K.9 Acceptance Tests and Maintenance Program

K.9.1 Acceptance Tests

The pre-operational testing requirements for the NUHOMS® system are given in Section 9.0 with the exceptions described in the following sections. The NUHOMS®-61BT DSC has been enhanced to provide leaktight confinement and the basket includes an updated poison plate design. Additional acceptance testing of the NUHOMS®-61BT DSC welds and of the poison plates are described.

K.9.1.1 Visual Inspection

No change.

K.9.1.2 Structural

The NUHOMS®-61BT DSC confinement welds are designed, fabricated, tested and inspected in accordance with ASME B&PV Code Subsection NB [9.1] with exceptions as listed in Section K.3.1. The following requirements are unique to the NUHOMS®-61BT DSC:

- The inner bottom cover weld is inspected in accordance with Article NB-5231.
- The outer bottom cover weld root and cover are penetrant tested.
- The canister shell longitudinal and circumferential welds are 100% radiographically inspected.
- The outer top cover plate weld root, middle and cover are penetrant tested.

The NUHOMS®-61BT DSC basket is designed, fabricated, and inspected in accordance with ASME B&PV Code Subsection NG [9.1] with exceptions as listed in Section K.3.1. The following requirements are unique to the NUHOMS®-61BT DSC:

- The fuel compartment wrapper welds are inspected in accordance with Article NG-5231.
- The fuel compartment welds are inspected in accordance with Article NG-5231.

K.9.1.3 Leak Tests

The NUHOMS®-61BT DSC confinement is leak tested to verify it is leaktight in accordance with ANSI N14.5 [9.2].

The leak tests are typically performed using the helium mass spectrometer method. Alternative methods are acceptable, provided that the required sensitivity is achieved.

K.9.1.4 Components

No change.

K.9.1.5 Shielding Integrity

No change.

K.9.1.6 Thermal Acceptance

The analyses to ensure that the NUHOMS®-61BT DSCs are capable of performing their heat transfer function are presented in Section K.4.

K.9.1.7 Poison Acceptance

Functional Requirements of Poison Plates

The poison plates only serve as a neutron absorber for criticality control and as a heat conduction path; the NUHOMS®-61BT DSC safety analyses do not rely upon their mechanical strength. The basket structural components surround the plates on all sides. The radiation and temperature environment in the cask is not sufficiently severe to damage the aluminum matrix that retains the boron-containing particles. To assure performance of the plates' Important-to-Safety function, the only critical variables that need to be verified are thermal conductivity and B10 areal density as discussed in the following paragraphs.

Thermal Conductivity Testing

The poison plate material will be qualification tested to verify that the thermal conductivity equals or exceeds the values listed in Section K.4.3. Acceptance testing of the material in production may be done at only one temperature in that range to verify that the conductivity equals or exceeds the corresponding value in Section K.4.3.

Testing may be by ASTM E1225 [9.3], ASTM E1461 [9.4] , or equivalent method, performed on a sample of specimens removed from coupons adjacent to the final plates (see Section K.9.1.7 for more detail on coupons).

B10 Areal Density Testing

There are three types of NUHOMS®-61BT DSC baskets (Type A, B, and C), each identical with the exception of the minimum B10 content in the poison plates, as described in Table K.6-1. Only one type of poison plate is used in a specific NUHOMS®-61BT DSC, based on the maximum enrichment of the fuel that will be placed in the NUHOMS®-61BT DSC. There are three acceptable poison materials, Boral®, Borated Aluminum and Boron Carbide/Aluminum Metal Matrix Composite (MMC). There are two variations on the MMC, one with billets produced by vacuum hot pressing (Boralyn®), and the second produced by cold isostatic pressing

followed by vacuum sintering (Metamic®). All materials shall be subject to thermal conductivity, dimensional, and visual acceptance testing. The B10 areal density and uniformity of the poison plates shall be verified, based on type, using approved procedures, as follows.

A. Borated Aluminum Using Enriched Boron, 90% B10 Credit

Material Description

The poison consists of borated aluminum containing a specified weight percent (wt. %) boron, depending on the NUHOMS®-61BT DSC Type, which is isotopically enriched to 95 wt. % B10. Because of the negligibly low solubility of boron in solid aluminum, the boron appears entirely as discrete second phase particles of AlB_2 in the aluminum matrix. The matrix is limited to any 1000 series aluminum, aluminum alloy 6063, or aluminum alloy 6351 so that no boron-containing phases other than AlB_2 are formed. Titanium may also be added to form TiB_2 particles, which are finer. The effect on the properties of the matrix aluminum alloy are those typically associated with a uniform fine (1-10 micron) dispersion of an inert equiaxed second phase.

The cast ingot may be rolled, extruded, or both to the final plate dimensions.

The specified wt. % boron for full thickness (0.305 inch) plates, by NUHOMS®-61BT DSC Type is given in Table K.9-1. For example, the 2.1 wt. % converts to a nominal areal density of B10 as follows: (2.69 g BAl/cm^3)(2.1 wt. % B)(95 wt. % B10)(0.305 inch)(2.54 cm/inch) = 0.0416 g B10/cm^2, which is intentionally 4% above the design minimum of 0.040 g B10/cm^2. If thinner poison sheets are paired with aluminum sheets (see drawing NUH-61B-1065), the boron content shall be proportionately higher, up to that needed to maintain the minimum required B10 areal density.

Test Coupons

The poison plates are manufactured in a variety of sizes. Coupons will be removed between every other plate or at the end of the plate so that there is at least one coupon contiguous with each plate. Coupons will generally be the full width of the plate. Thermal conductivity coupons may be removed from the full width coupon. The minimum dimension of the coupon shall be as required for acceptance test specimens; 1 to 2 inches is generally adequate. Neutron absorption samples are taken from roughly one centimeter diameter samples through the thickness of the plate.

Acceptance Testing, Neutronic

Effective B10 content is verified by neutron transmission testing of these coupons. The transmission through the coupons is compared with transmission through calibrated standards composed of a homogeneous boron compound without other significant poisons, for example zirconium diboride or titanium diboride. These standards are paired with aluminum shims sized to match the scattering by aluminum in the poison plates. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing

shows them to be equivalent to a homogeneous standard. The effective B10 content of each coupon, minus 3s based on the number of neutrons counted for that coupon, must be greater than or equal to the minimum value given in Table K.9-1.

Macroscopic uniformity of B10 distribution is verified by neutron radioscopy or radiography of the coupons. The acceptance criterion is that there be uniform luminance across the coupon. This inspection shall cover the entire coupon. In addition, a statistical analysis of the neutron transmission results for all accepted plates in a lot shall be used to demonstrate that applying the one-sided tolerance factors for a 95% probability / 95% confidence level results in a minimum areal density greater than specified minimum value given in Table K.9-1. A lot may be defined as all the plates rolled from a single cast ingot. The analysis shall be based on full data set for the lot. For any lot which fails the test, the plate shall not be used for that level of required B10 content but may be used for alternative level of B10 for which the lot passes this test.

Initial sampling of coupons for neutron transmission measurements and radiography/radioscopy shall be 100%. Rejection of a given coupon shall result in rejection of its associated plate. Reduced sampling (50%) may be introduced based upon acceptance of all coupons in the first 25% of the lot. A rejection during reduced inspection will require a return to 100% inspection of the lot.

In the event that a coupon fails the single neutron measurement, four additional measurements shall be made at separate locations on the plate itself. For each of the additional measurements, the value of areal density less than 3s based on the number of neutrons counted must be greater than or equal to the specified minimum value given in Table K.9-1 in order to accept the plate.

If any of those four fails, the plate associated with the measurements shall be rejected. However, the average of the five measurements made is to be used as a datum in subsequent analysis conduced on the lot. The use of the datum allows for the possibility that the rejected plate is really identical to the plate that was not rejected.

Neutron absorption samples are taken from roughly one centimeter sample through the thickness of the plate. Any data from materials which are rejected based on physical examination of the materials are not to be used in the statistical analysis. For example, rejection based on thickness or malformation detected by examination of the plate are grounds for excluding the data associated with these materials.

