quad \text{for} \quad P_a = P_y \left[\frac{1 - \frac{\lambda^2}{4}}{1.11 + 0.5\lambda + 0.17\lambda^2 - 0.28\lambda^3}\right]$$

and $\lambda = \frac{1}{\pi}\left(\frac{kl}{r}\right)\sqrt{\frac{S_y}{E}}$ (accident conditions)

$$Pe = 1.92 \times A \times Fe$$

$$F_e = \frac{\pi^2 \cdot E}{1.3\left(\frac{k \cdot l}{r}\right)^2} \qquad \text{(Level D–Accident)}$$

$$P_y = S_y \times A$$

$C_m =$ 0.85 for members with joint translation (sideways)

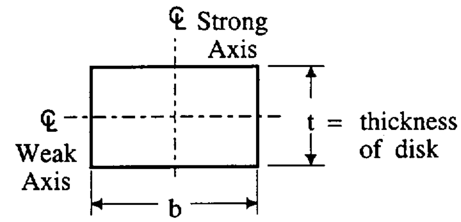
$$M_p = S_y \times Z_x$$

$$M_m = M_p \cdot \left(1.07 - \frac{\left(\frac{l}{r}\right) \cdot \sqrt{S_y}}{3160}\right) \leq M_p$$

Buckling evaluation is performed in all sections in the disk ligaments defined in Figure 11.2.12.3-5. Using the cross-sectional stresses calculated at each section located in the web for each loading condition the maximum corresponding compressive forces (P) and bending moment (M) are determined as:

$$P = \sigma_m A$$

$$M = \sigma_b S$$



where, σ_m is the membrane stress, σ_b is the bending stress, A is the area (b × t), and S is the section modulus ($tb^2/6$).

To determine the margin of safety:

$$P_1 = P/P_{cr} \qquad M_1 = \frac{C_m M}{(1 - P/P_e)M_m} \qquad (P_1 + M_1 \leq 1)$$

and

$$P_2 = P/P_y \qquad M_2 = \frac{M}{1.18\,M_p} \qquad (P_1 + M_1 \leq 1)$$

The margins of safety are:

$$MS1 = \frac{1}{P_1 + M_1} - 1$$

and

$$MS2 = \frac{1}{P_2 + M_2} - 1$$

Buckling evaluation results are provided in Tables 11.2.12.3-14 through 11.2.12.3-18. As the tables demonstrate, the support disks meet the requirements of NUREG/CR-6322.

11.2.12.3.5 Basket Impact Orientation Evaluation

This section presents the justification for considering the 45° basket impact orientation as the bounding case for the support disk evaluation for the concrete cask tip-over accident.

Due to the symmetry of the basket, three basket impact angles, 0°, 22.9° and 45° (shown in Figure 11.2.12.3-8) with two side impact conditions (20g and 55g) are considered in the evaluation. The orientation angles of 22.9° and 45° are selected because a minimal ligament between the corner of the fuel assembly slot and the disk outer radius occurs at those orientations. The evaluation in this section shows that the maximum stresses occur for the 45° impact orientation and, thus, the 45° impact orientation is the bounding case for the support disk evaluation.

As shown in Figure 11.2.12.3-9, a finite element model for the support disk is generated using the ANSYS program to perform analyses for six side impact cases:

Case No.	Side Impact Acceleration (g)	Basket Orientation (Degree)
1	20	0
2	20	22.9
3	20	45
4	55	0
5	55	22.9
6	55	45

The model consists of a support disk and a section of the canister shell, as shown in Figure 11.2.12.3-9. ANSYS SHELL63 elements are used to model the disk and canister. As shown in Figure 11.2.12.3-10, CONTAC52 elements are used to simulate the interface between the support disk and the canister shell. A value of 1.0 x 10^6 lb/inch is used for the stiffness of CONTAC52 elements. BEAM3 elements with very small properties (Area = 5 x 10^{-4} inch^2, I_{zz} = 5 x 10^{-2} inch^4, Modulus of Elasticity = 1 psi) are applied at the same locations as the CONTAC52 elements to prevent rigid body motion of the model. The canister shell outer diameter is constrained to prevent translation of the canister. Applying a concentrated load (with the acceleration factor) simulates the fuel assembly and tube weight at the mid-span of each ligament. The value of the force varies according to the impact orientation. There is no fuel

assembly in the center slot of the basket; therefore, no forces are applied at the ligaments of the center slot.

The maximum nodal stress intensity for each basket impact orientation angle (0°, 22.9° and 45° [20 g and 55 g]) is summarized as:

Basket Side Impact Orientation	Maximum Stress Intensity (ksi)	
	20 g	55 g
0°	33.3	84.1
22.9°	48.1	81.8
45°	48.9	85.3

The maximum stress intensity occurs in the 45° orientation case. Therefore, it is concluded that the 45° orientation is the bounding case for the support disk evaluations for the concrete cask tip-over event.

11.2.12.4 Radiological Consequences

There is an adverse radiological consequence in the hypothetical tipover event, since the bottom end of the storage cask and the canister have significantly less shielding than the sides and tops of these same components. The dose rate at 1 meter is calculated to be approximately 156 rem/hour, and the dose at 5 meters is estimated to be approximately 1 rem/ hour. Consequently, following a tip-over event, supplemental shielding should be used until the concrete cask can be righted. Stringent access controls must be applied to ensure that personnel do not enter the area of radiation shine from the exposed bottom of the tipped over concrete cask.

11.2.12.5 NAC-MPC Performance

Functionally the NAC-MPC does not suffer significant adverse consequences from the tip over event. The storage cask and canister maintain design basis shielding, geometry control of contents, and contents confinement performance requirements.

Damage to the edges or surface of the concrete cask may occur in the tipover, which could result in marginally higher dose rates at the bottom edge or at surface cracks in the concrete. This

increased dose rate is not expected to be significant, but would be dependent on the specific damage incurred.

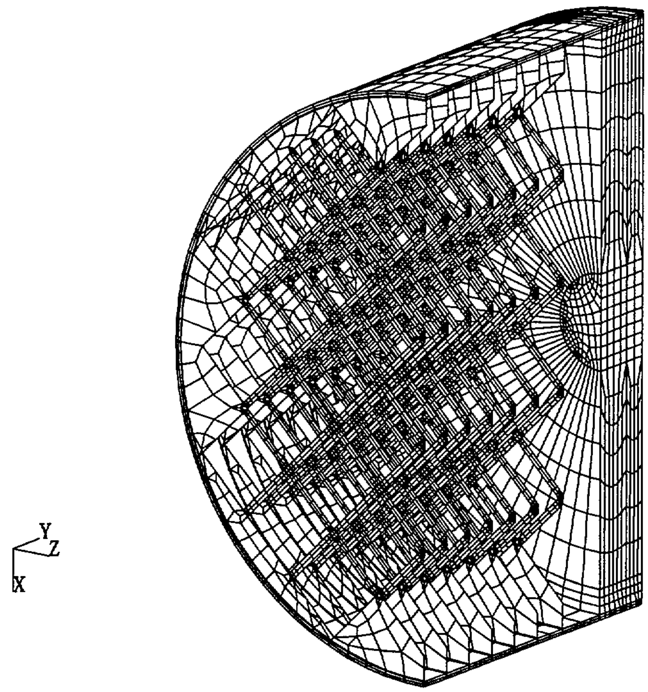
11.2.12.6 Recovery and/or Corrective Actions

The most important recovery step required following a cask tip-over accident is the uprighting of the concrete cask to eliminate the high dose rate from the exposed bottom end. The uprighting operation will require a heavy lift capability and rigging expertise. The concrete cask must be returned to the vertical by rotation around a convenient bottom edge. The concrete cask should be returned to the vertical using a method and rigging that controls the rotation to vertical.

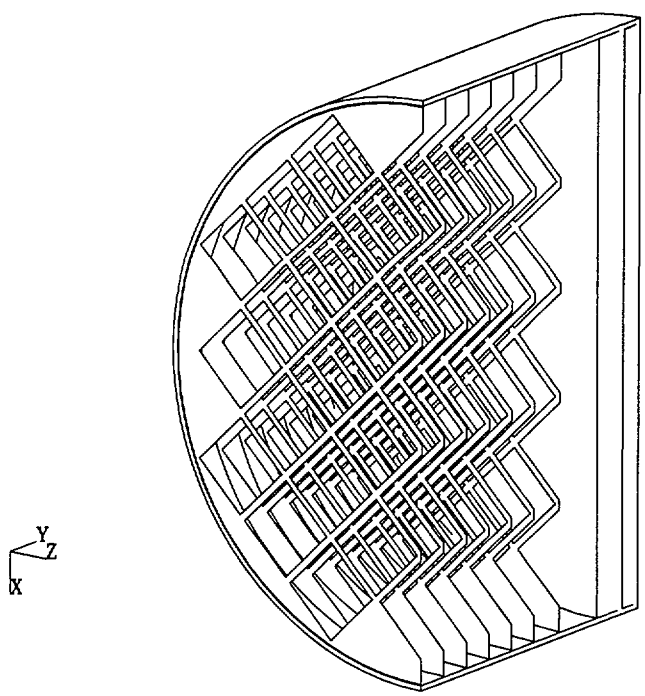
Surface and top and bottom edges of the concrete cask would be expected to exhibit cracking and possibly loss of concrete down to the layer of reinforcing bar. If only minor damage occurs, the concrete may be repairable using grout. Otherwise, it may be necessary to remove the canister and install it in a new storage cask.

The storage pad must be repaired to preclude the intrusion of water that could cause further deterioration of the pad in freeze-thaw cycles.

Figure 11.2.12.3-1 Three-Dimensional Canister and Basket Model



Model With Element Edges Displayed



Model Without Element Edges Displayed

Figure 11.2.12.3-2 Basket Assembly

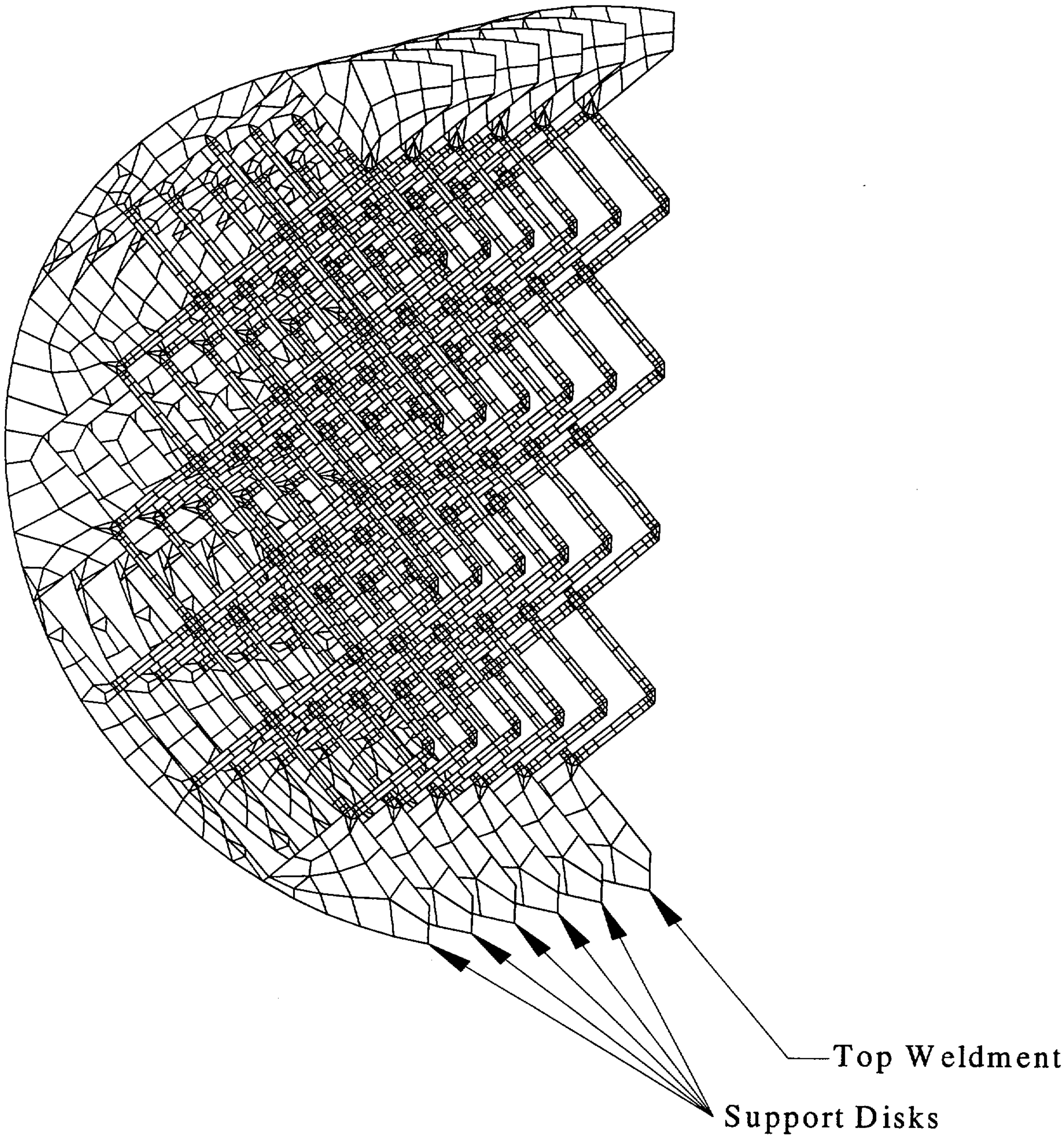


Figure 11.2.12.3-3 Support Disk Detail

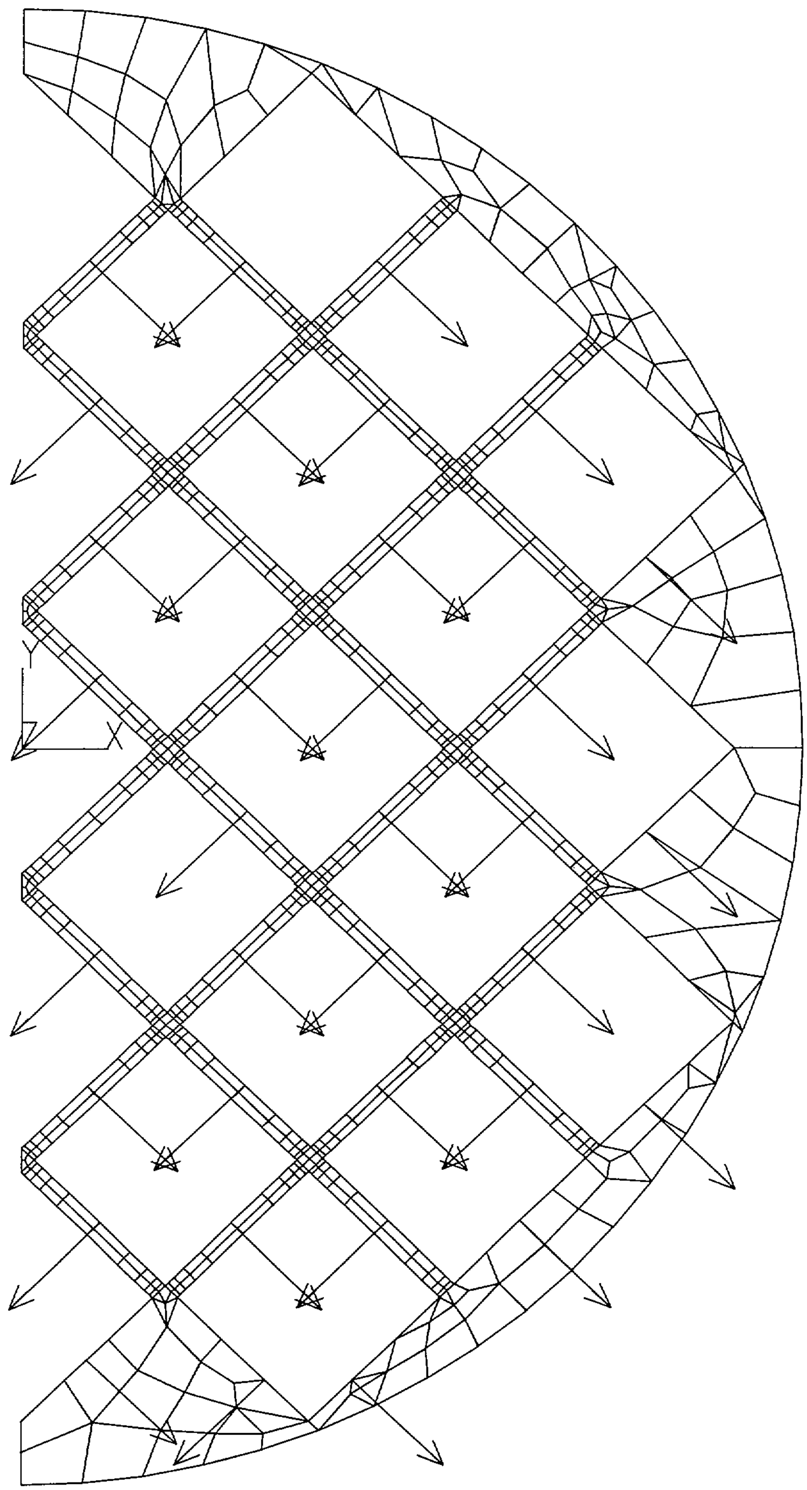


Figure 11.2.12.3-4 Canister Stress Sections Locations

Section	Node 1		Node 2	
	X	Y	X	Y
1	34.695	84.720	35.320	84.720
2	34.695	89.130	35.320	89.130
3	34.695	93.540	35.320	93.540
4	34.695	97.950	35.320	97.950
5	34.695	102.360	35.320	102.360
6	34.695	107.250	35.320	107.250
7	34.695	114.500	35.320	114.500
8	34.695	118.500	35.320	118.500
9	34.695	119.500	35.320	119.500
10	34.695	121.620	35.320	121.620
11	34.695	118.500	34.695	119.500
12	34.695	121.620	34.695	122.500
13	0.000	114.500	0.000	119.480
14	0.000	119.520	0.000	122.500

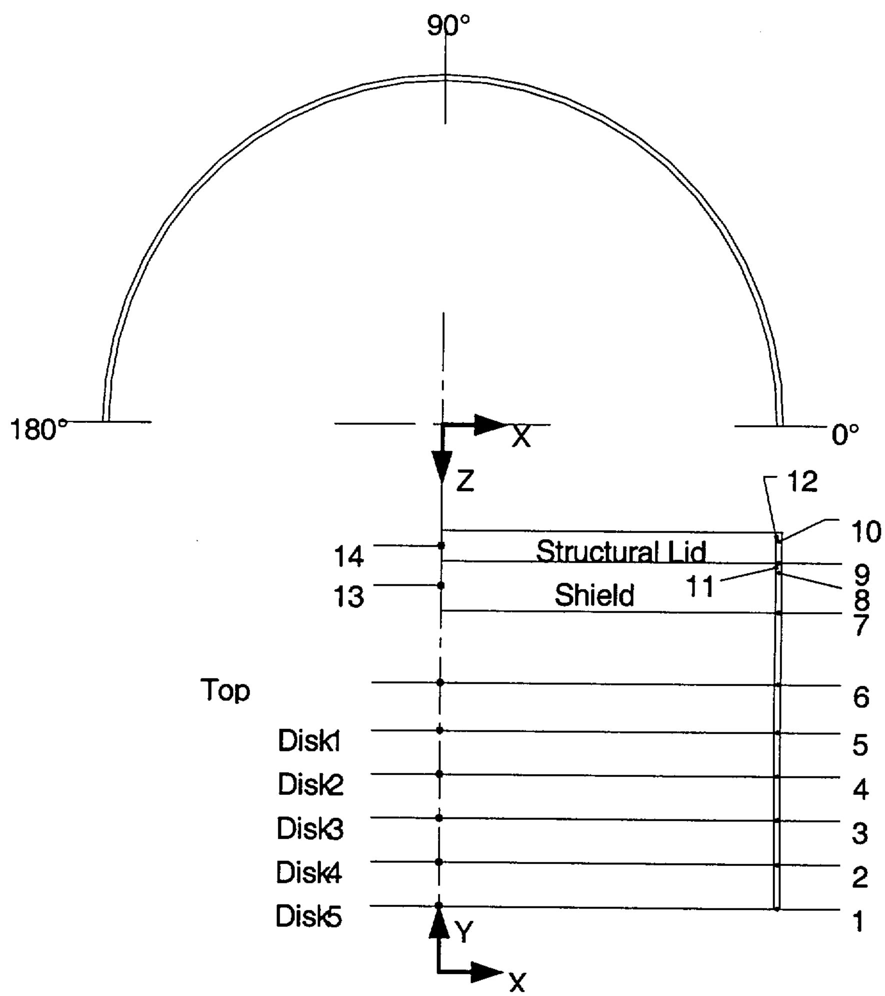


Figure 11.2.12.3-5 Location of Support Disk Sections to Obtain Linearized Stresses

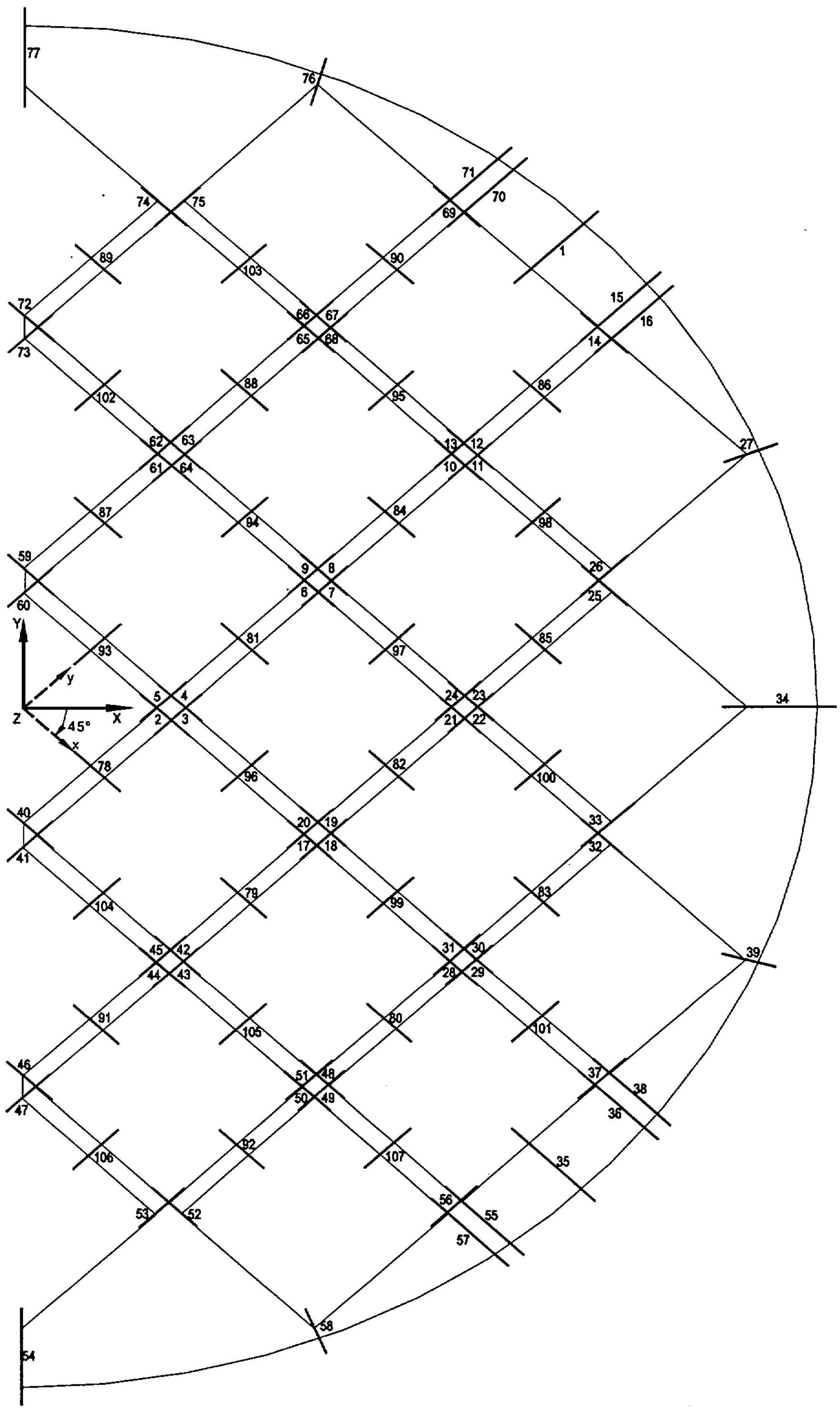


Figure 11.2.12.3-6 Locations of the 10 Highest P_m Support Disk Linearized Stress Sections

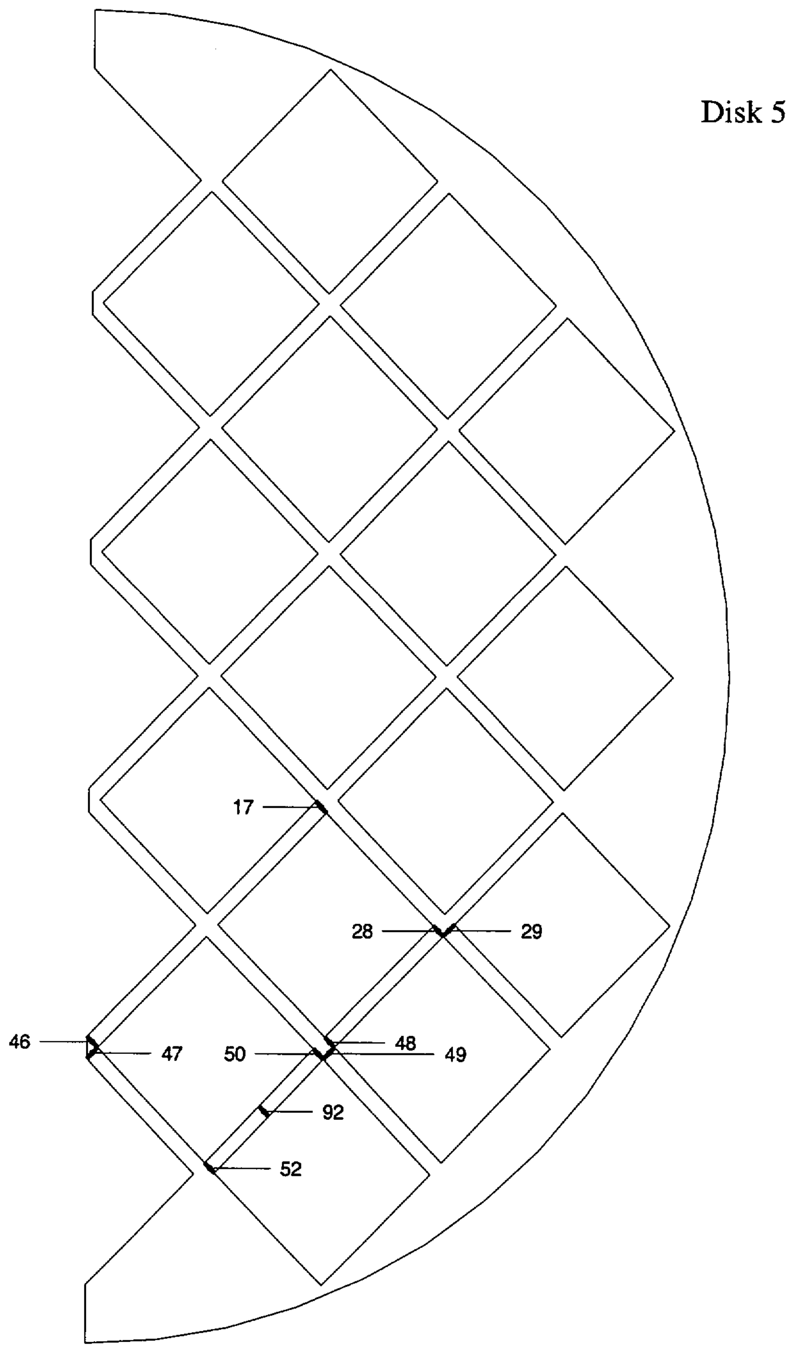


Figure 11.2.12.3-7 Locations of the 10 Highest P_m+P_b Support Disk Linearized Stress Sections

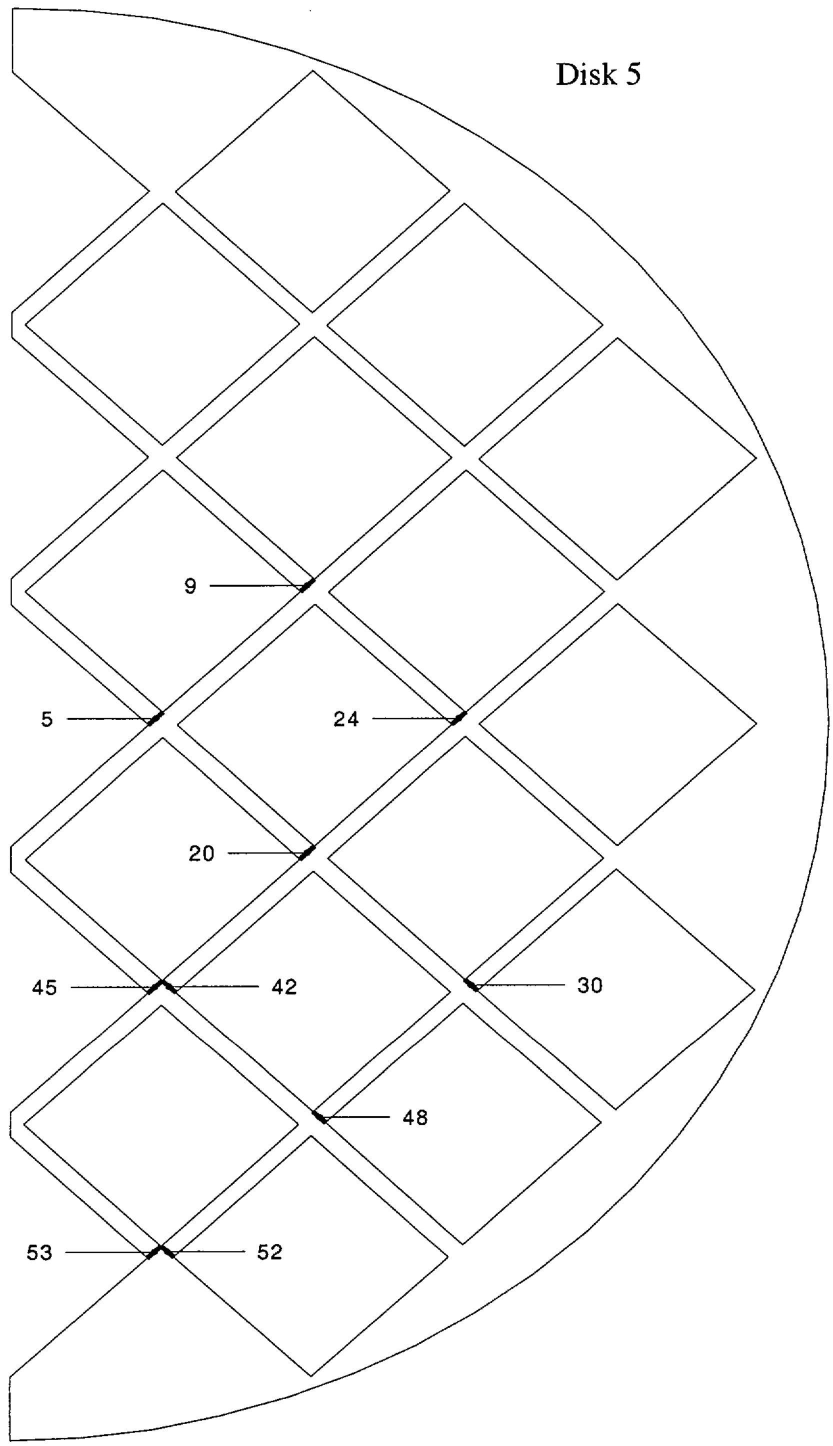


Figure 11.2.12.3-8 Evaluated Basket Impact Orientations

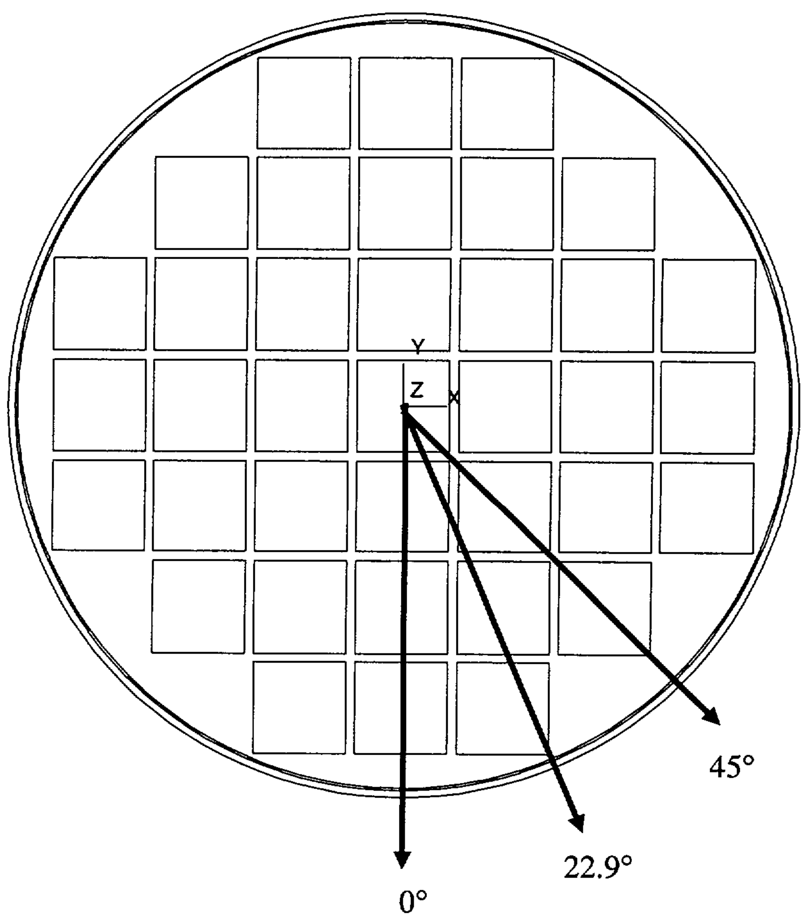


Figure 11.2.12.3-9 ANSYS Model for the Support Disk

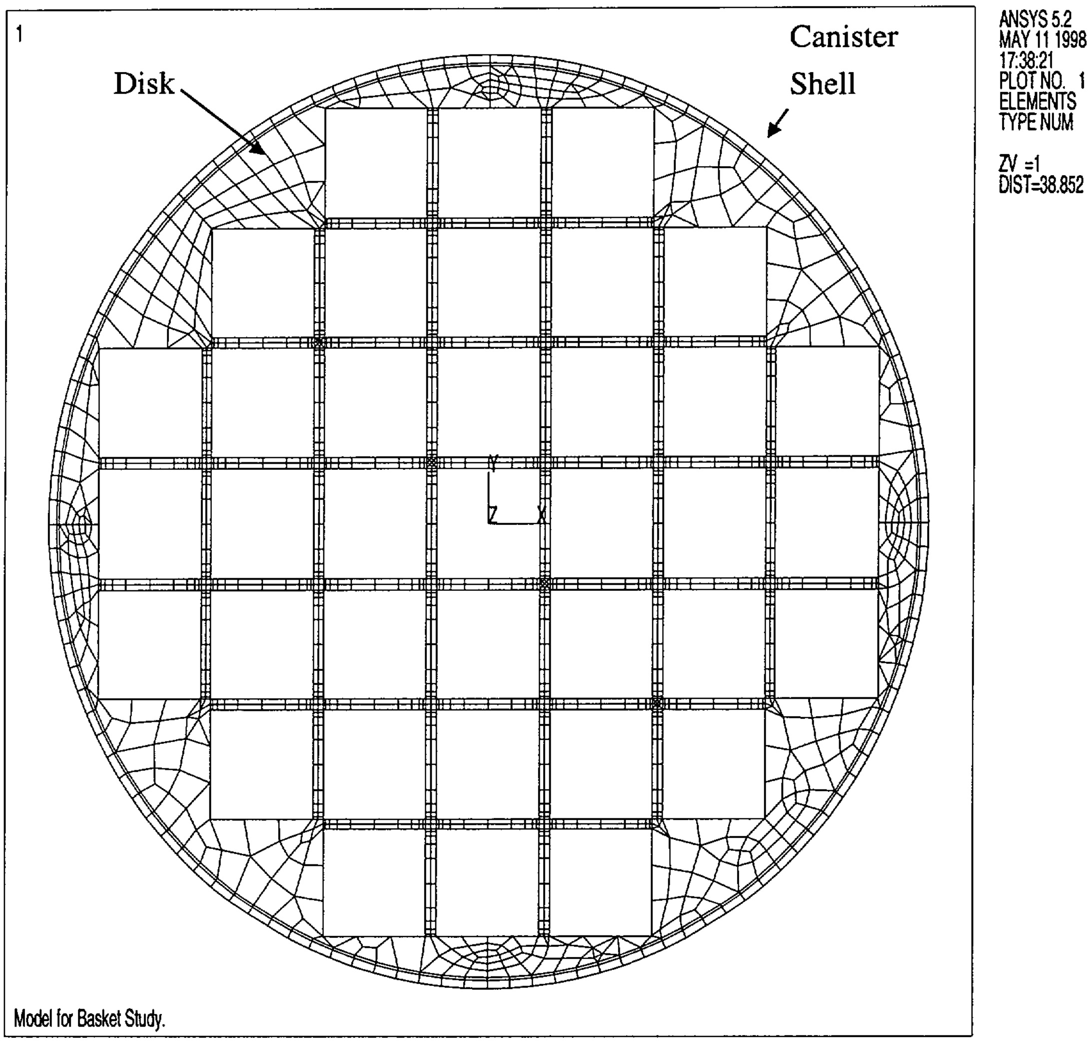


Figure 11.2.12.3-10 Support Disk ANSYS Model Detail

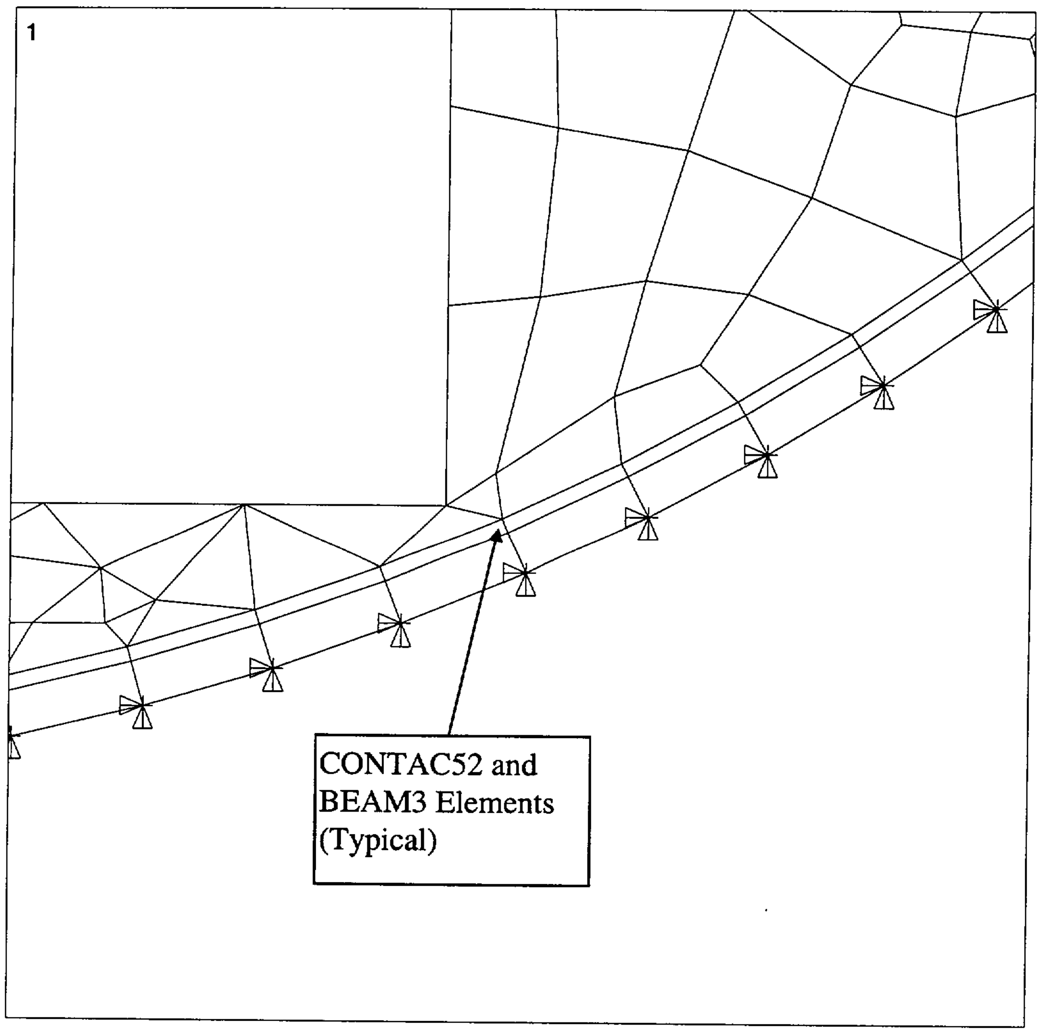


Table 11.2.12.3-1 Canister Primary Membrane Stresses[1]

Section	Angle (deg)	Sx (ksi)	Sy (ksi)	Sz (ksi)	Sxy (ksi)	Syz (ksi)	Sxz (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	0.00	-4.10	16.60	-3.80	1.70	-0.10	0.90	21.67	38.52	0.78
2	0.00	-1.20	15.20	-3.30	0.00	-0.20	0.60	18.67	38.52	1.06
3	0.00	-1.80	12.50	-2.80	-0.30	-0.20	0.30	15.40	38.52	1.50
4	99.00	0.00	4.10	-3.90	0.00	7.20	0.20	16.43	38.52	1.34
5	94.50	0.10	3.80	-2.00	0.00	9.40	0.00	19.63	38.52	0.96
6	90.00	0.00	1.40	-0.50	-0.10	11.50	0.00	23.08	38.52	0.67
7	85.50	0.00	-0.40	-0.40	0.00	11.40	0.00	22.85	38.52	0.69
8[2]	9.00	-0.07	0.79	8.71	3.16	-5.83	-1.10	16.13	38.52	1.39
9[2]	9.00	4.42	-0.51	5.04	0.45	-3.07	-1.77	9.36	38.52	3.12
10[2]	9.00	4.81	-3.21	1.56	1.88	-3.33	0.50	10.53	38.52	2.66
11	0.00	-37.60	-22.30	-37.70	0.60	-2.40	-9.70	25.84	38.52	0.49
12	0.0-4.5	-31.18	-15.03	-8.88	4.89	-1.41	-1.22	24.25	24.65[3]	0.02
13	0.00	-1.10	0.40	0.00	0.00	0.00	-0.10	1.55	45.74	28.51
14	0.00	-1.50	0.40	0.00	0.00	0.00	0.00	1.97	38.52	18.57

Notes:

1 Stresses are in cylindrical coordinate system (x-radial, y-circumferential, z-axial).

2 Stresses are not presented for the region with localized bearing stresses. Per ASME Section III, Appendix F, bearing stresses need not be evaluated for Level D service (accident) conditions.

3 Includes two stress reduction factors for weld = 0.8 x 0.8 = 0.64 (See Section 11.5.1).

Table 11.2.12.3-2 Canister Primary Membrane + Bending Stresses[1]

Section	Angle (deg)	Sx (ksi)	Sy (ksi)	Sz (ksi)	Sxy (ksi)	Syz (ksi)	Sxz (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
1	0.00	-4.40	32.20	-0.50	1.20	-0.30	0.90	36.87	57.79	0.57
2	0.00	-1.90	29.50	0.70	-0.60	-0.50	-0.60	31.63	57.79	0.83
3	0.00	-2.70	25.90	1.60	-0.80	-0.20	0.40	28.72	57.79	1.01
4	0.00	-2.10	24.90	-0.20	-0.60	0.00	-0.10	26.96	57.79	1.14
5	0.00	-2.90	22.60	2.00	0.40	0.10	0.00	25.51	57.79	1.27
6	90.00	0.00	1.80	2.00	-0.10	14.40	0.00	28.89	57.79	1.00
7	0.00	-1.50	-42.70	-27.80	5.20	-2.20	-1.10	42.76	57.79	0.35
8[2]	9.00	0.43	10.41	29.77	0.37	-2.53	0.86	45.14	57.79	0.28
9	0.00	-16.50	-11.60	27.90	-1.80	-2.80	-10.2	49.72	57.79	0.16
10	0.00	-30.60	-17.90	21.20	-2.10	-2.30	3.00	52.62	57.79	0.10
11	0.00	-21.60	-13.00	-19.10	0.90	-0.90	-15.00	30.23	57.79	0.91
12	0.0-4.5	-30.92	-13.32	-6.14	5.70	-0.80	1.30	26.66	36.99[3]	0.37
13	0.00	-1.30	0.70	0.00	0.00	0.00	-0.10	1.94	57.79	28.76
14	0.00	-0.90	1.50	0.00	0.00	0.00	0.00	2.44	57.79	22.73

Notes:

1 Stresses are in cylindrical coordinate system (x-radial, y-circumferential, z-axial).

2 Stresses are not presented for the region with bearing stress (membrane) and secondary (Q) stress (bending). Per ASME Section III, Appendix F, both bearing stresses and secondary stresses are not required for evaluation for Level D service (accident) conditions.