Justification for Acceptance Test Requirements, Borated Aluminum

According to NUREG/CR-5661 [9.5],

> "Limiting added poison material credit to 75% without comprehensive tests is based on concerns for potential 'streaming' of neutrons due to nonuniformities. It has been shown that boron carbide granules embedded in aluminum permit channeling of a beam of neutrons between the grains and reduce the effectiveness for neutron absorption."

Furthermore,

> "A percentage of poison material greater than 75% may be considered in the analysis only if comprehensive tests, capable of verifying the presence and uniformity of the poison, are implemented." [emphasis added]

The calculations in Section K.6 use boron areal densities that are 90% of the minimum values given in Table K.9-1. This is justified by the following considerations.

a) The coupons for neutronic inspection are removed between every other finished plate. As such, they are taken from locations that are representative of the finished product. Coupons are also removed at the ends of the "stock plate", where under thickness of the plates or defects propagated from the pre-roll ingot would be most likely. The use of representative coupons for inspection is analogous to the removal of specimens from structural materials for mechanical testing.

b) Neutron radiography/radioscopy of coupons across the full width of the plate will detect macroscopic non-uniformities in the B10 distribution such as could be introduced by the fabrication process.

c) Neutron transmission measures effective B10 content directly. The term "effective" is used here because if there are any of the effects noted in NUREG/CR-5661, the neutron transmission technique will measure not the physical B10 areal density, but a lower value. Thus, this technique by its nature screens out the microscopic non-uniformities which have been the source of the recommended 75% credit for B10 in criticality evaluations.

d) The use of neutron transmission and radiography/radioscopy satisfies the "and uniformity" requirement emphasized in NUREG/CR-5661 on both the microscopic and macroscopic scales.

e) The recommendations of NUREG/CR-5661 are based upon testing of a poison with boron carbide particles averaging 85 microns. The boride particles in the borated aluminum are much finer (5-10 microns). Both the manufacturing process and the neutron radioscopy assure that they are uniformly distributed. For a given degree of uniformity, fine particles will be less subject to neutron streaming than coarse particles. Furthermore, because the material reviewed in the NUREG was a sandwich panel, the thickness of the boron carbide containing center could not be directly verified by thickness measurement. The alloy specified here is uniform throughout its thickness.

B. Boralyn®, 90% B10 credit

Material Description

The poison plates consist of a composite of aluminum with a specified volume % boron carbide particulate reinforcement, depending on the NUHOMS®-61BT DSC Type. The material is formed into a billet by powder metallurgical processes and either extruded, rolled, or both to

final dimensions. The finished product has near-theoretical density and metallurgical bonding of the aluminum matrix particles. It is "uniform" blend of powder particles from face to face, i.e.; it is not a "sandwich" panel.

The specified volume % boron carbide, by NUHOMS®-61BT DSC Type, is given in Table K.9-2. For example, 15 volume % boron carbide corresponds to a B10 areal density of 0.15(2.52 g/cm^3 B_4C)(0.782 gB/gB_4C)(0.185 g B10/gB)(0.305 in)(2.54 cm/in) = 0.0424 g B10/cm^2, which is intentionally 6% above the design minimum of 0.040 g B10/cm^2.

The process specifications for the material shall be subject to qualification testing to demonstrate that the process results in a material that:

- has a uniform distribution of boron carbide particles in an aluminum alloy with few or none of the following: voids, oxide-coated aluminum particles, B_4C fracturing, or B_4C/aluminum reaction products,
- meets the requirements for B10 areal density and thermal conductivity, and
- will be capable of performing its Important-to-Safety functions under the thermal and radiological environment of the NUHOMS®-61BT DSC over its 40-year lifetime.

The production of plates for use in the NUHOMS®-61BT DSC is consistent with the process used to produce the qualification test material. Processing changes may be incorporated into the production process, only if they are reviewed and approved by the holder of an NRC-approved QA plan who is supervising fabrication. The basis for acceptance shall be that the changes do not have an adverse effect on either the microstructure or the uniformity of the boron carbide distribution, because these are the characteristics that determine the durability and neutron absorption effectiveness of the material. The evaluation may consist of an engineering review, or it may consist of additional testing. In general, changes in key billet forming variables such as the temperature or pressure would require testing, while changes in mechanical processing variables, such as extrusion speed, would not have to be evaluated. Increasing the boron carbide content would require testing, while decreasing it would not.

Typical processing consists of:

- blending of boron carbide powder with aluminum alloy powder,
- billet formed by vacuum hot pressing,
- billet extruded to intermediate or to final size,
- hot roll, cold roll and flatten as required, and
- anneal.

Test Coupons

The poison plates are manufactured in a variety of sizes. Coupons will be removed between every other plate or at the end of the plate so that there is at least one coupon contiguous with each plate. Coupons will generally be the full width of the plate. Thermal conductivity coupons may be removed from the full width coupon. The minimum dimension of the coupon shall be as required for acceptance test specimens; 1 to 2 inches is generally adequate. Neutron absorption

samples are taken from roughly one centimeter diameter samples through the thickness of the plate.

Acceptance Testing, B10 Density

Effective B10 content is verified by neutron transmission testing of these coupons. Acceptance testing is as described for borated aluminum in Section K.9.1.7.A, except that the acceptance criterion is taken from Table K.9-2.

In this method, the transmission through the coupons is compared with transmission through calibrated standards containing a uniform distribution of boron without other significant poisons, for example zirconium diboride, titanium diboride, or boron carbide metal matrix composites. These standards are paired with aluminum shims sized to match the scattering by aluminum in the poison plates. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to be equivalent to a homogeneous standard. The effective B10 content of each coupon, minus 3s based on the number of neutrons counted for that coupon, must be greater than or equal to the minimum value given in .

Sampling of B10 density measurement shall be in accordance with Section K.9.1.7.A for borated aluminum.

Justification for Acceptance Test Requirements, Boralyn®

Macroscopic uniformity of B10 distribution is verified by the qualification testing.

According to NUREG/CR-5661,

> "...Limiting added poison material credit to 75% without comprehensive tests is based on concerns for potential 'streaming' of neutrons due to nonuniformities. It has been shown that boron carbide granules embedded in aluminum permit channeling of a beam of neutrons between the grains and reduce the effectiveness for neutron absorption."

Furthermore,

> "A percentage of poison material greater than 75% may be considered in the analysis only if comprehensive tests, capable of verifying the presence and uniformity of the poison, are implemented." [emphasis added]

The calculations in Section K.6 use boron areal densities that are 90% of the minimum values given in Table K.9-2. This is justified by the following considerations.

a) The coupons for neutronic inspection are removed between every other finished plate. As such, they are taken from locations that are truly representative of the finished product, and every plate is represented by a contiguous coupon. Coupons are also removed at the ends of the "stock plate," where under thickness of the plates or defects propagated from the

pre-roll ingot would be most likely. The use of representative coupons for inspection is analogous to the removal of specimens from structural materials for mechanical testing.

b) Macroscopic uniformity of B10 distribution is verified as part of qualification testing. Thereafter it is assured by controls over the powder metallurgical process and is verified by subsequent measurement of B10 content on coupon samples of production material.

c) Neutron transmission measures effective B10 content directly. The term "effective" is used here because if there are any of the effects noted in NUREG/CR-5661, the neutron transmission technique will measure not the physical B10 areal density, but a lower value. Thus, this technique by its nature screens out the microscopic non-uniformities which have been the source of the recommended 75% credit for B10 in criticality evaluations.

d) The use of neutron transmission and powder metallurgical processing satisfies the "and uniformity" requirement emphasized in NUREG/CR-5661 on both the microscopic and macroscopic scales.

e) The recommendations of NUREG/CR-5661 are based upon testing of a poison with boron carbide particles on the order of 80-100 microns. The boron carbide particles in a typical metal matrix composite are much finer (1-25 microns). The powder metal manufacturing process controls and the qualification testing assure that they are uniformly distributed. For a given degree of uniformity, fine particles will be less subject to neutron streaming than coarse particles. Furthermore, because the material reviewed in the NUREG was a sandwich panel, the thickness of the boron carbide containing center could not be directly verified by thickness measurement. The metal matrix composite specified here is uniform throughout its thickness.