3 Includes two stress reduction factors for weld = 0.8 x 0.8 = 0.64 (See Section 11.5.1).

Table 11.2.12.3-3 Listing of Cross Sections for Stress Evaluation of Support Disk

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
1	1	2	22.15	22.15	24.39	24.39
2	3	4	5.84	0	6.46	-0.62
3	5	6	6.46	-0.62	7.07	0
4	7	8	7.07	0	6.46	0.62
5	9	10	6.46	0.62	5.84	0
6	11	12	12.29	6.46	12.91	5.84
7	13	14	12.91	5.84	13.48	6.41
8	15	16	13.48	6.41	12.86	7.03
9	17	18	12.86	7.03	12.29	6.46
10	19	20	18.7	12.86	19.32	12.25
11	21	22	19.32	12.25	19.85	12.78
12	23	24	19.85	12.78	19.23	13.4
13	25	26	19.23	13.4	18.7	12.86
14	27	28	25.07	19.23	25.69	18.61
15	29	30	25.07	19.23	27.13	21.3
16	31	32	25.69	18.61	27.67	20.59
17	33	34	12.29	-6.46	12.86	-7.03
18	35	36	12.86	-7.03	13.48	-6.41
19	37	38	13.48	-6.41	12.91	-5.84
20	39	40	12.91	-5.84	12.29	-6.46
21	41	42	18.75	0	19.32	-0.57
22	43	44	19.32	-0.57	19.89	0
23	45	46	19.89	0	19.32	0.57
24	47	48	19.32	0.57	18.75	0
25	49	50	25.16	6.41	25.73	5.84
26	51	52	25.16	6.41	25.69	6.94
27	53	54	31.52	12.78	31.97	12.96
28	55	56	18.7	-12.86	19.23	-13.4
29	57	58	19.23	-13.4	19.85	-12.78
30	59	60	19.85	-12.78	19.32	-12.25
31	61	62	19.32	-12.25	18.7	-12.86
32	63	64	25.16	-6.41	25.69	-6.94
33	65	66	25.16	-6.41	25.73	-5.84
34	67	68	31.57	0	34.49	0
35	69	70	22.15	-22.15	24.39	-24.39
36	71	72	25.07	-19.23	27.13	-21.3
37	73	74	25.07	-19.23	25.69	-18.61
38	75	76	25.69	-18.61	27.67	-20.59
39	77	78	31.52	-12.78	31.95	-12.9
40	79	80	0	-5.84	0.62	-6.46
41	81	82	0.62	-6.46	0	-7.07
42	83	84	6.46	-12.29	7.03	-12.86
43	85	86	7.03	-12.86	6.41	-13.48
44	87	88	6.41	-13.48	5.84	-12.91

Table 11.2.12.3-3 Listing of Cross Sections for Stress Evaluation of Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
45	89	90	5.84	-12.91	6.46	-12.29
46	91	92	0	-18.75	0.57	-19.32
47	93	94	0.57	-19.32	0	-19.89
48	95	96	12.86	-18.7	13.4	-19.23
49	97	98	13.4	-19.23	12.78	-19.85
50	99	100	12.78	-19.85	12.25	-19.32
51	101	102	12.25	-19.32	12.86	-18.7
52	103	104	6.41	-25.16	6.94	-25.69
53	105	106	6.41	-25.16	5.84	-25.73
54	107	108	0	-31.57	0	-34.49
55	109	110	19.23	-25.07	21.3	-27.13
56	111	112	19.23	-25.07	18.61	-25.69
57	113	114	18.61	-25.69	20.59	-27.67
58	115	116	12.78	-31.52	12.96	-31.97
59	117	118	0	7.07	0.62	6.46
60	119	120	0.62	6.46	0	5.84
61	121	122	6.46	12.29	5.84	12.91
62	123	124	5.84	12.91	6.41	13.48
63	125	126	6.41	13.48	7.03	12.86
64	127	128	7.03	12.86	6.46	12.29
65	129	130	12.86	18.7	12.25	19.32
66	131	132	12.25	19.32	12.78	19.85
67	133	134	12.78	19.85	13.4	19.23
68	135	136	13.4	19.23	12.86	18.7
69	137	138	19.23	25.07	18.61	25.69
70	139	140	19.23	25.07	21.3	27.13
71	141	142	18.61	25.69	20.59	27.67
72	143	144	0	19.89	0.57	19.32
73	145	146	0.57	19.32	0	18.75
74	147	148	6.41	25.16	5.84	25.73
75	149	150	6.41	25.16	6.94	25.69
76	151	152	12.78	31.52	12.9	31.95
77	153	154	0	31.57	0	34.49
78	155	156	2.92	-2.92	3.54	-3.54
79	157	158	9.37	-9.37	9.95	-9.95
80	159	160	15.78	-15.78	16.31	-16.31
81	161	162	9.37	3.54	9.99	2.92
82	163	164	15.83	-2.92	16.4	-3.49
83	165	166	22.24	-9.33	22.77	-9.86
84	167	168	15.78	9.95	16.4	9.33
85	169	170	22.24	3.49	22.81	2.92
86	171	172	22.15	16.31	22.77	15.69
87	173	174	3.54	9.37	2.92	9.99
88	175	176	9.95	15.78	9.33	16.4
89	177	178	3.49	22.24	2.92	22.81

Table 11.2.12.3-3 Listing of Cross Sections for Stress Evaluation of Support Disk (continued)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
90	179	180	16.31	22.15	15.69	22.77
91	181	182	2.92	-15.83	3.49	-16.4
92	183	184	9.33	-22.24	9.86	-22.77
93	185	186	2.92	2.92	3.54	3.54
94	187	188	9.37	9.37	9.95	9.95
95	189	190	15.78	15.78	16.31	16.31
96	191	192	9.37	-3.54	9.99	-2.92
97	193	194	15.83	2.92	16.4	3.49
98	195	196	22.24	9.33	22.77	9.86
99	197	198	15.78	-9.95	16.4	-9.33
100	199	200	22.24	-3.49	22.81	-2.92
101	201	202	22.15	-16.31	22.77	-15.69
102	203	204	2.92	15.83	3.49	16.4
103	205	206	9.33	22.24	9.86	22.77
104	207	208	3.54	-9.37	2.92	-9.99
105	209	210	9.95	-15.78	9.33	-16.4
106	211	212	3.49	-22.24	2.92	-22.81
107	213	214	16.31	-22.15	15.69	-22.77

Table 11.2.12.3-4 Support Disk 5 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.70	-32.00	3.30	35.40	89.00	1.51
48	6.60	-27.20	3.20	34.40	89.00	1.59
49	-15.70	-33.90	-0.90	33.90	89.00	1.62
50	-32.90	-32.00	-0.70	33.30	89.00	1.67
92	-1.40	-32.00	-0.70	32.00	89.00	1.78
47	-19.10	-31.90	-0.50	32.00	89.00	1.78
46	2.80	-20.70	-9.70	30.40	89.00	1.92
17	-29.80	-9.70	0.10	29.80	89.00	1.99
28	-29.20	-27.20	-0.90	29.50	89.00	2.01
29	-14.80	-29.30	-0.90	29.30	89.00	2.03
44	-28.70	-14.70	0.10	28.70	89.00	2.10
21	-28.60	-4.50	-0.30	28.60	89.00	2.11
30	5.10	-22.80	2.90	28.50	89.00	2.12
25	-27.70	0.50	-1.20	28.30	89.00	2.14
80	-1.40	-27.20	-0.80	27.20	89.00	2.27
32	-25.30	-22.70	-1.10	25.70	89.00	2.46
59	0.20	-9.70	-11.40	24.80	89.00	2.58
83	-1.40	-22.80	2.90	23.20	89.00	2.84
42	11.60	-9.80	3.90	22.80	89.00	2.91
40	-4.10	-11.10	-10.80	22.80	89.00	2.91
43	-12.30	-21.50	-0.30	21.50	89.00	3.13
19	14.70	-4.50	3.50	20.40	89.00	3.36
53	-19.20	-6.70	3.30	20.00	89.00	3.45
39	-9.80	-18.10	-3.40	19.30	89.00	3.61
106	-19.20	-1.40	-0.50	19.20	89.00	3.64
37	-14.90	-16.10	2.60	18.20	89.00	3.90
2	-17.20	-7.10	2.20	17.70	89.00	4.03
56	-15.80	-13.20	2.60	17.40	89.00	4.12
10	-17.00	0.00	-0.70	17.10	89.00	4.19
23	16.60	0.40	2.60	17.10	89.00	4.22
6	-16.40	-3.50	0.20	16.40	89.00	4.41
13	-2.60	12.10	3.20	16.00	89.00	4.55
27	-6.60	-0.30	7.30	15.90	89.00	4.60
26	-6.90	7.60	3.20	15.90	89.00	4.61
107	-15.70	-1.40	-0.90	15.80	89.00	4.63
18	-11.50	-15.40	-0.70	15.50	89.00	4.74
20	-8.30	4.10	4.10	15.00	89.00	4.95
58	-1.10	-11.20	-5.50	14.90	89.00	4.97
101	-14.80	-1.40	-0.90	14.90	89.00	4.98
91	-1.40	-14.70	0.20	14.70	89.00	5.06

Table 11.2.12.3-5 Support Disk 5 Primary Membrane + Bending Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-16.80	-104.30	6.50	104.80	127.10	0.21
45	-95.60	-27.50	2.90	95.80	127.10	0.33
5	-94.50	-33.20	4.70	94.90	127.10	0.34
20	-94.00	-25.00	2.90	94.10	127.10	0.35
48	-11.60	-93.50	2.60	93.60	127.10	0.36
42	-15.00	-92.40	0.60	92.40	127.10	0.38
53	-89.50	-26.20	7.60	90.50	127.10	0.41
24	-83.80	-17.80	2.60	83.90	127.10	0.51
30	-10.50	-79.90	2.40	80.00	127.10	0.59
9	-76.40	-19.90	2.80	76.60	127.10	0.66
51	-75.50	-29.10	4.60	76.00	127.10	0.67
19	-8.70	-75.80	-1.00	75.80	127.10	0.68
26	-75.20	-1.60	-0.30	75.20	127.10	0.69
4	-23.20	-73.00	1.60	73.00	127.10	0.74
56	-68.30	-22.30	8.90	70.00	127.10	0.82
13	-69.30	-5.80	0.00	69.30	127.10	0.83
37	-66.20	-28.90	9.10	68.30	127.10	0.86
2	-43.70	-65.30	7.60	67.70	127.10	0.88
31	-65.70	-24.30	3.90	66.00	127.10	0.93
62	-63.70	-17.50	2.40	63.80	127.10	0.99
92	-2.90	-60.00	-0.70	60.00	127.10	1.12
66	55.70	26.30	6.10	56.90	127.10	1.23
80	-2.80	-55.90	-0.90	55.90	127.10	1.27
44	-45.20	-47.60	9.00	55.50	127.10	1.29
33	-55.10	-15.30	3.90	55.50	127.10	1.29
47	-28.40	-50.10	9.20	53.50	127.10	1.38
17	-45.10	-42.50	9.00	52.90	127.10	1.40
3	-52.00	-30.20	3.30	52.50	127.10	1.42
12	29.60	50.00	7.00	52.10	127.10	1.44
54	-11.10	-41.70	-20.40	51.90	127.10	1.45
41	-50.00	-37.20	4.10	51.20	127.10	1.48
50	-39.90	-42.30	9.90	51.10	127.10	1.49
8	29.90	48.60	5.80	50.20	127.10	1.53
60	-48.20	-39.30	4.30	49.90	127.10	1.55
23	32.80	44.20	8.00	48.30	127.10	1.63
46	29.50	1.20	-18.60	46.70	127.10	1.72
67	26.90	43.50	6.40	45.70	127.10	1.78
91	-3.70	-45.00	0.10	45.00	127.10	1.83
63	27.30	43.20	5.30	44.80	127.10	1.84
49	-8.60	-42.30	9.30	44.70	127.10	1.85

Table 11.2.12.3-6 Support Disk 4 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.50	-31.20	3.30	34.30	89.00	1.59
49	-15.80	-33.40	-0.90	33.40	89.00	1.66
48	6.30	-26.40	3.20	33.30	89.00	1.67
50	-32.50	-31.10	-0.80	32.90	89.00	1.71
47	-18.90	-31.70	-0.60	31.70	89.00	1.80
92	-1.40	-31.20	-0.70	31.20	89.00	1.85
46	3.00	-20.40	-9.40	30.00	89.00	1.97
17	-29.80	-9.50	0.00	29.80	89.00	1.99
28	-29.00	-26.40	-0.90	29.20	89.00	2.04
29	-15.00	-28.90	-0.90	28.90	89.00	2.08
44	-28.60	-14.40	0.10	28.60	89.00	2.11
21	-28.60	-4.30	-0.30	28.60	89.00	2.12
25	-27.60	0.70	-1.20	28.40	89.00	2.13
30	4.80	-22.00	2.90	27.50	89.00	2.24
80	-1.40	-26.40	-0.90	26.40	89.00	2.37
32	-25.10	-21.90	-1.10	25.50	89.00	2.49
59	0.20	-9.80	-11.20	24.50	89.00	2.63
42	11.50	-9.60	3.80	22.40	89.00	2.97
83	-1.40	-22.00	2.90	22.40	89.00	2.98
40	-4.00	-11.10	-10.50	22.20	89.00	3.00
43	-12.40	-21.50	-0.40	21.50	89.00	3.14
19	14.50	-4.30	3.40	20.00	89.00	3.45
53	-19.00	-6.30	3.20	19.80	89.00	3.50
39	-9.90	-18.10	-3.30	19.30	89.00	3.61
106	-18.90	-1.40	-0.50	19.00	89.00	3.69
37	-15.10	-16.10	2.60	18.20	89.00	3.89
2	-17.40	-7.10	2.10	17.80	89.00	3.99
56	-15.90	-13.10	2.60	17.40	89.00	4.11
10	-17.20	0.00	-0.70	17.20	89.00	4.17
23	16.40	0.60	2.60	16.90	89.00	4.28
6	-16.60	-3.60	0.10	16.60	89.00	4.37
26	-7.10	7.90	3.20	16.30	89.00	4.47
13	-2.70	12.20	3.20	16.20	89.00	4.49
107	-15.90	-1.40	-0.90	15.90	89.00	4.59
27	-6.40	-0.30	7.20	15.60	89.00	4.72
18	-11.70	-15.40	-0.70	15.50	89.00	4.74
20	-8.50	4.30	4.10	15.20	89.00	4.85
58	-1.20	-11.30	-5.60	15.10	89.00	4.89
101	-15.00	-1.40	-0.90	15.10	89.00	4.90
45	-8.90	3.50	4.10	14.80	89.00	5.00

Table 11.2.12.3-7 Support Disk 4 Primary Membrane + Bending Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-16.70	-102.50	6.40	103.00	127.10	0.23
45	-94.30	-26.70	2.80	94.40	127.10	0.35
5	-93.70	-32.70	4.60	94.00	127.10	0.35
20	-92.90	-24.30	2.80	93.00	127.10	0.37
48	-11.60	-92.00	2.60	92.00	127.10	0.38
42	-14.70	-90.90	0.60	90.90	127.10	0.40
53	-87.70	-25.40	7.40	88.50	127.10	0.44
24	-83.00	-17.30	2.60	83.10	127.10	0.53
30	-10.60	-78.70	2.50	78.80	127.10	0.61
9	-75.70	-19.50	2.70	75.90	127.10	0.68
51	-74.40	-28.00	4.40	74.80	127.10	0.70
19	-8.60	-74.70	-1.00	74.70	127.10	0.70
26	-74.60	-1.10	-0.40	74.60	127.10	0.70
4	-22.80	-72.10	1.60	72.20	127.10	0.76
56	-68.00	-22.10	8.90	69.70	127.10	0.82
13	-68.90	-5.60	0.00	68.90	127.10	0.85
37	-66.20	-28.80	9.10	68.30	127.10	0.86
2	-43.30	-64.10	7.60	66.60	127.10	0.91
31	-65.00	-23.40	3.70	65.30	127.10	0.95
62	-63.20	-17.30	2.30	63.40	127.10	1.01
92	-2.90	-58.90	-0.80	58.90	127.10	1.16
66	55.20	26.20	6.10	56.40	127.10	1.25
80	-2.80	-54.80	-0.90	54.80	127.10	1.32
33	-54.50	-14.60	3.80	54.80	127.10	1.32
44	-44.60	-45.80	8.90	54.10	127.10	1.35
47	-26.90	-49.10	9.10	52.40	127.10	1.43
17	-44.60	-41.00	8.90	51.90	127.10	1.45
12	29.30	49.60	7.00	51.70	127.10	1.46
3	-50.90	-29.90	3.30	51.40	127.10	1.47
41	-48.60	-36.60	4.10	49.90	127.10	1.55
54	-10.70	-39.60	-19.70	49.60	127.10	1.56
50	-39.30	-40.40	9.70	49.60	127.10	1.56
8	29.50	47.90	5.80	49.60	127.10	1.56
60	-47.30	-38.90	4.30	49.10	127.10	1.59
23	32.40	43.80	8.00	47.90	127.10	1.66
46	28.90	1.10	-18.10	45.60	127.10	1.79
67	26.60	43.20	6.40	45.40	127.10	1.80
91	-3.60	-44.30	0.10	44.30	127.10	1.87
63	27.00	42.60	5.30	44.30	127.10	1.87
49	-8.70	-41.60	9.20	43.90	127.10	1.89

Table 11.2.12.3-8 Support Disk 3 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	2.60	-30.00	3.20	33.20	89.00	1.68
49	-16.00	-32.70	-1.00	32.80	89.00	1.71
50	-32.30	-29.90	-0.80	32.60	89.00	1.73
48	6.10	-25.20	3.10	32.00	89.00	1.78
47	-18.20	-30.90	-0.60	30.90	89.00	1.88
92	-1.40	-29.90	-0.80	30.00	89.00	1.97
17	-29.70	-8.90	0.00	29.70	89.00	2.00
28	-29.00	-25.20	-0.90	29.20	89.00	2.04
46	3.40	-19.60	-9.00	29.20	89.00	2.05
25	-27.40	1.30	-1.20	28.90	89.00	2.08
21	-28.60	-3.60	-0.40	28.60	89.00	2.11
29	-15.40	-28.30	-0.90	28.40	89.00	2.13
44	-28.30	-13.70	0.00	28.30	89.00	2.14
30	4.60	-20.80	2.90	26.00	89.00	2.42
32	-25.10	-20.70	-1.20	25.40	89.00	2.50
80	-1.40	-25.20	-0.90	25.20	89.00	2.53
59	0.20	-10.00	-10.90	24.00	89.00	2.70
42	11.20	-8.90	3.70	21.40	89.00	3.15
40	-3.90	-11.00	-10.10	21.30	89.00	3.17
83	-1.40	-20.80	2.90	21.20	89.00	3.20
43	-12.50	-21.10	-0.40	21.10	89.00	3.21
39	-10.00	-18.20	-3.00	19.20	89.00	3.63
53	-18.20	-5.90	3.10	19.00	89.00	3.68
19	14.00	-3.70	3.40	18.90	89.00	3.71
106	-18.20	-1.40	-0.60	18.20	89.00	3.88
37	-15.50	-15.70	2.50	18.20	89.00	3.90
2	-17.70	-7.20	2.00	18.10	89.00	3.92
56	-16.00	-12.80	2.50	17.40	89.00	4.11
10	-17.30	-0.10	-0.80	17.30	89.00	4.13
6	-16.90	-3.60	0.10	16.90	89.00	4.27
26	-7.30	8.30	3.20	16.80	89.00	4.29
23	16.00	1.20	2.60	16.40	89.00	4.42
13	-2.90	12.10	3.10	16.30	89.00	4.47
107	-16.00	-1.40	-0.90	16.00	89.00	4.55
20	-8.90	5.00	4.00	16.00	89.00	4.55
101	-15.50	-1.40	-0.90	15.50	89.00	4.73
18	-12.10	-15.20	-0.70	15.40	89.00	4.79
58	-1.30	-11.60	-5.70	15.30	89.00	4.81
45	-9.00	4.10	4.00	15.30	89.00	4.82
27	-6.00	-0.30	6.90	14.90	89.00	4.96

Table 11.2.12.3-9 Support Disk 3 Primary Membrane + Bending Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-16.00	-99.30	6.20	99.80	127.10	0.27
5	-92.30	-31.80	4.50	92.70	127.10	0.37
45	-91.90	-25.10	2.60	92.00	127.10	0.38
20	-91.40	-22.90	2.60	91.50	127.10	0.39
48	-11.20	-89.30	2.50	89.40	127.10	0.42
42	-14.20	-88.30	0.50	88.30	127.10	0.44
53	-85.20	-24.50	7.10	86.00	127.10	0.48
24	-82.10	-16.30	2.40	82.20	127.10	0.55
30	-10.70	-77.00	2.40	77.10	127.10	0.65
9	-74.90	-18.90	2.70	75.10	127.10	0.69
26	-73.70	-0.40	-0.50	73.70	127.10	0.72
51	-72.90	-26.40	4.10	73.30	127.10	0.73
19	-8.60	-72.90	-1.00	72.90	127.10	0.74
4	-22.30	-70.90	1.60	70.90	127.10	0.79
13	-68.10	-5.30	0.00	68.10	127.10	0.87
56	-66.40	-21.60	8.80	68.10	127.10	0.87
37	-65.60	-28.20	9.10	67.60	127.10	0.88
31	-64.40	-21.90	3.50	64.70	127.10	0.97
2	-42.80	-61.90	7.60	64.60	127.10	0.97
62	-63.10	-17.10	2.40	63.20	127.10	1.01
92	-2.80	-57.20	-0.80	57.20	127.10	1.22
66	54.70	25.80	6.00	55.90	127.10	1.27
33	-54.20	-13.60	3.60	54.60	127.10	1.33
80	-2.70	-53.20	-0.90	53.20	127.10	1.39
44	-43.40	-42.60	8.70	51.70	127.10	1.46
12	28.80	48.80	6.90	51.00	127.10	1.49
47	-24.80	-47.30	8.80	50.40	127.10	1.52
17	-43.80	-38.20	8.80	50.20	127.10	1.53
3	-49.40	-29.40	3.30	50.00	127.10	1.54
8	28.80	47.10	5.70	48.80	127.10	1.61
60	-45.80	-38.50	4.40	47.90	127.10	1.65
23	31.60	44.00	7.90	47.80	127.10	1.66
41	-46.30	-35.40	4.10	47.70	127.10	1.67
54	-10.40	-38.00	-19.00	47.70	127.10	1.67
50	-38.40	-37.20	9.50	47.30	127.10	1.68
67	26.40	42.50	6.40	44.70	127.10	1.84
46	28.20	1.20	-17.40	44.00	127.10	1.89
63	-10.90	-43.80	0.00	43.80	127.10	1.90
91	-3.50	-43.00	0.00	43.00	127.10	1.96
25	-35.90	4.80	6.80	42.90	127.10	1.96

Table 11.2.12.3-10 Support Disk 2 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	3.90	-29.20	3.20	33.70	89.00	1.64
50	-32.60	-29.10	-0.90	32.80	89.00	1.71
49	-15.90	-32.30	-1.10	32.30	89.00	1.75
48	6.70	-24.40	3.10	31.70	89.00	1.81
28	-29.70	-24.30	-1.00	29.90	89.00	1.98
25	-27.10	2.60	-1.20	29.80	89.00	1.99
17	-29.60	-7.50	-0.10	29.60	89.00	2.00
47	-16.70	-29.20	-0.60	29.30	89.00	2.04
92	-1.40	-29.20	-0.90	29.20	89.00	2.05
21	-28.80	-2.30	-0.40	28.80	89.00	2.09
46	4.10	-18.30	-8.80	28.50	89.00	2.13
29	-16.10	-28.10	-1.00	28.20	89.00	2.16
44	-27.70	-12.30	-0.10	27.70	89.00	2.21
32	-25.80	-19.80	-1.20	26.00	89.00	2.42
30	4.50	-19.90	2.90	25.10	89.00	2.55
80	-1.40	-24.30	-1.00	24.40	89.00	2.65
59	0.10	-10.40	-10.60	23.70	89.00	2.75
40	-3.70	-10.80	-9.60	20.50	89.00	3.35
83	-1.40	-19.90	2.80	20.30	89.00	3.39
43	-12.40	-20.30	-0.50	20.30	89.00	3.39
42	10.90	-7.60	3.70	19.90	89.00	3.47
39	-10.00	-18.20	-2.60	19.00	89.00	3.69
2	-18.10	-7.10	2.00	18.40	89.00	3.82
37	-16.20	-15.10	2.50	18.20	89.00	3.89
53	-16.80	-6.10	3.10	17.60	89.00	4.04
20	-9.50	6.10	4.00	17.50	89.00	4.09
6	-17.30	-3.60	0.00	17.30	89.00	4.15
26	-7.20	8.90	3.10	17.30	89.00	4.15
10	-17.20	0.00	-0.70	17.20	89.00	4.17
56	-16.00	-12.50	2.40	17.20	89.00	4.17
19	13.30	-2.40	3.40	17.10	89.00	4.20
106	-16.70	-1.40	-0.60	16.80	89.00	4.31
101	-16.10	-1.40	-1.00	16.20	89.00	4.49
13	-2.90	11.90	3.10	16.00	89.00	4.55
107	-15.90	-1.40	-1.00	16.00	89.00	4.56
45	-8.90	5.00	3.90	16.00	89.00	4.57
24	-8.40	6.00	3.50	16.00	89.00	4.57
23	15.40	2.50	2.60	15.90	89.00	4.61
58	-1.40	-11.90	-5.60	15.40	89.00	4.78
18	-12.70	-14.70	-0.80	14.90	89.00	4.96

Table 11.2.12.3-11 Support Disk 2 Primary Membrane + Bending Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-14.40	-96.00	5.70	96.40	127.10	0.32
5	-91.30	-30.80	4.40	91.60	127.10	0.39
20	-90.30	-21.20	2.30	90.40	127.10	0.41
45	-89.40	-23.20	2.30	89.50	127.10	0.42
48	-10.00	-86.60	2.20	86.70	127.10	0.47
42	-13.80	-85.30	0.50	85.30	127.10	0.49
53	-83.80	-24.50	7.10	84.60	127.10	0.50
24	-82.40	-15.00	2.10	82.40	127.10	0.54
30	-10.40	-75.40	2.30	75.50	127.10	0.68
9	-74.90	-18.40	2.60	75.00	127.10	0.69
26	-73.10	0.20	-0.60	73.30	127.10	0.73
51	-72.20	-25.10	3.90	72.50	127.10	0.75
19	-8.90	-71.10	-0.90	71.10	127.10	0.79
4	-22.20	-69.90	1.60	69.90	127.10	0.82
13	-67.40	-5.30	0.10	67.40	127.10	0.89
37	-64.00	-27.00	8.90	66.10	127.10	0.92
31	-64.70	-20.70	3.30	65.00	127.10	0.96
56	-63.10	-20.80	8.50	64.70	127.10	0.96
62	-63.80	-17.30	2.40	63.90	127.10	0.99
2	-42.40	-59.60	7.60	62.50	127.10	1.03
92	-2.70	-56.00	-0.90	56.00	127.10	1.27
66	54.70	25.20	5.90	55.90	127.10	1.27
33	-55.30	-12.60	3.40	55.60	127.10	1.29
80	-2.60	-51.80	-1.00	51.80	127.10	1.45
12	28.50	48.00	6.90	50.20	127.10	1.53
23	31.10	45.80	7.80	49.20	127.10	1.58
44	-42.10	-39.30	8.40	49.20	127.10	1.58
3	-48.60	-29.10	3.40	49.10	127.10	1.59
8	28.10	47.30	5.60	48.80	127.10	1.61
54	-10.60	-38.80	-19.40	48.70	127.10	1.61
17	-43.20	-35.10	8.60	48.70	127.10	1.61
47	-23.40	-45.40	8.30	48.10	127.10	1.64
60	-44.70	-38.50	4.60	47.20	127.10	1.70
50	-38.00	-34.20	9.50	45.80	127.10	1.78
41	-44.10	-34.20	4.00	45.50	127.10	1.80
63	-11.10	-44.30	0.10	44.30	127.10	1.87
67	26.40	41.40	6.40	43.70	127.10	1.91
25	-35.50	5.30	6.60	42.90	127.10	1.96
46	28.20	2.00	-16.90	42.80	127.10	1.97
21	-38.80	-20.60	7.90	41.70	127.10	2.05

Table 11.2.12.3-12 Support Disk 1 Primary Membrane Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	6.20	-28.10	3.00	34.80	89.00	1.56
50	-33.50	-28.00	-1.00	33.70	89.00	1.64
49	-16.10	-31.80	-1.20	31.90	89.00	1.79
48	7.70	-23.10	3.00	31.30	89.00	1.84
28	-30.90	-23.00	-1.10	31.10	89.00	1.86
25	-26.00	4.10	-1.10	30.20	89.00	1.95
17	-29.10	-5.80	-0.20	29.10	89.00	2.06
21	-28.70	-0.70	-0.40	28.70	89.00	2.10
92	-1.40	-28.00	-1.00	28.10	89.00	2.17
29	-17.10	-27.60	-1.10	27.80	89.00	2.21
32	-27.10	-18.40	-1.20	27.30	89.00	2.26
46	4.50	-16.30	-8.50	26.90	89.00	2.31
47	-14.60	-26.50	-0.60	26.50	89.00	2.35
44	-26.40	-10.40	-0.20	26.40	89.00	2.36
30	4.80	-18.40	2.80	24.00	89.00	2.71
80	-1.40	-23.00	-1.10	23.10	89.00	2.86
59	0.00	-10.90	-10.10	23.00	89.00	2.87
20	-10.40	7.50	3.80	19.50	89.00	3.57
43	-12.60	-19.30	-0.50	19.30	89.00	3.61
2	-18.80	-7.20	1.80	19.10	89.00	3.67
83	-1.40	-18.40	2.80	18.90	89.00	3.71
40	-3.40	-10.50	-8.70	18.90	89.00	3.72
24	-9.60	7.70	3.40	18.60	89.00	3.78
37	-17.10	-14.40	2.30	18.50	89.00	3.82
39	-9.80	-17.80	-1.90	18.30	89.00	3.88
6	-18.10	-3.60	-0.10	18.10	89.00	3.93
42	9.90	-5.80	3.60	17.30	89.00	4.14
45	-9.00	6.50	3.70	17.20	89.00	4.17
26	-6.80	9.30	3.10	17.20	89.00	4.18
101	-17.10	-1.40	-1.10	17.20	89.00	4.18
56	-16.10	-11.60	2.20	17.10	89.00	4.22
10	-17.00	-0.10	-0.80	17.00	89.00	4.23
107	-16.10	-1.40	-1.20	16.20	89.00	4.49
53	-14.70	-6.90	3.20	15.80	89.00	4.62
58	-1.70	-12.20	-5.50	15.30	89.00	4.83
13	-2.60	11.20	3.10	15.10	89.00	4.88
106	-14.70	-1.40	-0.60	14.70	89.00	5.06
18	-13.60	-14.00	-0.80	14.60	89.00	5.09
23	13.90	4.00	2.60	14.60	89.00	5.10
61	-14.40	-5.50	-0.10	14.40	89.00	5.16

Table 11.2.12.3-13 Support Disk 1 Primary Membrane + Bending Stresses for Tip Over Accident

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
52	-11.70	-90.00	4.70	90.20	127.10	0.41
5	-89.10	-29.10	4.20	89.40	127.10	0.42
20	-87.40	-18.50	1.80	87.50	127.10	0.45
45	-84.50	-20.00	1.70	84.50	127.10	0.50
53	-82.50	-24.80	7.30	83.40	127.10	0.52
48	-8.00	-82.60	1.80	82.70	127.10	0.54
24	-81.80	-12.90	1.70	81.80	127.10	0.55
42	-13.60	-80.70	0.50	80.70	127.10	0.58
9	-74.40	-17.30	2.50	74.50	127.10	0.71
30	-9.50	-72.70	2.00	72.70	127.10	0.75
51	-71.50	-22.90	3.60	71.70	127.10	0.77
26	-70.50	0.50	-0.70	71.10	127.10	0.79
19	-9.60	-68.10	-0.70	68.10	127.10	0.87
4	-21.50	-67.60	1.60	67.70	127.10	0.88
31	-65.40	-18.90	3.00	65.60	127.10	0.94
13	-65.50	-5.50	0.20	65.50	127.10	0.94
62	-64.50	-17.10	2.50	64.70	127.10	0.97
37	-61.00	-25.20	8.80	63.00	127.10	1.02
56	-57.50	-18.90	8.10	59.10	127.10	1.15
2	-41.50	-55.60	7.70	58.90	127.10	1.16
33	-57.80	-10.90	3.10	58.00	127.10	1.19
66	54.60	24.10	5.70	55.60	127.10	1.29
92	-2.60	-54.10	-1.10	54.10	127.10	1.35
54	-11.10	-41.10	-20.40	51.40	127.10	1.47
23	29.80	48.60	7.60	51.30	127.10	1.48
80	-2.50	-49.70	-1.10	49.70	127.10	1.56
8	26.90	47.10	5.40	48.50	127.10	1.62
12	27.90	45.60	6.80	48.00	127.10	1.65
3	-46.00	-28.30	3.50	46.70	127.10	1.72
17	-41.70	-30.20	8.20	46.00	127.10	1.77
60	-42.30	-38.10	4.80	45.40	127.10	1.80
63	-11.30	-45.10	0.20	45.10	127.10	1.82
44	-39.50	-33.50	7.80	44.80	127.10	1.84
47	-22.00	-42.10	7.50	44.60	127.10	1.85
50	-37.60	-28.80	9.50	43.70	127.10	1.91
67	26.20	39.10	6.40	41.70	127.10	2.05
41	-39.60	-32.00	3.90	41.20	127.10	2.08
25	-34.30	5.00	6.20	41.20	127.10	2.09
21	-38.30	-17.10	7.60	40.80	127.10	2.12
46	27.60	2.90	-16.00	40.40	127.10	2.15

Table 11.2.12.3-14 Buckling Evaluation Summary for Disk 5

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	12.02	35.92	32.00	3.39	6.00	5.75	0.14	0.17
48	10.22	35.92	32.00	3.11	6.00	5.75	0.29	0.32
53	7.79	39.79	34.56	3.85	7.00	6.77	0.43	0.45
45	3.86	43.95	37.31	5.53	8.16	7.95	0.45	0.47
42	3.97	39.75	34.53	4.51	6.99	6.76	0.47	0.51
20	3.65	43.95	37.31	5.46	8.16	7.95	0.48	0.50
5	2.97	44.00	37.34	5.60	8.17	7.96	0.49	0.51
30	8.54	35.87	31.97	2.67	5.99	5.74	0.52	0.55
24	2.87	39.79	34.56	4.20	7.00	6.77	0.65	0.69
51	5.40	43.95	37.31	4.03	8.16	7.95	0.77	0.78
92	12.01	35.92	32.00	1.31	6.00	5.75	0.83	0.78
26	2.60	35.92	32.00	3.20	6.00	5.75	0.81	0.88
9	1.68	39.75	34.53	3.95	6.99	6.76	0.84	0.90
19	1.83	39.79	34.56	3.90	7.00	6.77	0.85	0.90
56	6.90	43.95	37.31	3.35	8.16	7.95	0.90	0.88
37	6.51	43.95	37.31	3.27	8.16	7.95	0.97	0.94
4	1.55	44.00	37.34	4.43	8.17	7.96	0.95	0.99
80	10.19	35.87	31.97	1.34	5.99	5.74	1.01	0.97
31	5.05	43.95	37.31	3.45	8.16	7.95	1.03	1.03
13	0.97	35.92	32.00	3.13	6.00	5.75	1.03	1.12
2	3.09	44.00	37.34	3.72	8.17	7.96	1.12	1.13
50	11.99	35.87	31.97	0.48	5.99	5.74	1.43	1.26
62	0.54	39.79	34.56	3.41	7.00	6.77	1.26	1.33
33	4.08	39.79	34.56	2.46	7.00	6.77	1.39	1.40
44	5.94	39.79	34.56	1.80	7.00	6.77	1.61	1.56
46	8.37	39.79	34.56	1.20	7.00	6.77	1.72	1.58
3	3.62	44.00	37.34	2.79	8.17	7.96	1.60	1.59
41	3.83	44.00	37.34	2.63	8.17	7.96	1.68	1.66
91	5.94	39.75	34.53	1.65	6.99	6.76	1.74	1.68
28	10.19	35.92	32.00	0.36	6.00	5.75	1.93	1.71
106	7.77	39.79	34.56	1.18	7.00	6.77	1.86	1.72
83	8.54	35.92	32.00	0.63	6.00	5.75	1.98	1.81
60	2.94	44.00	37.34	2.65	8.17	7.96	1.83	1.83
8	0.01	44.00	37.34	3.10	8.17	7.96	2.02	2.10
17	3.94	39.75	34.53	1.79	6.99	6.76	2.04	2.02
79	3.96	39.79	34.56	1.70	7.00	6.77	2.15	2.12
63	0.22	44.00	37.34	2.79	8.17	7.96	2.30	2.38
47	7.75	39.75	34.53	0.51	6.99	6.76	2.82	2.50
105	5.38	43.95	37.31	1.27	8.16	7.95	2.83	2.62
32	8.53	35.92	32.00	0.04	6.00	5.75	3.09	2.67

Table 11.2.12.3-15 Buckling Evaluation Summary for Disk 4

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	11.70	35.92	32.00	3.35	6.00	5.75	0.16	0.19
48	9.91	35.92	32.00	3.07	6.00	5.75	0.31	0.34
53	7.69	39.79	34.56	3.76	7.00	6.77	0.46	0.48
45	3.90	43.95	37.31	5.44	8.16	7.95	0.47	0.49
20	3.72	43.95	37.31	5.38	8.16	7.95	0.49	0.52
42	3.89	39.75	34.53	4.44	6.99	6.76	0.50	0.54
5	3.03	44.00	37.34	5.54	8.17	7.96	0.50	0.53
30	8.25	35.87	31.97	2.66	5.99	5.74	0.55	0.58
24	2.93	39.79	34.56	4.15	7.00	6.77	0.66	0.70
51	5.44	43.95	37.31	3.95	8.16	7.95	0.80	0.80
26	2.67	35.92	32.00	3.17	6.00	5.75	0.82	0.89
92	11.68	35.92	32.00	1.30	6.00	5.75	0.87	0.82
9	1.74	39.75	34.53	3.90	6.99	6.76	0.85	0.91
19	1.76	39.79	34.56	3.85	7.00	6.77	0.88	0.93
56	6.95	43.95	37.31	3.32	8.16	7.95	0.91	0.88
37	6.59	43.95	37.31	3.26	8.16	7.95	0.97	0.94
4	1.59	44.00	37.34	4.37	8.17	7.96	0.98	1.01
80	9.89	35.87	31.97	1.33	5.99	5.74	1.05	1.01
31	5.13	43.95	37.31	3.39	8.16	7.95	1.05	1.04
13	1.03	35.92	32.00	3.10	6.00	5.75	1.04	1.13
2	3.13	44.00	37.34	3.64	8.17	7.96	1.15	1.17
62	0.59	39.79	34.56	3.38	7.00	6.77	1.27	1.35
50	11.66	35.87	31.97	0.43	5.99	5.74	1.53	1.35
33	4.14	39.79	34.56	2.42	7.00	6.77	1.41	1.42
46	8.25	39.79	34.56	1.17	7.00	6.77	1.77	1.63
3	3.69	44.00	37.34	2.71	8.17	7.96	1.64	1.63
44	5.85	39.79	34.56	1.72	7.00	6.77	1.71	1.65
41	3.87	44.00	37.34	2.54	8.17	7.96	1.75	1.72
91	5.85	39.75	34.53	1.63	6.99	6.76	1.79	1.72
106	7.68	39.79	34.56	1.17	7.00	6.77	1.89	1.75
28	9.88	35.92	32.00	0.32	6.00	5.75	2.07	1.82
60	3.00	44.00	37.34	2.58	8.17	7.96	1.88	1.87
83	8.25	35.92	32.00	0.63	6.00	5.75	2.04	1.88
8	0.05	44.00	37.34	3.06	8.17	7.96	2.05	2.13
17	3.86	39.75	34.53	1.72	6.99	6.76	2.15	2.13
79	3.87	39.79	34.56	1.68	7.00	6.77	2.19	2.17
63	0.28	44.00	37.34	2.76	8.17	7.96	2.32	2.40
105	5.43	43.95	37.31	1.26	8.16	7.95	2.83	2.62
47	7.66	39.75	34.53	0.44	6.99	6.76	3.00	2.64
93	3.01	44.00	37.34	1.82	8.17	7.96	2.77	2.71

Table 11.2.12.3-16 Buckling Evaluation Summary for Disk 3

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	11.25	35.92	32.00	3.25	6.00	5.75	0.20	0.23
48	9.46	35.92	32.00	3.01	6.00	5.75	0.36	0.39
53	7.39	39.79	34.56	3.66	7.00	6.77	0.50	0.52
45	3.94	43.95	37.31	5.29	8.16	7.95	0.51	0.53
20	3.89	43.95	37.31	5.26	8.16	7.95	0.51	0.54
5	3.20	44.00	37.34	5.43	8.17	7.96	0.51	0.54
42	3.61	39.75	34.53	4.33	6.99	6.76	0.55	0.59
30	7.80	35.87	31.97	2.63	5.99	5.74	0.59	0.62
24	3.10	39.79	34.56	4.08	7.00	6.77	0.67	0.72
51	5.49	43.95	37.31	3.85	8.16	7.95	0.83	0.83
26	2.72	35.92	32.00	3.12	6.00	5.75	0.84	0.90
9	1.90	39.75	34.53	3.84	6.99	6.76	0.87	0.92
92	11.23	35.92	32.00	1.28	6.00	5.75	0.93	0.88
56	7.01	43.95	37.31	3.21	8.16	7.95	0.95	0.92
19	1.50	39.79	34.56	3.79	7.00	6.77	0.93	0.99
37	6.78	43.95	37.31	3.19	8.16	7.95	0.98	0.95
4	1.62	44.00	37.34	4.29	8.17	7.96	1.01	1.05
31	5.31	43.95	37.31	3.33	8.16	7.95	1.06	1.05
13	1.09	35.92	32.00	3.06	6.00	5.75	1.06	1.15
80	9.43	35.87	31.97	1.31	5.99	5.74	1.13	1.08
2	3.16	44.00	37.34	3.49	8.17	7.96	1.22	1.24
62	0.74	39.79	34.56	3.35	7.00	6.77	1.27	1.34
33	4.32	39.79	34.56	2.38	7.00	6.77	1.41	1.42
50	11.21	35.87	31.97	0.34	5.99	5.74	1.72	1.51
3	3.86	44.00	37.34	2.59	8.17	7.96	1.71	1.69
46	7.94	39.79	34.56	1.14	7.00	6.77	1.87	1.72
91	5.56	39.75	34.53	1.60	6.99	6.76	1.88	1.82
106	7.37	39.79	34.56	1.15	7.00	6.77	1.97	1.83
41	3.91	44.00	37.34	2.39	8.17	7.96	1.87	1.84
44	5.55	39.79	34.56	1.58	7.00	6.77	1.91	1.84
60	3.16	44.00	37.34	2.47	8.17	7.96	1.95	1.94
83	7.80	35.92	32.00	0.64	6.00	5.75	2.16	1.99
28	9.43	35.92	32.00	0.25	6.00	5.75	2.31	2.03
8	0.08	44.00	37.34	3.02	8.17	7.96	2.08	2.17
79	3.60	39.79	34.56	1.65	7.00	6.77	2.31	2.29
63	0.42	44.00	37.34	2.73	8.17	7.96	2.31	2.39
17	3.58	39.75	34.53	1.60	6.99	6.76	2.38	2.35
105	5.47	43.95	37.31	1.24	8.16	7.95	2.84	2.63
93	3.18	44.00	37.34	1.79	8.17	7.96	2.76	2.69
107	6.99	44.00	37.34	0.78	8.17	7.96	3.09	2.73

Table 11.2.12.3-17 Buckling Evaluation Summary for Disk 2

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	10.96	35.92	32.00	3.14	6.00	5.75	0.24	0.27
48	9.13	35.92	32.00	2.92	6.00	5.75	0.40	0.43
5	3.45	44.00	37.34	5.33	8.17	7.96	0.53	0.55
20	4.16	43.95	37.31	5.15	8.16	7.95	0.53	0.55
53	6.80	39.79	34.56	3.67	7.00	6.77	0.54	0.56
45	3.91	43.95	37.31	5.13	8.16	7.95	0.55	0.57
42	3.08	39.75	34.53	4.24	6.99	6.76	0.61	0.66
30	7.45	35.87	31.97	2.60	5.99	5.74	0.63	0.66
24	3.41	39.79	34.56	4.05	7.00	6.77	0.66	0.70
51	5.46	43.95	37.31	3.81	8.16	7.95	0.85	0.85
26	2.69	35.92	32.00	3.09	6.00	5.75	0.85	0.92
9	2.19	39.75	34.53	3.79	6.99	6.76	0.86	0.91
92	10.94	35.92	32.00	1.26	6.00	5.75	0.98	0.92
37	7.08	43.95	37.31	3.05	8.16	7.95	1.01	0.97
56	6.98	43.95	37.31	3.00	8.16	7.95	1.04	1.00
19	0.98	39.79	34.56	3.76	7.00	6.77	1.00	1.07
31	5.60	43.95	37.31	3.31	8.16	7.95	1.04	1.02
4	1.59	44.00	37.34	4.23	8.17	7.96	1.04	1.08
13	1.07	35.92	32.00	3.03	6.00	5.75	1.08	1.17
80	9.11	35.87	31.97	1.29	5.99	5.74	1.19	1.14
62	1.02	39.79	34.56	3.35	7.00	6.77	1.23	1.30
2	3.13	44.00	37.34	3.35	8.17	7.96	1.31	1.32
33	4.65	39.79	34.56	2.40	7.00	6.77	1.35	1.35
50	10.92	35.87	31.97	0.24	5.99	5.74	1.92	1.67
3	4.14	44.00	37.34	2.50	8.17	7.96	1.74	1.70
46	7.41	39.79	34.56	1.11	7.00	6.77	2.02	1.87
41	3.88	44.00	37.34	2.25	8.17	7.96	2.01	1.97
106	6.78	39.79	34.56	1.16	7.00	6.77	2.12	1.98
91	5.00	39.75	34.53	1.58	6.99	6.76	2.03	1.98
60	3.42	44.00	37.34	2.36	8.17	7.96	2.00	1.98
8	0.05	44.00	37.34	3.03	8.17	7.96	2.08	2.17
83	7.45	35.92	32.00	0.64	6.00	5.75	2.25	2.09
44	4.99	39.79	34.56	1.48	7.00	6.77	2.17	2.09
63	0.64	44.00	37.34	2.74	8.17	7.96	2.25	2.32
28	9.11	35.92	32.00	0.16	6.00	5.75	2.60	2.26
79	3.06	39.79	34.56	1.63	7.00	6.77	2.51	2.50
93	3.43	44.00	37.34	1.76	8.17	7.96	2.72	2.64
105	5.44	43.95	37.31	1.23	8.16	7.95	2.87	2.65
101	7.07	44.00	37.34	0.80	8.17	7.96	3.01	2.67
17	3.05	39.75	34.53	1.50	6.99	6.76	2.72	2.70

Table 11.2.12.3-18 Buckling Evaluation Summary for Disk 1

Section Number	P (kip)	Pcr (kip)	Py (kip)	M (in-kip)	Mp (in-kip)	Mm (in-kip)	MS1	MS2
52	10.54	35.92	32.00	2.90	6.00	5.75	0.33	0.35
48	8.65	35.92	32.00	2.80	6.00	5.75	0.47	0.50
5	3.80	44.00	37.34	5.14	8.17	7.96	0.55	0.58
20	4.54	43.95	37.31	4.91	8.16	7.95	0.57	0.58
53	5.96	39.79	34.56	3.71	7.00	6.77	0.59	0.61
45	3.95	43.95	37.31	4.81	8.16	7.95	0.63	0.65
24	3.89	39.79	34.56	3.95	7.00	6.77	0.66	0.69
30	6.91	35.87	31.97	2.54	5.99	5.74	0.70	0.74
42	2.36	39.75	34.53	4.09	6.99	6.76	0.72	0.77
9	2.63	39.75	34.53	3.71	6.99	6.76	0.85	0.90
51	5.52	43.95	37.31	3.75	8.16	7.95	0.87	0.86
26	2.54	35.92	32.00	2.99	6.00	5.75	0.92	0.99
31	5.99	43.95	37.31	3.30	8.16	7.95	1.01	0.99
92	10.52	35.92	32.00	1.22	6.00	5.75	1.05	0.99
37	7.49	43.95	37.31	2.80	8.16	7.95	1.09	1.04
4	1.61	44.00	37.34	4.08	8.17	7.96	1.10	1.14
19	0.32	39.79	34.56	3.68	7.00	6.77	1.12	1.20
13	0.97	35.92	32.00	2.95	6.00	5.75	1.15	1.24
56	7.06	43.95	37.31	2.64	8.16	7.95	1.22	1.16
62	1.44	39.79	34.56	3.34	7.00	6.77	1.18	1.24
33	5.18	39.79	34.56	2.47	7.00	6.77	1.23	1.23
80	8.62	35.87	31.97	1.25	5.99	5.74	1.29	1.24
2	3.16	44.00	37.34	3.09	8.17	7.96	1.46	1.47
3	4.51	44.00	37.34	2.28	8.17	7.96	1.85	1.80
50	10.50	35.87	31.97	0.04	5.99	5.74	2.35	2.00
8	0.08	44.00	37.34	3.02	8.17	7.96	2.09	2.17
60	3.77	44.00	37.34	2.15	8.17	7.96	2.14	2.09
46	6.62	39.79	34.56	1.05	7.00	6.77	2.30	2.13
63	0.95	44.00	37.34	2.74	8.17	7.96	2.17	2.23
106	5.94	39.79	34.56	1.16	7.00	6.77	2.33	2.20
91	4.22	39.75	34.53	1.53	6.99	6.76	2.29	2.24
41	3.92	44.00	37.34	1.95	8.17	7.96	2.32	2.25
83	6.91	35.92	32.00	0.65	6.00	5.75	2.41	2.25
49	7.03	44.00	37.34	0.93	8.17	7.96	2.82	2.51
101	7.48	44.00	37.34	0.78	8.17	7.96	2.91	2.55
93	3.78	44.00	37.34	1.71	8.17	7.96	2.69	2.60
29	7.46	44.00	37.34	0.75	8.17	7.96	2.96	2.60
44	4.21	39.79	34.56	1.27	7.00	6.77	2.73	2.63
105	5.50	43.95	37.31	1.22	8.16	7.95	2.87	2.65
28	8.62	35.92	32.00	0.02	6.00	5.75	3.12	2.68

11.2.13 Tornado and Tornado Driven Missiles

This analysis evaluates the strength and stability of the concrete storage cask for a maximum tornado wind loading and for the impacts of tornado generated missiles. The design basis tornado characteristics have been selected in accordance with Regulatory Guide 1.76.