C. Boral® and Metamic®, 75% B10 Credit

Material Description, Boral®

Boral® consists of a core of mechanically bonded aluminum and boron carbide powders sandwiched between two outer layers of aluminum 1100, which is mechanically bonded to the core. The boron carbide particles average approximately 85 microns in diameter. The sheet is formed by filling an aluminum 1100 box with the boron carbide/aluminum powder mixture, and then hot-rolling the box. The walls of the box form the cladding, while the powder mixture forms the core of the Boral®. Additional information on the fabrication, specification, and performance of Boral® may be found in References [9.8] and [9.9].

Material Description, Metamic®

The poison plates consist of a composite of aluminum with boron carbide particulate reinforcement. The material is formed into a billet by powder metallurgical processes and either extruded, rolled, or both to final dimensions. The finished product has near-theoretical density and metallurgical bonding of the aluminum matrix particles. It is a "uniform" blend of powder particles from face to face, i.e.; it is not a "sandwich" panel.

Typical processing consists of:

- blending of boron carbide powder with aluminum alloy powder,
- billet formed by cold isostatic pressing followed by vacuum sintering
- billet extruded to intermediate or to final size,
- hot roll, cold roll and flatten as required, and
- anneal (optional).

Acceptance Testing, Neutronic

Boral® will be procured using AAR Advance Structures' standard specification for guidance [9.8]. In accordance with Section 7.3 of that specification, B10 areal density will be verified by chemical analysis or by neutron attenuation testing, using a sampling plan that will verify that the coupon meets the specified minimum values of Table K.9-3 with 95% probability at the 95% confidence level The procedure for data analysis shall be the same as that described for borated aluminum in Section 9.1.7.A. Both neutron absorption and chemical samples are taken from roughly one centimeter diameter sample through the thickness of the plate.

The areal density of B10 in Metamic® will be verified by coupon removal, sampling, and neutron transmission testing as described above for Boralyn® in Section K.9.1.7.B. The acceptance criteria of Table K.9-3 shall apply to Metamic® as well.

K.9.2 Maintenance Program

NUHOMS®-61BT system is a totally passive system and therefore will require little, if any, maintenance over the lifetime of the ISFSI. Typical NUHOMS®-61BT system maintenance tasks will be performed in accordance with Section 4.

K.9.3 References

9.1 ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition including 1999 addenda.

9.2 ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," February 1998.

9.3 ASTM E1225, "Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique."

9.4 ASTM E1461, "Thermal Diffusivity of Solids by the Flash Method."

9.5 NUREG/CR-5661, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," 1997.

9.6 ASTM C 791, "Standard Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Boron Carbide."

9.7 ASTM D 3553, "Fiber Content by Digestion of Reinforced Metal Matrix Composites."

9.8 AAR Advanced Structures, "Boral®, The Proven Neutron Absorber."

9.9 AAR Advanced Structures, Boral® Product Performance Report 624.

Table K.9-1
Specified Boron Content
Borated Aluminum (90% B10 Credit)

Reference	Section K.6 Analysis	Specified Minimum
Boron Content (wt. % Boron)	**B10 Content (g/cm^2)**	**B10 Content (g/cm^2)**
1.1	0.019	0.021
1.6	0.029	0.032
2.1	0.036	0.040
For Damaged Fuel		
2.1	0.036	0.040

Table K.9-2
Specified Boron Carbide Content
Boralyn® (90% B10 Credit)

Reference	Section K.6 Analysis	Specified Minimum
Boron Carbide Content (volume %)	B10 Content (g/cm^2)	B10 Content (g/cm^2)
8	0.019	0.021
12	0.029	0.032
15	0.036	0.040
For Damaged Fuel		
15	0.036	0.040

Table K.9-3
Specified B10 Areal Density
Boral® and Metamic® (75% B10 credit)

Section K.6 Analysis	Specified Minimum
B10 Content (g/cm^2)	**B10 Content (g/cm^2)**
0.019	0.025
0.029	0.039
0.036	0.048
For Failed Fuel	
0.036	0.048

K.10 Radiation Protection

Section 7.4.1 discusses the anticipated cumulative dose exposure to site personnel during the fuel handling and transfer activities associated with utilizing one NUHOMS® HSM for storage of one DSC. Chapter 5 describes in detail the NUHOMS® operational procedures, several of which involve potential exposure to personnel.

K.10.1 Occupational Exposure

The expected occupational dose for placing a canister of spent fuel into dry storage for the operational steps listed in Table 7.4-1 is less than 1.2 person-rem. The additional occupational dose due to placing a single NUHOMS®-61BT DSC into storage is conservatively estimated to be 1.8 person-rem. This is a very conservative estimate because the dose rates on and around the 61BT DSC used in these calculations are based on very conservative assumptions for the design basis source terms and not taking credit for any of the basket materials in the shielding evaluation. This increase is due mainly to the increase in expected gamma dose rate during preparation for welding. The increase is also due to draining the NUHOMS®-61BT DSC to meet a 100-ton crane limit as described in Section K.8.

The NUHOMS® system loading operations, the number of workers required for each operation, and the amount of time required for each operation are presented in Table 7.4-1. This information is used as the basis for estimating the total occupational exposure associated with one fuel load. This evaluation is performed for the storage of one design basis NUHOMS®-61BT DSC in an HSM. The dose rates applicable for each operation are based on the results presented in Section K.5.4 for loading operations. Engineering judgment and operational experience are used to estimate dose rates that were not explicitly evaluated. This evaluation assumes that a transfer trailer/skid with an integral ram is used for the DSC transfer operations. Licensees may elect to use different equipment and/or different procedures. Each Licensee must evaluate any such changes in accordance with their ALARA program.

The amount of time required to complete some operations is sometimes far greater than the actual amount of time spent in a radiation field. The process of vacuum drying the DSC includes setting up the vacuum drying system (VDS), verifying that the VDS is operating correctly, evacuating the DSC cavity, monitoring the DSC pressure, and disconnecting the VDS from the DSC. Of these tasks, only setup and removal of the VDS require a worker to spend time near the DSC. The most time consuming task, evacuating the DSC, does not require anyone to be present at all. The total exposure calculated for each task is therefore not necessarily equal to the number of workers multiplied by the time required multiplied by a dose rate. The exposure estimation for each task accounts for cases such as vacuum drying correctly, and assumes that good ALARA practices are followed.

The results of the evaluation are presented in Table K.10-1.

K.10.2 Off-Site Dose Calculations

Calculated dose rates in the immediate vicinity of the NUHOMS®-61BT system are presented in Section K.5 which provides a detailed description of source term configuration, analysis models and bounding dose rates. Dose rates at longer distances (off-site dose rates and doses) are presented in this section. This evaluation determines the neutron and gamma-ray off-site dose rates including skyshine in the vicinity of the two generic Independent Spent Fuel Storage Installations (ISFSI) layouts containing design basis fuel in the NUHOMS®-61BT DSCs. The first generic ISFSI evaluated is a 2x10 array (back-to-back) of Horizontal Storage Modules (HSMs) loaded with design basis fuel, including fuel channels, in NUHOMS®-61BT DSCs. The second generic layout evaluated is two 1x10 arrays (front-to-front) of Horizontal Storage Modules (HSMs) loaded with design basis fuel, including fuel channels, in NUHOMS®-61BT DSCs. This calculation provides results for distances ranging from 6.1 to 600 meters from each face of the two arrays of HSMs.

The total annual exposure for each ISFSI layout as a function of distance from each face is given in Table K.10-2 and plotted in Figure K.10-1. The total annual exposure assumes 100% occupancy for 365 days.

The Monte Carlo computer code MCNP [10.1] calculated the dose rates at the specified locations around the arrays of HSMs. The results of this calculation provide an example of how to demonstrate compliance with the relevant radiological requirements of 10CFR20 [10.2], 10CFR72 [10.3], and 40CFR190 [10.4] for a specific site. Each site must perform specific site calculations to account for the actual layout of the HSMs and fuel source.

The assumptions used to generate the geometry of the two ISFSIs for the MCNP analysis are summarized below.

- The 20 HSMs in the 2x10 back-to-back array are modeled as a box enveloping the 2x10 array of HSMs including the six inch vents between modules and the 2-foot shield walls on the two sides of the array. MCNP starts the source particles on the surfaces of the box.
- The 20 HSMs in the two 1x10 face-to-face arrays are modeled as two boxes which envelope each 1x10 array of HSMs including the six inch vents between modules and the 2-foot shield walls on the two sides of each array. MCNP starts the source particles on the surfaces of one of the boxes.
- The ISFSI approach slab is modeled as concrete. Because the ground composition has, at best, only a secondary impact on the dose rates at the detectors, any differences between this assumed layout and the actual layout would not have a significant affect on the site dose rates.
- For the 2x10 array, the interiors of the HSMs and shield walls are modeled as air. Most particles that enter the interiors of the HSMs and shield walls will therefore pass through unhindered.
- For the two 1x10 arrays, the interiors of the HSMs and shield walls modeled the 1x10 array in which the source is as air. Most particles that enter the interiors of these HSMs and shield walls will therefore pass through unhindered. Model the other 1x10 array as concrete to simulate the shielding

provided by the second array of HSMs for the direct radiation from the front of the opposing 1x10 array.

- The "universe" is a sphere surrounding the ISFSI. To account for skyshine radius of this sphere (r=500,000 cm) is more than 10 mean free paths for gammas and 50 mean free paths for neutrons greater than that of the outermost surface, thus ensuring that the model is of a sufficient size to include all interactions, including skyshine, affecting the dose rate at the detectors.

The assumption used to generate the HSM surface sources for the MCNP analysis is summarized below.

- The HSM surface sources are bootstrapped (input to provide an equivalent boundary condition) using the HSM surface average dose rates calculated in Section K.5.4.

The assumptions used for the MCNP analysis are summarized below.

MCNP starts the source particles on the ISFISI array surface with initial directions following a cosine distribution. Radiation fluxes outside thick shields such as the HSM walls and roof tend to have forward peaked angular distributions; therefore, a cosine function is a reasonable approximation for the starting direction distribution. Vents through shielding regions such as the HSM vents tend to collimate particles such that a semi-isotropic assumption would not be appropriate.

Point detectors determine the dose rates on the four sides of the ISFSI as a function of distance from the ISFSI. All detectors represent the dose rate at three feet above ground level.

Source information required by MCNP includes gamma-ray and neutron spectra for the HSM array surfaces, total gamma-ray and neutron activities for each HSM array face and total gamma-ray and neutron activities for the entire ISFSI. The neutron and gamma-ray spectra are determined using a 1-D ANISN[10.6] run through the HSM roof using the design basis In-core neutron and gamma fuel sources. Use of the roof is conservative because it represents the thickest cross section of the HSM shield. The thicker shield increases the dose rate importance of the higher energy neutrons and gamma-rays from the fuel because the thicker shield filters out the lower energy particles. Therefore, use of the thickest part of the shield results in a harder spectrum for all of the other surfaces. The HSM spectra as determined from ANISN are normalized to a one mrem/hour source using the flux-to-dose-factors from Reference [10.5]. These normalized spectra are then input in the MCNP ERG source variable.

The probability of a particle being born on a given surface is proportional to the total activity of that surface. The activity of each surface is determined by multiplying the sum of the normalized group fluxes, calculated above, by the average surface dose rate and by the area of the surface. This calculation is performed for the roof, sides, back and front of the HSM. The sum of the surface activities is then input as the tally multiplier for each of the MCNP tallies to convert the tally results to fluxes (particles per second per square centimeter).

Gamma-ray spectrum calculations for the HSM are shown in Table K.10-3. The group fluxes on the HSM roof are taken from the ANISN run. The dose rate contribution from each group is the product of the flux and the flux-to-dose factor. The "Input Flux" column in Table K.10-3 is simply the roof flux in each group, divided by the total dose rate and represents the roof flux normalized to one mrem per hour. Similar calculations for neutrons are shown in Table K.10-4.

K.10.2.1 Activity Calculations

2x10 Back-To-Back Array

A box that envelops the HSM array and shield walls, as modeled in MCNP, approximates the 2x10 back-to-back array of HSMs. The dimensions of the box also include the width of the HSM end shield walls. As discussed above, the total activity of each face of the box is calculated by multiplying the flux per mrem/hr by the average dose rate of the face and by the area of the face.

Two 1x10 Front-To-Front Array

A box that envelops the HSM array and shield walls, as modeled in MCNP, approximates the two 1x10 arrays of HSMs. The dimensions of the box also include the width of the HSM end and back shield walls. As discussed above, the total activity of each face of the box is calculated by multiplying the flux per mrem/hr by the average dose rate of the face and by the area of the face.

The HSM surface activities are summarized in Table K.10-5.

K.10.2.2 Dose Rates

Dose rates are calculated for distances of 6.1 meters (20 feet) to 600 meters from the edges of the two ISFSI designs. The HSM is modeled in MCNP as a box, representing the HSM arrays.

Neutron and gamma-ray sources are placed on each HSM, with shield walls, surface using the spectra and activities determined above. The angular distribution of source particles is modeled as a cosine distribution. The contribution of capture gamma-rays has been neglected, as has the contribution of bremsstrahlung electrons. The inclusion of coherent scattering greatly increases the variance in a problem with point detector tallies without improving the accuracy of the calculation. Thus, coherent scattering of photons is ignored.

The MCNP model of the two ISFSI layouts are described herein. For the 2x10 back-to-back array of HSMs with end shield walls the "box", dimensions are as follows. The total width is 1158.24 cm. The length of the "box" is 3220.72 cm and the height of the "box" is 457.20 cm.

For the two 1x10 front-to-front arrays of HSMs with end and back shield walls the "box", dimensions for each array are as follows. The total width is 640.08 cm. The length of the "box" is 3220.72 cm and the height of the "box" is 457.20 cm. The two 1x10 arrays are 1066.8 cm (35 ft) apart.

Point detectors are placed at the following locations as measured from each face of the "box": 6.095 m (20ft), 10 m, 20 m, 30 m, 40 m, 50 m, 60 m, 70 m, 80 m, 90 m, 100 m, 200 m, 300 m, 400 m, 500 m, and 600 m. Each point detector is placed 91.4 cm (3 feet) above the ground.

The MCNP results for each detector from the front of 2x10 back-to-back array are summarized in Table K.10-6. The MCNP results as a function of distance from the back of the two 1x10 front-to-front array are summarized in Table K.10-7. The MCNP results as a function of distance from the side of the 2x10 back-to-back array and the two 1x10 front-to-front arrays are summarized in Table K.10-8. The results from Table K.10-6, Table K.10-7 and Table K.10-8 are plotted in Figure K.10-1.

K.10.3 References

10.1 "MCNP 4 - Monte Carlo Neutron and Photon Transport Code System," CCC-200A/B, Oak Ridge National Laboratory, RSIC Computer Code Collection, October 1991.

10.2 Title 10, "Energy," Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation."

10.3 Title 10, "Energy," Code of Federal Regulations, Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

10.4 Title 40, "Protection of Environment," Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations."

10.5 "American National Standard Neutron and Gamma-Ray Fluence-to-Dose Factors," ANSI/ANS-6.1.1-1977, American Nuclear Society, La Grange Park, Illinois, March 1977.

10.6 "ANISN-ORNL - One-Dimensional Discrete Ordinates Transport Code System with Anisotropic Scattering," CCC-254, Oak Ridge National Laboratory, RSIC Computer Code Collection, April 1991.