Classical techniques are used to evaluate the loading conditions. Cask stability analysis for the maximum tornado wind loading is based on NUREG-0800, Section 3.3.1, "Wind Loadings," and Section 3.3.2, "Tornado Loadings." Loads, due to tornado generated missiles, are based on NUREG-0800, Section 3.5.3, "Barrier Design Procedures."

11.2.13.1 Cause of Tornado Event

A tornado is a random weather event having a higher probability of occurrence at certain times of the year and in certain geographical areas.

Wind loading and tornado driven missiles have the potential for causing damage from pressure differential loading and from impact loadings.

A tornado event is expected to be visually observed. Warning of a tornado probability and of a tornado sighting may be received from the National Weather Service, local radio and television, local law enforcement officials, and site personnel.

11.2.13.2 Analysis of the Tornado Event

Classical analysis is applied to the evaluation of the consequences of tornado wind and missile events.

The concrete cask stability in a maximum tornado wind is evaluated based on the design wind pressure calculated in accordance with ANSI/ASCE 7-93 and using classical free body stability analysis methods.

Local damage to the concrete shell is assessed using a formula developed by the National Defense Research Committee. This formula has been selected as the basis for predicting depth

of missile penetration and minimum concrete thickness requirements to prevent scabbing of the concrete. Penetration depths calculated using this formula have been shown to provide reasonable correlation with test results (EPRI Report NP-440).

The local shear strength of the concrete shell is evaluated based on ACI 349-85, Section 11.11.2.1, discounting the reinforcing and steel shell.

The concrete shell shear capacity and shear-friction reinforcing steel area requirements are also evaluated for missile loading using ACI 349-85, Section 11.7.

The cask has the following properties that are considered in this evaluation:

H =	Height = 160 in
D_o =	Outside Diameter = 128 in
D_i =	Inside Diameter of concrete shell = 86 in
W_{VCC} =	Weight of the storage cask with canister, basket and full fuel load
=	206,100 lbs
A_c =	Cross section area of concrete shell = 7,059 in^2
I_c =	Moment of inertia of concrete shell = 10.49×10^6 in^4
f_c' =	Compressive strength of concrete shell = 4,000 psi

11.2.13.2.1 Tornado Wind Loading (Storage Cask)

The tornado wind velocity is transformed into an effective pressure applied to the cask using procedures delineated in ANSI/ASCE 7-93 Building Code Requirements for Minimum Design Loads in Buildings and Other Structures. The maximum pressure, q, is determined from the maximum tornado wind velocity as follows:

$$q = (0.00256)\ V^2 \text{ psf}$$

where:

V = Maximum tornado wind speed = 360 mph

The velocity pressure exposure coefficient for local terrain effects, K, Importance Factor, I, and the Gust Factor, G, may be taken as unity (1) for evaluating the effects of tornado wind velocity pressure.

Then:

$$q = (0.00256)(360)^2 = 331.8 \text{ psf}$$

Considering the cask is small with respect to the tornado radius, the velocity pressure is assumed uniform over the projected area of the cask.

Then the total wind loading on the projected area of the cask, F_w, is then computed as:

$$F_w = q \times G \times C_f \times A_p$$

where:

q = Effective velocity pressure (psf)
C_f = Force Coefficient = 0.50 (ASCE 7-93, Table 12 with $D\,q^{1/2}$ = 194 for a moderately smooth surface, h/D = 13.33 ft /10.66 ft = 1.25)
A_f = Projected area of cask = 10.67 ft x 13.33 ft = 142.2 ft^2
F_w = 331.8 x 0.50 x 142.2 = 23,590 lbs

The wind overturning moment, M_w, is computed as:

$M_w = F_w \times H/2$, where, H, is the cask height

$$M_w = 23{,}590 \text{ lbs} \times 160. \text{ in}/12 \times 1/2 = 157{,}267. \text{ ft-lbs}$$

The stability moment, M_s, of the cask with the canister, basket and full fuel load about an edge of the base is:

$$M_s = W_{VCC} \times D_o/2$$

where:

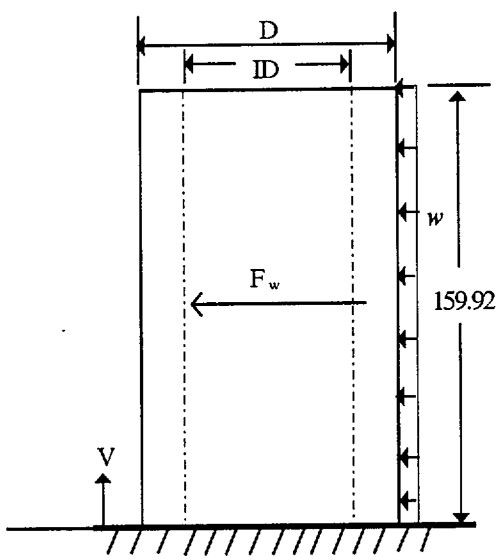
D_o = Diameter of the cask = 128 in

W_{VCC} = Weight of the cask with canister
= 206,100 lbs

M_s = 206,100 lbs x 128. In /12 x 1/2 = 1.099×10^6 ft-lbs

Thus, the cask has a Safety Factor of approximately +7 ($1.099 \times 10^6 / 1.573 \times 10^5$) against overturning with respect to the maximum tornado wind loading and requires only a coefficient of friction of about 0.12 (23.6×10^3 / $206. \times 10^3$) to be developed between the concrete cask base and ISFSI support deck to inhibit sliding via friction.

The stresses in the concrete due to the tornado wind load are conservatively calculated as below. The concrete cask is considered to be fixed at its base.



F_W	= 21,720 lb		
D	= 128 in. (concrete exterior diameter)		
ID	= 86 in. (concrete interior diameter)		
A	$= \pi (D^2 - ID^2) / 4$	= 7,059.2 in.^{2}	
I	$= \pi (D^4 - ID^4) / 64$	= 10.492 x10^6 in.^{4}	(Moment of Inertia)
S_{outer}	= 2I /D	= 163,937.5 in.^{3}	(Section Modulus for inner surface)
S_{inner}	= 2I / (ID)	= 244,000.0 in.^{3}	(Section Modulus for outer surface)
w	$= F_w / 159.92$	= 147.5 lbf / in	
M	$= w (159.92)^2 / 2$	= 1.886 x 10^6 in.-lb	(Bending Moment at the base)

Maximum stresses at the base surface:

$\sigma_{v\ outer} = M / S_{outer} = 11.5$ psi (tension or compression)

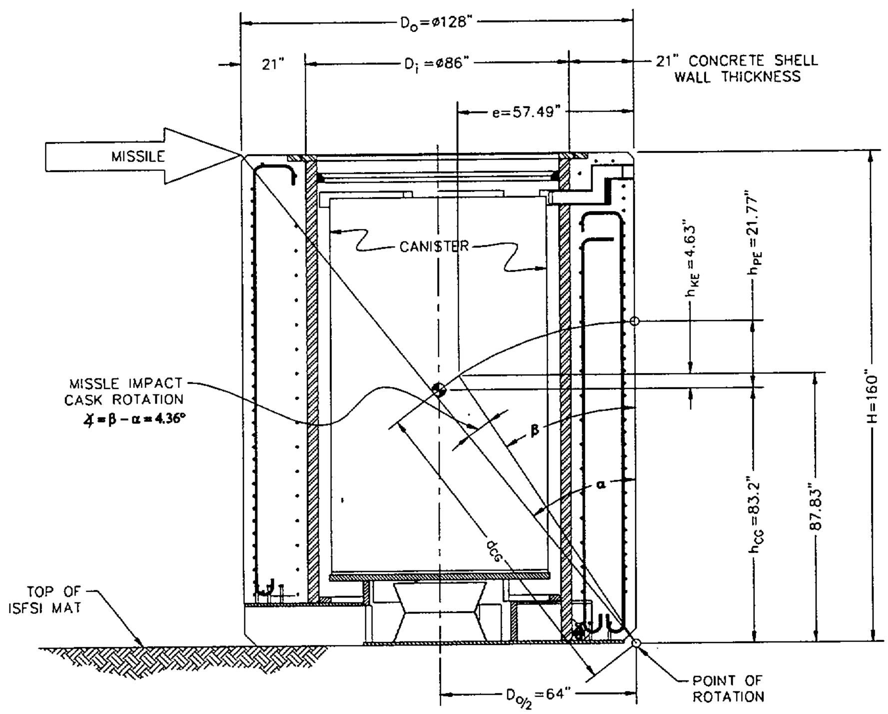
$\sigma_{v\ inner} = M / S_{inner} = 7.7$ psi (tension or compression)

The compressive stresses are included in the load combination No. 8 in Table 3.4.4.2-1, since they are governing stresses for the load combination. As shown in Tables 3.4.4.2-1 and 3.4.4.2-2, the maximum combined stresses for the load combination of dead, live, thermal and tornado wind are below the allowable stress.

11.2.13.2.2 Tornado Missile Loading (Storage Cask)

The NAC-MPC concrete cask is designed to withstand the effects of impacts associated with postulated tornado generated missiles identified in NUREG-0800, Section 3.5.1.4.III.4, Spectrum I missiles. Consisting of: 1) a high kinetic energy missile (3,960 lb automobile, with a frontal area of 20 square feet that deforms on impact); 2) a 275 lb, 8 in diameter armor piercing artillery shell; and 3) a small 1-inch diameter solid steel sphere. All of these missiles are assumed to impact in a manner that produces the maximum damage at a velocity of 126 mph (35 percent of the maximum tornado wind speed of 360 mph). The cask has been evaluated for impact effects associated with each of the above missiles.

The principal dimensions and moment arms used in this evaluation are shown below:



The concrete cask has no openings except for the four outlets at the top and four inlets at the bottom of the cask. These openings are configured such that a 1-inch diameter solid steel missile cannot directly enter the concrete cask interior. In addition, the canister is protected from the inlet (bottom) openings by a steel pedestal (bottom plate), and from the outlet (top) openings by the canister structural and shield lids. Therefore, a detailed analysis of the impact of a 1-inch diameter steel missile is not required.

Concrete Shell Local Damage Prediction (Penetration Missile)

Local damage to the cask body has been assessed using the National Defense Research Committee (NDRC) formula. This formula has been selected as the basis for predicting depth of penetration and minimum concrete thickness requirements to prevent scabbing. Penetration depths calculated using this formula have been shown to provide reasonable correlation with test results (EPRI Report NP-440, Section 4 "Local Response Evaluation").

Concrete shell penetration depths are calculated as follows:

For $x/2d \leq 2.0$:

where:

x = Missile penetration depth

d = Missile diameter = 8 in

$x = [4KNWd^{-0.8} (V/1000)^{1.8}]^{0.5}$

where:

K = Coefficient depending on concrete strength

$= 180/(f_c')^{1/2} = 180/(4000)^{1/2} = 2.846$

N = 1.14 Shape factor for sharp nosed missiles

W = Missile weight = 275 lb

V = Missile velocity = 126 mph = 185 ft/sec

$x = [(4)(2.846)(1.14)(275)(8^{-0.8})(185/1000)^{1.8}]^{0.5}$

$= 5.68$ inches

$x/2d = 5.68/(2)(8) = 0.355 < 2.0$

The minimum concrete shell thickness required to prevent scabbing is three times the predicted penetration depth of 5.68 inches based on the NDRC formula, or 17.04 inches. The concrete cask wall thickness includes 21 inches of concrete, which is more than the thickness required to

prevent damage due to the penetration missile. This analysis conservatively neglects the 3.5 inch steel shell at the inside face of the concrete shell.

Closure Plate Local Damage Prediction (Penetration Missile)

The concrete cask is closed with a 1.5-inch thick steel plate bolted in place. The following missile penetration analysis shows that the 1.5-inch steel closure plate is adequate to withstand the impact of the 275 lb armor piercing missile, impacting at 126 mph.

The perforation thickness of the closure steel plate is calculated by the Ballistic Research Laboratories Formula with K = 1, formula number 2-7, in Section 2.2 of Topical Report BC-TOP-9A, Revision 2.

$$T = [0.5M_mV^2]^{2/3}/672d$$
$$= 0.516 \text{ inch}$$

where:

T = Perforation thickness
$M_m =$ Missile mass = W/g = 275 lbs/32.2 ft/sec^2 = 8.54 slugs
g = Acceleration of gravity = 32.2 ft/sec^2
W, V and d are as defined above

BC-TOP-9A, recommends that the plate thickness be 25 percent greater than the calculated perforation thickness, T, to prevent perforation.

Thus, the recommended plate thickness is: 1.25 x 0.516 in. = 0.645 in.

The closure plate is 1.5 inches thick; therefore, the plate is adequate to withstand the local impingement damage due to the specified armor piercing missile.

Overall Damage Prediction for a Tornado Missile Impact (High Energy Missile)

The concrete cask is a freestanding structure. Therefore, the principal consideration in overall damage response is the potential of upsetting or overturning the cask as a result of the impact of a

high energy missile. Based on the following analysis, it is concluded that the cask can sustain an impact from the defined high energy missile and does not overturn.

From the principle of conservation of momentum, the impulse of the force from the missile impact on the cask must equal the change in angular momentum of the cask. Also, the impulse force due to the impact of the missile must equal the change in linear momentum of the missile. These relationships may be expressed as follows:

Change in momentum of the missile, during the deformation phase:

$$\int_{t_1}^{t_2} (F)(dt) = M_M (v_2 - v_1)$$

where:

F = Impact Impulse force on missile

M_M = Mass of missile = 3960 lbs/g = 123 slugs/12 =

= 10.25 lbm (lb sec^2 /in)

t_1 = Time at missile impact

t_2 = Time at conclusion of deformation phase

v_1 = Velocity of missile at impact = 126 mph = 185 ft/sec

v_2 = Velocity of missile at time t_2

The change in angular momentum of the cask, about the bottom outside edge/rim, opposite the side of impact is:

$$\int_{t_1}^{t_2} (M_c)(dt) = \int_{t_1}^{t_2} (H)(F)\, dt = I_m (\varpi_1 - \varpi_2)$$

Thus, $\int (F)(dt) = M_M (v_2 - v_1) = I_m (\varpi_1 - \varpi_2)/H$

where:

M_c = Moment of the impact force on the cask

I_m = Storage cask mass moment of inertia, about point of rotation on the bottom rim

ϖ_1 = Angular velocity at time t_1

ϖ_2 = Angular velocity at time t_2

M_{VCC} = Mass of the VCC cask = W_{VCC}/g

= 6,400 slugs/12 = 533.4 lbm (lb sec^2 /in)

I_{mx} = Mass moment of inertia of VCC cask about x axis through center of gravity

$\cong 1/12(M_{VCC})(3r^2 + H^2)$

$\cong (1/12)(533.4)\,[(3)(64)^2 + (160)^2] = 1.684 \times 10^6\ in^2\,lbm$

$I_m = I_{mx} + (M_{VCC})(d_{CG})^2$, where: d_{CG} is the distance (105 inches) between the cask CG and a rotation point on base rim

Thus, $I_m \cong 1.684 \times 10^6 + (533.4)(105)^2$
$= 7.565 \times 10^6\ in^2\,lbm$

Based on conservation of momentum, the impulse of the impact force on the missile is equated to the impulse of the force on the cask.

$M_M (v_2 - v_1) = I_m(\varpi_1 - \varpi_2)/H,$

at time t_1, v_1 = 185 ft/sec and ϖ_1 = 0 rad/sec

at time t_2, = v_2 = 0 ft/sec based on the following:

During the restitution phase, the final velocity of the missile will depend upon the coefficient of restitution of the missile, the geometry of the missile and target, the angle of incidence, and on the amount of energy dissipated in deforming the missile and target. It is assumed, based on tests conducted by EPRI (Ref. EPRI Report NP-440), that the final velocity of the missile, v_f, following the impact is zero. If it is conservatively assumed that all of the missile energy is transferred to the cask:

Then: $(10.25)(v_2 - 185\ ft/sec \times 12\ in/ft) = 7.565 \times 10^6\ in^2\,lbm\,(0 - \varpi_2)/160$

Setting v_2 = 0 and solving for ϖ_2,

ϖ_2 = 0.481 rad/sec

and $v_2 = 205\,\varpi_2$

Then, $v_2 = (205)(0.481) = 98.6$ in/sec

Equating the impulse of the force on the missile during restitution to the impulse of the force on the cask yields:

$$-[M(v_f - v_2] = I_m(\varpi_f - \varpi_2)/H$$

With: $v_f = 0$, $v_2 = 98.6$ in/sec and $\varpi_2 = 0.481$ rad/sec

Then: $-[10.25(0 - 98.6)] = 7.565 \times 10^6$ in^2-lbm $(\varpi_f - 0.481)/160$

$\varpi_f = 0.502$ rad/sec

Thus, the final energy of the cask following the impact, E_k, is:

$$E_k = (I_m)(\varpi_f)^2/(2)$$
$$= (7.565 \times 10^6)(0.502)^2/(2)$$
$$E_k = 9.53 \times 10^5 \text{ in-lb}_f$$

The energy required to overturn cask must be equal to or greater than its potential energy, E_p:

$$E_p = (W_{VCC})(h_{PE})$$
$$E_p = 206{,}100 \text{ lbs} \times 21.77 \text{ in}$$
$$E_p = 4.487 \times 10^6 \text{ in-lb}_f$$

The high energy tornado generated missile imparts insufficient kinetic energy to produce a cask overturning due to the missile impact.

Combined Tornado Wind and Missile Loading (High Energy Missile)

The cask rotation due to the heavy missile impact is calculated as:

$$h_{EK} = E_k / W_{VCC} = 9.53 \times 10^5 \text{ in-lb}_f / 20\,6{,}100. \text{ lbs} = 4.63 \text{ in}$$

Then: $\cos\beta = (h_{CG} + h_{KE}) / d_{CG}$

$\cos\beta = (83.2 + 4.63) / 104.97 = 0.8367$

$\beta = 33.21$ deg

$\cos\alpha = 83.2 / 104.97 = 0.7926$

$\alpha = 37.57$ deg

$e = d_{CG} \sin\beta$

$e = 104.97 \sin 33.21 = 57.49$ in

Thus, cask rotation after impact = $\alpha - \beta = 37.57 - 33.21 = 4.36$ deg

Available gravity restoration moment after missile impact = $(W_{VCC})(e)$

= 206,100 lb x 57.49 in / 12 =
987,391 ft-lb >> Tornado Wind Moment = 157,267. ft-lb

Therefore, the combined effects of tornado wind loading and the high energy missile impact loading will not overturn the cask.

Local Shear Strength Capacity of Concrete Shell (High Energy Missile)

This section evaluates the shear strength of the concrete at the top edge of the concrete shell due to a high energy missile impact based on ACI 349-85, Chapter 11, Section 11.11.2.1, on concrete punching shear strength.

The force developed by the missile using the methodology presented in Topical Report, BC-TOP-9A, is:

$F = 0.625(v)(W_M)$

$F = 0.625(185 \text{ ft/sec})(3960 \text{ lbs}) = 457.8$ kips

$F_u = LF \times F = 1.1 \times 457.8 = 503.6$ kips

Based on a rectangular missile contact area, having proportions of 2 horizontal to 1 vertical and the top of the area flush with the top of the concrete cask, the required missile contact area based on the concrete punching shear strength, neglecting reinforcing is:

$V_c = (2+4/\beta_c)(f_c')^{1/2} b_o\, d$, where $\beta_c = 2/1 = 2$

$V_c = 4 (f_c')^{1/2} b_o\, d$

$d = 21 \text{in} - 3 \text{ in} = 18 \text{ in}$

$(f_c')^{1/2} = 63.24$ psi, where $f_c' = 4{,}000$ psi

$b_o =$ perimeter of punching shear area at d/2 from missile contact area

$b_o = (2b + 18) + 2(b + 9) = 4b + 36$

$V_u = \Phi(V_c + V_s)$, where $V_s = 0$, assuming no steel shear

$V_u = \Phi V_c = \Phi\, 4 (f_c')^{1/2} b_o\, d = (.85)(4)(63.24)(4b + 36)(18)$

$= 15{,}481\ b + 139{,}330.$

Setting, V_u equal to F_u and solving for b:

$503.6 \times 10^3 = 15{,}481\ b + 139{,}330$

$b = 23.53$ inches (say 2.0 ft)

The implied missile impact area required $= 2b \times b = 2 \times 2 \times 2 = 8.0$ sq ft < 20.0 sq ft.

Thus, the concrete shell alone, based on the concrete conical punching strength and discounting the steel reinforcement and shell, has sufficient capacity to react to the high energy missile impact force.

The effects of tornado winds and missiles have been considered both separately and combined in accordance with NUREG-800, Section 3.3.2 II.3.d. For the case of tornado wind plus missile loading, the stability of the cask has been assessed and found to be acceptable. Equating the kinetic energy of the cask following missile impact to the potential energy yields a maximum postulated rotation of the cask, as a result of the impact, of 4.36 degrees. Applying the total tornado wind load to the cask in this configuration results in an available restoring moment considerably greater than the tornado wind overturning moment. Therefore, overturning of the cask under the combined effects of tornado winds, plus tornado-generated missiles, does not occur.

11.2.13.2.3 Tornado Effects on the Canister

The postulated tornado wind loading and missile impacts are not capable of overturning the cask, or penetrating the boundary established by the concrete cask. Consequently, there is no effect on the canister.

11.2.13.3 Radiological Consequences

This evaluation shows that there is little potential for significant damage to the concrete cask, which provides radiation shielding.

Under the worst tornado missile impact, a penetration of 5.68 inches into the concrete shield is possible. This would result in a local surface radiation dose rate at the point of penetration of 125 mrem/hr. Since the area of reduced shielding is very small, there would not be a noticeable increase in the dose rate at the site boundary. The estimated dose rate is well below the 1000 mrem/hr limit for dose rates one meter from the cask wall after an accident.

Repair of the damage would likely require two persons to form the damaged area and apply grout. This is estimated to require 30 minutes. The estimated extremity dose is 125 mrem. The whole body dose would be less. The dose rate of clearing inlets and outlets has been estimated in Section 11.1.1.3 at approximately 25 mrem per opening.

11.2.13.4 NAC-MPC Performance

The concrete cask is demonstrated to be stable in tornado wind loading in conjunction with impact from a high energy tornado missile. The performance of the NAC-MPC is not significantly affected by the tornado event.

The storage cask has a safety factor of 7.0 against overturning under the sustained maximum wind loading. The maximum concrete shell stresses under maximum tornado wind loading are 3.34 psi in shear and 11.51 psi in bending, which are well below their respective ACI 349-85 code allowables of 107.5 psi and 1,904 psi, respectively.

The concrete shell of the storage cask is more than three times thicker than the calculated missile penetration depth, which is adequate to prevent significant scabbing of the concrete.

11.2.13.5 Recovery and/or Corrective Actions

A tornado event is not expected to result in the need to take any corrective action other than an inspection of the ISFSI. This inspection would be directed at ensuring that inlets and outlets had not become blocked by wind-blown debris and at checking for obvious (concrete) surface damage.

As shown in the evaluation, in the worse case, a missile could dislodge concrete to a depth of approximately 6 inches. To repair the cask surface this area would need to be filled with grout. As noted, penetration to 6 inches is unlikely, since the reinforcing bar cage is encountered at a depth of 2 to 3 inches, depending on the location on the cask surface.

11.3 Design Basis Loading of the Transportable Storage Canister

The Transportable Storage Canister (canister) is designed to be stored in the NAC-MPC storage cask and transported in the NAC-STC Storable Transport Cask. The NAC-STC is licensed to transport spent fuel in accordance with 10 CFR 71 and has been issued Certificate of Compliance Number 71-9235. The NAC-STC has a design weight when loaded of 250,000 pounds and is intended to be transported by rail.

An amendment to the Safety Analysis Report (SAR) for the NAC-STC is being requested, in conjunction with this Safety Analysis Report for storage of Yankee class fuel, to include the loaded canister as authorized contents.

The load condition imposed on the canister and its basket by the transport conditions—including the 30 foot end and side impacts and the fire accident—are more rigorous than those imposed by design basis storage normal, off-normal and accident conditions.

Sections 11.1.2 and 11.2.11 use the results of analysis performed for transport end and side impact conditions to show adequate performance of the canister in the canister off-normal handling condition (Section 11.1.2) and of the canister and basket in the 6-inch concrete cask drop accident (Section 11.2.11). This section summarizes the transport analysis upon which the results of sections 11.1.2 and 11.2.11 are based. The canister and basket are evaluated in accordance with ASME Section III, Subsection NB, and Subsection NG, respectively.

The complete evaluation of the transport normal and accident conditions loading on the canister and basket is presented in the NAC-STC SAR, Docket Number 71-9235.

11.3.1 Canister Impact Analysis

The canister is a right-circular shell fabricated from rolled 5/8-inch thick, Type 304L stainless steel plate and closed by a 1-inch thick, Type 304L stainless steel plate that is welded to one end of the shell. The canister is closed at the top end by the installation and welding of the 5-inch thick, Type 304 stainless steel shield lid and the 3-inch thick, Type 304L stainless steel structural lid.

11.3.1.1 Finite Element Model Description - Canister

A finite element model of the canister was constructed using ANSYS solid (SOLID45) elements. The model represents a one-half (180°) section of the canister and basket. The basket support discs were modeled with three-dimensional shell (SHELL63) elements. The model uses gap-spring elements to simulate contact between adjacent components. Interaction between the basket and canister were accomplished using three-dimensional gap elements (CONTACT52) along the periphery of the support disks. Contact between the canister and the cask inner shell is also modeled using CONTACT52 gap elements. Contact between the canister structural lid and shield lid is modeled using COMBIN40 combination elements in the axial degree of freedom. Simulation of the backing ring is accomplished using a ring of COMBIN40 spring gap elements connecting the shield lid and the canister in the axial direction at the lid lower outside radius. In addition, CONTACT52 elements are used to model interaction between the structural lid and canister shell and the shield lid and canister shell just below the respective lid weld joints. The size of the CONTACT52 gaps were determined from the nominal dimensions of contacting components. The COMBIN40 elements used between the structural and shield lids and for the backing ring were assigned small gap sizes of 1E-8 inches. All gap-spring elements are assigned a stiffness of 1E8 lb/in.

Boundary conditions were applied to enforce symmetry at the plane of symmetry of the model. All nodes on the cask shell side of the canister to cask spring gap elements were fixed in all degrees of freedom. In addition, the axial and inplane rotational degrees of freedom of the basket nodes were fixed.

Figure 11.3.1.1-1 is a plot of the entire canister finite element model. An isolated view of the canister shield and structural lids portion of the model is presented in Figure 11.3.1.1-2 and an enlarged view of the model in the structural lid and shield lid weld regions is shown in Figure 11.3.1.1-3. The canister bottom plate portion of the model is shown in Figure 11.3.1.1-4. Identification of the sections for evaluating the linearized stresses in the canister is shown in Figure 11.3.1.1-5.

In the bottom end impact orientation, the fuel weight as well as the basket weight are transferred to the canister bottom plate. In the finite element model, the canister content weight is represented by applying a pressure load to the surface of the canister bottom plate. The support

disks inside the canister as shown in Figure 11.3.1.1-1 are set to be in-active for the bottom end impact analysis. The canister bottom plate is considered to be fully supported.

For the side impact condition, the loads from the canister contents weight is transferred through the support disks into the canister wall, which is considered to be backed by a rigid shell support of 71.0 inside diameter. The basket, canister and the assumed support shell have different radii, which implies that the contact angle between the components is dependent on the loading. Gap elements between the basket and the canister allow the interface to be dependent on the loading. The interface between the canister and the support shell is also represented by gap elements. The load due to the contents is applied to the basket via pressure acting in the plane of the disks. The weight is assumed to act over the effective width of 8.254 inches in which the disk is 0.5 inches thick. The content weight includes the 900 pounds per fuel assembly (for 36 fuel assemblies) plus the fuel tube weight (58.6 pounds/tube). This weight is distributed over the 22 support disks.

Use of the minimum size gap between the transportable storage canister structural and shield lids, 1×10^{-8} inch, results in the maximum stress and minimum margin of safety for the transportable storage canister impact analysis. Use of the maximum gap size (0.08 inches) results in a reduced margin of safety in some section locations, but does not result in the maximum stress / lowest margin of safety condition.

Figure 11.3.1.1-1 Canister Assembly Finite Element Model

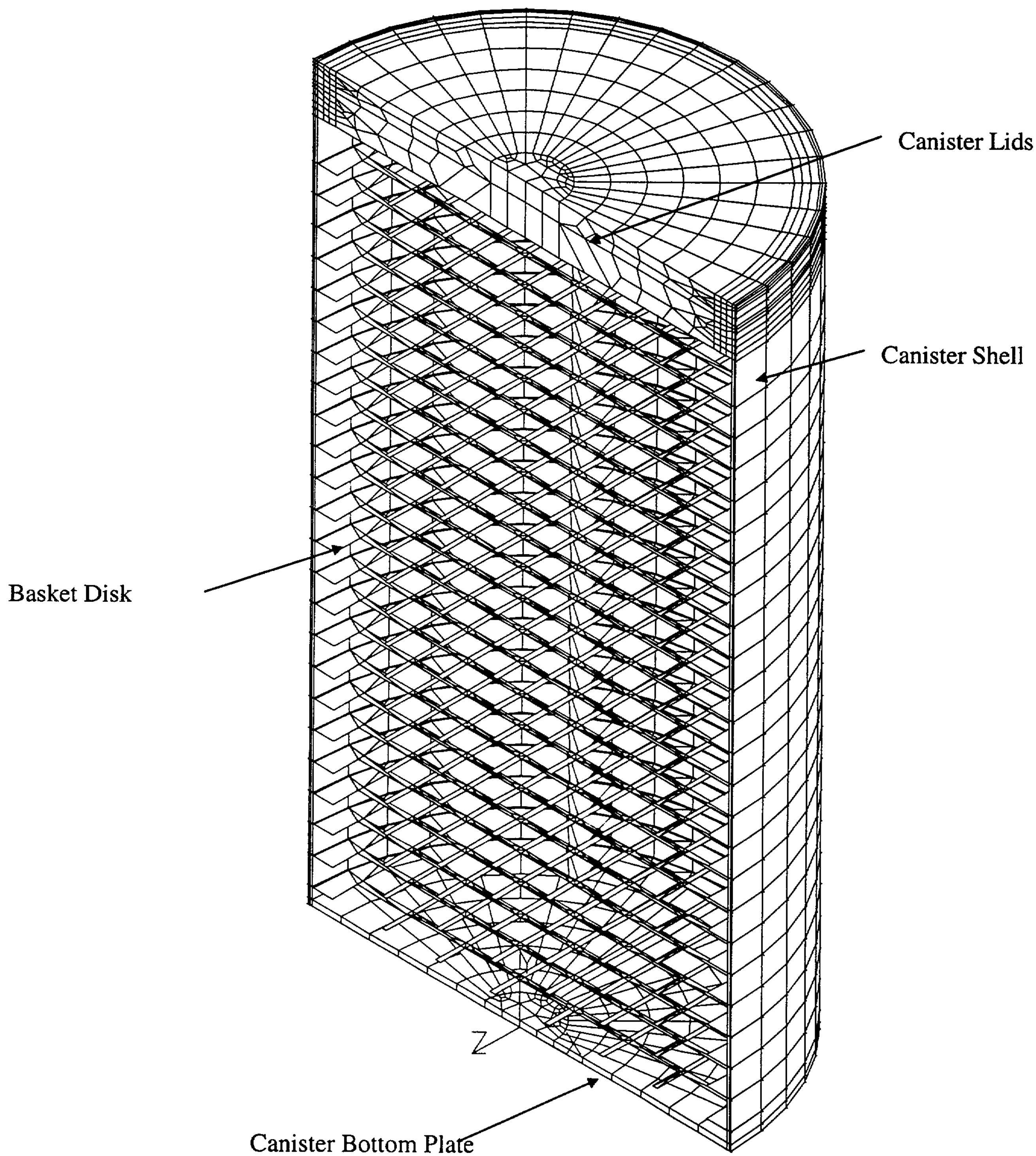


Figure 11.3.1.1-2 Canister Structural and Shield Lid Finite Element Mesh

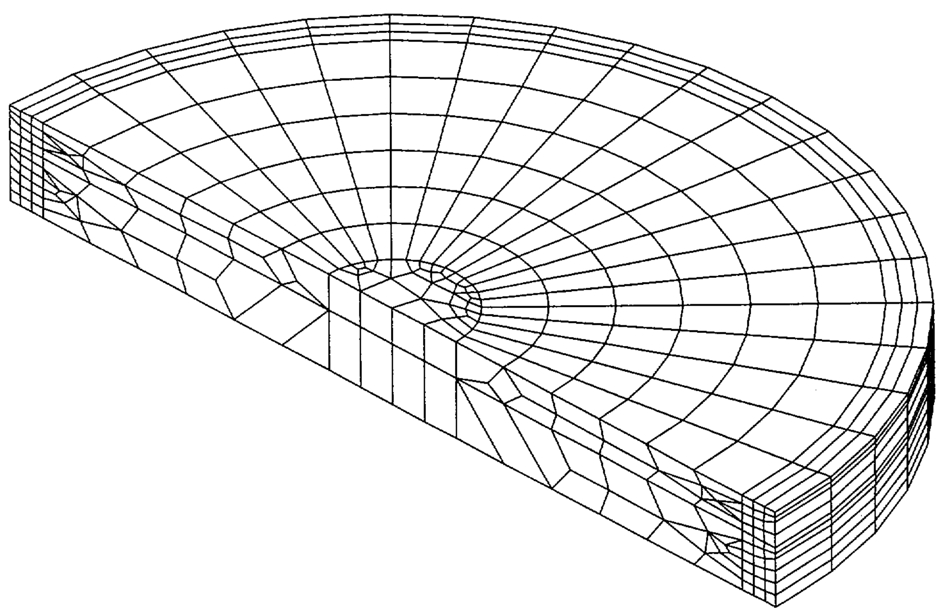


Figure 11.3.1.1-3 Structural and Shield Lid Weld Regions Finite Element Mesh

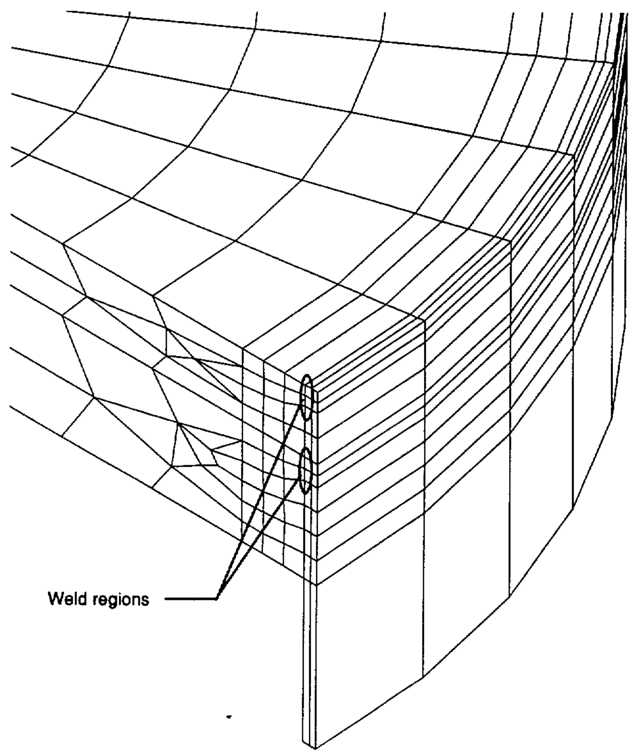


Figure 11.3.1.1-4 Canister Bottom Plate Finite Element Mesh

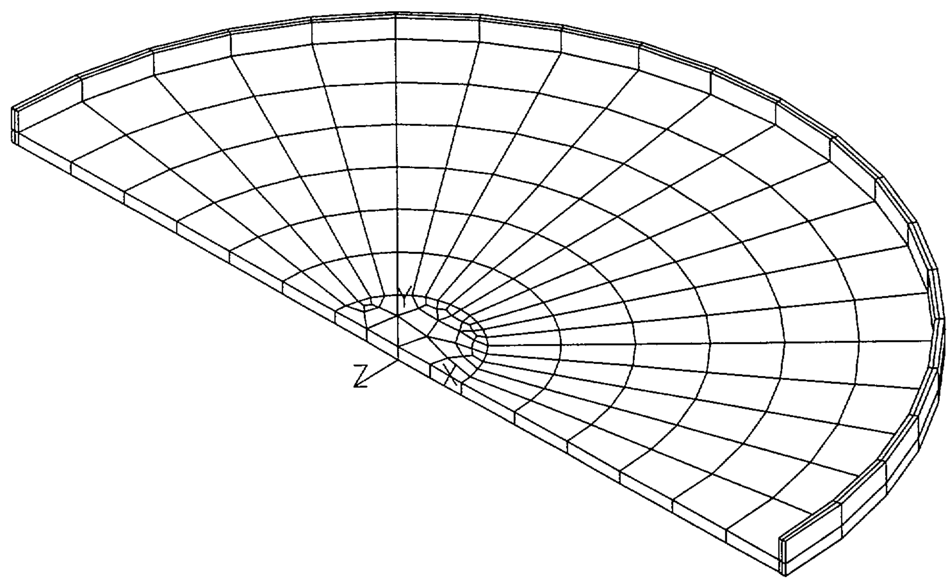
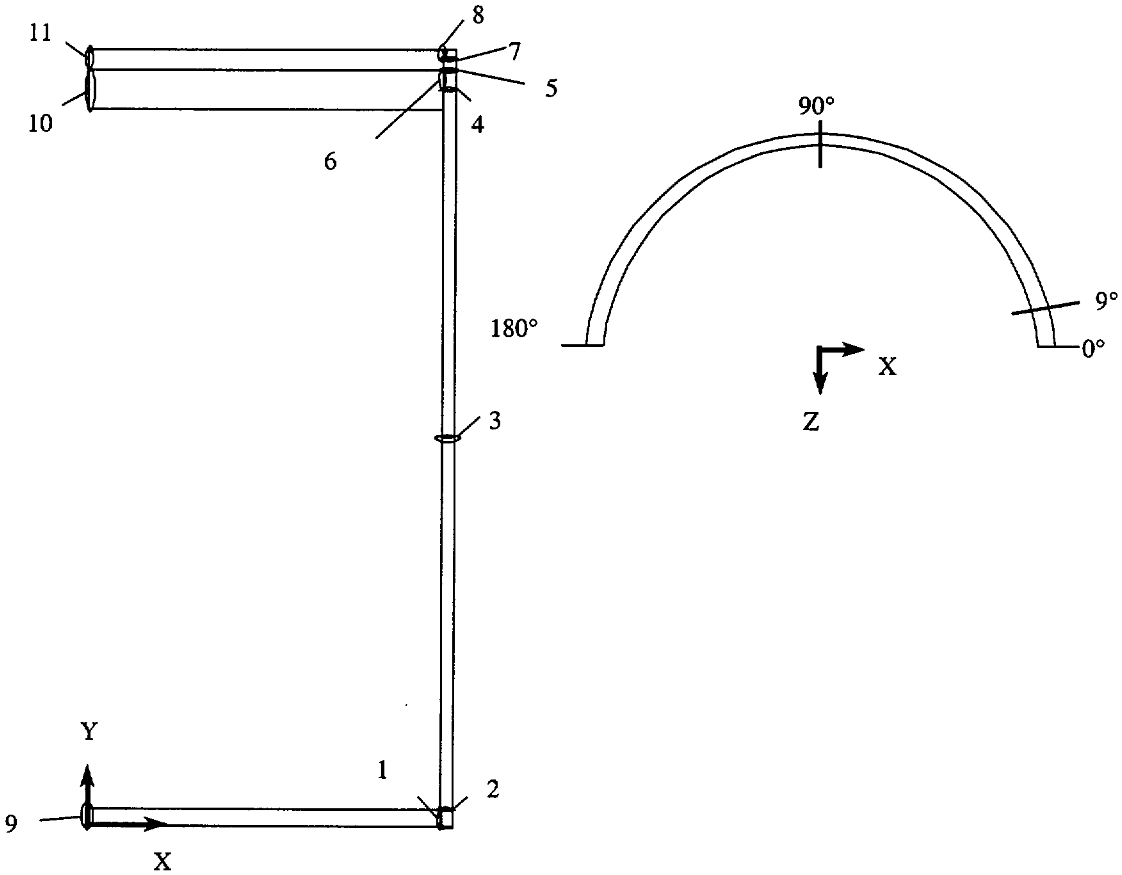


Figure 11.3.1.1-5 Identification of the Sections for Evaluating the Linearized Stresses in the Canister



	Node 1		Node 2	
Section	X (in.)	Y (in.)	X (in.)	Y (in.)
1	34.695	0.000	34.695	1.000
2	34.695	1.000	35.320	1.000
3	34.695	57.269	35.320	57.269
4	34.695	118.000	35.320	118.000
5	34.695	119.000	35.320	119.000
6	34.695	118.000	34.695	119.000
7	34.695	121.120	35.320	121.120
8	34.695	121.120	34.695	122.000
9	0.000	0.000	0.000	1.000
10	0.000	114.000	0.000	119.000
11	0.000	119.000	0.000	122.000[1]

1. The actual length of the canister is 122.5 inches. There is no significant effect on the analysis results due to the 0.5-inch difference in the evaluated length and the actual canister length.

11.3.1.2 Canister Bottom and Side Impact Analysis

This section documents the evaluation of the canister for the 56.1 g bottom end impact and 55 g side impact load conditions. In addition to the impact loads, a 20 psig pressure load internal to the canister is considered. Note that the use of 20 psig is conservative, since the maximum internal pressure for the canister is 7.9 psi for normal conditions of storage. To determine the effect of the 20 psig pressure load, analyses with and without the pressure load were performed. The maximum nodal stresses are summarized as:

Impact Orientation	Internal Pressure (psi)	Maximum Stress Intensity (ksi)
Bottom End	0	4.6
Bottom End	20	3.0
Side	0	24.5
Side	20	27.1

It is concluded that the impact loading without pressure is the limiting condition for the bottom end impact case. For the side impact case, the addition of pressure to the impact loading is limiting. Therefore, a 20 psig pressure is conservatively applied to the inner surface of the canister model for the side impact conditions, while no internal pressure is used for the bottom end impact analyses.

The analysis results of the 56.1 g bottom impact conditions are presented in Tables 11.3.1.2-1 and 11.3.2-2. Results for the 55 g side impact condition are shown in Tables 11.3.1.2-3 and 11.3.1.2-4. The section stresses presented in the tables are identified by a section number. A cross-section of the canister showing the section numbers is presented in Figure 11.3.1.1-5. A summary of the canister minimum Margins of Safety for the evaluated impact conditions are shown in Table 11.3.1.2-5. The margins of safety are calculated as: M.S. = (allowable stress/S.I.) –1, where S.I. is the calculated stress intensity.

For the bottom end impacts, the stresses are essentially uniform around the circumference. For the side impact, the stresses vary around the circumference. Therefore, the circumferential angle at which the maximum stress occurs is noted in the table, in parentheses beside the section number. The allowable stresses presented in the tables are for Type 304L stainless steel, except

for section 10, which is for Type 304 stainless steel. These allowables are evaluated at 350°F (maximum calculated temperature in the canister is 319°F for normal conditions of storage).