Table K.10-1
Occupational Exposure Summary

Task	Number of Workers	Completion Time (hours)
Location: Auxiliary Building and Fuel Pool		
Ready the DSC and TC for Service[1]	2	4
Place the DSC into the TC[1]	3	1
Fill the Cask/DSC Annulus with Clean Water and Install the Inflatable Seal	2	2
Fill the DSC Cavity with Water[2]	1	6
Install Shield Plug and Connect VDS	2	0.5
Place the Cask Containing the DSC in the Fuel Pool	5	0.5
Verify and Load the Candidate Fuel Assemblies into the DSC	3	10
Place the Top Shield Plug on the DSC	2	1
Raise the Cask/DSC to the Fuel Pool Surface	5	0.5
Drain Water from DSC Cavity	1	1
Remove the Cask/DSC from the Fuel Pool and Place them in the Decon Area	2	0.5
Location: Cask Decon Area		
Decontaminate the Outer Surface of the Cask (on the hook)[3]	3	1
Fill Cask Neutron Shield and Cask Cavity	1	0.1
Cask Decontamination (in the decon area)[3]	3	1
Remove the Cask/DSC Annulus Seal and Set-up Welder[3]	2	1.5
Drain the DSC Cavity[3]	2	0.5
Weld the Inner Top Cover to the DSC Shell and Perform NDE[3]	2	6
Vacuum Dry and Backfill the DSC with Helium[3]	2	16
Helium Leak Test the Shield Plug Weld	2	1
Seal Weld the Prefabricated Plugs to the Vent and Siphon Port and Perform NDE	1	1
Install DSC Outer Top Cover Plate[3]	2	1
Weld the Outer Top Cover Plate to DSC Shell and Perform NDE[3]	2	16
Drain Cask/DSC Annulus[3]	1	0.25
Install the Cask Lid	2	1

Table K.10-1
Occupational Exposure Summary (Concluded)

Task	Number of Workers	Completion Time (hours)
Location: Reactor /Fuel Building Bay		
Ready the Cask Support Skid and Transport Trailer for Service(1)	2	2
Place the Cask Onto the Skid and Secure(2)	3	0.5
Location: ISFSI Site		
Ready the HSM and Hydraulic Ram System for Service(1)	2	2
Transport the Cask to the ISFSI(1)	6	1
Position the Cask in Close Proximity with the HSM(1)	3	1
Remove the Cask Lid	3	1
Align and Dock the Cask with the HSM	2	0.25
Position and Align Ram with Cask(3)	2	0.5
Remove the RAM Access Cover Plate	2	0.25
Transfer the DSC from the Cask to the HSM(1)	3	0.5
Un-Dock the Cask from the HSM	2	0.083
Install the HSM Access Door	2	0.5
Total		83
Total estimated dose is 2.97 person-rem per canister load.		

(1) Performed away from any significant radiation sources.

(2) Personnel are not present throughout this activity.

(3) Dose rates and locations vary during this task.

Table K.10-2
Total Annual Exposure

2x10 Back-To-Back Array

Distance (meters)	Front Total Dose (mrem)	Side Total Dose (mrem)
6.096	494247	30835
10	289568	21505
20	108275	12137
30	53351	7709
40	31337	5947
50	20362	4413
60	14258	3855
70	10287	3155
80	7678	2489
90	5656	1915
100	5017	1627
200	792	361
300	213	104
400	75	33
500	33	12
600	10	5

Two 1x10 Front-To-Front Arrays

Distance (meters)	Front Total Dose (mrem)	Side Total Dose (mrem)
6.096	23545	332687
10	19270	168848
20	13114	56308
30	8898	28541
40	6958	18668
50	5177	12903
60	4242	9021
70	3485	7662
80	2638	5819
90	2218	4657
100	1990	4054
200	389	745
300	128	401
400	39	119
500	15	24
600	11	9

Table K.10-3
HSM Gamma-Ray Spectrum Calculation Results

Group Number	E_{upper} (MeV)	E_{mean} (MeV)	Flux-Dose ANSI/ANS-6.1.1-1977 (mrem/hr)/(γ/cm²-sec)	Roof Flux (γ/cm²-sec)	Dose Rate (mrem/hr)	Input Flux (γ/cm²-sec per mrem/hr)
23	10	9	8.772E-03	1.02E+00	8.93E-03	2.00E-02
24	8	7.25	7.479E-03	8.56E+00	6.40E-02	1.68E-01
25	6.5	5.75	6.375E-03	1.09E+01	6.93E-02	2.14E-01
26	5	4.5	5.414E-03	1.43E+01	7.73E-02	2.81E-01
27	4	3.5	4.622E-03	2.69E+01	1.24E-01	5.29E-01
28	3	2.75	3.960E-03	3.77E+01	1.49E-01	7.42E-01
29	2.5	2.25	3.469E-03	3.55E+02	1.23E+00	6.99E+00
30	2	1.83	3.019E-03	3.82E+02	1.15E+00	7.52E+00
31	1.66	1.495	2.628E-03	1.69E+03	4.44E+00	3.32E+01
32	1.33	1.165	2.205E-03	3.24E+03	7.15E+00	6.38E+01
33	1	0.9	1.833E-03	3.03E+03	5.56E+00	5.96E+01
34	0.8	0.7	1.523E-03	4.55E+03	6.93E+00	8.95E+01
35	0.6	0.5	1.173E-03	7.15E+03	8.38E+00	1.41E+02
36	0.4	0.35	8.759E-04	4.90E+03	4.29E+00	9.63E+01
37	0.3	0.25	6.306E-04	6.67E+03	4.21E+00	1.31E+02
38	0.2	0.15	3.834E-04	1.52E+04	5.85E+00	3.00E+02
39	0.1	0.08	2.669E-04	4.29E+03	1.14E+00	8.43E+01
40	0.05	0.03	9.348E-04	1.23E+01	1.15E-02	2.42E-01
			Totals	5.16E+04	5.08E+01	1.02E+03

Table K.10-4
HSM Neutron Spectrum Calculations

Group Number	E_{upper} (MeV)	E_{mean} (MeV)	Flux-Dose ANSI/ANS-6.1.1-1977 (mrem/hr)/(n/cm^2-sec)	Roof Flux (n/cm^2-sec)	Dose Rate (mrem/hr)	Input Flux (n/cm^2-sec per mrem/hr)
1	1.49E+01	1.36E+01	1.945E-01	1.74E-04	3.38E-05	3.78E-04
2	1.22E+01	1.11E+01	1.597E-01	1.07E-03	1.71E-04	2.32E-03
3	1.00E+01	9.09E+00	1.471E-01	3.96E-03	5.83E-04	8.61E-03
4	8.18E+00	7.27E+00	1.477E-01	2.94E-02	4.34E-03	6.37E-02
5	6.36E+00	5.66E+00	1.534E-01	8.13E-02	1.25E-02	1.77E-01
6	4.96E+00	4.51E+00	1.506E-01	7.65E-02	1.15E-02	1.66E-01
7	4.06E+00	3.54E+00	1.389E-01	8.95E-02	1.24E-02	1.94E-01
8	3.01E+00	2.74E+00	1.284E-01	2.16E-01	2.78E-02	4.70E-01
9	2.46E+00	2.41E+00	1.253E-01	2.00E-01	2.51E-02	4.34E-01
10	2.35E+00	2.09E+00	1.263E-01	3.22E-01	4.06E-02	6.98E-01
11	1.83E+00	1.47E+00	1.289E-01	5.00E-01	6.45E-02	1.09E+00
12	1.11E+00	8.30E-01	1.169E-01	5.25E-01	6.13E-02	1.14E+00
13	5.50E-01	3.31E-01	6.521E-02	7.55E-01	4.92E-02	1.64E+00
14	1.11E-01	5.72E-02	9.188E-03	1.27E+00	1.16E-02	2.75E+00
15	3.35E-03	1.97E-03	3.713E-03	6.10E-01	2.27E-03	1.32E+00
16	5.83E-04	3.42E-04	4.009E-03	7.34E-01	2.94E-03	1.59E+00
17	1.01E-04	6.50E-05	4.295E-03	6.16E-01	2.64E-03	1.34E+00
18	2.90E-05	1.96E-05	4.476E-03	4.45E-01	1.99E-03	9.67E-01
19	1.01E-05	6.58E-06	4.567E-03	6.05E-01	2.76E-03	1.31E+00
20	3.06E-06	2.09E-06	4.536E-03	5.44E-01	2.47E-03	1.18E+00
21	1.12E-06	7.67E-07	4.370E-03	5.79E-01	2.53E-03	1.26E+00
22	4.14E-07	2.12E-07	3.714E-03	3.27E+01	1.21E-01	7.09E+01
			Totals	4.09E+01	4.61E-01	8.87E+01