Additionally, stress results for a 20 g bottom end impact and a 20 g side impact are listed in Table 11.3.1.2-6 through 11.3.1.2-9. Since the results are bounded by those of the 56.1 g bottom end impact and the 55 g side impact conditions, the stresses are listed without showing the Margin of Safety.

Table 11.3.1.2-1 Canister Analysis Results for the 56.1 g Bottom End Impact (Primary Membrane Stress)

Section[1] No.	Component Stresses (psi)						Principal Stresses (psi)			S.I.	Allow. Stress	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3			
1	-70.7	-1971.0	-361.1	176.2	70.3	22.4	-51.8	-360.9	-1990.0	1938.0	39000	19.12
2	289.7	-5185.0	-1182.0	91.4	54.3	94.4	297.4	-1187.0	-5187.0	5485.0	39000	6.11
3	2.1	-4867.0	0.9	0.0	0.2	0.0	2.1	0.9	-4867.0	4869.0	39000	7.01
4	-2131.0	-2251.0	-1084.0	0.0	734.3	0.0	-729.3	-2131.0	-2605.0	1876.0	39000	19.79
5	2510.0	-2096.0	-1535.0	-310.9	-0.9	278.1	2549.0	-1553.0	-2117.0	4667.0	39000	7.36
6	551.9	1897.0	-676.0	15.4	84.7	-106.6	1900.0	561.0	-688.0	2588.0	39000	14.07
7	-3028.0	979.9	-1533.0	-368.1	39.6	55.9	1014.0	-1531.0	-3063.0	4077.0	39000	8.57
8	588.3	-3496.0	-2019.0	466.6	119.6	210.4	659.5	-2031.0	-3554.0	4214.0	39000	8.25
9	82.5	-682.0	94.2	6.5	58.3	-0.5	98.5	82.5	-686.4	785.0	39000	48.68
10	183.8	-98.9	168.1	43.7	-77.1	5.7	195.2	183.5	-125.7	320.9	45640	141.22
11	-469.6	-9.4	-467.5	48.0	-75.2	-1.2	7.4	-470.1	-483.8	491.2	39000	78.40

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-2 Canister Analysis Results for the 56.1 g Bottom End Impact (Primary Membrane Plus Primary Bending Stress)

Section[1] No.	Component Stresses (psi)						Principal Stresses (psi)			S.I.	Allow. Stress	Margin of Safety
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3			
1	398.0	-2678.0	-380.7	125.9	67.7	37.0	405.2	-380.8	-2685.0	3090.0	58500	17.93
2	-1988.0	-7553.0	85.1	0.0	-32.4	0.0	85.2	-1988.0	-7553.0	7638.0	58500	6.66
3	2.1	-4867.0	2.9	1.1	0.4	-0.1	3.0	2.1	-4867.0	4870.0	58500	11.01
4	-2259.0	-3096.0	-704.5	0.0	805.1	0.0	-458.8	-2259.0	-3342.0	2883.0	58500	19.29
5	1450.0	-10380.0	-4379.0	304.5	3.7	410.7	1486.0	-4407.0	-10390.0	11880.0	58500	3.92
6	3324.0	5269.0	932.2	817.6	53.3	-170.6	5567.0	3041.0	917.1	4650.0	58500	11.58
7	-2361.0	8380.0	938.8	-472.4	41.6	196.1	8401.0	950.4	-2393.0	10790.0	58500	4.42
8	4403.0	-1585.0	-491.6	605.7	160.4	345.7	4490.0	-503.9	-1659.0	6149.0	58500	8.51
9	105.1	-686.4	100.3	8.1	60.4	-1.7	106.1	104.0	-691.1	797.2	58500	72.38
10	6941.0	230.8	6895.0	28.2	-72.6	35.9	6960.0	6876.0	229.9	6730.0	65200	8.69
11	-4093.0	-195.3	-4098.0	47.4	-79.5	-18.6	-193.1	-4079.0	-4115.0	3922.0	58500	13.92

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-3 Canister Analysis Results for the 55 g Side Impact + Internal Pressure (20 psi) (Primary Membrane Stress)

Section[1] No.	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1(0°)	-14680.4	1080.1	-9311.6	-235.5	-21.1	-904.6	1083.2	-9163.7	-14827.2	15917.7	39000	1.45
2(0°)	-3395.4	62.4	-7415.7	-314.3	-438.9	-478.6	111.6	-3358.7	-7501.7	7612.8	39000	4.12
3(180°)	-4.6	-1213.2	586.7	0.1	-4.0	-45.8	590.3	-8.1	-1213.2	1802.5	39000	20.64
4(9°)	-16945.4	3043.0	-4750.2	-336.0	2851.1	2020.7	3978.4	-5329.0	-17301.9	21276.1	39000	0.83
5(0°)	-10863.5	1232.1	-7804.7	-1756.4	1333.8	92.4	1662.0	-7961.0	-11146.6	12803.4	39000	2.05
6(0°)	-23467.7	-3813.8	-11125.6	-2768.3	1168.1	38.0	-3262.2	-11293.4	23855.7	20594.5	39000	0.89
7(9)	-11503.1	654.7	-4158.7	-31.6	1865.5	961.7	1299.2	-4673.6	-11639.5	12939.7	39000	2.01
8(0°)	-19367.6	-4979.8	-8614.2	-982.6	865.8	-756.5	-4697.7	-8785.2	-19472.5	14774.8	39000	1.64
9	-2146.5	-15.3	1105.2	-2.9	-14.7	-78.0	1107.3	-15.5	-2148.6	3255.9	39000	10.98
10	-1032.3	-8.4	331.8	-59.4	-2.9	-27.1	332.3	-4.9	-1036.3	1368.4	45640	32.35
11	-1131.4	-1.3	373.3	-25.5	-5.1	-32.8	374.1	-0.7	-1132.5	1506.8	39000	24.88

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-4 Canister Analysis Results for the 55 g Side Impact + Internal Pressure (20 psi) (Primary Membrane Plus Primary Bending Stress)

Section[1] No.	Component Stresses (psi)						Principal Stresses (psi)				Allow.	Margin of
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.	Stress	Safety
1(0°)	-24841.3	457.1	-12761.5	-195.8	106.1	-824.5	459.5	-12709.0	-24904.3	25365.6	58500	1.31
2(0°)	-2630.9	-1326.5	-8993.8	-290.8	-641.0	-126.3	-1218.5	-2682.3	-9050.5	7832.0	58500	6.47
3(0°)	89.9	2039.5	3198.2	2.7	38.7	156.9	3207.7	2038.5	81.9	3125.9	58500	17.71
4(9°)	-13894.0	9446.8	-2019.6	93.3	2241.9	2829.1	9886.2	-1813.0	-14533.6	24421.9	58500	1.40
5(0°)	-14261.0	2077.3	-6923.9	-2052.1	1046.5	-15.1	2446.4	-7037.2	-14512.6	16966.3	58500	2.45
6(0°)	-32968.0	-7832.0	-15215.2	-4140.9	1477.5	185.3	-6920.8	-15456.4	-33639.1	26718.3	58500	1.19
7(9°)	-9079.8	4969.3	-1993.4	53.6	1402.0	1674.6	5250.3	-1894.8	-9460.5	14711.9	58500	2.98
8(0°)	-28144.4	-7245.8	-12646.1	-2107.7	1351.6	-307.9	-6716.3	-12971.2	-28354.1	21643.1	58500	1.70
9	-2172.7	-33.2	1088.4	-2.9	-14.9	-75.6	1089.5	-33.5	-2174.8	3264.3	58500	16.92
10	-1360.0	-10.9	297.9	-63.0	-2.9	-40.8	299.0	-8.0	-1364.2	1663.1	65200	38.20
11	-1344.3	-1.2	354.1	-25.6	-5.0	-39.5	355.1	-0.7	-1346.4	1700.8	58500	33.40

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-5 Summary of Minimum Margin of Safety for Canister Impact Analysis

Drop Orientation	Loading Condition	Stress Evaluated	Minimum Margin of Safety	Section No.*
Bottom end	56.1 g impact	P_m	6.11	2
Bottom end	56.1 g impact	$P_m + P_b$	3.92	5
Side	55 g impact + internal pressure (20 psi)	P_m	0.83	4
Side	55 g impact + internal pressure (20 psi)	$P_m + P_b$	1.19	6

* See Figure 11.3.1.1-5 for section locations.

Table 11.3.1.2-6 Bottom End Impact (20 g) - Primary Membrane Stresses[1]

Section No.	P_m Stresses (psi)						Principal Stresses (psi)			
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	-25.3	-704.5	-129.2	63.1	25.1	8.0	-18.5	-129.1	-711.3	692.8
2	103.7	-1854.0	-422.7	32.7	19.4	33.8	106.4	-424.7	-1855.0	1961.0
3	0.8	-1740.0	0.3	0.0	0.1	0.0	0.8	0.3	-1740.0	1741.0
4	-760.4	-800.7	-389.0	0.0	263.2	0.0	-260.7	-760.4	-929.1	668.4
5	905.9	-756.4	-546.9	-107.1	0.2	99.9	919.5	-553.5	-763.5	1683.0
6	196.5	704.2	-233.2	5.1	30.5	-37.5	705.2	199.7	-237.4	942.6
7	-1072.0	339.2	-546.8	-127.7	13.9	19.5	350.9	-546.2	-1084.0	1435.0
8	207.7	-1240.0	-718.6	162.8	42.2	74.7	232.4	-723.0	-1260.0	1493.0
9	29.5	-243.2	33.7	2.3	20.8	-0.2	35.3	29.5	-244.7	280.0
10	70.7	23.7	69.5	16.0	-20.2	0.7	80.9	71.0	12.1	68.8
11	-161.1	50.4	-157.0	16.1	-39.4	-1.4	58.9	-161.5	-165.1	223.9

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-7 Bottom End Impact (20 g)-Primary Membrane Plus Primary Bending Stresses[1]

Section No.	$P_m + P_b$ Stresses (psi)						Principal Stresses (psi)			
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	S.I.
1	142.5	-957.2	-136.2	45.1	24.2	13.3	145.1	-136.2	-959.7	1105.0
2	-711.1	-2701.0	30.4	0.0	-11.5	0.0	30.5	-711.1	-2701.0	2731.0
3	0.8	-1741.0	1.0	0.4	0.1	0.0	1.053	0.8	-1741.0	1742.0
4	-808.8	-1111.0	-254.6	0.0	290.6	0.0	-165.3	-808.8	-1200.0	1035.0
5	522.1	-3735.0	-1569.0	111.2	1.6	147.5	535.4	-1580.0	-3738.0	4273.0
6	1194.0	1910.0	344.1	288.9	19.6	-60.7	2012.0	1097.0	338.7	1674.0
7	-838.6	2970.0	331.1	-166.6	14.8	69.5	2977.0	335.2	-850.0	3827.0
8	1555.0	-560.8	-178.8	213.3	56.8	122.6	1586.0	-183.1	-587.0	2173.0
9	37.6	-244.7	35.9	2.9	21.5	-0.6	38.0	37.2	-246.4	284.4
10	2529.0	140.9	2515.0	13.6	-17.2	12.0	2536.0	2508.0	140.7	2395.0
11	-1383.0	-19.4	-1389.0	14.6	-41.9	-6.1	-17.9	-1380.0	-1393.0	1375.0

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-8 Side Impact (20 g) + Internal Pressure (20 psi) - Primary Membrane Stresses[1]

Section No.	P_m Stresses (psi)						Principal Stresses (psi)			S.I.
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	
1	-10227.0	856.0	-4685.1	375.9	199.7	-908.3	873.9	-4543.6	-10386.4	11262.0
2	5431.7	1884.3	-732.0	-276.8	-292.7	-442.5	5481.0	1902.2	-800.0	6281.1
3	-692.7	765.9	1360.0	4.7	-5.3	114.9	1367.4	765.9	-699.1	2065.7
4	-292.6	2090.9	659.1	159.2	1019.3	427.2	2660.3	279.9	-482.3	3142.7
5	-9019.0	-32.9	-3701.6	-1049.6	954.2	-599.5	345.1	-3914.4	-9184.7	9529.7
6	-15561.2	-2614.2	-4803.6	-1996.5	811.3	-748.8	-2010.2	-5071.0	-15896.8	13883.5
7	1925.2	1097.9	814.8	69.9	485.8	-45.5	1931.5	1460.7	446.1	1484.8
8	-14051.2	-2852.2	-3555.8	-677.4	842.2	-1202.7	-2161.2	-4080.1	-14219.0	12058.9
9	-478.9	-198.6	806.7	71.4	22.0	-22.2	807.5	-181.7	-496.6	1304.5
10	-425.3	-1.7	78.9	-25.7	6.7	-10.9	79.7	-0.7	-427.1	506.8
11	-382.5	-2.7	174.5	-16.4	2.8	-13.3	174.9	-2.1	-383.6	558.5

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

Table 11.3.1.2-9 Side Impact (20 g) + Internal Pressure (20 psi) - Primary Membrane Plus Primary Bending Stresses[1]

Section No.	$P_m + P_b$ Stresses (psi)						Principal Stresses (psi)			S.I.
	SX	SY	SZ	SXY	SYZ	SXZ	S1	S2	S3	
1	-26047.2	-2107.7	-10104.3	413.8	217.7	-1116.8	-2095.1	-10030.9	-26131.1	24044.4
2	-4429.3	-11241.0	1092.6	364.4	886.8	-75.4	1156.6	-4409.4	-11324.9	12478.3
3	-759.6	1198.5	2829.1	7.8	-5.9	227.3	2842.8	1198.5	-774.0	3617.7
4	599.0	4274.1	2236.7	208.0	755.2	1088.4	4603.4	2456.9	50.1	4553.0
5	-11146.6	26.7	-3044.1	-1644.2	728.4	-827.9	466.5	-3185.6	-11450.7	11912.1
6	-19996.8	-4548.8	-6797.0	-2643.5	1026.7	-594.2	-3707.8	-7185.0	-20447.7	16735.7
7	2385.6	321.5	419.3	86.5	664.6	-648.9	1677.8	651.1	-962.1	2639.3
8	-18046.4	-4398.9	-5819.7	-1420.9	1203.8	-864.6	-3522.2	-6506.6	-18235.2	14711.9
9	-956.6	-172.7	869.4	75.4	9.5	10.3	869.6	-165.6	-963.9	1833.0
10	-1095.8	-29.5	-493.6	-25.3	7.2	-18.4	-28.7	-493.2	-1096.8	1068.5
11	-814.4	-19.7	-190.1	-16.0	3.0	-15.9	-19.4	-189.8	-815.2	795.8

1. Sections are identified in Figure 11.3.1.1-5. Stresses are reported in a cylindrical coordinate system (X,Y,Z) corresponding to radial, circumferential and axial directions respectively.

11.3.1.3 Canister Buckling Evaluation for the Bottom End Impact

The canister shell is axially loaded by the weights of the structural lid, the shield lid, and the inertial weight of the shell during a bottom end impact. The impact load amplification factor is 56.1g. The shell is evaluated as an unsupported, right circular cylinder using a critical buckling load per Blake, 2nd Edition, "Practical Stress Analysis in Engineering Design."

$$S_{cr} = \frac{E\left(0.605 - 10^{-7} M^2\right)}{M\left(1 + 0.004\phi\right)}$$

$= 40.3$ ksi

The canister material is Type 304L stainless steel. Conservatively assume the material temperature to be at 400°F for this impact condition.

$E = 26.5E{+}03$ ksi $\quad R = (69.39 + 0.625)/2$

$= 35.01$ inches (mid-radius of the canister shell)

$S_y = 17.5$ ksi $\quad t = 0.625$ inches (thickness of the canister)

$\phi = E/S_y$ and $m = R/t$

$= 1514.3$ $\quad = 56.0$

The axial compression load in the canister shell is:

$P_a = [\,(\pi/4)(69.03^2)(8)(0.291) + (\pi/4)(70.64^2 - 69.39^2)(121.5)(0.291)\,]\ (56.1)$

$P_a = 761{,}457$ pounds

and the axial compression stress is:

$$S_a = \frac{P_A}{\left(\pi/4\right)\left(70.64^2 - 69.39^2\right)}$$

$S_a = 5{,}540$ psi

The margin of safety is:

$(S_{cr}/S_a) - 1 = +\ 6.3$

11.3.2 Canister Fuel Basket End Impact Analysis

Section 11.2.11 uses the results of analysis performed for the transport end impact condition to show adequate performance of the basket for the 6-inch concrete cask end drop accident. This section presents the transport end impact analysis upon which the results of Section 11.2.11 are based.

The fuel basket in the transportable storage canister is designed to contain up to 36 Yankee class fuel assemblies. The basket structure has a right circular cylinder configuration and consists of 36 square tubes supported by 22 circular support disks, and a circular top and bottom plate, which are retained by eight axial tie rods. The support disks and top and bottom plates are seperated and supported by split spacers at the tie rods. The configuration of the basket is shown in Figure 11.3.2-1.

Each fuel tube has an 7.8-inch square inside dimension, a 0.048-inch thick wall, and can hold one intact fuel assembly. The fuel assemblies together with the tubes are laterally supported in square holes in the stainless steel support disks. Each circular support disk is 0.5 inches thick and 69.15 inches in diameter. There are three different web widths in the support disks. One web width is 0.750 inches between the holes, one web width is 0.810 inches between the holes, and one web width is 0.875 inches between holes. The top and bottom plates are both 0.5 inch thick and have the same diameter as the support disks. The disks are spaced and retained by tie rods and split spacers (spacers) at eight locations near the periphery of each disk to form an integral basket assembly. The fuel basket contains the fuel and is enclosed by the canister. The canister has a 70.64 inch outer diameter and 5/8 inch thick walls. The overall length of the canister cavity is 122.5 inches, which encompasses the entire fuel assembly length and the thickness of the shield lid and structural lid. The canister shell is fabricated from Type 304L stainless steel.

The material of the support disks is 17-4 PH stainless steel. The top plate and the bottom plate are fabricated from Type 304 stainless steel. The fuel tubes are made from Type 304 stainless steel, which also encases the BORAL neutron absorbing material. The tie rods and spacers are fabricated from Type 304 stainless steel. The fuel tubes are not structural components; and are not considered in the basket evaluation. The tie rods and spacers locate and structurally assemble the circular support disks, heat transfer disks, and the top and bottom plates to form an integral assembly. The spacers carry the weight of the support disks, heat transfer disks, endplate and

their own weight in the end impact loading condition. The end impact analysis uses classical closed form methods that are evaluated independent of the finite element basket model. The support disk structural evaluation is performed using a finite element model of a single disk.

The structural analysis of the basket components is in accordance with ASME Code, Section III, Division 1, Subsection NG, "Core Support Structures." In addition, the stainless steel/BORAL composite fuel tube has been evaluated for a postulated impact load.

11.3.2.1 Stress Evaluation of Support Disk in the End Impact

To determine the structural adequacy of the support disks in the end drop event, a load equal to the weight of the fuel and tubes multiplied by an amplification factor is applied to the support disk structure to simulate an end impact. For accident conditions, the amplification factor for the end impact is 56.1 g.

A finite element analysis is performed, utilizing the ANSYS computer code, to calculate the stresses in a support disk in accordance with ASME Code Section III, Subsection NG. In this subsection, linearized stresses of cross sections of the structure are compared to the allowable stresses. The maximum primary membrane stress intensity calculated in the support disk is compared to the allowable stress limits for accident conditions is, 0.7 S_u or 2.4 S_m, whichever is less.

11.3.2.1.1 Finite Element Model Description

A finite element model is used to evaluate the basket support disk for the end impact accident condition in which the loads are perpendicular to the plane of the disk.

The model for the end drop condition is constructed using ANSYS SHELL63 elements. It consists of a single support disk with a thickness of 0.5 inches. The shell elements accommodate the out-of-plane bending, which is present in the end-drop condition. In the end drop, the support disk is restrained by the split spacers on the eight tie rods. The nodes corresponding to the location of the tie rods are restrained in the out of plane direction (the cask axial direction). Four additional in-plane transitional restraints are specified at the outer edge of the model (located 90° apart from each other) in the tangential direction to prohibit rigid body displacements. The only loading is the inertial weight (56.1 g) of the support disk in the out-of-plane direction. The finite element model is shown in Figure 11.3.2-2.

Three thermal conditions are considered:

Thermal Condition	Ambient Temperature	Solar Insolence Applied to Cask Surface	12.5 kW Fuel Load
1	100°F	yes	yes
2	-40°F	no	yes
3	-40°F	no	no

The temperature distribution of the support disk for these Thermal Conditions are determined by the thermal analysis. The bounding thermal conditions (2 and 3) are used in the analysis to determine the material properties. Allowable stresses are determined based on conservative temperatures of 539° F for Thermal Condition 2 and -40° F for Thermal Condition 3.

To determine the most critical regions, a series of cross sections are considered. The section locations are identified in Figure 11.3.2-3. Table 11.3.2-1 shows the coordinate location of the cross section end points.

11.3.2.1.2 Support Disk End Impact Analysis Results

A structural analysis is performed using ANSYS to evaluate the effect of a 56.1 g end impact which corresponds to the most severe out-of-plane loading. Linearized stresses at the cross sections identified in Figure 11.3.2-3 are compared to stress allowables in accordance with the ASME Code, Section III, Subsection NG.

The stress evaluation results for the 56.1 g end impact condition are:

Thermal Condition	P_m Stress Intensity (ksi)	M.S.	P_m+P_b Stress Intensity (ksi)	M.S.
2	0	N/A	52.9	1.42
3	0	N/A	53.9	1.51

The margin of safety (M.S.) is:

M.S. = (Allowable Stress/Stress Intensity) –1,

where the allowable stress is 1.0 S_u for 17-4PH Type 630 stainless steel.

The minimum margin of safety is +1.42. The P_m stresses in the support disk for end drop conditions are essentially zero because there is no in-plane loading. Tables 11.3.2-2 and 11.3.2-3 list the 40 highest P_m+P_b stress intensities for thermal conditions 2 and 3, respectively.

11.3.2.2 Evaluation of Tie Rods and Spacers for an End Impact Condition

The design end impact loading for the basket is 56.1 g. The structural capacity of the spacers supporting the basket is evaluated using classical analysis. Accident loading due to the 56.1 g impact of the fuel basket was compared to the stress limit of 0.7 S_u in accordance with Subarticle NF 1440 of the ASME Code.

No detailed evaluation of the tie rods is required. The tie rods serve basket assembly purposes and are not part of the load path for the condition evaluated. The tie rods are loaded during fabrication by a 190 ft-lbs preload. Under impact conditions, the preload will be reduced. The tie rod design is, therefore, acceptable by inspection.

During the end impact, the spacers are loaded with the weight of 22 support disks, the aluminum heat transfer disks, one end plate, and the weight of the spacers. The load is resisted by the effective area of 8 spacers. The compressive stresses are calculated on the effective area of the spacer.

The material allowable stress is conservatively selected at a temperature of 500°F. The analysis input is:

stress limits	=	0.7 S_u (accident condition) (more limiting than 2.4 S_m)
loading criteria (g)	=	56.1g (accident condition)
evaluation temperature	=	500°F

Canister Basket Parameters

fuel basket weight	=	9,530 lbs
bottom weldment weight	=	438 lbs
fuel tube weight (36 tubes)	=	2,164 lbs
rod diameter	=	1.13 in
spacer outer diameter	=	2.50 in

Materials

tie rod	=	SA 479 Type 304 Stainless Steel
spacer	=	A511 Type 304 Stainless Steel

Material Allowable

Type 304 SS	=	S_m = 17,500 psi (500°F)
	=	S_u = 63,500 psi (500°F)

The spacer load is calculated as follows:

Total weight of basket	=	9,530 lbs
Less weight of bottom weldment	=	-438 lbs
Less weight of fuel tubes	=	-2,164 lbs
Therefore,		
1 g load on spacers	=	6,928 lbs
Applied g level	=	56.1g
End impact load on spacers	=	6,928 x 56.1
	=	388,661 lbs

The effective area of one spacer at each of eight locations supporting the weight of the support disks is equal to the net area of the spacer and is calculated as:

$$A = \frac{3.14 \times \left(2.5^2 - 1.25^2\right)}{4}$$

$$= 3.68 \text{ in}^2$$

The average compressive stress, S_c, in the spacer is:

$$S_c = \frac{388{,}661}{8 \times 3.68}$$

$= 13{,}202$ psi

The allowable stress for Type 304 SS under accident conditions is 0.7 S_u.

$$S_u = 63{,}500 \text{ psi}$$
$$0.7\, S_u = 0.7 \times 63{,}500$$
$$= 44{,}500 \text{ psi}$$

The margin of safety (MS), which is defined as $\frac{0.7S_u}{S_c} - 1$, is calculated as:

$$\frac{44{,}450}{13{,}202} - 1 = 2.37$$

Therefore, the spacers are structurally adequate for a 56.1 g end impact under accident conditions.

Figure 11.3.2-1 Canistered Yankee Class Fuel Basket Assembly

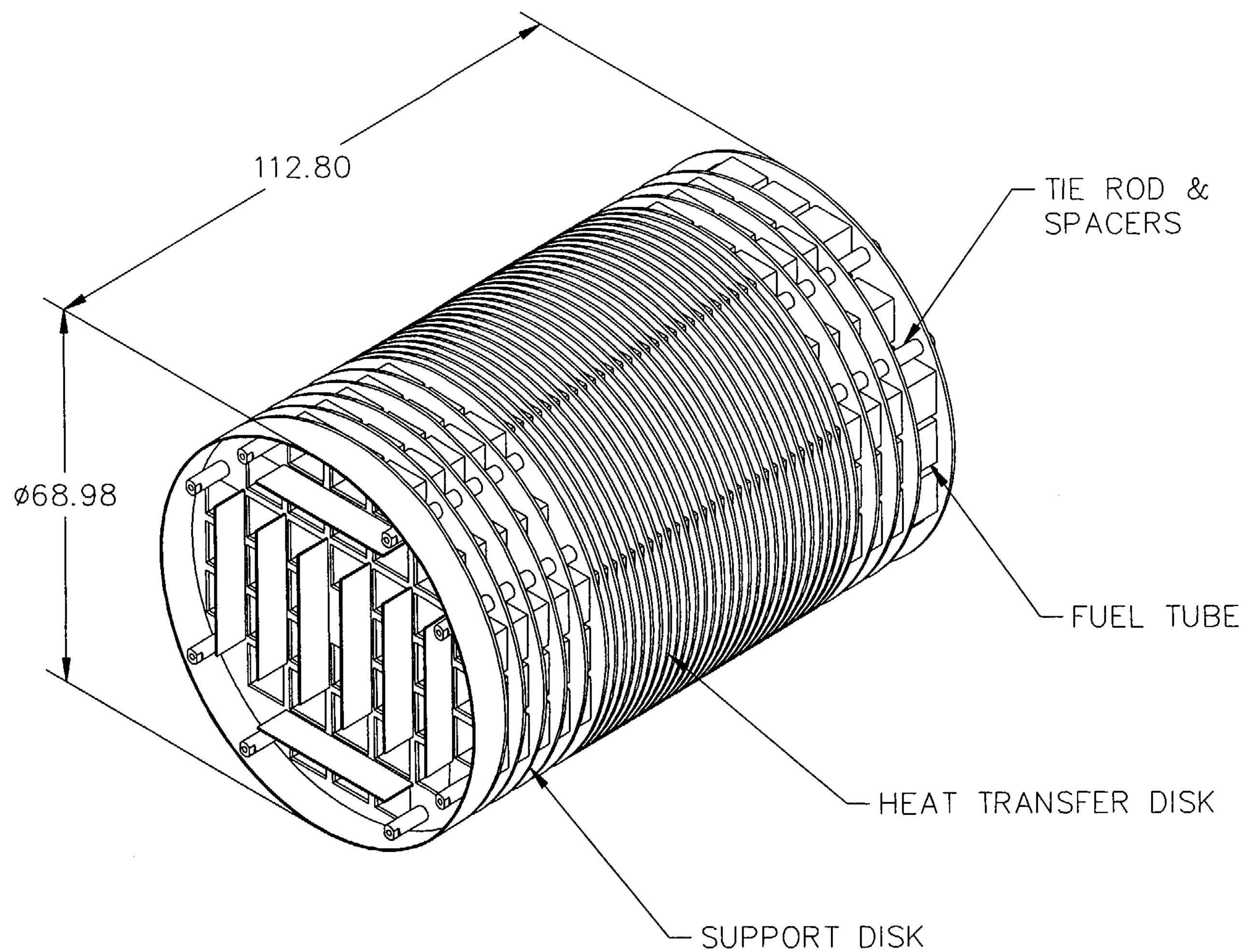


Figure 11.3.2-2 Fuel Basket Support Disk Finite Element Model

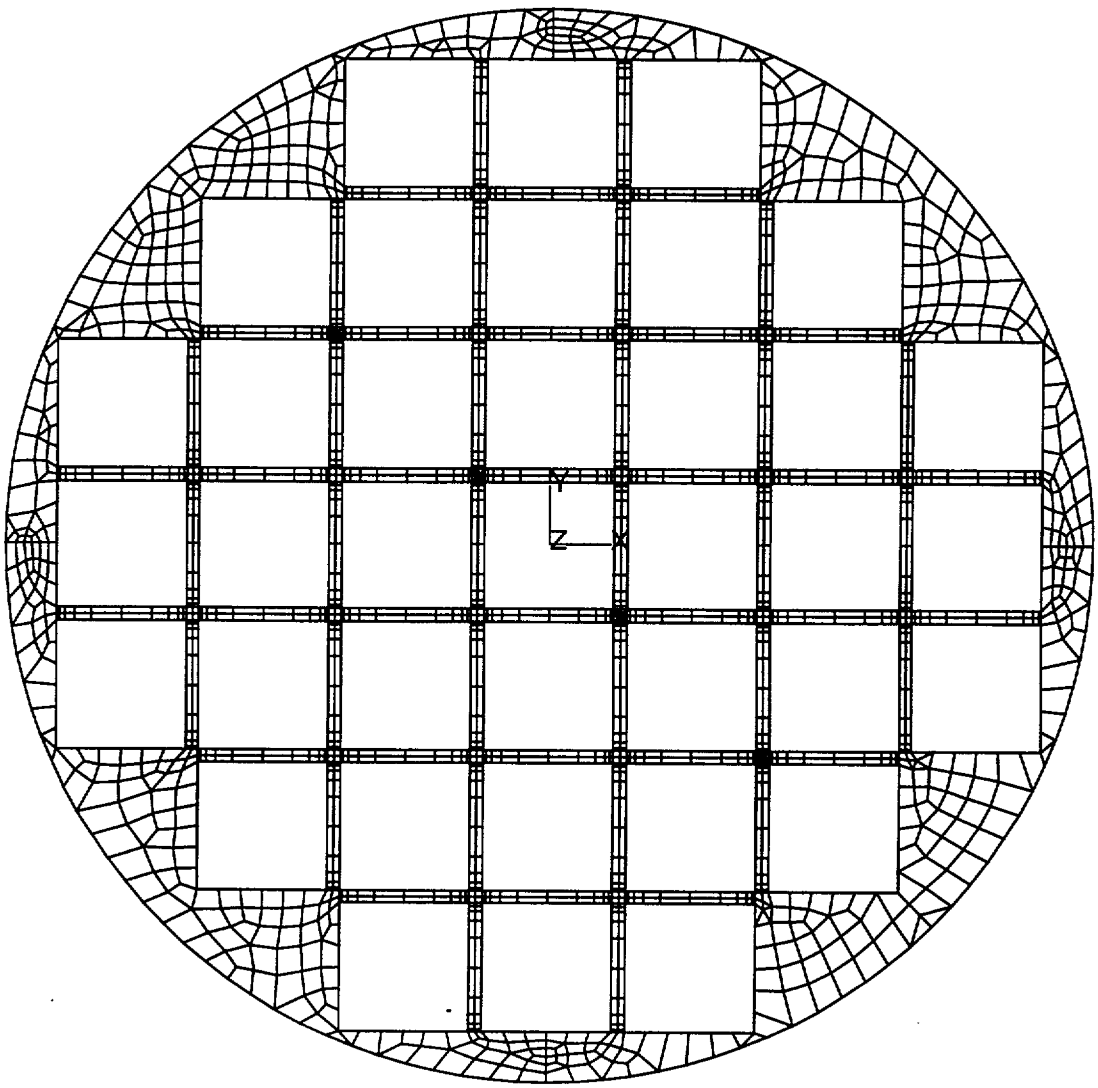


Figure 11.3.2-3 Location of the Support Disk Sections to Obtain Linearized Stresses

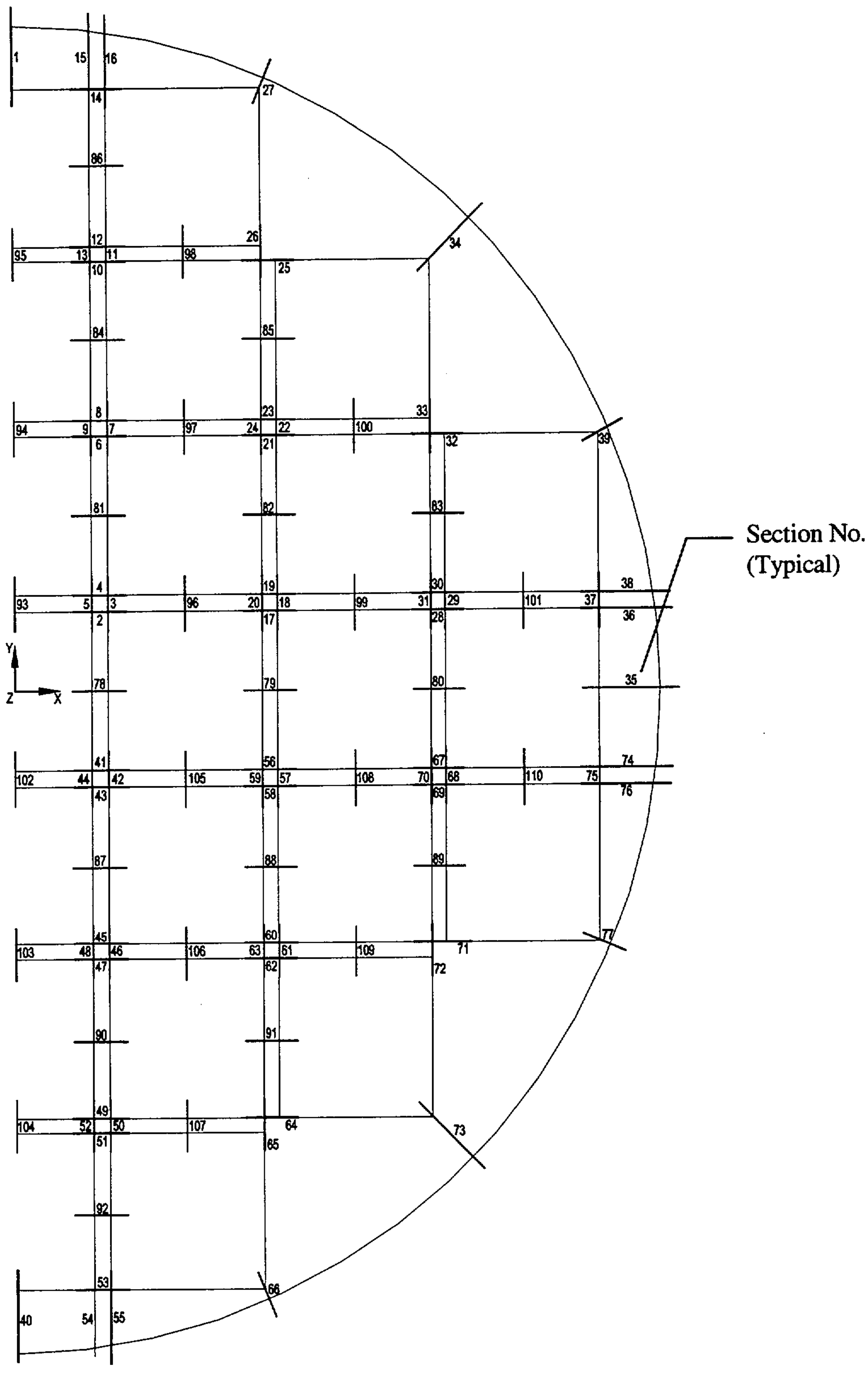


Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of the Support Disk (0° Basket Drop Orientation)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
1	1	2	0.00	31.32	0.00	34.49
2	3	4	4.13	4.13	5.00	4.13
3	5	6	5.00	4.13	5.00	5.00
4	7	8	5.00	5.00	4.13	5.00
5	9	10	4.13	5.00	4.13	4.13
6	11	12	4.13	13.26	5.00	13.26
7	13	14	5.00	13.26	5.00	14.07
8	15	16	5.00	14.07	4.13	14.07
9	17	18	4.13	14.07	4.13	13.26
10	19	20	4.13	22.32	5.00	22.32
11	21	22	5.00	22.32	5.00	23.07
12	23	24	5.00	23.07	4.13	23.07
13	25	26	4.13	23.07	4.13	22.32
14	27	28	4.13	31.32	5.00	31.32
15	29	30	4.13	31.32	4.13	34.24
16	31	32	5.00	31.32	5.00	34.13
17	33	34	13.26	4.13	14.07	4.13
18	35	36	14.07	4.13	14.07	5.00
19	37	38	14.07	5.00	13.26	5.00
20	39	40	13.26	5.00	13.26	4.13
21	41	42	13.26	13.26	14.07	13.26
22	43	44	14.07	13.26	14.07	14.07
23	45	46	14.07	14.07	13.26	14.07
24	47	48	13.26	14.07	13.26	13.26
25	49	50	13.26	22.32	14.07	22.32
26	51	52	13.26	22.32	13.26	23.07
27	53	54	13.26	31.32	13.44	31.76
28	55	56	22.32	4.13	23.07	4.13
29	57	58	23.07	4.13	23.07	5.00
30	59	60	23.07	5.00	22.32	5.00
31	61	62	22.32	5.00	22.32	4.13
32	63	64	22.32	13.26	23.07	13.26
33	65	66	22.32	13.26	22.32	14.07
34	67	68	22.32	22.32	24.39	24.39
35	69	70	31.32	0.00	34.49	0.00

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk (0° BASKET DROP ORIENTATION) (CONTINUED)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
36	71	72	31.32	4.13	34.24	4.13
37	73	74	31.32	4.13	31.32	5.00
38	75	76	31.32	5.00	34.13	5.00
39	77	78	31.32	13.26	31.71	13.47
40	79	80	0.00	-31.32	0.00	-34.49
41	81	82	4.13	-4.13	5.00	-4.13
42	83	84	5.00	-4.13	5.00	-5.00
43	85	86	5.00	-5.00	4.13	-5.00
44	87	88	4.13	-5.00	4.13	-4.13
45	89	90	4.13	-13.26	5.00	-13.26
46	91	92	5.00	-13.26	5.00	-14.07
47	93	94	5.00	-14.07	4.13	-14.07
48	95	96	4.13	-14.07	4.13	-13.26
49	97	98	4.13	-22.32	5.00	-22.32
50	99	100	5.00	-22.32	5.00	-23.07
51	101	102	5.00	-23.07	4.13	-23.07
52	103	104	4.13	-23.07	4.13	-22.32
53	105	106	4.13	-31.32	5.00	-31.32
54	107	108	4.13	-31.32	4.13	-34.24
55	109	110	5.00	-31.32	5.00	-34.13
56	111	112	13.26	-4.13	14.07	-4.13
57	113	114	14.07	-4.13	14.07	-5.00
58	115	116	14.07	-5.00	13.26	-5.00
59	117	118	13.26	-5.00	13.26	-4.13
60	119	120	13.26	-13.26	14.07	-13.26
61	121	122	14.07	-13.26	14.07	-14.07
62	123	124	14.07	-14.07	13.26	-14.07
63	125	126	13.26	-14.07	13.26	-13.26
64	127	128	13.26	-22.32	14.07	-22.32
65	129	130	13.26	-22.32	13.26	-23.07
66	131	132	13.26	-31.32	13.44	-31.76

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk
(0° BASKET DROP ORIENTATION) (CONTINUED)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
67	133	134	22.32	-4.13	23.07	-4.13
68	135	136	23.07	-4.13	23.07	-5.00
69	137	138	23.07	-5.00	22.32	-5.00
70	139	140	22.32	-5.00	22.32	-4.13
71	141	142	22.32	-13.26	23.07	-13.26
72	143	144	22.32	-13.26	22.32	-14.07
73	145	146	22.32	-22.32	24.39	-24.39
74	147	148	31.32	-4.13	34.24	-4.13
75	149	150	31.32	-4.13	31.32	-5.00
76	151	152	31.32	-5.00	34.13	-5.00
77	153	154	31.32	-13.26	31.76	-13.44
78	155	156	4.13	0.00	5.00	0.00
79	157	158	13.26	0.00	14.07	0.00
80	159	160	22.32	0.00	23.07	0.00
81	161	162	4.13	9.13	5.00	9.13
82	163	164	13.26	9.13	14.07	9.13
83	165	166	22.32	9.13	23.07	9.13
84	167	168	4.13	18.19	5.00	18.19
85	169	170	13.26	18.19	14.07	18.19
86	171	172	4.13	27.20	5.00	27.20
87	173	174	4.13	-9.13	5.00	-9.13
88	175	176	13.26	-9.13	14.07	-9.13
89	177	178	22.32	-9.13	23.07	-9.13
90	179	180	4.13	-18.19	5.00	-18.19
91	181	182	13.26	-18.19	14.07	-18.19
92	183	184	4.13	-27.20	5.00	-27.20
93	185	186	0.00	4.13	0.00	5.00
94	187	188	0.00	13.26	0.00	14.07
95	189	190	0.00	22.32	0.00	23.07
96	191	192	9.13	4.13	9.13	5.00
97	193	194	9.13	13.26	9.13	14.07
98	195	196	9.13	22.32	9.13	23.07

Table 11.3.2-1 Listing of Cross Sections for Stress Evaluation of Support Disk
(0° BASKET DROP ORIENTATION) (CONTINUED)

Section Number	Point 1	Point 2	Coordinates (in.)			
			Point 1		Point 2	
			X	Y	X	Y
99	197	198	18.19	4.13	18.19	5.00
100	199	200	18.19	13.26	18.19	14.07
101	201	202	27.20	4.13	27.20	5.00
102	203	204	0.00	-4.13	0.00	-5.00
103	205	206	0.00	-13.26	0.00	-14.07
104	207	208	0.00	-22.32	0.00	-23.07
105	209	210	9.13	-4.13	9.13	-5.00
106	211	212	9.13	-13.26	9.13	-14.07
107	213	214	9.13	-22.32	9.13	-23.07
108	215	216	18.19	-4.13	18.19	-5.00
109	217	218	18.19	-13.26	18.19	-14.07
110	219	220	27.20	-4.13	27.20	-5.00
105	209	210	-10.02	-16.16	-11.52	-16.16
106	211	212	-20.29	-10.02	-20.29	-11.52
107	213	214	-10.02	-31.18	-10.02	-30.44
108	215	216	-31.18	-10.02	-30.44	-10.02
109	217	218	5.39	-11.02	5.39	-10.02
110	219	220	5.39	-20.29	5.39	-21.17

Table 11.3.2-2 P_m+P_b Stresses for Support Disk—56.1 g End Impact Thermal Condition 2

Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
50	-52.7	-5.6	-3.3	52.9	127.8	1.42
46	-52.6	-17.9	1.3	52.6	127.8	1.43
19	-18.3	-52.5	-0.3	52.5	127.8	1.44
5	-52.4	-27.8	0.1	52.4	127.8	1.44
30	-6.1	-51.5	2.9	51.7	127.8	1.47
56	-18.3	-51.6	0.5	51.6	127.8	1.48
9	-51.3	-19.0	-0.1	51.3	127.8	1.49
7	-51.2	-18.8	-0.6	51.3	127.8	1.49
4	-27.4	-51.2	-0.2	51.2	127.8	1.49
42	-50.8	-27.6	1.0	50.9	127.8	1.51
11	-50.6	-5.9	2.7	50.8	127.8	1.52
3	-50.3	-27.8	-0.2	50.3	127.8	1.54
67	-6.4	-46.7	-1.8	46.8	127.8	1.73
79	-0.1	-46.5	0.3	46.5	127.8	1.75
103	-46.4	0.0	0.3	46.4	127.8	1.75
13	-45.7	-6.6	1.3	45.8	127.8	1.79
94	-45.6	-0.1	-0.1	45.6	127.8	1.80
80	-0.1	-45.5	-0.2	45.5	127.8	1.81
104	-45.5	-0.1	-0.2	45.5	127.8	1.81
95	-44.5	-0.1	-0.2	44.5	127.8	1.87
78	-0.1	-44.0	0.3	44.0	127.8	1.90
102	-44.0	-0.1	0.3	44.0	127.8	1.90
93	-43.8	-0.1	0.1	43.8	127.8	1.92
77	-6.3	-35.1	-10.2	38.3	127.8	2.34
66	-35.1	-6.3	-10.2	38.3	127.8	2.34
89	-0.6	-37.7	-3.3	38.0	127.8	2.36
88	-0.5	-37.5	1.4	37.5	127.8	2.41
20	-37.2	-28.2	0.0	37.2	127.8	2.43
45	-28.1	-36.9	1.0	37.0	127.8	2.46
87	-0.3	-36.0	0.8	36.0	127.8	2.55
82	0.3	-35.7	-0.5	36.0	127.8	2.55
37	8.8	-25.9	3.9	35.5	127.8	2.60
81	0.2	-35.2	-0.3	35.4	127.8	2.61
53	-26.3	8.1	-4.3	35.4	127.8	2.61
106	-34.8	0.4	1.4	35.3	127.8	2.62
107	-34.0	0.5	-3.3	35.1	127.8	2.64
83	0.5	-33.9	2.9	34.9	127.8	2.66
97	-34.4	0.3	-0.7	34.7	127.8	2.68
105	-34.4	0.2	0.8	34.6	127.8	2.69
96	-34.4	0.2	-0.2	34.6	127.8	2.69

Note: See Figure 11.3.2-3 for section locations and definition of coordinate system.