Table K.10-5
Summary of ISFSI Surface Activities

2x10 Back-To-Back Array

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	$3.73x10^6$	$4.13x10^{11}$	$1.99x10^8$
Front 1	$1.47x10^6$	$1.63x10^{11}$	$1.12x10^9$
Front 2	$1.47x10^6$	$1.63x10^{11}$	$1.12x10^9$
Side 1	$5.30x10^5$	$1.92x10^9$	$1.97x10^6$
Side 2	$5.30x10^5$	$1.92x10^9$	$1.97x10^6$
Total		$7.43x10^{11}$	$2.43x10^9$

Two 1x10 Front-To-Front Array

Source	Area (cm^2)	Gamma-Ray Activity (γ/sec)	Neutron Activity (neutrons/sec)
Roof	$2.06x10^6$	$2.28x10^{11}$	$1.10x10^8$
Front	$1.47x10^6$	$1.63x10^{11}$	$1.12x10^9$
Back	$1.47x10^6$	$1.56x10^9$	$3.31x10^6$
Side 1	$2.93x10^5$	$1.06x10^9$	$1.09x10^6$
Side 2	$2.93x10^5$	$1.06x10^9$	$1.09x10^6$
Total		$3.95x10^{11}$	$1.23x10^9$

Table K.10-6
MCNP Front Detector Dose Rates for 2x10 Array

Distance (meters)	Gamma Dose Rate (mrem/hr)	Neutron Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
6.10E+00	5.14E+01	5.06E+00	5.64E+01
1.00E+01	3.02E+01	2.89E+00	3.31E+01
2.00E+01	1.13E+01	1.07E+00	1.24E+01
3.00E+01	5.59E+00	4.98E-01	6.09E+00
4.00E+01	3.29E+00	2.90E-01	3.58E+00
5.00E+01	2.14E+00	1.81E-01	2.32E+00
6.00E+01	1.51E+00	1.18E-01	1.63E+00
7.00E+01	1.08E+00	9.01E-02	1.17E+00
8.00E+01	8.19E-01	5.77E-02	8.76E-01
9.00E+01	6.02E-01	4.39E-02	6.46E-01
1.00E+02	5.35E-01	3.77E-02	5.73E-01
2.00E+02	8.48E-02	5.60E-03	9.04E-02
3.00E+02	2.28E-02	1.51E-03	2.43E-02
4.00E+02	7.66E-03	8.55E-04	8.51E-03
5.00E+02	3.50E-03	2.94E-04	3.80E-03
6.00E+02	1.05E-03	1.49E-04	1.19E-03

Table K.10-7
MCNP Back Detector Dose Rates for the Two 1x10 Arrays

Distance (meters)	Gamma Dose Rate (mrem/hr)	Neutron Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
6.10E+00	2.32E+00	3.65E-01	2.69E+00
1.00E+01	1.90E+00	3.02E-01	2.20E+00
2.00E+01	1.29E+00	2.03E-01	1.50E+00
3.00E+01	9.02E-01	1.14E-01	1.02E+00
4.00E+01	6.94E-01	1.01E-01	7.94E-01
5.00E+01	5.39E-01	5.17E-02	5.91E-01
6.00E+01	4.48E-01	3.61E-02	4.84E-01
7.00E+01	3.71E-01	2.67E-02	3.98E-01
8.00E+01	2.79E-01	2.19E-02	3.01E-01
9.00E+01	2.36E-01	1.76E-02	2.53E-01
1.00E+02	2.13E-01	1.41E-02	2.27E-01
2.00E+02	4.18E-02	2.61E-03	4.45E-02
3.00E+02	1.38E-02	8.56E-04	1.46E-02
4.00E+02	4.09E-03	3.34E-04	4.43E-03
5.00E+02	1.51E-03	1.51E-04	1.66E-03
6.00E+02	1.19E-03	5.88E-05	1.25E-03

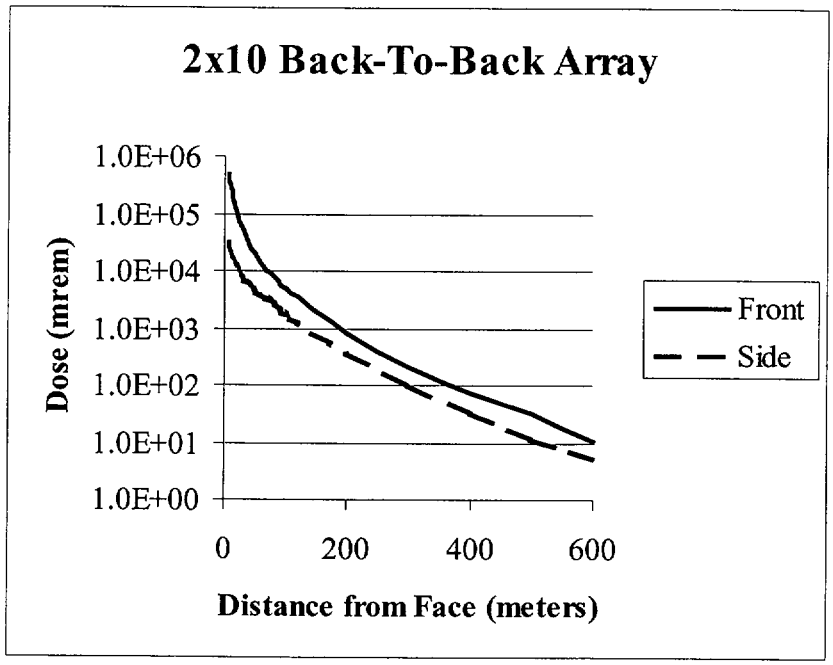
Table K.10-8
MCNP Side Detector Dose Rates

2x10 Back-To-Back Array

Distance (meters)	Gamma Dose Rate (mrem/hr)	Neutron Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
6.10E+00	3.11E+00	4.07E-01	3.52E+00
1.00E+01	2.16E+00	2.94E-01	2.45E+00
2.00E+01	1.20E+00	1.88E-01	1.39E+00
3.00E+01	7.90E-01	9.04E-02	8.80E-01
4.00E+01	6.11E-01	6.76E-02	6.79E-01
5.00E+01	4.47E-01	5.68E-02	5.04E-01
6.00E+01	4.01E-01	3.93E-02	4.40E-01
7.00E+01	3.28E-01	3.17E-02	3.60E-01
8.00E+01	2.65E-01	1.93E-02	2.84E-01
9.00E+01	1.98E-01	2.06E-02	2.19E-01
1.00E+02	1.75E-01	1.12E-02	1.86E-01
2.00E+02	3.88E-02	2.38E-03	4.12E-02
3.00E+02	1.10E-02	8.07E-04	1.18E-02
4.00E+02	3.42E-03	3.10E-04	3.73E-03
5.00E+02	1.04E-03	2.82E-04	1.32E-03
6.00E+02	5.05E-04	7.78E-05	5.83E-04

Two 1x10 Front-To-Front Array

Distance (meters)	Gamma Dose Rate (mrem/hr)	Neutron Dose Rate (mrem/hr)	Total Dose Rate (mrem/hr)
6.10E+00	3.44E+01	3.61E+00	3.80E+01
1.00E+01	1.76E+01	1.71E+00	1.93E+01
2.00E+01	5.83E+00	5.98E-01	6.43E+00
3.00E+01	2.94E+00	3.17E-01	3.26E+00
4.00E+01	1.89E+00	2.39E-01	2.13E+00
5.00E+01	1.36E+00	1.17E-01	1.47E+00
6.00E+01	9.42E-01	8.75E-02	1.03E+00
7.00E+01	7.85E-01	8.93E-02	8.75E-01
8.00E+01	6.05E-01	5.89E-02	6.64E-01
9.00E+01	4.96E-01	3.58E-02	5.32E-01
1.00E+02	4.28E-01	3.49E-02	4.63E-01
2.00E+02	8.08E-02	4.27E-03	8.51E-02
3.00E+02	4.45E-02	1.35E-03	4.58E-02
4.00E+02	1.30E-02	6.10E-04	1.36E-02
5.00E+02	2.52E-03	1.93E-04	2.71E-03
6.00E+02	8.99E-04	8.44E-05	9.84E-04