Table 11.3.2-3 P_m+P_b Stresses for Support Disk—56.1 g End Impact Thermal Condition 3

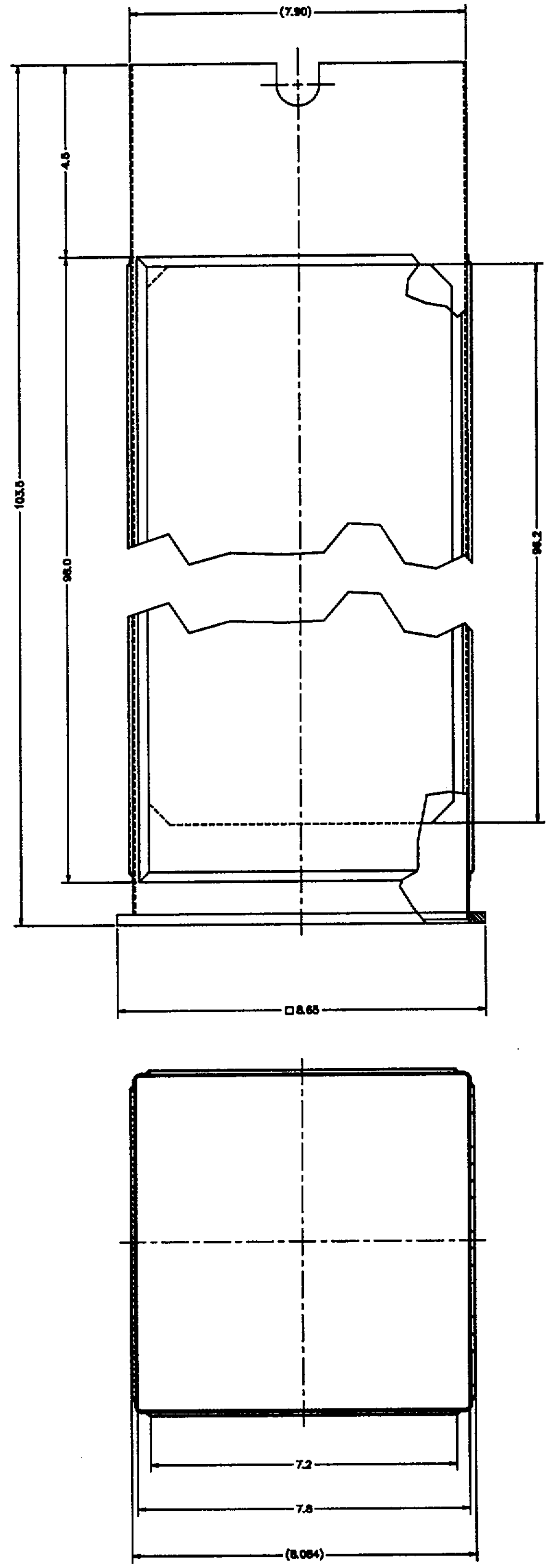
Section	Sx (ksi)	Sy (ksi)	Sxy (ksi)	Stress Intensity (ksi)	Allowable Stress (ksi)	Margin of Safety
5	-53.9	-28.5	0.0	53.9	135.0	1.51
46	-53.1	-18.3	1.6	53.1	135.0	1.54
19	-18.8	-52.9	-0.6	52.9	135.0	1.55
50	-52.6	-5.8	-3.1	52.8	135.0	1.56
4	-28.1	-52.4	-0.4	52.4	135.0	1.58
42	-52.0	-28.3	1.2	52.1	135.0	1.59
56	-18.7	-52.0	0.6	52.0	135.0	1.60
9	-51.7	-19.5	-0.2	51.7	135.0	1.61
7	-51.7	-19.2	-0.9	51.7	135.0	1.61
30	-6.3	-51.4	2.7	51.6	135.0	1.62
3	-51.5	-28.5	-0.3	51.5	135.0	1.62
11	-50.5	-6.1	2.5	50.7	135.0	1.66
79	-0.1	-46.7	0.3	46.7	135.0	1.89
103	-46.7	0.0	0.3	46.7	135.0	1.89
67	-6.6	-46.5	-1.7	46.6	135.0	1.90
94	-45.8	-0.1	-0.1	45.8	135.0	1.95
13	-45.6	-6.8	1.2	45.6	135.0	1.96
80	-0.1	-45.3	-0.2	45.3	135.0	1.98
78	-0.1	-45.3	0.3	45.3	135.0	1.98
104	-45.3	-0.1	-0.2	45.3	135.0	1.98
102	-45.3	-0.1	0.3	45.3	135.0	1.98
93	-45.0	-0.1	0.1	45.0	135.0	2.00
95	-44.3	-0.1	-0.2	44.3	135.0	2.05
20	-38.2	-28.4	-0.2	38.2	135.0	2.53
45	-28.3	-37.9	1.2	38.0	135.0	2.55
88	-0.5	-37.7	1.7	37.8	135.0	2.57
89	-0.6	-37.5	-3.1	37.8	135.0	2.57
77	-6.1	-34.3	-9.9	37.4	135.0	2.61
66	-34.3	-6.1	-9.9	37.4	135.0	2.61
87	-0.3	-36.9	1.0	36.9	135.0	2.66
81	0.2	-36.1	-0.5	36.3	135.0	2.72
82	0.3	-36.0	-0.7	36.3	135.0	2.72
106	-35.1	0.3	1.7	35.6	135.0	2.79
105	-35.3	0.2	1.0	35.5	135.0	2.80
96	-35.3	0.2	-0.3	35.5	135.0	2.80
37	8.7	-25.6	3.8	35.1	135.0	2.85
8	-27.5	-35.0	-0.4	35.0	135.0	2.85
97	-34.7	0.3	-0.9	35.0	135.0	2.86
53	-26.0	7.9	-4.2	35.0	135.0	2.86
107	-33.8	0.5	-3.1	34.9	135.0	2.87

Note: See Figure 11.3.2-3 for section locations and definition of coordinate system.

11.3.2.3 Fuel Tube Analysis

The BORAL neutron poison plates are supported by the fuel tubes within the canister basket. The fuel tube must preserve the geometry of the BORAL in the 6 inch drop and tip over accident events of the storage cask. The fuel tube has been evaluated for an end drop of 56.1 g and a side drop of 55 g for the hypothetical accident events for transport. That analysis is presented in the Safety Analysis Report for the NAC-STC, docket 71-9235. That analysis shows that the BORAL neutron poison remains in place in the end and side drop conditions. The fuel tube configuration is shown in Figure 11.3.2.3-1.

Figure 11.3.2.3-1 Yankee Class Fuel Basket Tube Configuration



11.3.2.4 Fuel Basket Weldment Analysis for End Impact Conditions

The response of the top and the bottom weldment plates of the fuel basket assembly to a 56.1g accident impact load are examined. The top and bottom weldment are 0.5-inch thick plates constructed of SA240, Type 304 stainless steel. The weldments support their own weight plus the weight of 36 fuel assembly tubes.

A finite element analysis is performed for both plates, since the support for each weldment is different due to the location of the welded ribs for each. Eight structural ribs, eight tie-rod ends, and a circumferential ring support the top weldment and its loads during a top end drop. These structural components are modeled as zero-translation restraints in the direction of the end drop. The load from the fuel tube (2,108 pounds) are represented as point forces applied to the nodes at the periphery of the fuel assembly slots. An average point force is applied. The application of the nodal loads at the slot periphery is accurate since the tube weight is transmitted to the edge of the slot, which provides support to the fuel tubes in the end drop condition. Both models use the SHELL63 element which permits out of plane loading. The finite element models represent one-quarter sections of the weldments. Figures 11.3.2.4-1 through 11.3.2.4-4 show the finite element models for the weldments.

Figure 11.3.2.4-1 Top Weldment Finite Element Model with Structural Boundary Conditions

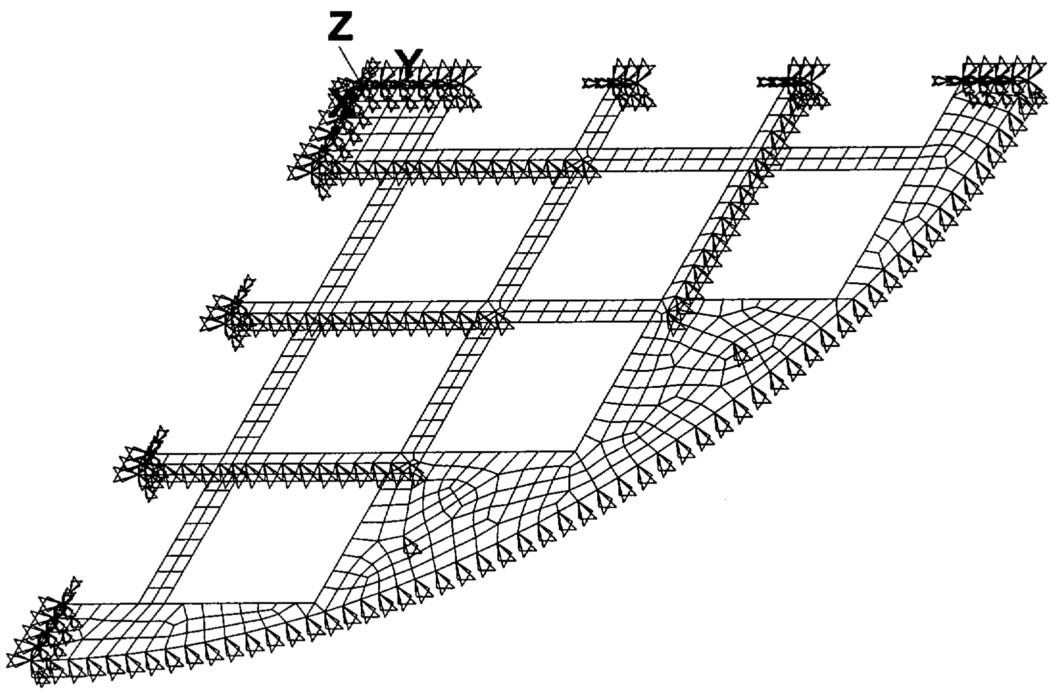
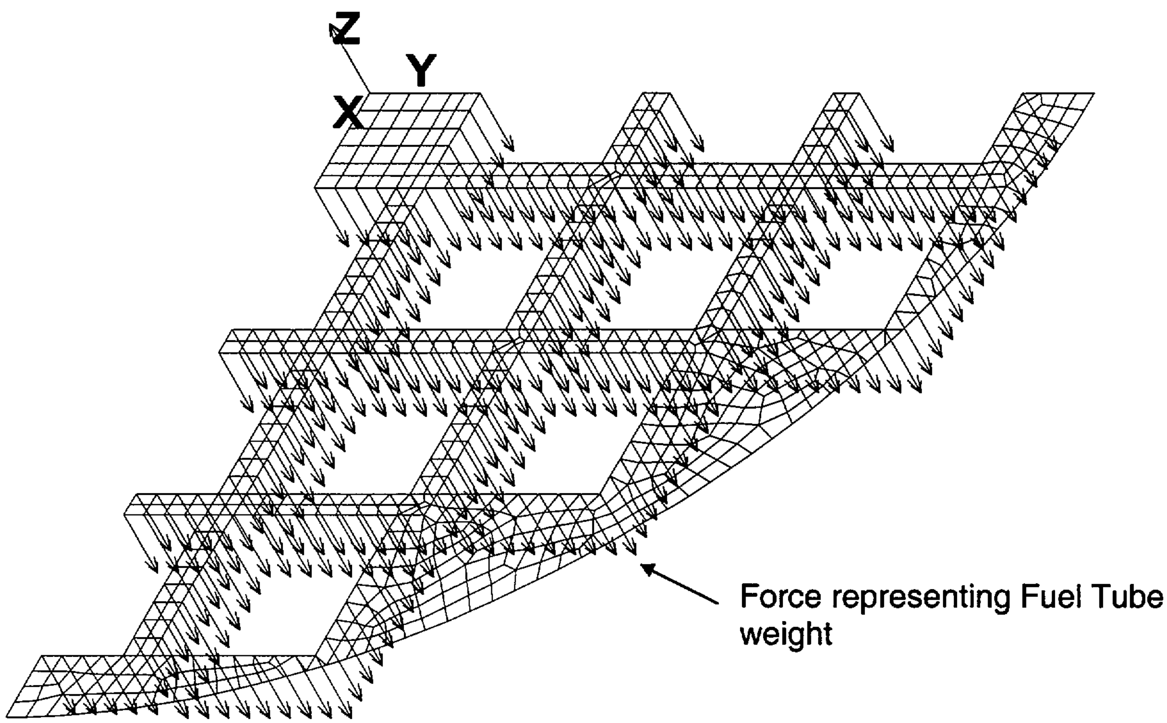


Figure 11.3.2.4-2 Top Weldment Finite Element Model with Structural Applied Loads[1]



1. Displacement conditions not shown.

Figure 11.3.2.4-3 Bottom Weldment Finite Element Model with Structural Boundary Conditions

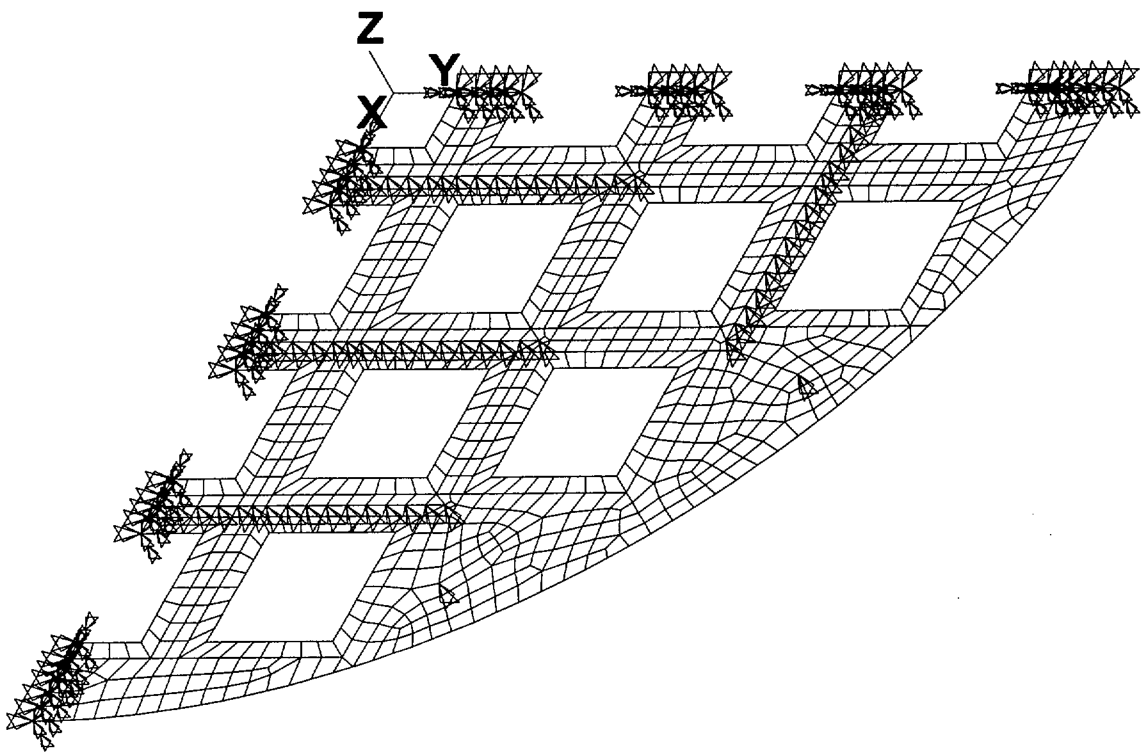
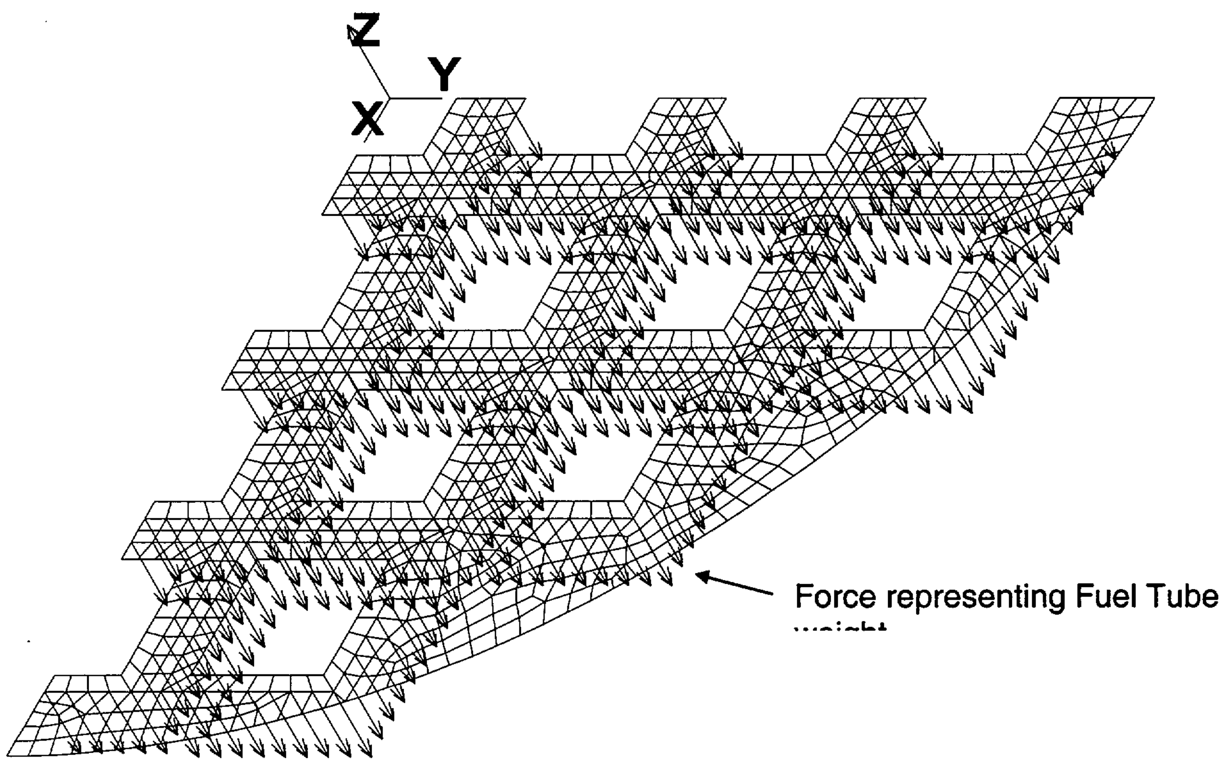


Figure 11.3.2.4-4 Bottom Weldment Finite Element Model with Structural Applied Conditions[1]



1. Displacement conditions not shown.

11.3.2.4.1 Results of Fuel Basket Weldment Analyses

The analysis using the applied nodal forces demonstrates that the weldment design satisfies the primary membrane (P_m) and the primary membrane plus bending ($P_m + P_b$) stress criteria in ASME Code, Section III Division I, Subsection NG. Conservatively, nodal stresses, in lieu of sectional stresses, are used to compare with the stress allowable. For the end impact conditions, the P_m stresses are essentially zero since the weldments are subjected to bending load only. Hence, the following criteria for the $P_m + P_b$ stresses was used in the evaluation:

$P_m + P_b < 3.6S_m$ or S_u, whichever is less.

(Note: For Type 304 stainless steel in these temperature ranges, S_u is smaller than 3.6 S_m.)

The margin of (MS) was calculated as:

$$M.S. = \frac{\text{Allowable Stress}}{\text{Nodal Stress Intensity}} - 1$$

The minimum margins of safety for each weldment for the end drop condition are shown in the table below. The allowable stress is determined based on a temperature of 530°F. This temperature is established by using the maximum temperature of the support disk for normal conditions of storage. The minimum Margins of Safety for the top/bottom weldments for the 56.1 g end impact are:

Component	$P_m + P_b$ (ksi)	Allowable (ksi)	M.S.
Top Weldment	58.0	62.2	+0.1
Bottom Weldment	48.1	62.2	+0.3

11.3.2.4.2 Top Weldment Structural Rib Buckling Evaluation

The structural ribs on the top weldment are subjected to axial loads during a top end drop. End constraints on the ribs during a top end drop consist of fixed at the end welded to the top weldment and free at the other end. Because there are no closed solutions readily available for evaluating a plate for buckling loads with end constraints matching those of the top weldment ribs, a closed-form solution for the buckling of a column was used to analyze a 1-inch section of one of the ribs.

For a column under axial loading with one end fixed and the other end free, the critical load (P_{cr}) is determined by:

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2}$$

where:

- I = moment of inertia,
- E = modulus of elasticity,
- L = length of the column, and
- K = effective length factor (K = 2 for a column with one end fixed and the other free).

Evaluating a 1-inch section of one of the ribs at the temperature of 540°F yields:

$$P_{cr} = \frac{\pi^2 \left(25.576 \times 10^6 \, lbf / in^2\right) \frac{1}{12} (1.0in)(0.38in)^3}{(2 \times 6.80in)^2} = 6,24\ 1lb$$

For the 30-foot top end drop, the sum of the forces on the nodes representing the ribs was a maximum of 3,681 lb. Thus, the maximum load (P) on a 1-inch section of one of the structural ribs is:

$$P = \frac{3{,}681 \text{ lb}}{27.5 \text{ in} / 2}(1 \text{ in}) = 268 \text{ lb}$$

Thus, the margin of safety (MS) for buckling of one of the structural ribs of the top weldment during a 30-foot top end drop is:

$$\text{M.S.} = \frac{6{,}241 \text{ lb}}{268 \text{ lb}} - 1 = 22.3$$

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11.4 Reconfigured Fuel Assembly Evaluation

The reconfigured fuel assembly is evaluated at the off-normal (Service Level B) and accident (Service Level D) conditions, which are the bounding conditions. The accelerations for Service Level B are 20 g for both the side impact and the end impact. The accelerations for Service Level D are 55 g for the side impact condition and 57 g for the end impact condition. The results for the off-normal condition are conservatively compared to the allowables for the normal (Service Level A) condition. Material properties are taken at 750°F, which envelopes all operating condition temperatures.

11.4.1 Shell Casing Weldment Evaluation

The section evaluates the reconfigured fuel assembly shell casing weldment for the side and end impact events.

11.4.1.1 Shell Casing Side Impact

The shell weldment is analyzed for bending stress resulting from horizontal-side bending in the longitudinal direction as a simple span with distributed load using material properties at a temperature of 750°F. Because the assembly is supported within the basket tube the maximum deflection at the weldment center, δ, is limited to 0.099 in. at which time the remaining energy will be transferred into the basket fuel tube assembly.

In accordance with ASME Section III, Subsection NF, NF-3322.2(d), members that are subjected to axial compression or compression due to bending are considered to be fully effective if the width-thickness ratio, b/t, meets the following criterion:

$$\frac{b}{t} \leq \frac{238}{\sqrt{S_y}}$$

Since, for the shell casing:

$$\frac{b}{t} = \frac{7.125-(2)(0.128)}{0.128} = 53.7 < \frac{238}{\sqrt{S_y}} = \frac{238}{\sqrt{17.3}} = 57.2$$

The shell casing meets the criteria and no reduction in allowable stress is applied.

The maximum bending stress, f_{bL}, is determined as:

$$\delta = \frac{5wL^4}{384EI} = 0.099 \text{ in., from which}$$

$$w = \frac{384EI\delta}{5L^4}$$

$$\text{Maximum moment, } M = \frac{wL^2}{8}$$

$$\text{Maximum bending stress, } f_{bL} = \frac{Mc}{I} = \frac{wL^2}{8} \times \frac{c}{I} = \frac{384E\delta c}{40L^2} = 8.73\,\text{ksi}$$

where:

E = modulus of elasticity for SA240, 304 stainless steel (24.4×10^3 ksi at 750°F)
c = 7.381/2 = 3.69 in.
L = 99.03 in. distance between supports (top end fitting and bottom end fitting)

The horizontal sides (top and bottom) are evaluated for transverse bending stress, f_{bt}, as follows.

w = 0.128 in. × 0.29 lb/in.^{3} × 1.0 = 0.037 lb/in for a 1-in.-wide strip
w_{20g} = 0.037(20 + 1) = 0.78 lb/in. (Service Level B)

$$S = \frac{1.0 \times 0.128^2}{6} = 2.731 \times 10^{-3} \text{ in.}^3$$

$$I = \frac{bt^3}{12} = \frac{1.0(0.128^3)}{12} = 0.175 \times 10^{-3} \text{ in.}^4$$

$$M = \frac{wL^2}{12} \text{ (conservative)}$$

$$f_{bt} = \frac{M}{S} = \frac{wL^2}{12S} = \frac{0.78(7.25^2)}{12(2.731 \times 10^{-3})} = 1.25 \text{ ksi}$$

$$f_b = \sqrt{f_{bL}^2 + f_{bt}^2} = \sqrt{8.73^2 + 1.25^2} = 8.82 \text{ ksi}$$

The margin of safety is:

$$M.S. = \frac{S_m}{f_b} - 1 = \frac{15.6\,\text{ksi}}{8.82\,\text{ksi}} - 1 = +0.76 \text{ (Service Level B)}$$

For Service Level D:

$$w_{55g} = 0.037(55+1) = 2.079 \text{ lb/in. (Service Level D)}$$

$$f_{bt} = \frac{wL^2}{12S} = \frac{2.079\left(7.25^2\right)}{12\left(2.73\times10^{-3}\right)} = 3.33 \text{ ksi}$$

$$f_b = \sqrt{f_{bl}^2 + f_{bt}^2} = \sqrt{8.73^2 + 3.33^2} = 9.34 \text{ ksi}$$

The margin of safety is:

$$M.S. = \frac{2.4S_m}{f_b} - 1 = \frac{37.4\,\text{ksi}}{9.34\,\text{ksi}} - 1 = +\text{large} \text{ (Service Level D)}$$

<u>Combined axial compression and bending of vertical sides</u>

$$\frac{KL}{r} = \frac{1\times7.25}{0.037} = 196 \qquad \text{(NUREG/CR-6322)}$$

where:

K = 1, effective length factor
L = 7.25 in.

$$r = \frac{t}{\sqrt{12}} = \frac{0.128}{\sqrt{12}} = 0.037 \text{, radius of gyration}$$

$$F_a = S_y\left(0.40 - \frac{KL/r}{600}\right) = 1.27 \text{ ksi}$$

For Service Level B:

$$f_a \max = \frac{0.78\left(7.25/2\right)}{0.128} + \frac{0.78(7.25)}{0.128} = 66.27 \text{ psi}$$

$$\frac{f_a}{F_a} = \frac{0.066}{1.27} = 0.05 < 0.15$$

$f_{bx} = 1.25$ ksi; $f_{by} = 8.73$ ksi

$F_b = 1.5\ S_m = 1.5 \times 15.6 \text{ ksi} = 23.4 \text{ ksi}$

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b} = 0.05 + \frac{1.25}{23.4} + \frac{8.73}{23.4} = 0.48$$

Since 0.48 < 1.0, the shell casing meets the NUREG/CR-6322 acceptance criteria.

For Service Level D:

$$f_a = \frac{2.079\left(7.25/2\right)}{0.128} + \frac{2.079(7.25)}{0.128} = 177 \text{ psi}$$

$$\frac{f_a}{F_a} = \frac{0.177}{1.27} = 0.14 < 0.15$$

$$F_B = 1.0 \times S_y = 63.1 \text{ ksi}$$

$$\left(\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b}\right) = \left(0.14 + \frac{3.33}{63.1} + \frac{8.73}{63.1}\right) = 0.33$$

Since 0.33 < 1.0, the shell casing meets the NUREG/CR-6322 acceptance criteria.

Welds, top and bottom fittings to shell casing

The shear force on the top-ring-to-casing and the bottom-fitting-to-casing welds is equal to 1/2 casing weight + 1/2 basket weight + 1/2 fuel weight = 261.3 lb; use 265 lb for evaluation. The top fitting design provides a shear key preventing the bolts from being loaded in shear.

The weld shear area = 7.25 in. × 0.128 in. × 4 = 3.712 in.^{2} and the dead load shear stress, τ_{DL}, is:

$$\tau_{DL} = \frac{265}{3.712} = 71.4 \text{ psi}$$

At Service Level B, the shear stress in the weld in the 20 g acceleration, τ_{20g}, is:

$$\tau_{20g} = 71.4 \times (20 + 1) = 1.5 \text{ ksi}$$

$$F_v = (\text{greater of } 0.6\ S_m \text{ or } 0.6\ S_y) \times \text{weld quality factor}$$

$$= 0.6 \times 17.3 \times 0.50 = 5.19 \text{ ksi}$$

The margin of safety is:

$$\text{M.S.} = \frac{5.19}{1.5} - 1 = +2.46$$

At service level D, the shear stress in the weld in the 55 g acceleration, τ_{55g}, is:

$$\tau_{55g} = 71.4 \times (55 + 1) = 4.0 \text{ ksi}$$

$$F_v = 0.42\ S_u \times \text{weld quality factor}$$

$$= 0.42 \times 63.1 \times 0.50 = 13.25 \text{ ksi}$$

The margin of safety is:

$$\text{M.S.} = \frac{13.25}{4.0} - 1 = +2.31$$

11.4.1.2 Shell Casing End Impact

For the bottom end impact, the top fitting and casing act against the bottom fitting assembly. For the top end impact, the bottom fitting and casing act against the top fitting assembly. Because the top fitting is heavier, the bottom end impact is the governing case.

K = 1
L = 99.03 in.

$$r = \sqrt{\frac{(b+t)^4 - (b-t)^4}{12A}} = 2.73$$

$$\frac{KL}{r} = \frac{1(99.03)}{2.73} = 36.3 < 120$$

Therefore, use $F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 6.72$ ksi

The axial stress in the shell casing wall is:

$$f_a = \frac{P_T}{A} = \frac{124(20+1)}{3.71} = 0.73 \text{ ksi (For Service Level B)}$$

$$f_a = \frac{P_T}{A} = \frac{124(57+1)}{3.71} = 1.94 \text{ ksi (For Service Level D)}$$

where:

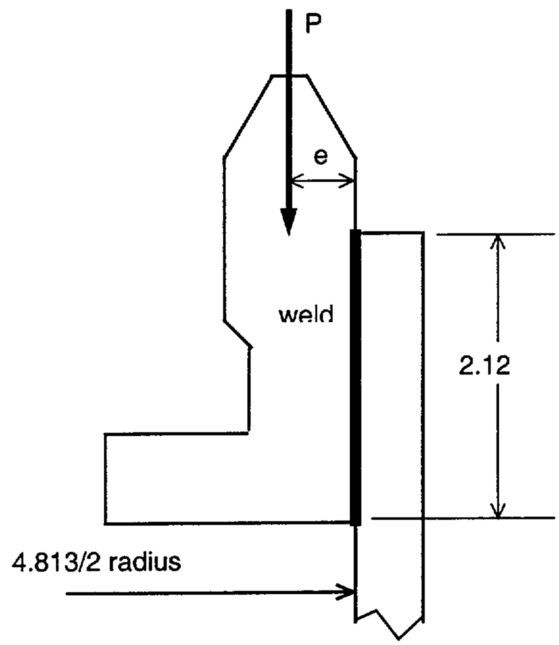
P_T = (total weight of top fitting + shell = 124 lb.)×(g + 1)
A = cross-sectional area = 2 x [(7.125 x 0.128)+(7.381x0.128)] = 3.71 in.^{2}

The margin of safety is:

$$MS = \frac{F_a}{f_a} - 1 = \frac{6.72 \text{ ksi}}{0.702 \text{ ksi}} - 1 = +8.57 \text{ (For Service Level B)}$$

$$MS = \frac{F_a}{f_a} - 1 = \frac{6.72\ \text{ksi}}{1.94\ \text{ksi}} - 1 = +2.46\ \text{(For Service Level D)}$$

11.4.1.3 Lifting Tab Welds



The lifting tabs will be subjected to bending and shear loads in the end impact condition.

For the Service Level B condition, the bending stress, f_b, on the weld is:

$$f_b = \frac{M}{S} = 6.52\ \text{ksi}$$

where:

$$M = \frac{Pe}{4} = \frac{0.555 \times (20+1)(0.53)}{4} = 1.5\ \text{in} \cdot \text{kips}$$

For the Service Level D condition, the bending stress, f_b, on the weld is:

$$f_b = \frac{M}{S} = 18.57\ \text{ksi}$$

where:

$$M = \frac{Pe}{4} = \frac{0.555 \times (57+1)(0.53)}{4} = 4.27\ \text{in} \cdot \text{kips}$$

$$P = \text{total weight} \times (g + 1)$$

$$e = \frac{4.813}{2} - \left(\frac{2.0 + 1.75}{2}\right) = 0.53\ \text{in.}$$

$$S = \frac{bd^2}{6} = \frac{3/8 \times \left(2.12 - 3/16\right)^2}{6} = 0.23\ \text{in.}^3$$

For Service Level B conditions, the shear stress, f_v, on the weld is:

$$f_v = \frac{P/4}{A_w} = \frac{0.555(20+1)}{4(0.72)} = 4.04 \text{ ksi}$$

For Service Level D conditions, the shear stress, f_v, on the weld is:

$$f_v = \frac{P/4}{A_w} = \frac{0.555(57+1)}{4(0.72)} = 11.18 \text{ ksi}$$

where:

$$A_w = \left(2.12 - 3/16\right)(0.375) = 0.72 \text{ in.}^2$$, the weld area.

For Service Level B, the total stress, f, on the weld is:

$$f = \sqrt{f_b^2 + f_v^2} = \sqrt{6.52^2 + 4.04^2} = 7.67 \text{ ksi (Service Level B)}$$

The allowable stress, F_a, for Service Level B is $1.5 \times S_m \times$ weld quality factor.

$$F_a = 1.5 \times 15.6 \times 0.5 = 11.7 \text{ ksi}$$

The margin of safety is:

$$MS = \frac{F_a}{f} - 1 = \frac{11.7 \text{ ksi}}{7.67 \text{ ksi}} - 1 = +0.53 \text{ (Service Level B)}$$

For Service Level D, the total stress, f, on the weld is:

$$f = \sqrt{f_b^2 + f_v^2} = \sqrt{18.57^2 + 11.18^2} = 21.68 \text{ ksi (Service Level D)}$$

The allowable stress, F_a, for Service Level D is $1.0 \times S_u \times$ weld factor.

$F_a = 1.0 \times 63.1 \times 0.5 = 31.55$ ksi

The margin of safety, M.S., for the Service Level D condition is:

$$MS = \frac{F_A}{f} - 1 = \frac{31.55}{21.68} - 1 = +0.46$$

11.4.2 Basket Assembly and Fuel Tube Evaluation

11.4.2.1 Corner Angle Side Impact

The side impact load will be shared by two corner leg angles. The maximum deflection, δ, that a corner leg angle can achieve is 0.102 inches.

$$W = \frac{384EI\delta}{5L^3}$$

$$\text{Max moment, } M = \frac{WL}{8}$$

$$\text{The bending stress, } f_b = \frac{Mc}{I} = \frac{384\,E\delta c}{40L^2} = \frac{384\left(24.4 \times 10^3\right)(0.102)(0.077)}{40\left(97.4^2\right)(0.091)} = 2.13 \text{ ksi}$$

where:

$$c = \frac{I}{S} = \frac{0.077}{0.091}$$

The margin of safety is:

$$MS = \frac{1.5 \times S_m}{f_b} - 1 = \frac{23.4}{2.13} = \text{large}$$

11.4.2.2 Corner Angle End Impact

In the end impact, the load from the tie plates will be shared by four corner leg angles. Because the fuel tubes are not attached to the tie plates, their load will not be transferred to the corner leg angles in the end impact condition.

$$\frac{KL}{r} = \frac{1(15)}{0.369} = 40.6 < 120$$

where:

$$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{0.077}{0.563}} = 0.369\,.$$

$$KL/r < 120 \text{ and } \frac{b}{t} = \frac{1.25}{0.25} = 5.0 < \frac{76}{\sqrt{S_y}} = \frac{76}{\sqrt{19.4}} = 17.25$$

Therefore, in accordance with NUREG/CR-6322,

$$F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 6.57 \text{ ksi}$$

The dead load, P_{DL}, on one corner leg angle = (7 × spacer plate weight)/4 +angle weight = 22 lb.

$P_{20g} = 22 \times (20 + 1) = 0.462$ kips at 20 g acceleration
$P_{57g} = 22 \times (57 + 1) = 1.28$ kips at 57 g acceleration

For the 20g acceleration:

$f_a = 0.462 \text{ kips}/0.56 \text{ in.}^2 = 0.825 \text{ ksi}$

The margin of safety is:

$$M.S. = \frac{6.57\,\text{ksi}}{0.825\,\text{ksi}} - 1 = +7.0$$

For the 57 g acceleration:

$$f_a = 1.28 \text{ kips}/0.56 \text{ in.}^2 = 2.29 \text{ ksi}$$

The margin of safety is:

$$M.S. = \frac{6.57\,\text{ksi}}{2.29\,\text{ksi}} - 1 = +1.87$$

11.4.2.3 Fuel Tube Side Impact

The fuel tube is evaluated for bending as a continuous beam with a uniform load and six equal spans at 15.0-in. on center.

$$M_{max} = -\left(0.106 \times wL^2\right)$$ (Manual of Steel Construction)

$$f_b = \frac{Mc}{I}$$

For Service Level B:

$$w = 0.0527 \text{ lb/in.} \times (20 + 1)g = 1.11 \text{ lb/in.}$$

$$f_b = \frac{Mc}{I} = 5.7 \text{ ksi}$$

For Service Level D:

$$w = 0.0527 \text{ lb/in.} \times (55 + 1)g = 2.95 \text{ lb/in.}$$

$$f_b = \frac{Mc}{I} = 15.2 \text{ ksi}$$

where:

w	= 0.0527 lb/in.
L	= 15.0 in.
c	= 0.50/2 = 0.25 in.
I	$= \frac{\pi}{64}\left(D^4 - d^4\right) = 1.16 \times 10^{-3}$ in.^{4}
D	= tube outside diameter, 0.50 in.
d	= tube inside diameter, 0.444 in.

The margin of safety at Service Level B is:

$$M.S. = \frac{1.5S_m}{f_b} - 1 = \frac{1.5(15.6)}{5.7} - 1 = +3.10$$

The margin of safety at Service Level D is:

$$M.S. = \frac{1.0S_u}{f_b} - 1 = \frac{1.0(63.1)}{15.2} - 1 = +3.15$$

11.4.2.4 Fuel Tube End Impact

For Service Level B, the fuel tubes are evaluated for axial compression in accordance with NUREG/CR-6322.

For Service Level B, the allowable stress, F_a, is:

$$F_a = S_y\left(0.47 - \frac{KL/r}{444}\right) = 4.70 \text{ ksi}$$

where:

$$r = \sqrt{\frac{I}{A}} = 0.17 \text{ in.}$$

$$\frac{KL}{r}\frac{(1)(15.0)}{0.17} = 88 < 120$$

$$f_a = \frac{P}{A} = \frac{5.14(20+1)}{.04} = 2.70 \text{ ksi}$$

where:

$L = 15.0$ in.

$I = \frac{\pi}{64}\left(D^4 - d^4\right) = 1.16 \times 10^{-3} \text{ in.}^4$

$D = 0.50$ in. (fuel tube outside diameter)

$d = 0.444$ in. (fuel tube inside diameter)

$A = \frac{\pi}{4}\left(D^2 - d^2\right) = 0.04 \text{ in.}^2$

P = (fuel + fuel tube + end cap weight) × end impact acceleration

The margin of safety for Level B Service is:

$$M.S. = \frac{F_a}{f_a} - 1 = \frac{4.70 \text{ ksi}}{2.70 \text{ ksi}} - 1 = +0.74$$

For Service Level D, the fuel tubes are evaluated for axial compression in accordance with NUREG/CR-6322 and ASME Section III, Appendix F-1334.3.

Because Subparagraph F-1334.3 specifies no criteria for austenitic stainless steel, the following method from NUREG/CR-6322 is used to determine the criteria for the hypothetical accident condition (Service Level D).

The maximum allowable axial load, P_{allow}, is determined using the relation:

$$\frac{P_{allow}}{P_y} = SS_{Level\ D} = \left(\frac{SS}{CS}\right)_{Level\ A} \times CS_{Level\ D} = 0.45$$

(NUREG/CR-6322 Equation 39)

where "SS" and "CS" stand for stainless steel and carbon steel, respectively.

$P_{allow} = P_y \times 0.45 = 0.75 \text{ ksi} \times 0.45 = 0.34 \text{ ksi}$

$$SS_{Level A} = \left(0.47 - \frac{\frac{KL\lambda}{r}}{444\sqrt{2}} \right) = 0.36$$ (NUREG/CR-6322 Equation 45)

$$CS_{Level A} = \frac{1 - \frac{\lambda^2}{4}}{\frac{5}{3} + \frac{3}{8}\left(\frac{\lambda}{\sqrt{2}}\right) - \frac{1}{8}\left(\frac{\lambda}{\sqrt{2}}\right)^3} = 0.46$$ (NUREG/CR-6322 Equation 43)

$$CS_{Level D} = \frac{1 - \frac{\lambda^2}{4}}{1.11 + 0.5\lambda + 0.17\lambda^2 - 0.28\lambda^3} = 0.58$$ (NUREG/CR-6322 Equation 33)

$$\lambda = \frac{1}{\pi}\left(\frac{KL}{r}\right)\sqrt{\left(\frac{S_y}{E}\right)} = 0.77$$

$P_y = S_y \times A = 18.8 \text{ ksi} \times 0.04 \text{ in.}^2 = 0.75 \text{ kips}$

The axial load, P, on the fuel tube is (fuel + fuel tube + end cap weight) × end impact acceleration:

$P \ = 5.14(57+1) = 0.30 \text{ kips}$

The margin of safety for the Service Level D condition is:

$$M.S. = \frac{P_{allow}}{P} - 1 = \frac{0.34\text{kips}}{0.30\text{kips}} - 1 = +0.13$$

11.4.2.5 Tie Plate End Impact

Analysis of the reconfigured fuel assembly tie plate uses a Stardyne finite element model to

represent the tie plate during an end impact. The model consists of a square grid of identical stainless steel beams spaced at 0.75 in. The beams are 0.375 in. deep and 0.23 inches wide (clear space between 0.50 in. dia. holes). The tie plate is welded to four corner angles where the plate is assumed fixed. The tie plate is made of 304 stainless steel. Loads are applied to the nodes to represent the (weight × g loading) of the plate.

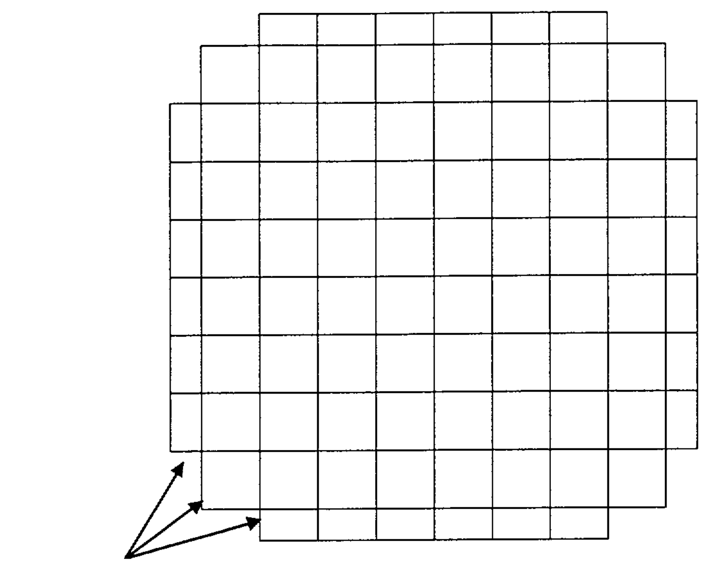


Figure 1

Analysis is done for Service Level B and Service Level D conditions.

Shear and Bending

Stresses from Stardyne output:

	Service Level B: (20 g loading)	Service Level D: (57 g loading)
Maximum Shear Stress:	97 psi	276 psi
Maximum Bending Stress:	726 psi	2070 psi

Service Level B allowable stress at 750°F:

Primary Bending: $1.5 \times S_m = 1.5 \times 15.6$ ksi = 23.4 ksi

Shear: greater of: $0.6 \times S_m = 0.6 \times 15.6 = 9.36$ ksi or

$0.6 \times S_y = 0.6 \times 17.3 = 10.4$ ksi

For Service Level D, at the same temperature, the allowable stresses are:

Primary Bending: $1.0 \times S_u = 63.1$ ksi

Shear: $0.42 \times S_u = 0.42 \times 63.1 = 26.5$ ksi

The margins of safety at Service Level B, are:

Primary Bending: $$MS = \frac{23.4}{0.726} - 1 = +Large$$

Shear: $$MS = \frac{10.4}{0.97} - 1 = +Large$$

At Service Level D, the margins of safety are:

Primary Bending: $$MS = \frac{63.1}{2.07} - 1 = +Large$$

Shear: $$MS = \frac{26.5}{0.276} - 1 = +Large$$

Welds at Tie Plates to Corner Angles

Each tie plate is welded to four corner angles with top and bottom 0.25-in. fillet welds. From the Stardyne output, the critical shear, torsion, and bending loads are:

Service Level B:	Service Level D:
Shear = 9.03 lbs.	Shear = 25.72 lbs
Torsion = 1.68 in-lbs	Torsion = 13.28 in-lbs
Bending = 5.91 in-lbs	Bending = 8.36 in-lbs

The stresses for Service Level D are calculated using the beam cross section (0.23 in. wide × 0.375 in. deep) and the weld effective throat.

The weld effective throat is: $0.707 \times 0.25 = 0.177$ in.

Therefore:

Shear Stress is: $F_s = \dfrac{25.72}{.23 \times .177} + \dfrac{13.28}{.0182 \times .177} = 4445 \text{ psi}$

and,

Bending Stress is: $F_b = \dfrac{8.36}{.086 \times .177} = 548 \text{ psi}$

Allowables for the weld are:

ASTM A240 Type 304 Stainless Steel (Section II-D ASME) at 750°F

$S_u = 63.1$ ksi $S_y = 17.3$ ksi $S_m = 15.6$ ksi

Per ASME Section III-NG the minimum quality factor for a Category E Type V weld is $n = 0.4$.

At Service Level B:

Membrane + Bending:	$F = 1.5 \times S_m \times n = 1.5 \times 15.6 \times 0.4 = 9.36$ ksi
Shear:(greater of)	$F = 0.6 \times S_m \times n = 0.6 \times 15.6 \times 0.4 = 3.74$ ksi
	$F = 0.6 \times S_y \times n = 0.6 \times 17.3 \times 0.4 = 4.15$ ksi

At Service Level D:

Membrane + Bending:	$F = 1.0 \times S_u \times n = 1.0 \times 63.1 \times 0.4 = 25.24$ ksi
Shear:	$F = 0.42 \times S_u \times n = 0.42 \times 63.1 \times 0.4 = 10.60$ ksi

Since the actual weld stress during Service Level D is equal to or less than the allowables during Service Level B, ¼-in. double fillet weld is satisfactory.

A conservative analysis of the RFA Tie Plate shows the plate to be satisfactory for a Service Level B and D end impact.

11.4.2.6 Tie Plate Side Impact

The fuel tubes are supported by tie plates at 15 inches on center spacing. During a side impact the weight of the fuel tube, amplified by the g loading, puts the bottom edge of the tie plate in compression. The tie plate is analyzed as compression beam model. The weight of each fuel tube is carried in compression only and does not have the ability to shear to the next row of

beams.

For Service Level B:

The weight of each fuel tube at 15 inch spacing is:

$$W_{20g} = \frac{1.18 \text{ lbs / tube}}{97.70 \text{ inches}} \times 15.0 \text{ inch spacing } \times (20+1)) = 3.80 \text{ lbs / tube}$$

For Service Level D:

The weight of each fuel tube at 15-inch spacing is:

$$W_{55g} = \frac{3.80 \times (55+1)}{(20+1)} = 10.14 \text{ lbs / tube}$$

The compression and shear load at the bottom of the tie plate during a side impact is:

For Service Level B:

$$P = 3.80 \times 8 = 30.4 \text{ lbs}$$

$$F = \frac{30.4}{.375 \times .23} = 352 \text{ psi for both shear and compression}$$

The critical margin of safety is for shear:

$$\text{M.S.} = \frac{10400}{352} - 1 = +\text{large}$$

For Service Level D:

$$P = 10.14 \times 8 = 81.1 \text{ lbs}$$

$$F = \frac{81.1}{.375 \times .23} = 941 \text{ psi for both shear and compression}$$

The critical margin of safety for shear is:

$$M.S. = \frac{26500}{941} - 1 = +\text{large}$$

Because the tie plate and corner angles are of the same material 304 SS and because the fuel tubes are not connected to the tie plates, thermal stresses can be ignored.

11.4.2.7 Tie Plate Thermal Stress Analysis

From Table 4.4.3-4 in Section 4.4.3, the maximum ΔT between the shell casing and the Reconfigured Fuel Assembly tube is 20°F. A ΔT of 25°F is conservatively used for the tie plate analysis.

The thermal stress is calculated using the formula (Roark):

$$S = K_t \text{ x } \frac{\Delta T \alpha E}{1-\nu} = 3 \text{x} \frac{25(9.76 \text{x} 10^{-6})(24.4 \text{x} 10^{6})}{1-0.275} = 24{,}636 \text{ psi (compression)}$$

where:

Material properties are taken at 750°F.

K_t is the stress concentration for a hole in an infinite plate.

For Service Level B:

S = 352 psi + 24,636 psi = 24,988 psi (compression)

The margin of safety is:

$$M.S. = \frac{3.0 x 15{,}600}{24{,}988} = +0.87$$

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11.5 Canister Closure Weld Evaluation – Accident Conditions

11.5.1 Stress Evaluation for the Canister Closure Weld

The closure weld for the canister is a partial penetration weld with a thickness of 0.9 inches. The evaluation of this weld, in accordance with NRC guidance, is to incorporate two separate weld stress reduction factors: a 0.8 factor based on weld type and a second 0.8 factor based on NRC ISG-4, Item 5. These two weld stress reduction factors are incorporated by applying a factor of 0.64 (0.8 x 0.8) to the stress allowable for this weld.

The stresses for the canister are evaluated using sectional stresses as permitted by Subsection NB. The canister stress results from the VCC tip-over accident evaluation (Section 11.2.12.3) are used for evaluation. The location of the section for the canister weld evaluation is shown in Figure 11.2.12.3-4 and corresponds to Section 12. The P_m and P_m+ P_b stress intensity for Section 12 and the associated allowables are listed in Table 11.2.12.3-1 and Table 11.2.12.3-2, respectively. The factored allowables, incorporating a 0.64 stress reduction factor, and the resulting controlling Margin of Safeties are:

Stress Type	Analysis Stress Intensity (ksi)	0.64 x Allowable Stress (ksi)	Margin of Safety
P_m	24.25	24.65	0.02
$P_m + P_b$	26.66	36.99	0.37

This confirms that the canister closure weld is acceptable for the accident conditions.

11.5.2 Critical Flaw Size for the Canister Closure Weld

The closure weld for the canister is comprised of multiple weld beads using a compatible weld material for Type 304L stainless steel. An allowable (critical) flaw evaluation has been performed to determine the critical flaw size in the weld region. The result of the flaw evaluation is used to define the minimum flaw size, which must be identifiable in the nondestructive examination of the weld. Due to the inherent toughness associated with Type 304L stainless steel, a limit load analysis is used in conjunction with a J-integral/tearing modulus approach. The safety margins used in this evaluation correspond to the stress limits contained in Section XI of the ASME Code.

The stress component used in the evaluation for the critical flaw size is the radial stress component in the weld region of the structural lid. For an accident (Level D) event, in accordance with ASME Code Section XI, a safety factor of $\sqrt{2}$ is required. For the purpose of identifying the stress for the flaw evaluation, the weld region corresponds to Section 12 in Figure 11.2.12.3-4 is considered. From additional post processing of the tipover analysis, the maximum tensile radial stress is 3.8 ksi. To perform the flaw evaluation, a 10 ksi stress is conservatively used, resulting in a significantly larger safety factor than the required safety factor of $\sqrt{2}$. Using 10 ksi as the basis for the evaluation, the minimum detectable flaw size is 0.52 inch for a flaw that extends 360 degrees around the circumference of the canister. Stress components for the circumferential and axial directions are also determined, which would be associated with flaws oriented in the radial or horizontal directions respectively. The maximum stress for these components is 1.7 ksi, which is enveloped by the stress value of ksi used for the critical flaw evaluation for radial directions. The 360-degree flaw employed for the circumferential direction is considered to be bounding with respect to any partial flaw in the weld, which could occur in the radial and horizontal directions. Therefore, using a minimum detectable flaw size of 0.375 inch is acceptable, since it is less than the very conservatively determined 0.52-inch critical flaw size.

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List of Tables

12.0 OPERATING CONTROLS AND LIMITS

This chapter identifies operating controls and limits, technical parameters and surveillance requirements imposed to ensure the safe operation of the NAC-MPC System. Section 12.1 provides the proposed operating controls and limits, which are presented in Technical Specification format in Appendix 12A of this Chapter. The bases for the specified controls and limits are presented in Appendix 12B of this Chapter.

Sections 4.4 and 4.5 of Appendix 12A present Site Specific Parameters and Design Specifications that are important to the safe operations of the NAC-MPC System, but that are not included as Technical Specifications. These include items which are singular events, those that cannot be readily determined or re-verified at the time of use of the system, or that are easily implemented, verified and corrected, if necessary, at the time the action is undertaken. Sections 5.1 and 5.2 of Appendix 12A provides a description of a suggested training program intended to assist the user in meeting the requirements of Subpart I of 10 CFR 72 for use of the NAC-MPC System. Section 5.3 of Appendix 12A presents the requirements for the first system placed in service. Section 5.4 of Appendix 12A presents the requirements for the NAC-MPC thermal monitoring program.

12.1 Proposed Operating Controls and Limits

The NAC-MPC System is designed to provide passive dry storage of containerized Yankee Class spent fuel. The system has few operating controls. The principal controls and limits for the NAC-MPC System are satisfied by the selection of fuel for storage that meets the technical specifications presented in Section 2.1 and in Tables 12A2-1 and 12A2-2 of Appendix 12A. The general areas where controls and limits are necessary for safe operation of the NAC-MPC System are shown in Table 12-1. The conditions for use of the system that are defined in the table, are based on the specifications and functionality of the system and on the safety assessments for normal and accident conditions. Appendix 12B presents the bases for the Technical Specifications, which describe the development of the operating controls and limits.

12.2 Proposed Training Topics for the NAC-MPC System

The proposed required training for using the NAC-MPC System is presented in Sections 5.1 and 5.2 of Appendix 12A to this Chapter. A principal purpose of the training program is to ensure that controls and limits of the system design are understood and met in operations and use. The training also ensures that design features of the system are correctly used, that procedural requirements are met, and that compliance with procedures is documented.

Training is considered in two venues. The first is discussion or classroom training. The second is dry run training. Classroom training considers documentation and procedure review, including controls and limits and their bases. Dry run training is performed at the licensee's site and considers equipment fitup, interfacing and operations, including documentation of tasks, inspections and test conditions.

Specific information included in any training topic may be site specific, but must consider and include, the approved site procedure(s) to be used in NAC-MPC System handling, loading, closing, and storage. Each training program should be developed in accordance with the licensee's general site training program requirements.

12.3 Special Requirements for the First System Placed in Service

The thermal performance of the first NAC-MPC System placed in service at a site shall be documented as described in Section 5.3 of Appendix 12A to this Chapter.

12.4 Surveillance After a Natural Phenomena Off-Normal or Accident Event

The NAC-MPC storage cask shall be inspected within 24 hours after the occurrence of a natural phenomena, off-normal or accident event in the area of the ISFSI. This inspection must specifically verify that the concrete cask air inlets and outlets are not blocked. At least one-half of the inlets and outlets must be cleared to restore air circulation within 24 hours.

An extended period of extreme heat can reduce the strength of the concrete below the design basis evaluated in Chapters 3 and 11.

The concrete cask and the canister shall be inspected if they experience a drop from a height of more than 6.0 inches or a tipover.

12.5 Administrative Controls

Controls used by NAC International as part of the NAC-MPC design and fabrication are provided in the NAC Quality Assurance Manual and Quality Procedures. The NAC International Quality Assurance Program is discussed in Chapter 13.0. If procurement and fabrication of the NAC-MPC System are performed by others, a Quality Assurance Program prepared in accordance with 10 CFR 72 Subpart G shall be implemented. Site-specific controls for the organization, administrative system, procedures, record keeping, review, audit and reporting necessary to ensure that the NAC-MPC storage system installation is operated in a safe manner are the responsibility of the user of the system.

Table 12-1 NAC-MPC System Controls and Limits

Control or Limit	Applicable Technical Specification	Condition or Item Controlled
1. Fuel Characteristics	Table 12A2-1	Type and Condition
	Table 12A2-2	Dimensions and Weight
	Table 12A2-1	Burnup and Minimum Initial Enrichment
	Table 12A2-1	Cool Time
2. Canister	LCO 3.1.6	Time in Transfer Cask
Fuel Loading	Table 12A2-1	Weight and Number of Assemblies
Drying	LCO 3.1.2	Vacuum Pressure
Backfilling	LCO 3.1.3	Helium Pressure
Sealing	LCO 3.1.4	Helium Leak Rate
Vacuum	LCO 3.1.5	Drying Time
External Surface	LCO 3.2.2	Level of Contamination
Unloading	LCO 3.1.7	Cooldown Requirements
3. Concrete Cask	LCO 3.2.1	Surface Dose Rates
	Note 1	Cask Spacing
	LCO 3.1.8	Cask Handling Height
4. Surveillance	Note 2	Air Inlets and Outlets
	Note 2	Air Outlet Temperature
	Note 3	Annual Vertical Concrete Cask Concrete Inspection
5. Transfer Cask	LCO 3.1.9	Minimum Temperature
	LCO 3.1.10	CANISTER Removal from the CONCRETE CASK
6. ISFSI Concrete Pad	Note 4	Pad Concrete Thickness
	Note 4	Pad Subsoil Thickness
	Note 4	Pad Concrete Compressive Strength

1. Limits are presented in Section 4.5.1.1 of Appendix 12A.
2. Monitoring requirements are presented in Section 5.4 of Appendix 12A.
3. Limits are applied annually.
4. Limits are verified at the time of construction of the ISFSI.

APPENDIX 12A

NAC-MPC SYSTEM
TECHNICAL SPECIFICATIONS

Appendix 12A
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Appendix 12A
Table of Contents (Continued)

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1.0 USE AND APPLICATION

1.1 Definitions

---NOTE---

The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications.

Term	Definition
ACTIONS	ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times.
CANISTER	See TRANSPORTABLE STORAGE CANISTER
CONCRETE CASK	See VERTICAL CONCRETE CASK
DAMAGED FUEL ASSEMBLY	DAMAGED FUEL ASSEMBLY is a fuel assembly having individual fuel rods with known or suspected cladding defects greater than a hairline crack or a pinhole leak.
DAMAGED FUEL ROD	DAMAGED FUEL ROD is a fuel rod with known or suspected cladding defects greater than a hairline crack or a pinhole leak.
FUEL DEBRIS	FUEL DEBRIS is fuel in the form of particles, loose pellets, and fragmented rods or assemblies.
INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI)	The facility within the perimeter fence licensed for storage of spent fuel within NAC-MPC SYSTEMs (see also 10 CFR 72.3).

1.1 Definitions (Continued)

INTACT FUEL ASSEMBLY	INTACT FUEL ASSEMBLY is a fuel assembly without known or suspected cladding defects greater than a pinhole leak or a hairline crack and which can be handled by normal means. A fuel assembly shall not be classified as an INTACT FUEL ASSEMBLY unless solid Zircaloy or stainless steel rods are used to replace missing fuel rods and which displaces an amount of water equal to that displaced by the original fuel rod(s).
INTACT FUEL ROD	INTACT FUEL ROD is a fuel rod without known or suspected cladding defects greater than a pinhole leak or a hairline crack.
LOADING OPERATIONS	LOADING OPERATIONS include all licensed activities on an NAC-MPC SYSTEM while it is being loaded with fuel assemblies. LOADING OPERATIONS begin when the first fuel assembly is placed in the CANISTER and end when the NAC-MPC SYSTEM is secured on the transporter.
RECONFIGURED FUEL ASSEMBLY (RFA)	A stainless steel canister having the same external dimensions as a standard Yankee Class spent fuel assembly that ensures criticality control geometry and which permits gaseous and liquid media to escape while minimizing dispersal of gross particulates. The RECONFIGURED FUEL ASSEMBLY may contain a maximum of 64 INTACT FUEL RODS, DAMAGED FUEL RODS or FUEL DEBRIS from any type of Yankee Class spent fuel assembly.

1.1 Definitions (Continued)

NAC-MPC SYSTEM	NAC-MPC SYSTEM includes the components approved for loading and storage of spent fuel assemblies at the ISFSI. The NAC-MPC SYSTEM consists of a CONCRETE CASK, a TRANSFER CASK and a CANISTER.
STORAGE OPERATIONS	STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI, while an NAC-MPC SYSTEM containing spent fuel is located on the storage pad within the ISFSI perimeter.
TRANSPORT OPERATIONS	TRANSPORT OPERATIONS include all licensed activities involved in moving a loaded NAC-MPC CONCRETE CASK AND CANISTER to and from the ISFSI. TRANSPORT OPERATIONS begin when the NAC-MPC SYSTEM is first secured on the transporter and end when the NAC-MPC SYSTEM is at its destination and no longer secured on the transporter.
TRANSPORTABLE STORAGE CANISTER (CANISTER)	TRANSPORTABLE STORAGE CANISTER is the sealed container that consists of a tube and disk fuel basket in a cylindrical canister shell that is welded to a baseplate, shield lid with welded port covers, and structural lid. The CANISTER provides the confinement boundary for the confined spent fuel.
TRANSFER CASK	TRANSFER CASK is a shielded lifting device that holds the CANISTER during LOADING and UNLOADING OPERATIONS and during closure welding, vacuum drying, leak testing, and non-destructive examination of the CANISTER closure welds. The TRANSFER CASK is also used to transfer the CANISTER into and from the CONCRETE CASK, and into the transport cask.

1.1 Definitions (Continued)

TRANSFER OPERATIONS	TRANSFER OPERATIONS include all licensed activities involved in transferring a loaded CANISTER from a CONCRETE CASK to another CONCRETE CASK or to a TRANSPORT CASK.
UNLOADING OPERATIONS	UNLOADING OPERATIONS include all licensed activities on an NAC-MPC SYSTEM to be unloaded of the contained fuel assemblies. UNLOADING OPERATIONS begin when the NAC-MPC SYSTEM is no longer secured on the transporter and end when the last fuel assembly is removed from the NAC-MPC SYSTEM. UNLOADING OPERATIONS may include transfer of a loaded CANISTER from the CONCRETE CASK to the transport cask.
VERTICAL CONCRETE CASK (CONCRETE CASK)	CONCRETE CASK is the cask that receives and holds the sealed CANISTER. It provides the gamma and neutron shielding and convective cooling of the spent fuel confined in the CANISTER.

1.0 USE AND APPLICATION

1.2 Logical Connectors

PURPOSE

The purpose of this section is to explain the meaning of logical connectors.

Logical connectors are used in Technical Specifications (TS) to discriminate between, and yet connect, discrete Conditions, Required Actions, Completion Times, Surveillances, and Frequencies. The only logical connectors that appear in Technical Specifications are "AND" and "OR." The physical arrangement of these connectors constitutes logical conventions with specific meanings.

BACKGROUND

Several levels of logic may be used to state Required Actions. These levels are identified by the placement (or nesting) of the logical connectors and by the number assigned to each Required Action. The first level of logic is identified by the first digit of the number assigned to a Required Action and the placement of the logical connector in the first level of nesting (i.e., left justified with the number of the Required Action). The successive levels of logic are identified by additional digits of the Required Action number and by successive indentations of the logical connectors.

When logical connectors are used to state a Condition, Completion Time, Surveillance, or Frequency, only the first level of logic is used; the logical connector is left justified with the statement of the Condition, Completion Time, Surveillance, or Frequency.

1.2 Logical Connectors (Continued)

EXAMPLES The following examples illustrate the use of logical connectors.

EXAMPLES EXAMPLE 1.2-1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met	A.1 Verify. . . AND A.2 Restore. . .	

In this example, the logical connector "AND" is used to indicate that when in Condition A, both Required Actions A.1 and A.2 must be completed.

1.2 Logical Connectors (Continued)

EXAMPLES (continued)

EXAMPLE 1.2-2

ACTIONS

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. LCO not met	A.1	Stop. . .	
	OR		
	A.2.1	Verify. . .	
	AND		
	A.2.2		
	A.2.2.1	Reduce. . .	
		OR	
	A.2.2.2	Perform. . .	
	OR		
	A.3	Remove. . .	

This example represents a more complicated use of logical connectors. Required Actions A.1, A.2, and A.3 are alternative choices, only one of which must be performed as indicated by the use of the logical connector "OR" and the left justified placement. Any one of these three Actions may be chosen. If A.2 is chosen, then both A.2.1 and A.2.2 must be performed as indicated by the logical connector "AND." Required Action A.2.2 is met by performing A.2.2.1 or A.2.2.2. The indented position of the logical connector "OR" indicated that A.2.2.1 and A.2.2.2 are alternative choices, only one of which must be performed.

1.0 USE AND APPLICATION

1.3 Completion Times

PURPOSE	The purpose of this section is to establish the Completion Time convention and to provide guidance for its use.
BACKGROUND	Limiting Conditions for Operations (LCOs) specify the lowest functional capability or performance levels of equipment required for safe operation of the NAC-MPC SYSTEM. The ACTIONS associated with an LCO state conditions that typically describe the ways in which the requirements of the LCO can fail to be met. Specified with each stated Condition are Required Action(s) and Completion Time(s).
DESCRIPTION	The Completion Time is the amount of time allowed for completing a Required Action. It is referenced to the time of discovery of a situation (e.g., equipment or variable not within limits) that requires entering an ACTIONS Condition, unless otherwise specified, provided that the NAC-MPC SYSTEM is in a specified condition stated in the Applicability of the LCO. Prior to the expiration of the specified Completion Time, Required Actions must be completed. An ACTIONS Condition remains in effect and the Required Actions apply until the Condition no longer exists or the NAC-MPC SYSTEM is not within the LCO Applicability. Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will <u>not</u> result in separate entry into the Condition, unless specifically stated. The Required Actions of the Condition continue to apply to each additional failure, with Completion Times based on initial entry into the Condition.

1.3 Completion Times (Continued)

EXAMPLES

The following examples illustrate the use of Completion Times with different types of Conditions and changing Conditions.

EXAMPLE 1.3-1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1 AND B.2 Perform Action B.2	12 hours 36 hours

Condition B has two Required Actions. Each Required Action has its own Completion Time. Each Completion Time is referenced to the time that Condition B is entered.

The Required Actions of Condition B are to complete action B.1 within 12 hours AND complete action B.2 within 36 hours. A total of 12 hours is allowed for completing action B.1 and a total of 36 hours (not 48 hours) is allowed for completing action B.2 from the time that Condition B was entered. If action B.1 is completed within six hours, the time allowed for completing action B.2 is the next 30 hours because the total time allowed for completing action B.2 is 36 hours.

1.3 Completion Times (Continued)

EXAMPLES (continued)

EXAMPLE 1.3-2

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One System not within limit.	A.1 Restore System to within limit.	7 days
B. Required Action and associated Completion Time not met.	B.1 Complete action B.1	12 hours
	AND	
	B.2 Complete action B.2	36 hours

When a System is determined not to meet the LCO, Condition A is entered. If the System is not restored within seven days, Condition B is also entered, and the Completion Time clocks for Required Actions B.1 and B.2 start. If the System is restored after Condition B is entered, Conditions A and B are exited; therefore, the Required Actions of Condition B may be terminated.

1.3 Completion Times (Continued)

EXAMPLES (continued)

EXAMPLE 1.3-3

ACTIONS

---NOTE---
Separate Condition entry is allowed for each component.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met	A.1 Restore compliance with LCO	4 hours
B. Required Action and associated Completion Time not met.	B.1 Complete action B.1	6 hours
	AND	
	B.2 Complete action B.2	12 hours

The Note above the ACTIONS table is a method of modifying how the Completion Time is tracked. If this method of modifying how the Completion Time is tracked was applicable only to a specific Condition, the Note would appear in that Condition rather than at the top of the ACTIONS Table.

The Note allows Condition A to be entered separately for each component, and Completion Times to be tracked on a per component basis. When a component is determined to not meet the LCO, Condition A is entered and its Completion Time starts. If subsequent components are determined to not meet the LCO, Condition A is entered for each component and separate Completion Times are tracked for each component.

1.3 Completion Times (Continued)

EXAMPLES	EXAMPLE 1.3-3 (continued)
IMMEDIATE COMPLETION TIME	When "Immediately" is used as a Completion Time, the Required Action should be pursued without delay and in a controlled manner.

1.0 USE AND APPLICATION

1.4 Frequency

PURPOSE

The purpose of this section is to define the proper use and application of Frequency requirements.

DESCRIPTION

Each Surveillance Requirement (SR) has a specified Frequency in which the Surveillance must be met in order to meet the associated Limiting Condition for Operation (LCO). An understanding of the correct application of the specified Frequency is necessary for compliance with the SR.

The "specified Frequency" is referred to throughout this section and each of the Specifications of Section 3.0, Surveillance Requirement (SR) Applicability. The "specified Frequency" consists of requirements of the Frequency column of each SR.

Situations where a Surveillance could be required (i.e., its Frequency could expire), but where it is not possible or not desired that it be performed until sometime after the associated LCO is within its Applicability, represent potential SR 3.0.4 conflicts. To avoid these conflicts, the SR (i.e., the Surveillance or the Frequency) is stated such that it is only "required" when it can be and should be performed. With a SR satisfied, SR 3.0.4 imposes no restriction.

The use of "met" or "performed" in these instances conveys specific meanings. A Surveillance is "met" only after the acceptance criteria are satisfied. Known failure of the requirements of a Surveillance, even without a Surveillance specifically being "performed", constitutes a Surveillance not "met."

1.4 Frequency

EXAMPLES The following examples illustrate the various ways that Frequencies are specified.

EXAMPLE 1.4-1

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify pressure within limit	12 hours

Example 1.4-1 contains the type of SR most often encountered in the Technical Specifications (TS). The Frequency specifies an interval (12 hours) during which the associated Surveillance must be performed at least one time. Performance of the Surveillance initiates the subsequent interval. Although the Frequency is stated as 12 hours, SR 3.0.2 allows an extension of the time interval to 1.25 times the interval specified in the Frequency for operational flexibility. The measurement of this interval continues at all times, even when the SR is not required to be met per SR 3.0.1 (such as when the equipment or variables are outside specified limits, or the facility is outside the Applicability of the LCO). If the interval specified by SR 3.0.2 is exceeded while the facility is in a condition specified in the Applicability of the LCO, the LCO is not met in accordance with SR 3.0.1.

If the interval as specified by SR 3.0.2 is exceeded while the facility is not in a condition specified in the Applicability of the LCO for which performance of the SR is required, the Surveillance must be performed within the Frequency requirements of SR 3.0.2, prior to entry into the specified condition. Failure to do so would result in a violation of SR 3.0.4.

1.4 Frequency (Continued)

EXAMPLE 1.4-2

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify flow is within limits	Once within 12 hours prior to starting activity AND 24 hours thereafter

Example 1.4-2 has two Frequencies. The first is a one time performance Frequency, and the second is of the type shown in Example 1.4-1. The logical connector "AND" indicates that both Frequency requirements must be met. Each time the example activity is to be performed, the Surveillance must be performed within 12 hours prior to starting the activity.

The use of "once" indicates a single performance will satisfy the specified Frequency (assuming no other Frequencies are connected by "AND"). This type of Frequency does not qualify for the 25% extension allowed by SR 3.0.2.

"Thereafter" indicates future performances must be established per SR 3.0.2, but only after a specified condition is first met (i.e., the "once" performance in this example). If the specified activity is canceled or not performed, the measurement of both intervals stops. New intervals start upon preparing to restart the specified activity.

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2.0 FUNCTIONAL AND OPERATING LIMITS

2.1 Functional and Operating Limits

2.1.1 Fuel to be Stored in the NAC-MPC SYSTEM

INTACT FUEL ASSEMBLIES, INTACT FUEL RODS, DAMAGED FUEL RODS and FUEL DEBRIS placed in a RECONFIGURED FUEL ASSEMBLY meeting the limits specified in Table 12A2-1 may be stored in the NAC-MPC SYSTEM.

The values shown in Tables 12A2-1 and 12A2-2 are design nominal record values.

2.2 Functional and Operating Limit Violations

If any Functional and Operating Limits of Table 12A2-1 are violated, the following actions shall be completed:

2.2.1 The affected fuel assemblies shall be placed in a safe condition.

2.2.2 Within 24 hours, notify the NRC Operations Center.

2.2.3 Within 30 days, submit a special report that describes the cause of the violation and actions taken to restore compliance and prevent recurrence.

Table 12A2-1
Fuel Assembly Limits

I. NAC-MPC CANISTER

A. Allowable Contents

1. Uranium oxide Yankee Class INTACT FUEL ASSEMBLIES listed in Table 12A2-2 and meet the following specifications:

a. Cladding Type: Zircaloy or Stainless Steel as specified in Table 12A2-2 for the applicable fuel assembly class (Note: Type A and Type B configurations in Table 12A2-2 identify variations in the arrangement of the outer row of fuel rods that accommodate the insertion of control blades in the reactor.)

b. Enrichment: As specified in Table 12A2-2 for the applicable fuel assembly type.

c. Decay Heat Per Assembly:

i. Zircaloy-Clad Fuel: ≤ 347 Watts

ii. Stainless Steel-Clad Fuel: ≤ 264 Watts

d. Post-irradiation Cooling Time and Average Burnup Per Assembly:

i. Zircaloy-Clad Fuel: As specified in Table 12A2-2 for the applicable fuel assembly type.

ii. Stainless Steel-Clad Fuel: As specified in Table 12A2-2 for the applicable fuel assembly type.

Table 12A2-1
Fuel Assembly Limits (Continued)

f. Nominal Fuel Assembly Length:	Maximum = 111.8 inches Minimum = 109.0 inches
g. Nominal Fuel Assembly Width:	≤ 7.64 inches
h. Fuel Assembly Weight:	
i. Zircaloy-Clad Fuel:	≤ 850 lbs
ii. Stainless Steel-Clad Fuel:	≤ 900 lbs
i. Minimum Length of Bottom Fuel Nozzle:	6.7 inches (17.0 cm)

2. Uranium oxide Yankee Class INTACT FUEL RODS, DAMAGED FUEL RODS or FUEL DEBRIS placed in RECONFIGURED FUEL ASSEMBLIES (RFA). The original fuel assemblies for the INTACT FUEL RODS, DAMAGED FUEL RODS and FUEL DEBRIS shall meet the criteria specified in Table 12A2-2 for the fuel assembly class, and meet the following additional specifications:

a. Cladding Type:	Zircaloy or Stainless Steel as specified in Table 12A2-2 for the applicable fuel assembly type.
b. Enrichment:	As specified in Table 12A2-2 for the applicable fuel assembly type.
c. Decay Heat Per RFA:	≤ 102 Watts
d. Post-irradiation Cooling Time and Average Burnup Per Original Assembly:	
i. Zircaloy-Clad Fuel:	As specified in Table 12A2-2 for the applicable fuel assembly type.

Table 12A2-1

Fuel Assembly Limits (Continued)

ii. Stainless Steel-Clad Fuel:	As specified in Table 12A2-2 for the applicable fuel assembly type.
e. Nominal Original Fuel Assembly Length:	≤ 111.8 inches
f. Nominal Original Fuel Assembly Width:	≤ 7.64 inches
g. Maximum Weight:	≤ 850 lbs, including RFA
h. Maximum mass U per RFA:	66.33 kg

B. Quantity per CANISTER:
Up to 36 INTACT FUEL ASSEMBLIES and RFAs to the maximum content weight limit of 30,600 pounds.

C. INTACT FUEL ASSEMBLIES and RFAs shall not contain control components.

D. INTACT FUEL ASSEMBLIES shall not contain empty fuel rod positions. A solid Zircaloy or stainless steel rod that would displace an equivalent amount of water as an intact fuel rod shall replace any missing fuel rods.

Table 12A2-2 INTACT FUEL ASSEMBLY Characteristics

Fuel Assembly Type	Combustion Engineering Type A	Combustion Engineering Type B	Exxon Type A	Exxon Type B	Exxon Type A	Exxon Type B	Westinghouse Type A	Westinghouse Type B	United Nuclear Type A	United Nuclear Type B
ASSEMBLY CONFIGURATION[2]										
Assembly Length (cm)	283.9	283.9	283.3	283.3	283.9	283.9	282.6	282.6	282.4	282.4
Assembly Width (cm)	19.2	19.2	19.3	19.3	19.3	19.3	19.3	19.3	19.4	19.4
Assembly Weight (kg)	352	350.6	372	372	372	372	408.2	408.2	385.5	385.5
Enrichment-wt. % ^{235}U										
Maximum	3.90	3.90	4.00	4.00	4.00	4.00	4.94	4.94	4.00	4.00
Minimum	3.70	3.70	3.50	3.50	3.50	3.50	4.94	4.94	4.00	4.00
Max. Burnup (MWD/MTU)	36,000[1]	36,000[1]	36,000	36,000	36,000	36,000	32,000	32,000	32,000	32,000
Max. Initial Heavy Metal KgU/assembly	239.4	238.4	239.4	238.4	239.4	238.4	286.9	286.0	245.6	244.6
Min. Cool Time (yr)	8.1[1]	8.1[1]	16.0	16.0	9.0	9.0	21.0	21.0	13.0	13.0
Max. Decay Heat (kW)	0.347[1]	0.347[1]	0.269	0.269	0.331	0.331	0.264	0.264	0.257	0.257
FUEL ROD CONFIGURATION										
Fuel Rod Pitch (cm)	1.20	1.20	1.20	1.20	1.20	1.20	1.07	1.07	1.19	1.19
Active Fuel Length (cm)	231.1	231.1	231.1	231.1	231.1	231.1	234.0	234.0	231.1	231.1
Rod OD (cm)	0.93	0.93	0.93	0.93	0.93	0.93	0.86	0.86	0.93	0.93
Clad ID (cm)	0.81	0.81	0.81	0.81	0.81	0.81	0.76	0.76	0.81	0.81
Clad Material	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	Zircaloy	SS	SS	Zircaloy	Zircaloy
Pellet OD (cm)	0.79	0.79	0.79	0.79	0.79	0.79	0.75	0.75	0.79	0.79
Rods per Assembly	231	230	231	230	231	230	305	304	237	236

1. Combustion Engineering fuel may be loaded at a maximum burnup of 32,000 MWD/MTU, a minimum enrichment of 3.5 wt% ^{235}U and cool time of 8.0 years. The maximum decay heat for this assembly is 0.304 kW.

2. Type A and Type B configurations identify variations in the arrangement of the outer row of fuel rods that accommodate the insertion of control blades in the reactor.

3.0 LIMITING CONDITION FOR OPERATION (LCO) APPLICABILITY

LCO 3.0.1	LCOs shall be met during specified conditions in the Applicability, except as provided in LCO 3.0.2.
LCO 3.0.2	Upon discovery of a failure to meet an LCO, the Required Actions of the associated Conditions shall be met, except as provided in LCO 3.0.5. If the LCO is met or is no longer applicable prior to expiration of the specified Completion Time(s), completion of the Required Action(s) is not required, unless otherwise stated.
LCO 3.0.3	Not applicable to an NAC-MPC SYSTEM.
LCO 3.0.4	When an LCO is not met, entry into a specified condition in the Applicability shall not be made except when the associated ACTIONS to be entered permit continued operation in the specified condition in the Applicability for an unlimited period of time. This Specification shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS or that are related to the unloading of an NAC-MPC SYSTEM. Exceptions to this Specification are stated in the individual Specifications. These exceptions allow entry into specified conditions in the Applicability where the associated ACTIONS to be entered allow operation in the specified conditions in the Applicability only for a limited period of time.
LCO 3.0.5	Equipment removed from service or not in service in compliance with ACTIONS may be returned to service under administrative control solely to perform testing required to demonstrate it meets the LCO or that other equipment meets the LCO. This is an exception to LCO 3.0.2 for the System to return to service under administrative control to perform the testing.

LCO 3.0.6	Not applicable to an NAC-MPC SYSTEM.
LCO 3.0.7	Not applicable to an NAC-MPC SYSTEM.

3.0 SURVEILLANCE REQUIREMENT (SR) APPLICABILITY

SR 3.0.1

SRs shall be met during the specified conditions in the Applicability for individual LCOs, unless otherwise stated in the SR. Failure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be a failure to meet the LCO. Failure to perform a Surveillance within the specified Frequency shall be failure to meet the LCO, except as provided in SR 3.0.3. Surveillances do not have to be performed on equipment or variables outside specified limits.

SR 3.0.2

The specified Frequency for each SR is met if the Surveillance is performed within 1.25 times the interval specified in the Frequency, as measured from the previous performance or as measured from the time a specified condition of the Frequency is met.

For Frequencies specified as "once," the above interval extension does not apply. If a Completion Time requires periodic performance on a "once per..." basis, the above Frequency extension applies to each performance after the initial performance.

Exceptions to this Specification are stated in the individual Specifications.

SR 3.0.3

If it is discovered that a Surveillance was not performed within its specified Frequency, then compliance with the requirement to declare the LCO not met may be delayed from the time of discovery up to 24 hours or up to the limit of the specified Frequency, whichever is less. This delay period is permitted to allow performance of the Surveillance.

If the Surveillance is not performed within the delay period, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.

3.0 SURVEILLANCE REQUIREMENT (SR) APPLICABILITY

SR 3.0.3 (continued)	When the Surveillance is performed within the delay period and the Surveillance is not met, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.
SR 3.0.4	Entry into a specified condition in the Applicability of an LCO shall not be made, unless the LCO's Surveillances have been met within their specified Frequency. This provision shall not prevent entry into specified conditions in the Applicability that are required to comply with Actions or that are related to the unloading of an NAC-MPC SYSTEM.

3.1 NAC-MPC SYSTEM Integrity

3.1.1 [Reserved]

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3.1 NAC-MPC SYSTEM Integrity

3.1.2 CANISTER Vacuum Drying Pressure

LCO 3.1.2 The CANISTER vacuum drying pressure shall meet the limit specified in Table 12A3-1.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

-----NOTE-----

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER vacuum drying pressure limit not met.	A.1 Establish CANISTER cavity vacuum drying pressure within limit.	25 days
B. Required Action and Associated Completion Time not met.	B.1 Remove all fuel assemblies from the NAC-MPC SYSTEM.	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.2.1	Verify CANISTER cavity vacuum drying pressure is within limit	Within 24 hours after completion of CANISTER draining.

3.1 NAC-MPC SYSTEM Integrity

3.1.3 CANISTER Helium Backfill Pressure

LCO 3.1.3 The CANISTER helium backfill pressure shall meet the limit specified in Table 12A3-1.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

-----------------------------------NOTE-----------------------------------

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER helium backfill pressure limit not met.	A.1 Establish CANISTER helium backfill pressure within limit.	25 days
B. Required Action and Associated Completion Time not met.	B.1 Remove all fuel assemblies from the NAC-MPC SYSTEM.	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.3.1	Verify CANISTER helium backfill pressure is within limit	Within 24 hours after completion of CANISTER draining.

3.1 NAC-MPC SYSTEM Integrity

3.1.4 CANISTER Helium Leak Rate

LCO 3.1.4 There shall be no indication of a helium leak at a test sensitivity of 4 x 10^{-8} cm^3/sec (helium) through the CANISTER shield lid to CANISTER shell confinement weld to demonstrate a helium leak rate less than 8 x 10^{-8} cm^3/sec (helium) as specified in Table 12A3-1.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

---NOTE---

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER helium leak rate limit not met.	A.1 Establish CANISTER helium leak rate within limit.	25 days
B. Required Action and Associated Completion Time not met.	B.1 Remove all fuel assemblies from the NAC-MPC SYSTEM.	5 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.4.1	Verify CANISTER helium leak rate is within limit	Prior to TRANSPORT OPERATIONS.

3.1 NAC-MPC SYSTEM Integrity

3.1.5 CANISTER Maximum Time in Vacuum Drying

LCO 3.1.5 The following limits for vacuum drying time shall be met, as appropriate:

1. The time duration from completion of draining the CANISTER through completion of vacuum dryness testing and the introduction of helium backfill shall not exceed 16 hours.
2. The time duration from end of external forced air cooling or in-pool cooling of the CANISTER through completion of vacuum dryness testing and the introduction of helium backfill shall not exceed 10 hours.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

--------------------------------------NOTE--------------------------------------
Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO time limits not met	A.1 Commence filling CANISTER with helium AND	2 hours
	A.1.1 Place TRANSFER CASK with helium filled loaded CANISTER in spent fuel pool. AND	2 hours
	A.1.2 Maintain TRANSFER CASK and CANISTER in spent fuel pool for a minimum of 24 hours. OR	Prior to restart of LOADING OPERATIONS

3.1 NAC-MPC SYSTEM Integrity

3.1.5 CANISTER Maximum Time in Vacuum Drying (Continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
	A.2 Commence filling CANISTER with helium	2 hours
	AND	
	A.2.1 Commence supplying air to the TRANSFER CASK bottom eight fill/drain lines at a rate of 250 CFM and a maximum temperature of 75°F	2 hours
	AND	
	A.2.2 Maintain airflow for a minimum of 24 hours	Prior to restart of LOADING OPERATIONS

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.5.1	Monitor elapsed time from completion of canister draining until start of helium backfill.	Once at completion of canister draining AND 3 hours thereafter.
SR 3.1.5.2	Monitor elapsed time from completion of canister draining following in-pool or forced air cooling until start of helium backfill.	Once at completion of canister draining AND 2 hours thereafter.

3.1 NAC-MPC SYSTEM Integrity

3.1.6 CANISTER Maximum Time in TRANSFER CASK

LCO 3.1.6 The following limits for CANISTER time in TRANSFER CASK shall be met, as appropriate:

1. The time duration from the introduction of helium backfill of the CANISTER through completion of the CANISTER transfer operation from the TRANSFER CASK to the CONCRETE CASK shall not exceed 26 hours.
2. The time duration from completion of in-pool or external forced air cooling of the CANISTER through completion of the CANISTER transfer operation from the TRANSFER CASK to the CONCRETE CASK shall not exceed 25 hours. This LCO time limit is also applicable if LCO 3.1.5.1 was not met during vacuum drying operations.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

-----NOTE-----
Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO time limits not met	A.1 A1.1. Place TRANSFER CASK with helium filled loaded CANISTER in spent fuel pool	2 hours
	AND A.1.2 Maintain TRANSFER CASK and CANISTER in spent fuel pool for a minimum of 24 hours	Prior to restart of LOADING OPERATIONS
	OR	

3.1 NAC-MPC SYSTEM Integrity

3.1.6 CANISTER Maximum Time in TRANSFER CASK (Continued)

	A.2 A.2.1 Commence supplying air to the TRANSFER CASK bottom eight fill/drain lines at a rate of 250 CFM and a maximum temperature of 75°F AND A.2.2 Maintain airflow for a minimum of 24 hours	2 hours Prior to restart of LOADING OPERATIONS

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.6.1	Monitor elapsed time from the introduction of helium backfill until completion of transfer of loaded CANISTER into CONCRETE CASK.	Once at completion of vacuum dryness verification test AND 3 hours thereafter.
SR 3.1.6.2	Monitor elapsed time from completion of in-pool or forced air cooling until completion of transfer of loaded CANISTER into CONCRETE CASK	Once at completion of cooling operations AND 3 hours thereafter.

3.1 NAC-MPC SYSTEM Integrity

3.1.7 Fuel Cooldown Requirements

LCO 3.1.7 A loaded CANISTER and its fuel contents shall be cooled down in accordance with the following specifications:

a. Nitrogen gas flush for a minimum of 10 minutes

b. Minimum cooling water temperature of 70 °F

c. Cooling water flow rate of 5 (+3, -0) gallons per minute at inlet pressure of 25 (+10, -0) psig

d. Maintain cooling water flow through CANISTER until outlet water temperature ≤ 200 °F

e. Maximum canister pressure ≤ 50 psig

APPLICABILITY: During UNLOADING OPERATIONS

-----NOTE-----

The LCO is only applicable to wet UNLOADING OPERATIONS.

ACTIONS

-----NOTE-----

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER cooldown requirements not met.	A.1 Initiate actions to meet CANISTER cooldown requirements.	Immediately

3.1 NAC-MPC SYSTEM Integrity

3.1.7 Fuel Cooldown Requirements (Continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.7.1	Initiate CANISTER cooldown flow to loaded CANISTER.	Within 30 hours after removal of CANISTER from CONCRETE CASK and placement in Transfer Cask.
SR 3.1.7.2	Verify that the cooldown water temperature and flow rate are within limits.	Once within 1 hour prior to initiating cooldown AND 1 hour thereafter.

3.1 NAC-MPC SYSTEM Integrity

3.1.8 CONCRETE CASK Maximum Lifting Height

LCO 3.1.8 A CONCRETE CASK containing a CANISTER loaded with INTACT FUEL ASSEMBLYs or RECONFIGURED FUEL ASSEMBLYs shall be lifted in accordance with the following requirement

a. A lift height $\leq$ 6 inches

APPLICABILITY: During TRANSPORT OPERATIONS

ACTIONS

---NOTE---

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. NAC-MPC SYSTEM lifting requirements not met.	A.1 Initiate actions to meet CONCRETE CASK maximum lifting height.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.8.1	Verify CONCRETE CASK lifting requirements are met.	After the CONCRETE CASK is raised to install or remove air pad and prior to TRANSPORT OPERATIONS

3.1 NAC-MPC SYSTEM Integrity

3.1.9 TRANSFER CASK Minimum Operating Temperature

LCO 3.1.9 The TRANSFER CASK shall not be used for loaded CANISTER transfer operations outside of the fuel handling facility when the external ambient temperature is ≤ 0°F.

APPLICABILITY: During LOADING or UNLOADING OPERATIONS

ACTIONS

--------------------------------------NOTE--------------------------------------

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. External ambient temperature below LCO limit	A.1 Do not perform TRANSFER CASK operations external to the facility.	Immediately

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.9.1	Measure external ambient temperature.	Prior to start of LOADING or UNLOADING OPERATIONS AND 1 hour thereafter.

3.1 NAC-MPC SYSTEM Integrity

3.1.10 CANISTER Removal from the CONCRETE CASK

LCO 3.1.10 The following limits for TRANSFER OPERATIONS shall be met, as appropriate:

1. The time duration for holding the CANISTER in the TRANSFER CASK shall not exceed 16 hours, without forced air cooling.
2. The time duration for holding the CANISTER in the TRANSFER CASK using external forced air cooling of the CANISTER is not limited.

APPLICABILITY: During TRANSFER OPERATIONS

ACTIONS

---------------------------------------NOTE---

Separate Condition entry is allowed for each NAC-MPC SYSTEM.

Separate Condition entry to this LCO is allowed following each 24-hour period of continuous forced air cooling.