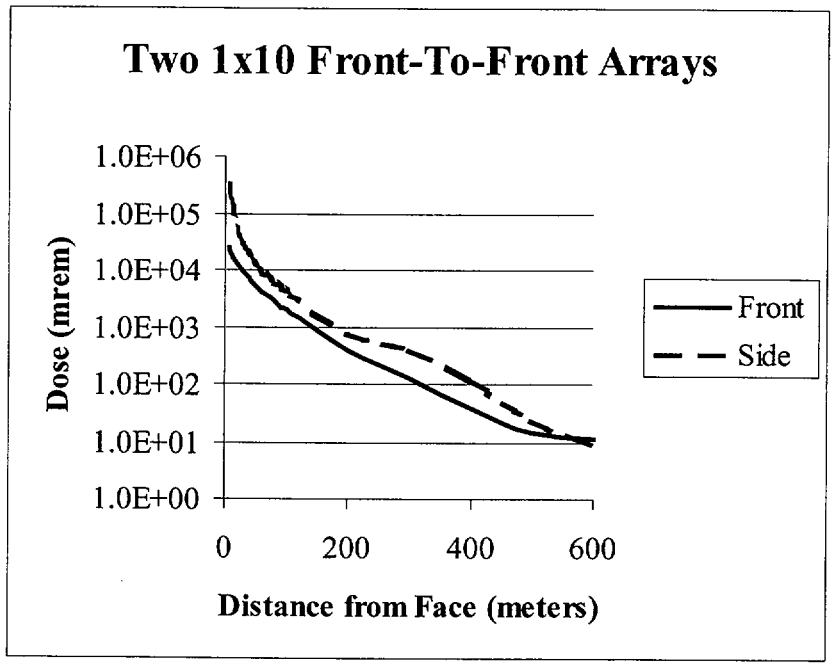


Figure K.10-1
Annual Exposure from the ISFSI as a Function of Distance

K.11 Accident Analyses

This section describes the postulated off-normal and accident events that could occur during transfer and storage of the NUHOMS®-61BT DSC. Sections which do not affect the evaluation presented in Section 8.0 are identified as "No change." Detailed analysis of the events are provided in other sections and referenced herein.

K.11.1 Off-Normal Operations

Off-normal operations are design events of the second type (Design Event II) as defined in ANSI/ANS 57.9 [11.1]. Off-normal conditions consist of that set of events that, although not occurring regularly, can be expected to occur with moderate frequency or on the order of once during a calendar year of ISFSI operation.

The off-normal conditions considered for the NUHOMS®-61BT DSC are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides.

K.11.1.1 Off-Normal Transfer Loads

The limiting off-normal event is the jammed DSC during loading or unloading from the HSM. This event is described in Section 8.1.2. Other off-normal events are bounded by the jammed DSC.

K.11.1.1.1 Postulated Cause of Event

Same as Section 8.1.2. The probability of a jammed DSC does not increase with the NUHOMS®-61BT DSC, since the outside diameter of the DSC is the same as the NUHOMS®-52B.

K.11.1.1.2 Detection of Event

No change.

K.11.1.1.3 Analysis of Effects and Consequences

A detailed evaluation of this event is presented in Section K.3.6.2 and is summarized below. The NUHOMS®-61BT DSC has a 0.5 inch shell wall thickness, while the NUHOMS®-24P and NUHOMS®-52B have a 0.62 inch shell. Therefore the stresses in the canister shell are increased. The DSC shell stress due to the 2,690 in-kip moment due to axial sticking of the DSC is S_{mx} = 1.51 ksi. This magnitude of stress is negligible when compared to the allowable membrane stress of 18.7 ksi.

The DSC shell stress due to the 1,400 pound axial load during the binding of the DSC is 15.7 ksi. This stress is well within the ASME Code Service Level C allowable of 22.4 ksi for an off-normal jammed DSC event.

The evaluation of the basket due to normal and off-normal handling and transfer loads is presented in Section K.3.6.1.3.3.

K.11.1.1.4 Corrective Actions

No change.

K.11.1.2 Extreme Temperatures

This event is described in Section 8.1.2.2.

K.11.1.2.1 Postulated Cause of Event

No change.

K.11.1.2.2 Detection of Event

No change.

K.11.1.2.3 Analysis of Effects and Consequences

The thermal evaluation of the NUHOMS®-61BT system for off-normal conditions is presented in Section K.4.5. The 100°F normal condition with solar insolation bounds the 125°F case without solar insolation for the DSC in the OS197 transfer cask. Therefore the normal condition maximum temperatures are bounding. The 125°F case with the DSC in the HSM is not bounded by the normal conditions.

The structural evaluation of the HSM's, NUHOMS®-61BT DSC and the OS197 transfer cask for the off-normal temperature conditions are presented in Section K.3.6.2.2. The structural evaluation of the basket due to off-normal thermal conditions is presented in Section K.3.4.4.

K.11.1.2.4 Corrective Actions

Restrictions for onsite handling of the transfer cask with a loaded DSC under extreme temperature conditions are presented in Technical Specifications 1.2.13 and 1.2.14. There is no change to this requirement as a result of addition of the NUHOMS®-61BT DSC.

K.11.1.3 Off-Normal Releases of Radionuclides

The NUHOMS®-61BT DSC is designed and tested to the leak tight criteria of ANSI N14.5 [11.2]. Therefore the estimated quantity of radionuclides expected to be released annually to the environment due to normal or off-normal events is zero.

K.11.1.3.1 Postulated Cause of Event

In accordance with the Standard Review Plan, NUREG-1536 [11.3] and Interim Staff Guidance Report ISG-5 Rev. 1 [11.4], for off-normal conditions, it is conservatively assumed that 10% of the fuel rods fail.

K.11.1.3.2 Detection of Event

Failed fuel rods would go undetected, but are not a safety concern since the canister is designed and tested to leak tight criteria.

K.11.1.3.3 Analysis of Effects and Consequences

The pressure within the NUHOMS®-61BT DSC canister due to the off-normal condition is calculated in Section K.4.5.3 to be 10 psig when in the HSM and 11.5 psig when in the OS197 cask using design basis fuel. The NUHOMS®-61BT DSC stresses due to these pressures are below the allowable stresses within the canister for off-normal conditions as shown in K.3.6.

The NUHOMS®-61BT DSC is designed and tested to the leak tight criteria of ANSI N14.5. Therefore the estimated quantity of radionuclides expected to be released annually to the environment due to normal or off-normal events is zero.

K.11.1.3.4 Corrective Actions

None required.

K.11.1.4 Radiological Impact from Off-Normal Operations

The NUHOMS®-61BT DSC is designed and tested to the leak tight criteria of ANSI N14.5. The off-normal conditions have been evaluated in accordance with the ASME B&PV code. The resulting stresses are below the allowable stresses, and there will be no breach of the confinement boundary due to the off-normal conditions. Therefore the estimated quantity of radionuclides expected to be released annually to the environment due to off-normal events is zero.

K.11.2 Postulated Accidents

K.11.2.1 Reduced HSM Air Inlet and Outlet Shielding

This event is described in Section 8.2.10.

K.11.2.1.1 Cause of Accident

No change.

K.11.2.1.2 Accident Analysis

There are no structural consequences that affect the safe operation of the NUHOMS®-61BT system resulting from the separation of the HSMs. The thermal effects of this accident results from the blockage of HSM air inlet and outlet openings on the HSM side walls in contact with each other. This would block the ventilation air flow provided to the HSMs in contact from these inlet and outlet openings. The increase in spacing between the HSM on the opposite side from 6 inches to 12 inches, will reduce the ventilation air flow resistance through the air inlet and outlet openings on these side walls, which will partially compensate the ventilation reduction from the blocked side. However, the effect on the NUHOMS®-61BT DSC, HSM and fuel temperatures is bounded by the complete blockage of air inlet and outlet openings described in Section K.11.2.7. The radiological consequences of this accident are described in the paragraph below.