CONDITION	REQUIRED ACTION		COMPLETION TIME
A. Loaded CANISTER held in TRANSFER CASK	A.1.1	Load CANISTER into operable CONCRETE CASK	16 hours
	<u>OR</u> A.2.1	Load CANISTER into TRANSPORT CASK	16 hours
	<u>OR</u> A.3.1	Perform A.1.1 or A.2.1 following a minimum of 24-hours of forced air cooling	16 hours
B. Required Actions in A and associated Completion Time not met	B.1.1	Commence supplying air to the TRANSFER CASK annulus fill/drain lines at a rate of 250 CFM and a maximum temperature of 75°F	4 hours
	<u>AND</u> B.2.1	Maintain forced air cooling. Condition A of this LCO may be re-entered after 24 hours of forced air cooling	24 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.1.10.1	Monitor elapsed time from closing of the TRANSFER CASK bottom shield doors until unloading of the CANISTER from the TRANSFER CASK	Once at closing of the TRANSFER CASK bottom shield doors AND 4 hours thereafter
SR 3.1.10.2	Monitor continuous forced air cooling operation until unloading of the CANISTER from the TRANSFER CASK	Once at start of cooling operations AND 6 hours thereafter

Table 12A3-1
CANISTER Limits

CANISTER	LIMITS
NAC-MPC CANISTER	
a. CANISTER Vacuum Drying Pressure	≤ 3 mm of Mercury for ≥ 30 min
b. CANISTER Helium Leak Rate	≤ $8x10^{-8}$ std cc/sec (helium)
c. CANISTER Helium Backfill Pressure	0 (+1, -0) psig

3.2 NAC-MPC SYSTEM Radiation Protection

3.2.1 NAC-MPC SYSTEM Average Surface Dose Rates

LCO 3.2.1 CONCRETE CASK dose rates shall be measured at the locations shown in Figure 12A3-1. The average surface dose rates of each CONCRETE CASK shall not exceed:

a. 50 mrem/hour (neutron + gamma) on the side (on the concrete surfaces)

b. 35 mrem/hour (neutron + gamma) on the top;

c. 100 mrem/hour (neutron + gamma) at air inlet and outlet vents.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

---NOTE---
Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CONCRETE CASK average surface dose rate limits not met.	A.1 Administratively verify correct fuel loading. <u>AND</u>	24 hours

3.2 NAC-MPC SYSTEM Radiation Protection

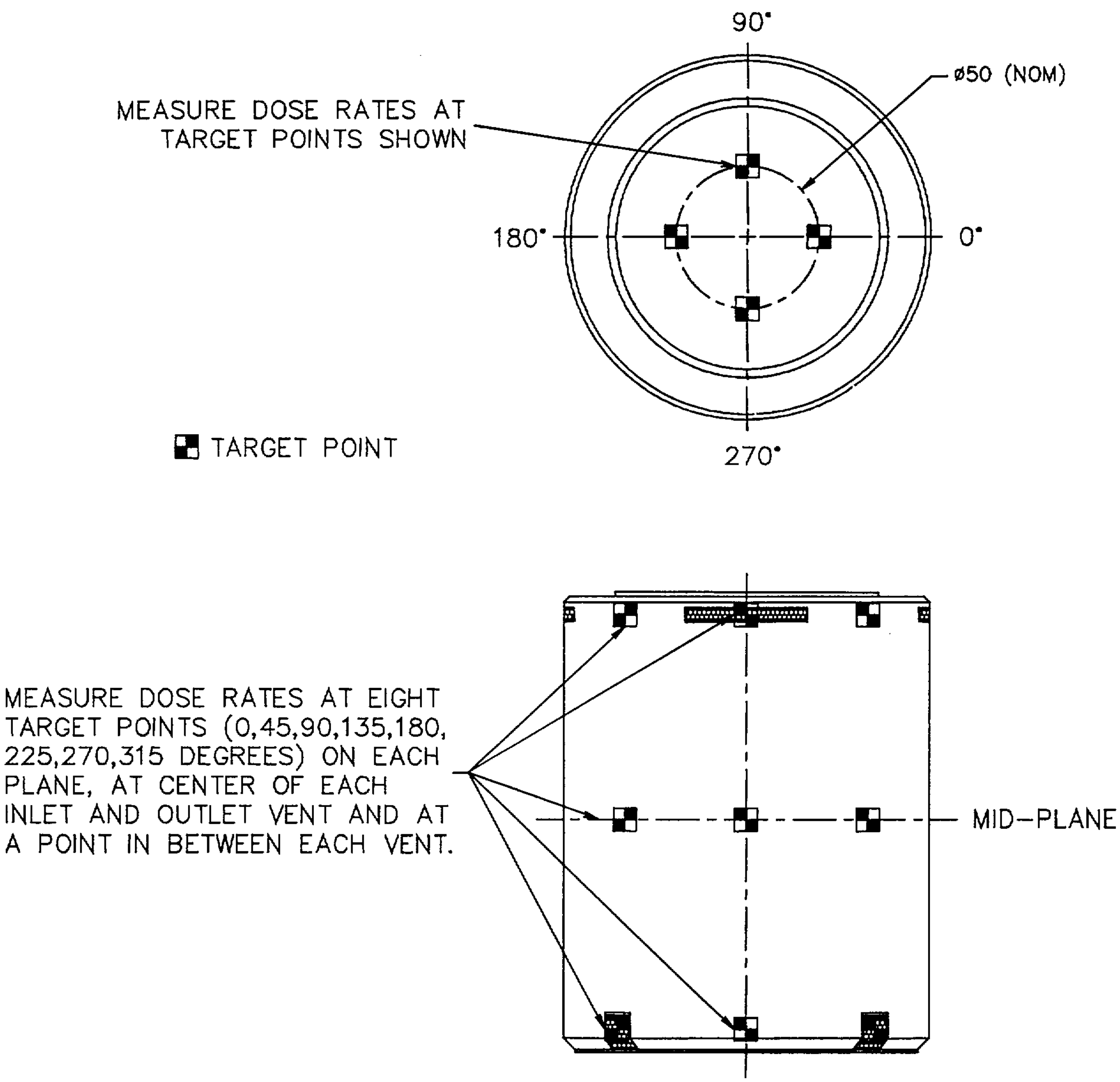
3.2.1 CONCRETE CASK Average Surface Dose Rates (Continued)

CONDITION	REQUIRED ACTION	COMPLETION TIME
	A.2 Verify that the dose rate from the cask will not cause the ISFSI to exceed the offsite radiation protection requirements of 10 CFR 20 and 10 CFR 72.	Prior to TRANSPORT OPERATIONS
B. Required Action and Associated Completion Time not met.	B.1 Remove all fuel assemblies from the NAC-MPC SYSTEM.	30 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.1.1	Verify average surface dose rates of CONCRETE CASK containing fuel assemblies are within limits.	Prior to TRANSPORT OPERATIONS

Figure 12A3-1
CONCRETE CASK Surface Dose Rate Measurement



3.2 NAC-MPC SYSTEM Radiation Protection

3.2.2 CANISTER Surface Contamination

LCO 3.2.2 Removable contamination on the accessible exterior surfaces of the CANISTER or accessible interior surfaces of the TRANSFER CASK shall each not exceed:

a. 1000 dpm/100 cm^2 from beta and gamma sources and

b. 20 dpm/100 cm^2 from alpha sources.

APPLICABILITY: During LOADING OPERATIONS

ACTIONS

-----NOTE-----
Separate Condition entry is allowed for each NAC-MPC SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. CANISTER or TRANSFER CASK removable surface contamination limits not met.	A.1 Restore CANISTER and TRANSFER CASK removable surface contamination to within limits.	Prior to TRANSPORT OPERATIONS

3.2 NAC-MPC SYSTEM Radiation Protection

3.2.2 CANISTER Surface Contamination (Continued)

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.2.1	Verify that the removable contamination on the accessible exterior surfaces of the CANISTER containing fuel is within limits.	Prior to TRANSPORT OPERATIONS
SR 3.2.2.2	Verify that the removable contamination on the accessible interior surfaces of the TRANSFER CASK do not exceed limits.	Prior to TRANSPORT OPERATIONS

4.0 DESIGN FEATURES

4.1 Site

4.1.1 Site Location

Not applicable

4.2 Storage Features

4.2.1 Storage Cask

The NAC-MPC SYSTEM consists of the VERTICAL CONCRETE CASK (CONCRETE CASK) and its integral TRANSPORTABLE STORAGE CANISTER (CANISTER).

4.2.2 Storage Capacity

The total storage capacity of the ISFSI is limited by plant-specific license conditions.

4.2.3 Storage Pad(s)

Not applicable

4.3 Codes and Standards

The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), 1995 Edition with Addenda, is the governing Code for the NAC-MPC CANISTER.

The American Concrete Institute Specifications ACI-349 and ACI-318 govern the NAC-MPC Vertical Concrete Cask design and construction, respectively.

The American National Standards Institute ANSI N14.6 and NUREG-0612 govern the NAC-MPC Transfer Cask design and construction.

4.1 Site (Continued)

4.3.1 Exceptions to the ASME Code

Codes and Standards

The NAC-MPC CANISTER and fuel basket structure are designed and fabricated in accordance with the ASME Code, Section III, Division 1, Subsections NB and NG, respectively. Exceptions to the applicable ASME Code requirements are listed in Table 12A4-1.

Proposed alternatives to ASME Code Section III, 1995 Edition with Addenda, including exceptions allowed by Table 12A4-1 may be used as authorized by the Director of the Office of Nuclear Material Safety and Safeguards or Designee. The justification in Table 12A4-1 demonstrates that:

1. The proposed alternatives will provide an acceptable level of quality and safety, or
2. Compliance with the specified requirements of ASME Code, Section III, 1995 Edition with Addenda would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Table 12A4-1

List of ASME Code Exceptions for the NAC-MPC CANISTER

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER	NB-1100	Statement of requirements for Code stamping of components.	CANISTER is designed and will be fabricated in accordance with ASME Code, Section III, Subsection NB to the maximum practical extent, but Code stamping is not required.
CANISTER Shield Lid and Structural Lid Welds	NB-4243	Full penetration welds required for Category C joints (flat head to main shell per NB-3352.3).	Shield lid and structural lid to canister shell welds are not full penetration welds. These field welds are performed independently to provide a redundant closure. Leaktightness of the canister is verified by testing.
CANISTER Structural Lid Weld	NB-4421	Requires removal of backing ring.	Structural lid to canister shell weld uses a backing ring that is not removed. The backing ring permits completion of the groove weld; it is not considered in any analyses; it has no detrimental effect on the canister's function.
CANISTER Vent Port Cover and Drain Port Cover to Shield Lid Welds; Shield Lid to Canister Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	Root and final surface liquid penetrant examination to be performed per ASME Code Section V, Article 6, with acceptance in accordance with NB-5350.

Table 12A4-1

List of ASME Code Exceptions for the NAC-MPC CANISTER (Continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Structural Lid to Shell Weld	NB-5230	Radiographic (RT) or ultrasonic (UT) examination required.	The CANISTER structural lid to canister shell closure weld is performed in the field following fuel assembly loading. The structural lid-to-shell weld will be verified by either ultrasonic (UT) or progressive liquid penetrant (PT) examination. If progressive PT examination is used, at a minimum, it will include the root and final surfaces and sufficient intermediate layers to detect critical flaws. If UT examination is used, it will be followed by a final surface PT examination. For either UT or PT examination, the maximum, undetectable flaw size is demonstrated to be smaller than the critical flaw size. The critical flaw size is determined in accordance with ASME Section XI methods. The examination of the weld will be performed by qualified personnel per ASME Code Section V, Articles 5 (UT) and 6 (PT) with acceptance per ASME Code Section III, NB-5330 (UT) and NB-5350 for (PT).

Table 12A4-1

List of ASME Code Exceptions for the NAC-MPC CANISTER (Continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Vessel and Shield Lid	NB-6111	All completed pressure retaining systems shall be pressure tested.	The CANISTER shield lid to shell weld is performed in the field following fuel assembly loading. The CANISTER, including the shield lid weld, is then pneumatically (air-over-water) pressure tested as defined in Chapter 9 and described in Chapter 8. Accessibility for leakage inspections precludes a Code compliant hydrostatic test. The shield lid-to-shell weld is re-examined by liquid penetrant (PT) examination following the pneumatic pressure test. The shield lid weld is also leak tested to leak-tight criteria of ANSI N14.5. The vent port and drain port cover welds are examined by root and final PT examination. The structural lid secondary enclosure weld is not pressure tested, but is examined by UT and final surface PT or progressive PT.
CANISTER Vessel	NB-7000	Vessels are required to have overpressure protection.	No overpressure protection is provided. The function of the CANISTER is to confine radioactive contents under normal, off-normal, and accident conditions of storage. The CANISTER vessel is designed to withstand a maximum internal pressure considering 100% fuel rod failure and maximum accident temperatures.

Table 12A4-1

List of ASME Code Exceptions for the NAC-MPC CANISTER (Continued)

Component	Reference ASME Code Section/Article	Code Requirement	Exception, Justification and Compensatory Measures
CANISTER Vessel	NB-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The NAC-MPC SYSTEM is marked and identified in accordance with 10 CFR 72 requirements. Code stamping is not required. The QA data package will be in accordance with NAC's approved QA program.
CANISTER Basket Assembly	NG-8000	States requirements for nameplates, stamping and reports per NCA-8000.	The NAC-MPC SYSTEM will be marked and identified in accordance with 10 CFR 72 requirements. No Code stamping is required. The CANISTER basket data package will be in conformance with NAC's approved QA program.
CANISTER Vessel and Basket Assembly Material	NB-2130/ NG-2130	States requirements for certification of material to NCA-3861 and NCA-3862	The NAC-MPC CANISTER Vessel and Basket Assembly component materials are procured in accordance with the specifications for materials in ASME Code Section II. The component materials will be obtained from NAC approved Suppliers in accordance with NAC's approved QA program.

4.4 Site Specific Parameters and Analyses

Site-specific parameters and analyses that will need verification by the NAC-MPC SYSTEM user, are as a minimum, as follows:

1. The temperature of 75°F is the maximum average yearly temperature. The average daily ambient temperature shall be 100°F or less.

2. The temperature extremes of 125°F with incident solar radiation and -40°F for storage of the CANISTER inside the CONCRETE CASK.

3. The design basis earthquake horizontal and vertical seismic acceleration levels are bounded by the values shown below:

Design-Basis Earthquake Input on the Top Surface of an ISFSI Pad

Horizontal g-level in each of Two Orthogonal Directions	Corresponding Vertical g-level (upward)
0.25g	0.25 x 0.667 = 0.167g

4. The analyzed flood condition of 15 fps water velocity and a height of 50 feet of water (full submergence of the loaded cask) are not exceeded.

5. The potential for fire and explosion shall be addressed, based on site-specific considerations. This includes the condition that the fuel tank of the cask handling equipment used to move the loaded CONCRETE CASK onto the ISFSI site contains no more than 50 gallons of fuel.

4.4 Site Specific Parameters and Analyses (Continued)

6. In addition to the requirement of 10 CFR 72.212(b)(2)(ii), the ISFSI pad and foundation shall include the following characteristics as applicable to the end drop and tip-over analyses:

a.	Concrete thickness	36 inch maximum
b.	Pad Subsoil thickness	72 inch minimum
c.	Concrete compressive strength	≤ 4,000 psi at 28 days
d.	Concrete density (ρ)	$125 \leq \rho \leq 150$ lbs/ft^3
e.	Soil density (ρ)	$85 \leq \rho \leq 130$ lbs/ft^3
f.	Soil Stiffness (k)	$k \leq 300$ psi/in.

The concrete pad maximum thickness excludes the ISFSI pad footer. The compressive strength of concrete should be determined according to the test method given in Section 5.6 of ACI 318. Steel reinforcement is used in the pad. The placement of the reinforcement, including its area and spacing, are determined by analysis and installed in accordance with ACI 318. The soil stiffness should be determined according to the test method described in Chapter 9 of the Civil Engineering Reference Manual, 6th Edition.

7. In cases where engineered features (i.e., berms, shield walls) are used to ensure that requirements of 10 CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assessment Category on a site specific basis.

4.5 Design Specifications

4.5.1 Specification Important for Thermal Performance

1. The spacing of the NAC-MPC SYSTEM shall be a minimum of 15 feet (center-to-center).
2. Helium shall have a minimum purity of 99.9%.

4.5.2 Specification Important to CANISTER Lifting

The minimum distance from the master link of the CANISTER lifting slings to the top of the CANISTER shall be 67 inches.

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5.0 ADMINISTRATIVE CONTROLS

5.1 NAC-MPC SYSTEM Training

Training modules shall be developed under the general licensee's training program as required by 10 CFR 72.212(b)(6). Training modules shall require a comprehensive, program for the operation and maintenance of the NAC-MPC SYSTEM and the Independent Spent Fuel Storage Installation (ISFSI). The training modules shall include the following elements, at a minimum:

- Regulatory Requirements Overview
- NAC-MPC SYSTEM Design and Operational Features
- ISFSI Facility Design (overview)
- Certificate of Compliance Conditions
- Technical Specifications, Controls, Limits and Conditions of Use
- Identification of Components and Equipment Important to Safety
- Surveillance Requirements
- NAC-MPC SYSTEM and ISFSI procedures, including:
    - Documentation, Inspection and Compliance Requirements
    - Handling the CONCRETE CASK and Empty CANISTER
    - Handling the Transfer Cask
    - Loading and Closing the CANISTER
    - Loading the CONCRETE CASK
    - Moving the CONCRETE CASK and CANISTER and Placement on the ISFSI
- Special Processes and Equipment, including Leak Testing, Welding and Weld Examination
- Auxiliary Equipment, including Lifting Yokes and Slings
- Off-Normal and Accident Conditions, Response and Corrective Actions
- Radiological Safety and ALARA
- Operating Experience

Training session participation should be documented as required to establish qualification to performed the designated tasks.

5.2 Dry Run Training

A dry run training exercise of the loading, closure, handling, unloading, and transfer of the NAC-MPC Storage System shall be conducted by the licensee before the system is initially loaded. This demonstrates equipment fitup and interfacing, provides the opportunity to illustrate key features, operations, inspections and test conditions. It also allows comparison of procedural steps to component handling requirements. The dry run may be performed in an alternate step sequence from the actual procedures, but all steps must be performed. The dry run shall include, but is not limited to, the following:

- Moving the Concrete Cask into its Designated Loading Area
- Moving the Transfer Cask Holding the Empty Canister into the Spent Fuel Pool
- Loading One or More Dummy Fuel Assemblies into the Canister, Including Independent Verification
- Installing the Shield Lid
- Removal of the Transfer Cask from the Spent Fuel Pool
- Closing and Sealing of the Canister to Demonstrate Pressure Testing, Vacuum Drying, Helium Backfilling, Welding, Weld Inspection and Documentation, and Leak Testing
- Transfer Cask Movement Through the Designated Load Path
- Transfer Cask Installation on the Concrete Cask
- Placement of the Canister in the Concrete Cask
- Transport of the Concrete Cask to the ISFSI
- Canister Unloading, Including Reflooding and Weld Removal or Cutting

Demonstration of closing and sealing the canister may be performed using a mockup of the canister. The mockup should closely approximate the actual canister to allow qualification of personnel in the welding and testing tasks as required. The closed mockup is also used to demonstrate the activities necessary to open and unload the canister.

Participation in dry run training should be documented as required to establish qualification to perform designated tasks.

5.3 Special Requirements for First NAC-MPC SYSTEM Placed in Service

The heat transfer characteristics of the NAC-MPC SYSTEM will be recorded by temperature measurements of the first NAC-MPC SYSTEM placed in service with a heat load equal to or greater than 7.5 kW.

5.4 Programs

5.4.1 CONCRETE CASK Thermal Monitoring Program

The following programs shall be established, implemented and maintained.

This program provides guidance for the temperature measurement and visual inspection activities that are used to monitor the thermal performance of each CONCRETE CASK.

a. The ambient air temperature and the air outlet temperatures are measured and compared every 24 hours. The temperature difference between the air outlet temperatures and the ambient air temperature is calculated and recorded.

b. If any air outlet temperature, or temperature difference between air outlet and ambient temperature shows an unexplained reading, appropriate actions are taken to determine the cause and to return the outlet temperatures to acceptable values. One of the immediate actions will be to increase the frequency of temperature monitoring until normal conditions are returned.

c. If an air outlet temperature exceeds the ambient air temperature by 92°F, the NRC will be notified and actions will be taken to evaluate the effects and impact of the elevated temperature on the CONCRETE CASK and CANISTER. A temperature differential of 92°F corresponds to a concrete temperature of 165°F. The long-term normal concrete temperature limit for the CONCRETE CASK is 200°F and the short-term bulk concrete temperature limit is 350°F.

APPENDIX 12B

NAC-MPC SYSTEM
TECHNICAL SPECIFICATIONS BASES

Appendix 12B
Table of Contents

1.0 Introduction

This Appendix presents the design or operational condition, or regulatory requirement, which establishes the bases for the Technical Specifications provided in Appendix 12A.

The section and paragraph numbering used in this Appendix corresponds to the numbering used in Appendix 12A for the Functional and Operating Limits (Section 2.0) and the Limiting Condition for Operations or Surveillance (Section 3.0). This allows direct comparison of the limit or condition described in Appendix 12A, with its corresponding bases in this Appendix.

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2.0 Functional And Operating Limits

2.1 Fuel to be Stored in the NAC-MPC SYSTEM

BASES

BACKGROUND

The NAC-MPC SYSTEM design requires specifications for the spent fuel to be stored, such as the type of spent fuel, minimum and maximum allowable enrichment prior to irradiation, maximum burnup, minimum acceptable port-irradiation cooling time prior to storage, maximum decay heat, and conditions of the spent fuel (i.e., INTACT FUEL, DAMAGED FUEL OR FAILED FUEL). Other important limitations are the dimensions and weight of the fuel assemblies.

Requirements for fuel to be loaded into the NAC-MPC SYSTEM are specified in Sections 2.1.1 and 2.1.2 of Appendix 12A.

Specific limitations for the NAC-MPC SYSTEM are specified in Table 12A2-1 as referred to in the Functional and Operating Limits, Section 2.1.1 of Appendix 12A. These limitations support the assumptions and inputs used in the thermal, structural, shielding, and criticality evaluations performed for the NAC-MPC SYSTEM.

Actions required to respond to violations of any Functional and Operating Limits are provided in Section 2.2.

APPLICABLE SAFETY ANALYSES

To ensure that the shield lid is not placed on a canister containing an unauthorized fuel assembly, facility procedures require verification of the loaded fuel assemblies to ensure that the correct fuel assemblies have been loaded in the canister.

FUNCTIONAL AND OPERATING LIMITS

2.1.1

Functional and Operating Limit 2.1.1 refers to Table 12A2-1 for the specific fuel assembly characteristic limits for Yankee Class fuel assemblies authorized for loading into the NAC-MPC SYSTEM. These fuel assembly characteristics include parameters such as cladding material, enrichment, decay heat generation, post-irradiation cooling time, burnup, and fuel assembly length, width, and weight. Table 12A2-2 is referenced from Table 12A2-1 and provides additional specific fuel characteristic limits for the fuel assemblies based on the fuel assembly class type.

The fuel assembly characteristic limits of Tables 12A2-1 and 12A2-2 must be met to ensure that the thermal, structural, shielding, and criticality analyses supporting the NAC-MPC SYSTEM Safety Analysis Report are bounding.

FUNCTIONAL AND OPERATING LIMITS VIOLATIONS

2.2.1

If any Functional and Operating Limit of 2.1.1 are violated, the limitations on fuel assemblies to be loaded are not met. Action must be taken to place the affected fuel assembly(s) in a safe condition. This safe condition may be established by returning the affected fuel assembly(s) to the spent fuel pool. However, it is acceptable for the affected fuel assemblies to temporarily remain in the NAC-MPC SYSTEM, in a wet or dry condition, if that is determined to be a safe condition.

2.2.2 and 2.2.3

Notification of the Functional and Operating Limit violation to the NRC is required within 24 hours. Written reporting of the violation must be accomplished within 30 days. This notification and written report are independent of any reports and notification that may be required by 10 CFR 72.216.

REFERENCES

1. SAR, Sections 2.1, 4.4; Chapters 5 and 6.

3.0 Limiting Condition for Operation (LCO) Applicability

BASES

LCOs	LCO 3.0.1, 3.0.2, 3.0.4, and 3.0.5 establish the general requirements applicable to all Specifications and apply at all times, unless otherwise stated.
LCO 3.0.1	LCO 3.0.1 establishes the Applicability statement within each individual Specification as the requirement for when the LCO is required to be met (i.e., when the NAC-MPC SYSTEM is in the specified conditions of the Applicability statement of each Specification).
LCO 3.0.2	LCO 3.0.2 establishes that upon discovery of a failure to meet an LCO, the associated ACTIONS shall be met. The Completion Time of each Required Action for an ACTIONS Condition is applicable from the point in time that an ACTIONS Condition is entered. The Required Actions establish those remedial measures that must be taken within the specified Completion Times when the requirements of an LCO are not met. This Specification establishes that: a. Completion of the Required Actions within the specified Completion Times constitutes compliance with a Specification; and, b. Completion of the Required Actions is not required when an LCO is meet within the specified Completion Time, unless otherwise specified. There are two basic Required Action types. The first Required Action type specifies a time limit, the Completion Time to restore a system or component or to restore variables to within specified limits, in which the LCO must be met. Whether stated as a Required Action or not, correction of the entered Condition is an action that may always be considered upon entering ACTIONS. The second Required Action type specifies the remedial measures that permit continued activities that are not further restricted by the Completion Time. In this case, compliance with the Required Actions provides an acceptable level of safety for continued operation.

LCO 3.0.2 (continued)

Completing the Required Actions is not required when an LCO is met or is no longer applicable, unless otherwise stated in the individual Specifications.

The Completion Times of the Required Actions are also applicable when a system or component is removed from service intentionally. The reasons for intentionally relying on the ACTIONS include, but are not limited to, performance of Surveillance, preventive maintenance, corrective maintenance, or investigation of operational problems. Entering ACTIONS for these reasons must be done in a manner that does not compromise safety. Intentional entry into ACTIONS should not be made for operational convenience.

LCO 3.0.3

This specification is not applicable to the NAC-MPC SYSTEM because it describes conditions under which a power reactor must be shut down when an LCO is not met and an associated ACTION is not met or provided. The placeholder is retained for consistency with the power reactor technical specifications.

LCO 3.0.4

LCO 3.0.4 establishes limitations on changes in specified conditions in the Applicability when an LCO is not met. It precludes placing the facility in a specified condition stated in that Applicability (e.g., Applicability desired to be entered) when the following exist:

a. NAC-MPC SYSTEM conditions are such that the requirements of the LCO would not be met in the Applicability desired to be entered; and

b. Continued noncompliance with the LCO requirements, if the Applicability were entered, would result in NAC-MPC SYSTEM activities being required to exit the Applicability desired to be entered to comply with the Required Actions.

Compliance with Required Actions that permit continued operation for an unlimited period of time in a specified condition provides an acceptable level of safety for continued operation. This is without regard to the status of the NAC-MPC SYSTEM. Therefore, in such cases, entry into a specified condition in the Applicability may be made in accordance with the provisions of the Required Actions.

LCO 3.0.4 (continued)	The provisions of this Specification should not be interpreted as endorsing the failure to exercise the good practice of restoring systems or components before entering an associated specified condition in the Applicability. The provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS. In addition, the provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are related to the unloading of the NAC-MPC SYSTEM. Exceptions to LCO 3.0.4 are stated in the individual Specifications. Exceptions may apply to all the ACTIONS or to a specific Required Action of a Specification.
LCO 3.0.5	LCO 3.0.5 establishes the allowance for restoring equipment to service under administrative controls when it has been removed from service or determined to not meet the LCO to comply with the ACTIONS. The sole purpose of the Specification is to provide an exception to LCO 3.0.2 (e.g. to not comply with the applicable Required Action[s]) to allow the performance of testing to demonstrate: a. The equipment being returned to service meets the LCO; or b. Other equipment meets the applicable LCOs. The administrative controls ensure the time the equipment is returned to service in conflict with the requirements of the ACTIONS is limited to the time absolutely necessary to perform the allowed testing. This Specification does not provide time to perform any other preventive or corrective maintenance.
LCO 3.0.6	Not Applicable
LCO 3.0.7	Not Applicable

3.0 Surveillance Requirement (SR) Applicability

BASES

Surveillance Requirements (SRs)	SR 3.0.1 through SR 3.0.4 establish the general requirements applicable to all Specifications and apply at all times, unless otherwise stated.

SR 3.0.1

SR 3.0.1 establishes the requirement that SRs must be met during the specified conditions in the Applicability for which the requirements of the LCO apply, unless otherwise specified in the individual SRs. This Specification is to ensure that Surveillance is performed to verify that systems and components meet the LCO and variables are within specified limits. Failure to meet Surveillance within the specified Frequency, in accordance with SR 3.0.2, constitutes a failure to meet an LCO.

Systems and components are assumed to meet the LCO when the associated SRs have been met. Nothing in this Specification, however, is to be construed as implying that systems or components meet the associated LCO when:

a. The systems or components are known to not meet the LCO, although still meeting the SRs; or,

b. The requirements of the Surveillance(s) are known to be not met between required Surveillance performances.

Surveillances do not have to be performed when the NAC-MPC SYSTEM is in a specified condition for which the requirements of the associated LCO are not applicable, unless otherwise specified.

Surveillances, including those invoked by Required Actions, do not have to be performed on equipment that has been determined to not meet the LCO because the ACTIONS define the remedial measures that apply. Surveillances have to be met and performed in accordance with SR 3.0.2, prior to returning equipment to service. Upon completion of maintenance, appropriate post maintenance testing is required. This includes ensuring applicable Surveillances are not failed and their most recent performance is in accordance with SR 3.0.2. Post maintenance

SR 3.0.1 (continued)

testing may not be possible in the current specified conditions in the Applicability, due to the necessary NAC-MPC SYSTEM parameters not having been established. In these situations, the equipment may be considered to meet the LCO provided testing has been satisfactorily completed to the extent possible and the equipment is not otherwise believed to be incapable of performing its function. This will allow operation to proceed to a specified condition where other necessary post maintenance tests can be completed.

SR 3.0.2

SR 3.0.2 establishes the requirements for meeting the specified Frequency for Surveillances and any Required Action with a Completion Time that requires the periodic performance of the Required Action on a "once per…" interval.

This extension facilitates Surveillance scheduling and considers facility conditions that may not be suitable for conducting the Surveillance (e.g., transient conditions or other ongoing Surveillance or maintenance activities).

The 25% extension does not significantly degrade the reliability that results from performing the Surveillance at its specified Frequency. This is based on the recognition that the most probable result of any particular Surveillance being performed is the verification of conformance with the SRs. The exceptions to SR 3.0.2 are those Suveillances for which the 25% extension of the interval specified in the Frequency does not apply. These exceptions are stated in the individual Specifications as a Note in the Frequency stating, "SR 3.0.2 is not applicable."

As stated in SR 3.0.2, the 25% extension also does not apply to the initial portion of a periodic Completion Time that requires performance on a "once per…" basis. The 25% extension applies to each performance after the initial performance. The initial performance of the Required Action, whether it is a particular Surveillance or some other remedial action, is considered a single action with a single Completion time. One reason for not allowing the 25% extension to this Completion Time is that such an action usually verifies that no loss of function has occurred by checking the status of redundant or diverse components or accomplishes the function of the affected equipment in an alternative manner.

SR 3.0.2 (continued)

The provisions of SR 3.0.2 are not intended to be used repeatedly, merely as an operational convenience to extend Surveillance intervals or periodic Completion Time intervals beyond those specified.

SR 3.0.3

SR 3.0.3 establishes the flexibility to defer declaring affected equipment as not meeting the LCO or an affected variable outside the specified limits when a Surveillance has not been completed within the specified Frequency. A delay period of up to 24 hours or up to the limit of the specified Frequency, whichever is less, applies from the point in time that it is discovered that the Surveillance has not been performed in accordance with SR 3.0.2, and not at the time that the specified Frequency was not met.

This delay period provides adequate time to complete Surveillances that have been missed. This delay period permits the completion of a Surveillance before complying with Required Actions or other remedial measures that might preclude completion of the Surveillance.

The basis for this delay period includes: consideration of facility conditions, adequate planning, availability of personnel, the time required to perform the Surveillance, the safety significance of the delay in completing the required Surveillance, and the recognition that the most probable result of any particular Surveillance being performed is the verification of conformance with the requirements. When a Surveillance with a Frequency, based not on time intervals, but upon specified NAC-MPC SYSTEM conditions, is discovered not to have been performed when specified, SR 3.0.3 allows the full delay period of 24 hours to perform the Surveillance.

SR 3.0.3 also provides a time limit for completion of Surveillances that become applicable as a consequence of changes in the specified conditions in the Applicability imposed by the Required Actions.

Failure to comply with specified Frequencies for SRs is expected to be an infrequent occurrence. Use of the delay period established by SR 3.0.3 is a flexibility, which is not intended to be used as an operational convenience to extent Surveillance intervals.

SR 3.0.3 (continued)

If a Surveillance is not completed within the allowed delay period, then the equipment is considered to not meet the LCO or the variable is considered outside the specified limits and the Completion Times of the Required Actions for the applicable LCO Conditions begin immediately upon expiration of the delay period. If a Surveillance is failed within the delay period, then the equipment does not meet the LCO, or the variable is outside the specified limits and the Completion Times of the Required Actions for the applicable LCO Conditions begin immediately upon the failure of the Surveillance.

Completion of the Surveillance within the delay period allowed by this Specification, or within the Completion Time of the ACTIONS, restores compliance with SR 3.0.1.

SR 3.0.4

SR 3.0.4 establishes the requirement that all applicable SRs must be met before entry into a specified condition in the Applicability.

This Specification ensures that system and component requirements and variable limits are met before entry into specified conditions in the Applicability for which these systems and components ensure safe operation of NAC-MPC SYSTEM activities.

The provisions of this Specification should not be interpreted as endorsing the failure to exercise the good practice of restoring systems or components before entering an associated specified condition in the Applicability.

However, in certain circumstances, failing to meet an SR will not result in SR 3.0.4 restricting a change in specified condition. When a system, subsystem, division, component, device, or variable is outside its specified limits, the associated SR(s) are not required to be performed per SR 3.0.1, which states that Surveillances do not have to be performed on equipment that has been determined to not meet the LCO.

SR 3.0.4 (continued)

When equipment does not meet the LCO, SR 3.0.4 does not apply to the associated SR(s), since the requirement for the SR(s) to be performed is removed. Therefore, failing to perform the Surveillance(s) within the specified Frequency does not result in a SR 3.0.4 restriction to changing specified conditions of the Applicability. However, since the LCO is not in this situation, LCO 3.0.4 will govern any restrictions that may be (or may not) apply to specified condition changes.

The provisions of SR 3.0.4 shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS. In addition, the provisions of LCO 3.0.4 shall not prevent changes in specified conditions in the Applicability that are related to the unloading of the NAC-MPC SYSTEM.

The precise requirements for performance of SRs are specified such that exceptions to SR 3.0.4 are not necessary. The specific time frames and conditions necessary for meeting the SRs are specified in the Frequency, in the Surveillance, or both. This allows performance of Surveillances, when the prerequisite condition(s) specified in a Surveillance procedure require entry into the specified condition in the Applicability of the associated LCO, prior to the performance or completion of a Surveillance. A Surveillance that could not be performed until after entering LCO Applicability, would have its Frequency specified such that is not "due" until the specific conditions needed are met.

Alternately, the Surveillance may be stated in the form of a Note as not required (to be met or performed) until a particular event, condition, or time has been reached. Further discussion of the specific formats of SRs' annotation is found in Section 1.4, Frequency.

3.1 NAC-MPC SYSTEM Integrity

3.1.1 [Reserved]

BASES

3.1 NAC-MPC SYSTEM Integrity

3.1.2 CANISTER Vacuum Drying Pressure

BASES

BACKGROUND

A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area, where dose rates are measured and the CANISTER shield lid is welded to the CANISTER shell and the lid welds are inspected and pressure tested. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is backfilled with helium and leak tested. Additional dose rates are measured, and the CANISTER vent port and drain port covers and structural lid are installed and welded. Non-destructive examinations are performed on the welds. Contamination measurements are completed prior to moving TRANSFER CASK and CANISTER in position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, average CONCRETE CASK surface dose rate measurements are taken. The CONCRETE CASK is then moved to the ISFSI.

CANISTER cavity vacuum drying is utilized to remove residual moisture from the CANISTER cavity after the water is drained from the CANISTER. Any water not drained from the CANISTER cavity evaporates, due to the vacuum. This is aided by the temperature increase, due to the heat generation of the fuel.

APPLLICABLE SAFETY ANALYSIS

The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of design basis spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix; the metallic fuel cladding tubes where the fuel pellets are contained; and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel and cladding depends on storage in an inert atmosphere. This is accomplished by removing water and oxidizing gases from the CANISTER and backfilling the cavity with helium. The thermal analysis assumes that the CANISTER cavity is dry and filled with helium.

The heat-up of the CANISTER and contents will occur during CANISTER vacuum drying but is controlled by LCO 3.1.5.

LCO

A vacuum pressure, meeting the limit specified in Table 12A3-1, indicates that liquid water has evaporated and been removed from the CANISTER cavity. Removing water from the CANISTER cavity helps to ensure the long-term maintenance of fuel cladding integrity.

APPLICABILITY OPERATIONS

Cavity vacuum drying is performed during LOADING OPERATIONS before the TRANSFER CASK holding the CANISTER is moved to transfer the CANISTER to the CONCRETE CASK. Therefore, the vacuum requirements do not apply after the CANISTER is backfilled with helium and leak tested prior to TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

<u>A.1</u>

If the CANISTER cavity vacuum drying pressure limit cannot be met, actions must be taken to meet the LCO. Failure to successfully complete cavity vacuum drying could have many causes, such as failure of the vacuum drying system, inadequate draining, ice clogging of the drain lines, or leaking CANISTER welds. The Completion Time is sufficient to determine and correct most failure mechanisms. Excessive heat-up of the CANISTER and contents is precluded by LCO 3.1.5.

<u>B.1</u>

If the CANISTER fuel cavity cannot be successfully vacuum dried, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met.

A.1 may be repeated as necessary prior to performing B.1. The time frame for completing B.1 cannot be extended by re-performing A.1. The Completion Time is reasonable based on the time required to reflood the CANISTER, perform fuel cooldown operations, cut the shield lid weld, move the TRANSFER CASK into the spent fuel pool, and remove the CANISTER shield lid in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 3.1.2.1

The long-term integrity of the stored fuel is dependent on storage in a dry, inert environment. Cavity dryness is demonstrated by evacuating the cavity to a very low absolute pressure and verifying that the pressure is held over a specified period of time. A low vacuum pressure is an indication that the cavity is dry. The surveillance must be performed within 24 hours after completion of CANISTER draining. This allows sufficient time to backfill the CANISTER cavity with helium, while minimizing the time the fuel is in the CANISTER without water or the assumed inert atmosphere in the cavity.

REFERENCES

1. SAR Sections 4.4, 7.1 and 8.1.

3.1 NAC-MPC SYSTEM Integrity

3.1.3 CANISTER Helium Backfill Pressure

BASES

BACKGROUND

A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area, where dose rates are measured and the CANISTER shield lid is welded to the CANISTER shell and the lid welds are inspected and pressure tested. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is backfilled with helium and leak tested. Additional dose rates are measured, and the CANISTER vent port and drain port covers and structural lid are installed and welded. Non-destructive examinations are performed on the welds. Contamination measurements are completed prior to moving TRANSFER CASK and CANISTER in position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, average CONCRETE CASK surface dose rate measurements are taken. The CONCRETE CASK is then moved to the ISFSI.

Backfilling of the CANISTER cavity with helium promotes heat transfer from the spent fuel to the CANISTER structure and the inert atmosphere protects the fuel cladding. Providing a helium pressure equal to atmospheric pressure ensures that there will be no in-leakage of air over the life of the CANISTER, which might be harmful to the heat transfer features of the NAC-MPC SYSTEM and harmful to the fuel.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix, the metallic fuel cladding tubes where the fuel pellets are contained, and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel and cladding depends on the ability of the NAC-MPC SYSTEM to remove heat from the CANISTER and reject it to the environment. This is accomplished by removing water from the

CANISTER cavity and backfilling the cavity with an inert gas. The heat-up of the CANISTER and contents will continue following backfilling with helium but is controlled by LCO 3.1.6.

The thermal analyses of the CANISTER assume that the CANISTER cavity is dry and filled with dry helium.

LCO

Backfilling the CANISTER cavity with helium at a pressure equal to atmospheric pressure ensures that there is no air in-leakage into the CANISTER, which could decrease the heat transfer properties and result in increased cladding temperatures and damage to the fuel cladding over the storage period. The helium backfill pressure specified in Table 12A3-1 was selected based on a minimum helium purity of 99.9% to ensure that the CANISTER internal pressure and heat transfer from the CANISTER to the environment is maintained consistent with the design and analysis bases of the CANISTER.

APPLICABILITY

Helium backfill is performed during LOADING OPERATIONS, before the TRANSFER CASK and CANISTER are moved to the CONCRETE CASK for transfer of the CANISTER. Therefore, the backfill pressure requirements do not apply after the CANISTER is backfilled with helium and leak tested prior to TRANSPORT OPERATIONS and STORAGE OPERATIONS.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs, that do not meet the LCO are governed by subsequent condition entry and application of associated Required Actions.

A.1

If the backfill pressure cannot be obtained, actions must be taken to meet the LCO. The Completion Time is sufficient to determine and correct most failures, which would prevent backfilling of the CANISTER cavity with helium.

B.1

If the CANISTER cavity cannot be backfilled with helium to the specified pressure, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met. A.1 may be repeated as necessary prior to performing B.1. The time frame for completing B.1 can not be extended by re-performing A.1. The Completion Time is reasonable based on the time required to re-flood the CANISTER, perform cooldown operations, cut the CANISTER shield lid weld, move the TRANSFER CASK and CANISTER into the spent fuel pool, remove the CANISTER shield lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 3.1.3.1

The long-term integrity of the stored fuel is dependent on the storage in a dry, inert atmosphere, and maintenance of adequate heat transfer mechanisms. Filling the CANISTER cavity with helium at a pressure within the range specified in Table 12A3-1 will ensure that there will be no air in-leakage, which could potentially damage the fuel. This pressure of helium gas is sufficient to maintain fuel cladding temperatures within acceptable levels.

Backfilling of the CANISTER cavity must be performed successfully on each CANISTER before placing it in storage. The Surveillance must be performed within 24 hours after draining the CANISTER. This allows sufficient time to backfill the annulus with helium, while minimizing the time the loaded CANISTER is in the TRANSFER CASK without the assumed inert atmosphere in the cavity.

REFERENCES

1. SAR Sections 4.4, 7.1 and 8.1.

3.1 NAC-MPC SYSTEM Integrity

3.1.4 CANISTER Helium Leak Rate

BASES

BACKGROUND

A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area, where dose rates are measured and the CANISTER shield lid is welded to the CANISTER shell and the lid welds are inspected and pressure tested. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is backfilled with helium and leak tested. Additional dose rates are measured, and the CANISTER vent port and drain port covers and structural lid are installed and welded. Non-destructive examinations are performed on the welds. Contamination measurements are completed prior to moving TRANSFER CASK and CANISTER in position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, average CONCRETE CASK surface dose rate measurements are taken. The CONCRETE CASK is then moved to the ISFSI.

Backfilling the CANISTER cavity with helium promotes heat transfer from the fuel to the CANISTER shell. The inert atmosphere protects the fuel cladding. Prior to transferring the CANISTER to the CONCRETE CASK, the CANISTER helium leak rate is verified to meet leak tight requirements to ensure that the fuel and radioactive materials are confined.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity (including fission product gases, fuel fines, volatiles, and crud) during the storage of spent fuel in the CANISTER is ensured by the multiple confinement boundaries and systems. The barriers relied on are: the fuel pellet matrix; the metallic fuel cladding tubes where the fuel pellets are contained; and the CANISTER where the fuel assemblies are stored. Long-term integrity of the fuel and cladding depends on maintaining an inert atmosphere, and maintaining the cladding temperatures below established long-term limits. This is accomplished by removing water and oxidizing gases

from the CANISTER and backfilling the cavity with helium. The heat-up of the CANISTER and contents will continue following backfilling the cavity and leak testing the shield lid-to-shell weld but is controlled by LCO 3.1.6.

LCO

Verifying that the CANISTER cavity helium leak rate is below the leak tight limit specified in Table 12A3-1 ensures the CANISTER shield lid is sealed. Verifying the helium leakage rate is below leak tight levels will also ensure that the assumptions in the accident analyses and radiological evaluations are maintained.

APPLICABILITY

The leak tight helium leak rate verification is performed during LOADING OPERATIONS before the TRANSFER CASK and integral CANISTER are moved for transfer operations to the CONCRETE CASK. TRANSPORT OPERTIONS would not commence if the CANISTER helium leak rate was not below the test sensitivity. Therefore, CANISTER leak rate testing is not required during TRANSPORT OPERATIONS or STORAGE OPERATIONS.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the helium leak rate limit is not met, actions must be taken to meet the LCO. The Completion Time is sufficient to determine and correct most failures, which could cause a helium leak rate in excess of the limit.

B.1

If the CANISTER leak rate cannot be brought within the limit, the fuel must be placed in a safe condition. Corrective actions may be taken after the fuel is placed in a safe condition to perform the A.1 action provided that the initial conditions for performing A.1 are met. A.1 may be repeated as necessary prior to performing B.1. The time frame

for completing B.1 can not be extended by re-performing A.1. The Completion Time is reasonable based on the time required to re-flood the CANISTER, perform fuel cooldown operations, cut the CANISTER shield lid weld, move the TRANSFER CASK and CANISTER into the spent fuel pool, remove the CANISTER shield lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 3.1.4.1

The primary design consideration of the CANISTER is that it is leak tight to ensure that off-site dose limits are not exceeded and to ensure that the helium remains in the CANISTER during long-term storage. Long-term integrity of the stored fuel is dependent on storage in a dry, inert environment.

Verifying that the helium leak rate meets leak tight requirements must be performed successfully on each CANISTER prior to TRANSPORT OPRATIONS. This allows sufficient time to backfill the CANISTER cavity with helium and perform the leak test, while minimizing the time the fuel is in the CANISTER and loaded in the TRANSFER CASK.

REFERENCES

1. SAR Sections 7.1 and 8.1.

3.1 NAC-MPC SYSTEM Integrity

3.1.5 CANISTER Maximum Time in Vacuum Drying

BASES

BACKGROUND	A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area, where dose rates are measured and the CANISTER shield lid is welded to the CANISTER shell and the lid welds are inspected and pressure tested. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is backfilled with helium and leak tested. Additional dose rates are measured, and the CANISTER vent port and drain port covers and structural lid are installed and welded. Non-destructive examinations are performed on the welds. Contamination measurements are completed prior to moving the TRANSFER CASK and CANISTER in position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, average CONCRETE CASK surface dose rate measurements are taken. The CONCRETE CASK is then moved to the ISFSI. Limiting the elapsed time from start of CANISTER vacuum drying operations through dryness verification testing and subsequent backfilling of the CANISTER with helium ensures that the short-term temperature limits established in the Safety Analyses Report for the spent fuel cladding and CANISTER materials are not exceeded.
APPLICABLE SAFETY ANALYSIS	Limiting the total time for loaded CANISTER vacuum drying operations ensures that the short-term temperature limits for the fuel cladding and CANISTER materials are not exceeded. If vacuum drying operations are not completed in the required time period, the CANISTER is backfilled with helium and either the TRANSFER CASK and loaded CANISTER are returned to the spent fuel pool or forced air cooling of the CANISTER in the TRANSFER CASK is initiated. The in-pool or forced air cooling of the loaded CANISTER is maintained for a minimum of 24 hours. Analysis reported in the Safety Analysis Report conclude that spent fuel

cladding and CANISTER material short-term temperature limits will not be exceeded for total elapsed times exceeding 16 hours in vacuum drying and an additional 26 hours in the TRANSFER CASK backfilled with helium. After 24 hours of in-pool or forced air cooling operations, the spent fuel cladding temperature will be below 466°F. Analyses in the Safety Analysis Report show that short-term limits will not be reached for a minimum of 10 hours under vacuum drying operations and an additional 15 hours in the TRANSFER CASK backfilled with helium following 24 hours of in-pool cooling.

The forced air cooling basis is an inlet maximum air temperature of 75°F which is the maximum normal ambient air temperature in the thermal analysis. The convection cooling of the CANISTER due to the forced 250 cubic feet per minute (CFM) air flow rate exceeds the cooling, due to the CONCRETE CASK natural convection cooling flow because the small annulus between the TRANSFER CASK and CANISTER results in a high flow velocity. The high flow velocity results in improved heat transfer from the CANISTER compared to normal storage conditions in the CONCRETE CASK.

LCO

Limiting the length of time for vacuum drying operations on the CANISTER ensures that the spent fuel cladding and CANISTER material temperatures remain below the short-term temperature limits in the SAR for the NAC-MPC SYSTEM.

APPLICABILITY

The elapsed time restrictions for vacuum drying operation on a loaded CANISTER apply during LOADING OPERATIONS from the completion point of CANISTER draining operations through the completion point of the CANISTER dryness verification testing. The LCO is not applicable to TRANSPORT OPERATIONS or STORAGE OPERATIONS.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC systems that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

ACTIONS

A.1
If the LCO time limit is exceeded, the CANISTER will be backfilled with helium to a pressure of 0 (+1,-0) psig.

AND

A.1.1
The TRANSFER CASK and loaded CANISTER shall be returned to the spent fuel pool for in-pool cooling operations.

AND

A.1.2
The TRANSFER CASK and loaded CANISTER shall be maintained in the spent fuel pool for a minimum of 24 hours. When problems, which caused a delay in completing the vacuum drying operation are resolved, if any, LOADING OPERATIONS can be re-commenced.

OR

A.2
If the LCO time limit is exceeded, the CANISTER will be backfilled with helium to a pressure of 0 (+1, -0) psig.

AND

A.2.1
A cooling airflow of 250 cfm at a maximum air temperature of 75°F shall be initiated. The airflow will be routed to the eight fill/drain lines at the base of the TRANSFER CASK and will flow through the annulus and cool the CANISTER.

AND

A.2.2
The cooling airflow shall be maintained for a minimum of 24 hours and when any problems, which caused a delay in completing the vacuum drying operation are resolved, LOADING OPERATIONS can be recommenced.

SURVEILLANCE REQUIREMENTS

SR 3.1.5.1

The elapsed time shall be monitored from completion of CANISTER draining through completion of the CANISTER vacuum dryness verification testing. Monitoring the elapsed time ensures that helium backfill and in-pool or forced air cooling operations can be initiated in a timely manner during LOADING OPERATIONS to prevent exceeding short-term temperature limits.

SR 3.1.5.2

The elapsed time shall be monitored from the end of the in-pool or forced air cooling through completion of the CANISTER vacuum dryness verification testing. Monitoring the elapsed time ensures that helium backfill and in-pool or forced air cooling operations can be initiated in a timely manner during LOADING OPERATIONS to prevent short-term temperature limits from being exceeded.

REFERENCES

1. SAR Sections 4.4 and 8.1.

3.1 NAC-MPC SYSTEM Integrity

3.1.6 CANISTER Maximum Time in the TRANSFER CASK

BASES

BACKGROUND	A TRANSFER CASK with an empty CANISTER is placed into the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield lid is then placed on the CANISTER. The TRANSFER CASK and CANISTER are raised out of the spent fuel pool. The TRANSFER CASK and CANISTER are then moved into the cask decontamination area, where dose rates are measured and the CANISTER shield lid is welded to the CANISTER shell and the lid welds are inspected and pressure tested. The water is drained from the CANISTER, and CANISTER cavity vacuum drying is performed. The CANISTER cavity is backfilled with helium and leak tested. Additional dose rates are measured, and the CANISTER vent port and drain port covers and structural lid are installed and welded. Non-destructive examinations are performed on the welds. Contamination measurements are completed prior to moving TRANSFER CASK and CANISTER in position to transfer the CANISTER to the CONCRETE CASK. After the CANISTER is transferred, average CONCRETE CASK surface dose rate measurements are taken. The CONCRETE CASK is then moved to the ISFSI. Backfilling the CANISTER cavity with helium promotes heat transfer from the fuel and the inert atmosphere protects the fuel cladding. Limiting the total time the loaded CANISTER is in the TRANSFER CASK, prior to its placement in the CONCRETE CASK, ensures that the short-term temperature limits established in the Safety Analysis Report for the spent fuel cladding and CANISTER materials are not exceeded.
APPLICABLE SAFETY ANALYSIS	Limiting the total time a loaded CANISTER backfilled with helium is authorized in the TRANSFER CASK, prior to placement in the CONCRETE CASK, ensures that the short-term temperature limits for the spent fuel cladding and CANISTER materials are not exceeded. Upon placement of the loaded CANISTER in the CONCRETE CASK, the temperatures of the CANISTER and stored spent fuel will return to below the established long-term temperature limits due to the more

efficient passive heat transfer characteristics of the CONCRETE CASK. Ensuring temperatures are maintained below short-term limits for a limited time period and returning them to below long-term limits will prevent damage to the spent fuel cladding and the as-analyzed performance of the CANISTER materials.

Analyses reported in the Safety Analysis Report conclude that spent fuel cladding and CANISTER material short-term temperature limits will not be exceeded for a total elapsed time in excess of 42 hours with the loaded CANISTER backfilled with helium and inside the TRANSFER CASK. After 24 hours of either in-pool cooling or forced airflow cooling operations, the spent fuel cladding and CANISTER temperatures will be at or below their long-term limits. Analyses in the Safety Analysis Report show that material short-term temperature limits will not be exceeded for a total elapsed time in excess of 25 hours with the CANISTER in the TRANSFER CASK. These elapsed times are based on vacuum drying times of 16 and 10 hours, respectively, prior to initiation of helium backfill operations.

The forced air cooling basis is an inlet maximum air temperature of 75°F which is the maximum normal ambient air temperature in the thermal analysis. The convection cooling of the CANISTER due to the forced 250 cubic feet per minute (CFM) air flow rate exceeds the cooling, due to the CONCRETE CASK natural convection cooling flow because the small annulus between the TRANSFER CASK and CANISTER results in a high flow velocity. The high flow velocity results in improved heat transfer from the CANISTER compared to normal storage conditions in the CONCRETE CASK.

LCO

Limiting the length of time that the loaded CANISTER backfilled with helium is allowed to remain in the TRANSFER CASK ensures that the spent fuel cladding and CANISTER material temperatures remain below the short-term temperature limits established in the SAR for the NAC-MPC SYSTEM. The time duration is a function of the design of the TRANSFER CASK and the NAC-MPC SYSTEM.

APPLICABILITY

The elapsed time restrictions on the loaded CANISTER apply during LOADING OPERATIONS from the completion point of the CANISTER vacuum dryness verification through completion of the transfer from the TRANSFER CASK to the CONCRETE CASK.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate condition entry is allowed for each NAC-MPC system. This is acceptable, since the Required Actions for each condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC systems that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

<u>A.1</u>

<u>A.1.1</u>
If either LCO time limit is exceeded, the TRANSFER CASK containing the loaded CANISTER backfilled with helium will be returned to the spent fuel pool to allow the cooler spent fuel pool water to reduce the TRANSFER CASK, CANISTER, and spent fuel cladding temperatures to below long-term temperature limits.

<u>AND</u>

<u>A.1.2</u>
The TRANSFER CASK and loaded CANISTER shall be kept in the spent fuel pool for minimum of 24 hours and when problems, which caused a delay in transferring the loaded CANISTER to the CONCRETE CASK are resolved, if any, the LOADING OPERATIONS can be re-commenced.

<u>OR</u>

<u>A.2</u>

<u>A.2.1</u>
If either LCO time limit is exceeded, the CANISTER will be backfilled with helium and a cooling airflow of 250 CFM at a maximum temperature of 75°F will be initiated. The airflow will be routed to the eight fill/drain lines at the base of the TRANSFER CASK and will flow through the annulus and cool the CANISTER.

<u>AND</u>

A.2.2

The cooling airflow shall be maintained for a minimum of 24 hours and when problems, which caused a delay in completing the CANISTER transfer to the CONCRETE CASK are resolved, if any, LOADING OPERATIONS can be re-commenced.

SURVEILLANCE REQUIREMENTS

SR 3.1.6.1

The elapsed time shall be monitored from completion of CANISTER dryness verification until CANISTER transfer operations into the CONCRETE CASK are completed. The SR ensures that CANISTER material and fuel cladding short-term temperature limits are not exceeded.

SR 3.1.6.2

The elapsed time shall be monitored from the completion of in-pool or forced air cooling until CANISTER transfer operations into the CONCRETE CASK are completed. This SR ensures that CANISTER materials and fuel cladding short-term temperature limits are not exceeded. This SR is applicable to the maximum time the CANISTER backfilled with helium can be loaded in the TRANSFER CASK if in-pool cooling, or forced air cooling, operations were performed during vacuum drying operations under LCO 3.1.5.

REFERENCES

1. SAR Sections 4.4 and 8.1.

3.1 NAC-MPC SYSTEM Integrity

3.1.7 Fuel Cooldown Requirements

BASES

BACKGROUND

In the event that a CANISTER must be unloaded, the CONCRETE CASK with its enclosed CANISTER is returned to the fuel building, the CANISTER is removed from the CONCRETE CASK using the TRANSFER CASK, and the TRANSFER CASK and CANISTER are placed in the cask preparation area to begin the process of fuel unloading. The structural lid and vent and drain port cover welds are removed. The CANISTER cavity gas is sampled to determine the level of radioactive gases in the cavity. A flow of nitrogen gas is established to flush radioactive gases from the cavity. A cooldown system is attached to the drain connection (inlet) and vent connection (outlet). A controlled water flow rate with a specified minimum water temperature is established to the drain connection with the steam and water being discharged from the vent to the spent fuel pool or radioactive water treatment system. Cooling water flow is maintained until the CANISTER is filled and the contents sufficiently cooled down to allow placement of the TRANSFER CASK and CANISTER in the spent fuel pool.

Following cooldown, the shield lid weld is removed and the TRANSFER CASK and CANISTER are placed in the fuel pool. The shield lid is removed and the fuel assemblies are removed and placed in storage rack locations. The TRANSFER CASK and CANISTER are removed from the spent fuel pool and decontaminated.

APPLICABLE SAFETY ANALYSIS

The use of a controlled cooldown process allows the reflooding of the CANISTER and cooling of the stored fuel assemblies in a manner which precludes the creation of excessive thermal stresses in the fuel cladding, which could result in cladding rupture and steam pressures in the cavity that could exceed the CANISTER's design pressure.

By controlling the water flow rate and minimum water temperature, the rate of fuel cooldown is controlled, thereby preventing fuel cladding failure and maintenance of a steam pressure within the CANISTER design pressure, thus ensuring CANISTER structural integrity.

LCO

Controlling the inlet water flow rate and temperature ensures that there is no excessive thermally induced stress in the fuel cladding leading to failure and the steam pressure will be maintained below analyzed design values. The exit water temperature is monitored to ensure that the CANISTER contents are sufficiently cooled down to allow return of the CANISTER to the spent fuel pool for fuel assembly unloading.

APPLICABILITY

The inlet water flow rate and temperature and water/steam outlet temperatures are controlled and measured during UNLOADING OPERATIONS after the CANISTER has been transferred to the TRANSFER CASK from the CONCRETE CASK. Therefore, the CANISTER fuel cooldown LCO does not apply during TRANSPORT OPERATIONS and STORAGE OPERATIONS. A note has been added to the Applicability for LCO 3.1.6, which states that the APPLICABILITY is only applicable to wet UNLOADING OPERATIONS. This is acceptable, since the intent of the LCO is to avoid uncontrolled CANISTER pressurization due to steam creation during CANISTER reflooding. This is not a concern for dry UNLOADING OPERATIONS.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the inlet water flow rate and minimum temperature requirements are not met, actions must be taken to restore the parameters to within the limits. The Completion Time is defined as Immediately to ensure actions are taken to correct the LCO before fuel cladding damage or overpressurization of the CANISTER has occurred. No additional actions are appropriate, since this LCO applies during UNLOADING OPERATIONS, which cannot proceed until the LCO is met.

SURVEILLANCE REQUIREMENTS

SR 3.1.7.1

This SR ensures that the temperatures of the CANISTER, basket and fuel contents do not exceed short-term limits prior to initiation of cooldown operations.

SR 3.1.7.2

The long-term integrity of the fuel assembly is dependent on the material condition of the fuel assembly cladding. Minimizing cladding damage, due to excessive thermally induced stresses in the cooldown process, ensures continuing cladding integrity for future wet or dry fuel storage. By controlling the flow rate and entry water temperature, the creation of steam pressures exceeding design values is prevented.

REFERENCES

1. SAR, Sections 4.4 and 8.3, and Chapter 3.

3.1 NAC-MPC SYSTEM Integrity

3.1.8 CONCRETE CASK Maximum Lifting Height

BASES

BACKGROUND

A loaded CONCRETE CASK is transported between the loading facility and the ISFSI using a heavy haul trailer. The CONCRETE CASK is handled in the vertical orientation. The height to which the CONCRETE CASK is lifted is limited to ensure that its structural integrity, and that of the installed CANISTER, are not compromised should it be dropped.

APPLICABLE SAFETY ANALYSIS

The structural analyses of the CONCRETE CASK and CANISTER demonstrate that the end drop of a CONCRETE CASK from the Technical Specification height limits to a surface having the structural characteristics described in Design Features Section 4.4.6, will not compromise the NAC-MPC SYSTEM integrity or result in physical damage to the contained fuel assemblies. The structural analyses evaluated a CONCRETE CASK tip-over event onto an ISFSI surface also having structural characteristics, as described in Design Features, Section 4.4.6.

LCO

Limiting the CONCRETE CASK lifting height during TRANSPORT OPERATIONS maintains the NAC-MPC SYSTEM within the design and analysis basis. The maximum lifting height is a function of the NAC-MPC SYSTEM design.

Site Specific Parameters and Analysis, Section 4.4, provides the characteristics of the drop surface assumed in the analyses. As required by 10 CFR 72.212(b)(3), each licensee must "...determine whether or not the reactor site parameters...are enveloped by the cask design bases... ."

APPLICABILITY

CONCRETE CASK lifting height restrictions apply during TRANSPORT OPERATIONS, which include movement of the CONCRETE CASK while secured on the heavy haul trailer. CONCRETE CASK and TRANSFER CASK handling and drop events postulated to occur in the fuel loading facilities are addressed in the user's FSAR or PSDAR.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC SYSTEMs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the CONCRETE CASK lifting height requirement is not met, immediate action must be initiated and completed expeditiously to comply with the lifting height requirements, in order to preserve the NAC-MPC SYSTEM design and analysis basis.

SURVEILLANCE REQUIREMENTS

SR 3.1.8.1

The CONCRETE CASK lift height requirement must be verified to be met after the CONCRETE CASK is secured to the transporter and prior to the transporter beginning to move the CONCRETE CASK to the ISFSI. This ensures potential drop accidents during TRANSPORT OPERATIONS are bounded by the drop analyses.

REFERENCES

1. SAR, Sections 8.1 and 8.3.

3.1 NAC-MPC SYSTEM Integrity

3.1.9 TRANSFER CASK Minimum Operating Temperature

BASES

BACKGROUND

The TRANSFER CASK is a shielded handling device designed to lift and protect the CANISTER during fuel LOADING and UNLOADING OPERATIONS. It is used to perform the vertical transfer of the CANISTER to and from the CONCRETE CASK. This transfer operation can occur within the confines of the fuel loading facility or in the open environment adjacent to the facility.

The structural integrity of the TRANSFER CASK and its capability to handle and shield a loaded CANISTER is ensured by maintaining the TRANSFER CASK ferrous material temperatures significantly above the materials' nil ductility transition temperatures (NDTT), thereby precluding brittle fracture.

APPLICABLE SAFETY ANALYSIS

The structural analysis of the TRANSFER CASK is based on the ductile performance of the structural material. The TRANSFER CASK structural materials were selected for their low temperature fracture toughness. In accordance with NRC Reg Guide 7.11 (Ref. 1), the lowest service temperature of a ferrous material component should be established at a minimum of 40°F above the NDTT for the material. For the NAC-MPC transfer cask, the NDTT established in the SAR is -50°F. Therefore the minimum ambient temperature limit of 0°F is established. Conservatively, the decay heat from the contained spent fuel is not assumed to maintain the TRANSFER CASK material temperatures above ambient.

LCO

Limiting the TRANSFER CASK operations outside of covered or heated facilities when the external ambient temperature is below the minimum temperature limit maintains the NAC-MPC SYSTEM within the design and analysis basis of the SAR (Ref. 2). The minimum operating temperature selected is based on the properties of the materials of construction of the TRANSFER CASK.

APPLICABILITY	The minimum operating temperature limit applies for TRANSFER CASK operations external to the fuel facility during LOADING or UNLOADING OPERATIONS
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC SYSTEMs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions. <u>A.1</u> For external TRANSFER CASK operations, if the external ambient temperature is at, or below, the minimum operating temperature limit, immediate action must be initiated to stop the LOADING or UNLOADING OPERATIONS sequence to ensure that the TRANSFER CASK is not operated outside of the fuel facility.
SURVEILLANCE REQUIREMENTS	SR 3.1.9.1 The external ambient temperature shall be measured, prior to and during the LOADING or UNLOADING OPERATIONS, to ensure that the ambient temperature does not fall below the established TRANSFER CASK minimum operating temperature for operations external to the fuel building.
REFERENCES	1. NRC RG 7.11. 2. SAR, Sections 2.2, 3.4, 4.1, 8.1 and 8.3.

3.1 NAC-MPC SYSTEM Integrity

3.1.10 CANISTER Removal from the CONCRETE CASK

BASES

BACKGROUND

A loaded CANISTER is removed from a CONCRETE CASK using the TRANSFER CASK, so that the CANISTER may be transferred to another CONCRETE CASK or transferred to a TRANSPORT CASK for purposes of transport. The CANISTER is removed from the CONCRETE CASK using the procedure provided in Section 8.2. Once in the TRANSFER CASK, the CANISTER begins to heat up due to the decay heat of the contents and the reduced heat transfer provided by the TRANSFER CASK compared to the CONCRETE CASK.

The CANISTER time in the TRANSFER CASK is limited when forced air cooling is not used to ensure that the short-term temperature limits established in the Safety Analysis Report for the spent fuel cladding and CANISTER materials are not exceeded.

If forced air cooling is maintained, then the CANISTER time in the TRANSFER CASK is not limited, since the short-term temperature limits of the spent fuel cladding and of the CANISTER components are not exceeded.

APPLICABLE SAFETY ANALYSIS

Limiting the total time that a loaded CANISTER backfilled with helium may be in the TRANSFER CASK, prior to unloading the CANISTER from the TRANSFER CASK, ensures that the short-term temperature limits for the spent fuel cladding and CANISTER materials are not exceeded. Upon placement of the loaded CANISTER in the CONCRETE CASK or TRANSPORT CASK, the temperatures of the

APPLICABLE SAFETY ANALYSIS (continued)

CANISTER and stored spent fuel will return to normal storage or transport condition values due to the more efficient passive heat transfer characteristics of the CONCRETE CASK or TRANSPORT CASK.

This ensures that temperatures are maintained below short-term limits for a limited time period. Returning these temperatures to values below long-term limits will prevent damage to the spent fuel cladding and the CANISTER materials.

From calculated temperatures reported in the Safety Analysis Report, it can be concluded that spent fuel cladding and CANISTER material short-term temperature limits will not be exceeded for a total elapsed time of greater than 22 hours, if the loaded CANISTER backfilled with helium is in the TRANSFER CASK. After 16 hours, forced airflow cooling is used to ensure cooling of the CANISTER. The analysis provided in the Safety Analysis Report shows that the spent fuel cladding and CANISTER temperatures will be at or below their long-term limits, as long as the cooling airflow is maintained. This forced airflow provides a similar rate of cooling to that provided by the passive airflow cooling provided by the CONCRETE CASK. Consequently, there is no time limit associated with the continued forced air cooling of the CANISTER while it is in the TRANSFER CASK. The basis for forced air cooling is an inlet maximum air temperature of 75°F, which is the maximum normal ambient air temperature in the thermal analysis. The specified 250 CFM air flow rate exceeds the CONCRETE CASK natural

APPLICABLE SAFETY ANALYSIS (continued)	convective cooling flow rate by a minimum of 10 percent. This comparative analysis conservatively excludes the higher flow velocity resulting from the smaller annulus between the TRANSFER CASK and CANISTER, which would result in improved heat transfer from the CANISTER. If forced air flow is continuously maintained for a period of 24 hours, or longer, then the temperatures of the spent fuel cladding and CANISTER components are at the values calculated for the CONCRETE CASK normal conditions. Consequently, forced air cooling may be ended, allowing a new entry into Condition A. This provides a new minimum 16-hour period in which continuation of the TRANSFER OPERATIONS may occur.
LCO	Limiting the length of time that the loaded CANISTER backfilled with helium is allowed to remain in the TRANSFER CASK without forced air cooling ensures that the spent fuel cladding and CANISTER material temperatures remain below the short-term temperature limits established in the SAR for the NAC-MPC SYSTEM. Once forced air cooling is established, the amount of time the CANISTER resides in the TRANSFER CASK is not limited since the cooling provided by the forced air is equivalent to the passive cooling that is provided by the CONCRETE CASK or TRANSPORT CASK. If forced air flow is continuously maintained for a period of 24 hours, or longer, then the temperatures of the spent fuel cladding and CANISTER components are at, or below, the values calculated for the CONCRETE CASK normal conditions. Therefore, forced air cooling

LCO (continued)

may be ended, allowing a new entry into Condition A of this LCO. This provides a new minimum 16-hour period in which continuation of TRANSFER OPERATIONS may occur.

APPLICABILITY

The elapsed time restrictions on the loaded CANISTER apply during TRANSFER OPERATIONS from the completion point of the closing of the TRANSFER CASK shield doors through completion of the unloading of the CANISTER from the TRANSFER CASK.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each NAC-MPC SYSTEM. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each NAC-MPC SYSTEM not meeting the LCO. Subsequent NAC-MPC SYSTEMS that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

Separate Condition A re-entry is also permitted after 24-hours of continuous forced air cooling in accordance with this LCO.

A.1.1

If the CANISTER can be loaded into an operable CONCRETE CASK without the LCO time limit being exceeded, then no further action is required since the spent fuel cladding and CANISTER component short-term temperature limits are not exceeded.

ACTIONS (continued)

OR

A.2.1

If the CANISTER can be loaded into a TRANSPORT CASK without the LCO time limit being exceeded, then no further action is required since the spent fuel cladding and CANISTER component short-term temperature limits are not exceeded.

OR

A.3.1

If forced air flow is continuously maintained for a period of 24 hours, or longer, then the temperatures of the spent fuel cladding and CANISTER components are at, or below, the values calculated for the CONCRETE CASK normal conditions. Consequently, forced air cooling may be ended, allowing a new entry into Condition A of this LCO. This provides a new minimum 16-hour period in which continuation or completion of TRANSFER OPERATIONS may occur.

B.1.1

Commence supplying air to the TRANSFER CASK annulus using the fill/drain lines at a rate of 250 CFM and a maximum temperature of 75°F. This action provides the equivalent cooling that would be provided by the passive heat removal systems of the CONCRETE CASK or TRANSPORT CASK in normal operations. Consequently, no short-term spent fuel cladding or CANISTER component temperature limits are exceeded.

AND

B.2.1

Maintain the airflow established by B.1.1 for the time period that the CANISTER remains in the TRANSFER CASK. This action provides the equivalent cooling that would be provided by the passive heat removal systems of the CONCRETE CASK or TRANSPORT CASK in normal operations. Consequently, no short-term spent fuel cladding or CANISTER component temperature limits are exceeded.

SURVEILLANCE REQUIREMENTS	SR 3.1.10.1 This SR ensures that the time that the CANISTER is in the TRANSFER CASK does not exceed the 16-hour limit without the use of forced air cooling of the CANISTER. This ensures that the short-term temperature limits of the spent fuel cladding and CANISTER components is not exceeded. SR 3.1.10.2 This SR ensures that short-term temperature limits of the spent fuel cladding and CANISTER components are not exceeded by initiating and maintaining forced air cooling of the CANISTER in the TRANSFER CASK, if the time limits established by Condition A are not met. Forced air cooling is maintained until unloading of the CANISTER from the TRANSFER CASK.

REFERENCES	1. SAR Sections 4.4 and 8.2.

3.2 NAC-MPC SYSTEM Radiation Protection

3.2.1 CONCRETE CASK Average Surface Dose Rates

BASES

BACKGROUND	The regulations governing the operation of an ISFSI set limits on the control of occupational radiation exposure and radiation doses to the general public (Ref. 1). Occupational radiation exposure should be kept as low as reasonably achievable (ALARA) and within the limits of 10 CFR Part 20. Radiation doses to the public are limited for both normal and accident conditions in accordance with 10 CFR 72.
APPLICABLE SAFETY ANALYSIS	The CONCRETE CASK average surface dose rates are not an assumption in any accident analysis, but are used to ensure compliance with regulatory limits on occupational dose and dose to the public.
LCO	The limits on CONCRETE CASK average surface dose rates are based on the shielding analysis of the NAC-MPC SYSTEM (Ref. 2). The limits are selected to minimize radiation exposure to the public and maintain occupational dose ALARA to personnel working in the vicinity of the NAC-MPC SYSTEMs. The LCO specifies sufficient locations for taking dose rate measurements to ensure the dose rates measured are indicative of the effectiveness of the shielding material.
APPLICABILITY	The CONCRETE CASK average surface dose rates apply during LOADING OPERATIONS. These limits ensure that the CONCRETE CASK average surface dose rates during TRANSPORT OPERATIONS, STORAGE OPERATIONS, and UNLOADING OPERATIONS are bounded by the shielding safety analyses. Radiation doses during STORAGE OPERATIONS are monitored by the NAC-MPC SYSTEM user in accordance with the plant-specific radiation protection program required by 10 CFR 72.212(b)(6).
ACTIONS	A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each loaded CONCRETE CASK. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each

CONCRETE CASK not meeting the LCO. Subsequent NAC-MPC SYSTEMs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the CONCRETE CASK average surface dose rates are not within limits, it could be an indication that a fuel assembly was inadvertently loaded into the CANISTER that did not meet the Functional and Operating Limits in Section 2.1. Administrative verification of the CANISTER fuel loading, by means such as review of video recordings and records of the loaded fuel assembly serial numbers, can establish whether a misloaded fuel assembly is the cause of the out-of-limit condition. The Completion time is based on the time required to perform such a verification.

A.2

If the CONCRETE CASK average surface dose rates are not within limits and it is determined that the CONCRETE CASK was loaded with the correct fuel assemblies, an analysis may be performed. This analysis will determine if the CONCRETE CASK, once located at the ISFSI, would result in the ISFSI offsite or occupational calculated doses exceeding regulatory limits in 10 CFR Part 20 or 10 CFR Part 72. If it is determined that the out of limit average surface dose rates do not result in an the regulatory limits being exceeded, TRANSPORT OPERATIONS may proceed.

B.1

If it is verified that the fuel was misloaded and the ISFSI offsite radiation protection requirements of 10 CFR Part 20 or 10 CFR Part 72 will not be met with the CONCRETE CASK average surface dose rates above the LCO limit, the fuel assemblies must be placed in a safe condition in the spent fuel pool. The Completion Time is reasonable based on the time required to transfer the CANISTER to the TRANSFER CASK, remove the structural lid and vent and drain port cover welds, perform fuel cooldown operations, cut the shield lid weld, move the TRANSFER CASK and CANISTER into the spent fuel pool, remove the shield lid, and remove the spent fuel assemblies in an orderly manner and without challenging personnel.

SURVEILLANCE REQUIREMENTS

SR 3.2.1.1

This SR ensures that the CONCRETE CASK average surface dose rates are within the LCO limits prior to transporting the NAC-MPC SYSTEM to the ISFSI. The surface dose rates are measured approximately at the locations indicated on Figure 12A3-1, following standard industry practices for determining average surface dose rates for large containers.

REFERENCES

1. 10 CFR Parts 20 and 72.

2. SAR Sections 5.1 and 8.1.

3.2 NAC-MPC SYSTEM Radiation Protection

3.2.2 CANISTER Surface Contamination

BASES

BACKGROUND	A TRANSFER CASK containing an empty CANISTER is immersed in the spent fuel pool in order to load the spent fuel assemblies. The external surfaces of the CANISTER are maintained clean by the application of clean water to the annulus of the TRANSFER CASK. However, there is potential for the surface of the CANISTER to become contaminated with the radioactive material in the spent fuel pool water. This contamination is removed prior to moving the CONCRETE CASK containing the CANISTER to the ISFSI in order to minimize the radioactive contamination to personnel or the environment. This allows the ISFSI to be entered without additional radiological controls to prevent the spread of contamination and reduces personnel dose, due to the spread of loose contamination or airborne contamination. This is consistent with ALARA practices.
APPLICABLE SAFETY ANALYSIS	The radiation protection measures implemented at the ISFSI are based on the assumption that the exterior surfaces of the CANISTER have been decontaminated. Failure to decontaminate the surfaces of the CANISTER could lead to higher-than-projected occupational dose and potential site contamination.
LCO	Removable surface contamination on the CANISTER exterior surfaces is limited to 1000 dpm/100 cm^2 from beta and gamma sources and 20 dpm/100 cm^2 from alpha sources. These limits are taken from the guidance in IE Circular 81-07 (Ref. 2) and are based on the minimum level of activity that can be routinely detected under a surface contamination control program using direct survey methods. Only loose contamination is controlled, as fixed contamination will not result from the CANISTER loading process. Experience has shown that these limits are low enough to prevent the spread of contamination to clean areas and are significantly less than the levels, which would cause significant personnel skin dose.

LCO 3.2.2 requires removable contamination to be within the specified limits for the accessible exterior surfaces of the CANISTER. The location and number of CANISTER surface swipes used to verify compliance with this LCO are determined based on standard industry practice and the user's plant-specific contamination measurement program for objects of this size. Accessible portions of the CANISTER are the upper portion of the CANISTER external shell wall accessible after draining of the TRANSFER CASK annulus and the structural lid. The user shall determine a reasonable number and location of swipes for the accessible portion of the CANISTER. The objective is to determine a removable contamination value representative of the entire upper circumference of the CANISTER and the structural lid, while implementing sound ALARA practices.

Verification swipes and measurements of removable surface contamination levels on the inside surfaces of the TRANSFER CASK shall be performed following transfer of the CANISTER to the CONCRETE CASK. These measurements will provide indirect evidence that the inaccessible surfaces of the CANISTER do not have removable contamination levels exceeding the limit.

APPLICABILITY

Verification that the CANISTER accessible surface contamination is less than the LCO limit is performed during LOADING OPERATIONS. This occurs before TRANSPORT OPERATIONS and STORAGE OPERATIONS. Measurement of the CANISTER surface contamination is unnecessary during UNLOADING OPERATIONS as surface contamination would have been measured prior to moving the subject CANISTER to the ISFSI.

ACTIONS

A note has been added to the ACTIONS, which states that, for this LCO, separate Condition entry is allowed for each CANISTER. This is acceptable, since the Required Actions for each Condition provide appropriate compensatory measures for each CANISTER not meeting the LCO. Subsequent CANISTERs that do not meet the LCO are governed by subsequent Condition entry and application of associated Required Actions.

A.1

If the removable surface contamination of the CANISTER that has been loaded with spent fuel is not within the LCO limits, action must be initiated to decontaminate the CANISTER and bring the removable surface contamination within limits. The Completion Time of "Prior to TRANSPORT OPERATIONS" is appropriate, given that the time needed to complete the decontamination is indeterminate and surface contamination does not affect the safe storage of the spent fuel assemblies. The heat-up of the CANISTER and stored spent fuel, and the allowable time in the TRANSFER CASK shall be controlled by LCO 3.1.6.

SURVEILLANCE REQUIREMENTS

SR 3.2.2.1

This SR verifies that the removable surface contamination on the accessible surface of the CANISTER is less than the limits in the LCO. The Surveillance is performed using smear surveys to detect removable surface contamination. The Frequency requires performing the verification prior to initiating TRANSPORT OPERATIONS in order to confirm that the CANISTER can be moved to the ISFSI without spreading loose contamination.

SR 3.2.2.2

This SR verifies that the removable surface contamination on the interior surfaces of the TRANSFER CASK is less than the limits, thereby providing indirect confirmation that the removable surface contamination on the inaccessible surfaces of the CANISTER are within the limits. It also confirms that the proper functioning of the annulus clean water fill system. The Surveillance is performed using smear surveys to detect removable surface contamination. The Frequency requires performing the verification prior to TRANSPORT OPERATIONS.

REFERENCES

1. SAR Section 8.1.
2. NRC IE Circular 81-07.

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13.0 QUALITY ASSURANCE

13.1 Introduction

The NAC International (NAC) Quality Assurance (QA) Program is designed and administered to meet all QA criteria of 10 CFR 72, Subpart G, 10 CFR 50, Appendix B, 10 CFR 71, Subpart H, and NQA-1 (Basic and Supplemental Requirements). The program is defined in a QA Program description document that has been reviewed and approved by the Nuclear Regulatory Commission (Approval No. 0018).

The NAC QA Program is described in a QA Manual. This QA Manual, as approved by the President & Chief Executive, contains policy as to how NAC intends to comply with the applicable regulatory QA criteria. Detailed implementing quality procedures are used to provide the procedural direction to comply with the policy of the QA Manual.

Employing a graded methodology, as described in USNRC Regulatory Guide 7.10, NAC applies quality controls to items and activities consistent with their safety significance. Table 13.1-1 identifies the relationships among the applicable quality criteria and the NAC QA Manual.

A synopsis of the NAC QA Program has been developed and is presented in Section 13.2 of this Safety Analysis Report.

Table 13.1-1 Relationship of the 18 Criteria to the NAC QA Program

Criteria of: **10 CFR 50 Appendix B** **10 CFR 71 Subpart H** **10 CFR 72 Subpart G**	**Corresponding NAC International QA Manual Section**
I. Organization	Quality Assurance Manual Section 1
II. Quality Assurance Program	Quality Assurance Manual Section 2
III. Design Control	Quality Assurance Manual Section 3
IV. Procurement Document Control	Quality Assurance Manual Section 4
V. Procedures, Instructions, and Drawings	Quality Assurance Manual Section 5
VI. Document Control	Quality Assurance Manual Section 6
VII. Control of Purchased Items and Services	Quality Assurance Manual Section 7
VIII. Identification and Control of Material, Parts and Components	Quality Assurance Manual Section 8
IX. Control of Special Processes	Quality Assurance Manual Section 9
X. Inspection	Quality Assurance Manual Section 10
XI. Test Control	Quality Assurance Manual Section 11
XII. Control of Measuring and Test Equipment	Quality Assurance Manual Section 12
XIII. Handling, Storage and Shipping	Quality Assurance Manual Section 13
XIV. Inspection and Test Status	Quality Assurance Manual Section 14
XV. Control of Nonconforming Items	Quality Assurance Manual Section 15
XVI. Corrective Action	Quality Assurance Manual Section 16
XVII. Records	Quality Assurance Manual Section 17
XVIII. Audits	Quality Assurance Manual Section 18

13.2 NAC Quality Assurance Program Synopsis

13.2.1 Organization

The President & Chief Executive of NAC has the ultimate authority and responsibility over all organizations and their functions within the corporation. However, the President delegates and empowers qualified personnel with the authority and responsibility over selected key areas, as identified in the NAC Organization Chart, Figure 13.2-1.

The Vice President, Quality is responsible for definition, development, implementation and administration of the NAC QA Program. The QA organization is independent from other organizations within NAC and has complete authority to assure adequate and effective program execution, including problem identification, satisfactory corrective action implementation and the authority to stop work, if necessary. The Vice President, Quality reports directly to the President & Chief Executive of NAC. The Vice President, Quality has sufficient expertise in the field of quality to direct the quality function and will be capable of qualifying as a lead auditor.

Strategic Business Unit (SBU) Vice Presidents direct operations under NAC operations, utilizing project teams as appropriate for a particular work scope. SBU Vice Presidents are responsible to the President & Chief Executive for the proper implementation of the NAC QA Program.

13.2.2 Quality Assurance Program

NAC has established a QA Program that meets the requirements of 10 CFR 72, Subpart G, 10 CFR 50 Appendix B, 10 CFR 71, Subpart H, and NQA-1. Employing a grading methodology consistent with U.S. NRC Regulatory Guide 7.10, the QA program provides control over activities affecting quality from the design to fabrication, operation, and maintenance of nuclear products and services for nuclear applications. The QA Program is documented in the QA Manual and implemented via Quality Procedures. These documents are approved by the Vice President, Quality, and the President & Chief Executive, as well as the Vice President from each SBU performing activities within the scope of the NAC QA plan.

Personnel assigned responsibilities by the QA Program may delegate performance of activities associated with that responsibility to other personnel in their group when those individuals are

qualified to perform those activities by virtue of their education, experience and training. Such delegations need not be in writing. The person assigned responsibility by the QA Program retains full accountability for the activities.

13.2.3 Design Control

The established Quality Procedures covering design control assure that the design activity is planned, controlled, verified and documented so that applicable regulatory and design basis requirements are correctly translated into specifications, drawings, and procedures with appropriate acceptance criteria for inspection and test delineated.

When computer software is utilized to perform engineering calculations, verifications of the computational accuracy are performed, and error tracking of the software is controlled in accordance with approved Quality Procedures.

Design interface control is established and adequate to assure that the review, approval, release, distribution and revision of design documents involving interfaces are performed by appropriately trained, cognizant design personnel using approved procedures.

Design verification is performed by individuals other than those who performed the original design. These verifications may include design reviews, alternate calculations or qualification tests. Selection of the design verification method is based on regulatory, contractual or design complexity requirements. When qualification testing is selected, the "worst case" scenario will be utilized. The verification may be performed by the originator's supervisor, provided the supervisor did not specify a singular design approach or rule out certain design considerations and did not establish the design inputs used in the design, or provided the supervisor is the only individual in the organization competent to perform the verification. When verification is provided by the supervisor, the need shall be so documented in advance and evaluated after performance by internal audit.

Design changes are controlled and require the same review and approvals as the original design.

13.2.4 Procurement Document Control

Procurement documents and their authorized changes are generated, reviewed and approved in accordance with the Quality Procedures. These procedures assure that all purchased material, components, equipment and services adhere to design specification, regulatory and contractual requirements including QA Program and documentation requirements.

NAC QA personnel review and approve all purchase orders invoking compliance with the QA Program for inclusion of quality related requirements in the procurement documents.

13.2.5 Procedures, Instructions, and Drawings

All activities affecting quality are delineated in the Quality Procedures, Specifications, Inspection/Verification Plans or on appropriate drawings. These documents are developed via approved Quality Procedures and include appropriate quantitative and qualitative acceptance criteria. These documents are reviewed and approved by QA personnel prior to use.

13.2.6 Document Control

All documents affecting quality, including revisions thereto, are reviewed and approved by authorized personnel and are issued and controlled in accordance with Quality Procedures by those persons or groups assigned responsibility for the document to be controlled. Transmittal forms, with provisions for receipt acknowledgment, are utilized and controlled document distribution logs are maintained.

All required support documentation for prescribed activities is available at the work location prior to initiation of the work effort.

13.2.7 Control of Purchased Items and Services

Items and services affecting quality are procured from qualified and approved suppliers. These suppliers have been evaluated and selected in accordance with the Quality Procedures based upon their capability to comply with applicable regulatory and contractual requirements.

Objective evidence attesting to the quality of items and services furnished by NAC suppliers is provided with the delivered item or service and is based on contract requirements and item or service complexity. This vendor documentation requirement is delineated in the procurement documents.

Source inspection, receipt inspection, vendor audits and vendor surveillance are performed as required to assure product quality, documentation integrity, and supplier compliance to the procurement, regulatory and contractual requirements.

13.2.8 Identification and Control of Material, Parts, and Components

Identification is maintained either on the item or in quality records traceable to the item throughout fabrication and construction to prevent the use of incorrect or defective items.

Identification, in accordance with drawings and inspection plans, is verified by QA personnel prior to releasing the item for further processing or delivery.

13.2.9 Control of Special Processes

Special processes, such as welding, heat treating and nondestructive testing, are performed in accordance with applicable codes, standards, specifications and contract requirements by qualified personnel. NAC and NAC suppliers' special process procedures and personnel certifications are reviewed and approved by NAC QA prior to their use.

13.2.10 Inspection

NAC has an established and documented inspection program that identifies activities affecting quality and verifies their conformance with documented instructions, plans, procedures and drawings.

Inspections are performed by individuals other than those who performed the activity being inspected. Inspection personnel report directly to the Vice President, Quality.

Process monitoring may also be used in conjunction with identified inspections, if beneficial to achieve required quality.

Mandatory inspection hold points are used to assure verification of critical characteristics. Such hold points are delineated in appropriate process control documents.

13.2.11 Test Control

NAC testing requirements are developed and applied in order to demonstrate satisfactory performance of the tested items to design/contract requirements.

The NAC test program is established to assure that preoperational or operational tests are performed in accordance with written test procedures. Test procedures developed in accordance with approved Quality Procedures identify test prerequisites, test equipment and instrumentation and suitable environmental test conditions. Test procedures are reviewed and approved by NAC QA personnel.

Test results are documented, evaluated and accepted by qualified personnel as required by the QA inspection instructions prepared for the test, as approved by cognizant quality personnel.

13.2.12 Control of Measuring and Testing Equipment

Control of measuring and testing equipment/instrumentation is established to assure that devices used in activities affecting quality are calibrated and properly adjusted at specified time intervals to maintain their accuracy.

Calibrated equipment is identified and traceable to calibration records, which are maintained. Calibration accuracy is traceable to national standards when such standards exist. The basis of calibration shall always be documented.

Whenever measuring and testing equipment is found to be out of calibration, an evaluation shall be made and documented of the validity of inspection or test results performed and of the acceptability of items inspected or tested since the previous calibration.

13.2.13 Handling, Storage and Shipping

Requirements for handling, storage and shipping are documented in specifications and applicable procedures or instructions. These requirements are designed to prevent damage or deterioration to items and materials.

Information pertaining to shelf life, environment, packaging, temperature, cleaning and preservation are also delineated as required.

QA Surveillance/Inspection personnel are responsible for verifying that approved handling, storage, and shipping requirements are met.

13.2.14 Inspection, Test and Operating Status

Procedures are established to indicate the means of identifying inspection and test status on the item and/or on records traceable to the item. These procedures assure identification of items that have satisfactorily passed required inspections and/or tests, to preclude inadvertent bypassing of inspection/test.

Inspection, test, and operating status indicators may only be applied or modified by QA personnel or with formal QA concurrence.

13.2.15 Control of Nonconforming Items

NAC has established and implemented procedures that assure appropriate identification, segregation, documentation, notification and disposition of items that do not conform to specified requirements. These measures prevent inadvertent usage of the item and assure appropriate authorization or approval of the item's disposition.

All nonconformances are reviewed and accepted, rejected, repaired or reworked in accordance with documented approved procedures. If necessary, a Review Board is convened, consisting of members of engineering, licensing, quality, operations and testing to provide disposition of nonconforming conditions.

NAC procurement documents provide for control, review and approval of nonconformances noted on NAC items, including associated dispositions.

13.2.16 Corrective Action

Conditions adverse to quality, such as failures, malfunction, deficiencies, defective material/ equipment, and nonconformances are promptly identified, documented and corrected.

Significant conditions adverse to quality will have their cause determined and sufficient corrective action taken to preclude recurrence. These conditions are documented and reported to the Vice President, Quality who assures awareness by the President & Chief Executive on an annual basis.

13.2.17 Records

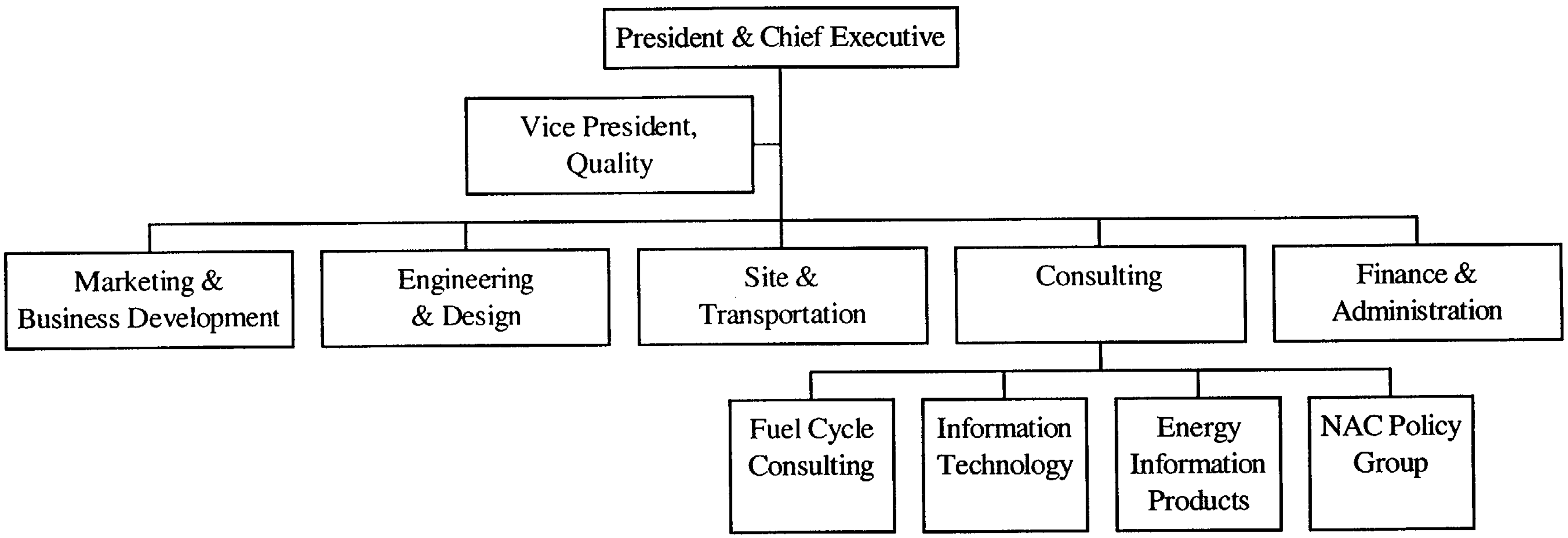
NAC maintains a records system in accordance with approved procedures to assure that documented objective evidence pertaining to quality related activities is identifiable, retrievable and retained to meet regulatory and contract requirements, including retention duration, location and responsibility.

Quality records include, but are not limited to, inspection and test reports, audit reports, quality personnel qualifications, design documents, purchase orders, supplier evaluations, fabrication documents, nonconformance reports, drawings, specifications, etc. QA maintains a complete list of records and provides for record storage and disposition to meet regulatory and contractual requirements.

13.2.18 Audits

Approved Quality Procedures provide for a comprehensive system of planned and periodic audits performed by qualified personnel, independent of activities being audited. These audits are performed in accordance with written procedures and are intended to verify program adequacy and its effective implementation and compliance, both internally and at approved-supplier locations. Internal audits are conducted annually and approved suppliers are audited on a triennial basis, as a minimum.

Figure 13.2-1 NAC International Organization Chart



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