K.11.2.1.3 Accident Dose Calculations

The off-site radiological effects that result from a partial loss of adjacent HSM shielding is an increase in the air scattered (skyshine) and direct doses from the 12 inch gap between the separated HSMs. The air scattered (skyshine) and direct doses are reduced from the gap between the HSMs that are in contact with each other. On-site radiological effects result from an increase in the direct radiation during recovery operations and increased skyshine radiation. Table 8.2-2 shows the comparisons of the increased dose rate as a function of distance due to the reduced shielding effects of the adjacent HSM for the 24P DSC with 5-year cooled design basis fuel. Table K.11-1 provides a similar table for the NUHOMS®-61BT system. For the NUHOMS®-61BT system the dose increase to a person located 100 meters away from the NUHOMS® installation for eight hours a day for five days (estimated recovery time) would be 44 mrem. The increased dose to an off-site person for 24 hours a day for five days located 2000 feet away would be about 0.29 mrem. Thus, the 10CFR72 requirements for this postulated event are met.

K.11.2.1.4 Corrective Actions

No change.

K.11.2.2 Earthquake

This event is described in Section 8.2.3.1.

K.11.2.2.1 Cause of Accident

No change.

K.11.2.2.2 Accident Analysis

Section 8.2.3.2 describes the analyses performed to demonstrate that the NUHOMS® system will withstand the design basis seismic event. Section K.3.7.3 presents the changes to this analysis resulting from the addition of NUHOMS®-61BT DSC. There are no changes to the design of the HSM or the OS197 transfer cask. Therefore, only those analyses affected by the DSC weight have been modified. The analysis of the NUHOMS®-61BT DSC is presented in Section K.3.7. The results of this analysis show that the leak-tight integrity of the canister is not compromised. No damage to the HSM is postulated. The basket stresses are also low and do not result in deformations that would prevent fuel from being unloaded from the canister.

K.11.2.2.3 Accident Dose Calculations

The Design earthquake does not damage the NUHOMS®-61BT system. Hence, no radioactivity is released and there is no associated dose increase due to this event.

K.11.2.2.4 Corrective Actions

No change.

K.11.2.3 Extreme Wind and Tornado Missiles

this event is described in Section 8.2.2.

K.11.2.3.1 Cause of Accident

The determination of the tornado wind and tornado missile loads action on the HSM are detailed in Section 3.2.2.

K.11.2.3.2 Accident Analysis

An evaluation of the HSM and transfer cask with respect to tornado winds and tornado missiles is presented in Section 8.2.2. Changes to this analysis, as a result of the addition of the NUHOMS®-61BT DSC, are presented in Section K.3.7.2. The analysis presented in Section 8.2.2 is bounding.

K.11.2.3.3 Accident Dose Calculations

The NUHOMS®-61BT DSC is designed and tested as a leak-tight containment boundary. Tornado wind and tornado missiles do not breach the containment boundary. Therefore there is no increase in site boundary dose due to this accident event.

K.11.2.3.4 Corrective Actions

No change.

K.11.2.4 Flood

This event is described in Section 8.2.4.

K.11.2.4.1 Cause of Accident

No change.

K.11.2.4.2 Accident Analysis

The HSM is evaluated for flooding in Section 8.2.4. This evaluation is bounding for the NUHOMS®-61BT DSC as described in Section K.3.7.4.1. The evaluation of the NUHOMS®-61BT DSC due to the design basis flood is presented in Section K.3.7.4.1. The canister is designed and tested to be leak tight. The stresses in the canister due to the design basis flood are well below the allowable stresses for Service Level C of the ASME Code Subsection NB [11.5]. Therefore, the NUHOMS®-61BT DSC will withstand the design basis flood without breach of the confinement boundary.

K.11.2.4.3 Accident Dose Calculations

The radiation dose due to flooding of the HSM is negligible. The NUHOMS®-61BT DSC is designed and tested as a leak-tight containment boundary. Flooding does not breach the containment boundary. Therefore radioactive material inside the DSC will remain sealed in the DSC and, therefore, will not contaminate the encroaching flood water.

K.11.2.4.4 Corrective Actions

No change.

K.11.2.5 Accidental TC Drop

This event is described in Section 8.2.5.

K.11.2.5.1 Cause of Accident

See Section K.3.7.5.1.

K.11.2.5.2 Accident Analysis

The evaluation of the DSC, basket and the transfer cask is presented in Section K.3.7.5. As shown in Section K.3.7.5, the DSC, basket and transfer cask stress intensities are within the appropriate ASME Code Service Level D allowable limits and maintain their structural integrity.

For the case of a liquid neutron shield, a complete loss of neutron shield was evaluated at the 100°F ambient condition with full solar load. It is conservatively assumed that the neutron shield jacket is still present but all the liquid is lost. The maximum DSC shell temperature is 378°F. The maximum cask inner shell, cask outer shell, and cask neutron shield jacket temperatures are bounded by analyses presented in Section 8.1.3.3 which are 393°F, 384°F and 238°F respectively. The DSC shell temperatures and hence fuel cladding temperature are bounded by the HSM plugged vent case shown in Table K.4-1. Accident thermal conditions, such as loss of the liquid neutron shield, need not be considered in the load combination evaluation. Rather the peak stresses resulting from the accident thermal conditions must be less than the allowable fatigue stress limit for 10 cycles from the appropriate fatigue design curves in Appendix I of the ASME Code. Similar analyses of other NUHOMS® transfer casks have shown that fatigue is not a concern. Therefore, these stresses in a transfer cask with a liquid neutron shield need not be evaluated for the accident condition.

K.11.2.5.3 Accident Dose Calculations for Loss of Neutron Shield

The postulated accident condition for the onsite transfer cask assumes that after a drop event, the water in the neutron shield is lost and any damaged fuel rods (seven damaged rods are permitted in each of 16 damaged fuel assemblies) collect at the bottom of the DSC. The loss of neutron shield is modeled using the four normal operations models (one for each source) described in Section K.5.4 modified by replacing the neutron shield with air. A fifth model is then used to estimate the contribution from the damaged rods at the bottom of the DSC.

The damaged rod source includes the total neutron and gamma sources per assembly (refer to Section K.5.2), multiplied by 16 failed assemblies per DSC and by 7/47 to account for the fraction of failed rods (7 damaged rods per 47 total fuel rods). The result is then multiplied by the maximum axial peaking factors from Table K.5-18. This source is then smeared into a ring source defined by I-interval 22 and J-interval 59 (bottom of DSC, between fuel and shell, See Figure K.5-11). This source volume is 1.69 cm tall with inner and outer radii of 84.05 cm and 84.15 cm, respectively. The resulting source volume is 89.25 cm^3. The neutron and gamma sources are shown in Table K.11-2 and Table K.11-3.

The accident condition dose rates are summarized in Table K.11-4 and Figure K.11-1. As can be clearly seen in Figure K.11-1, the ring of damaged fuel at the bottom of the DSC produces a significant spike in the cask surface dose rates.

A comparison of the results in Table K.11-4 and Table K.5-4, demonstrates a cask surface contact dose rate increase from 1160 mrem/hr to 6160 mrem/hr. The cask surface bottom dose rate increases from 2540 mrem/hr to 6820 mrem/hr for the same condition. These dose rates are approximately 3.2 times those reported in Section 8.2.5.3.2. Therefore, one would expect that the additional dose rate to an average on-site worker at an average distance of fifteen feet would also increase from 310 mrem/hr to 1000 mrem/hr. Similarly the exposure to off-site individuals at a distance of 2000 feet would also be expected to increase from 0.04 mrem for an assumed eight hour exposure to 0.13 mrem. This exposure is still well within the limits of 10CFR72 for an accident condition.

K.11.2.5.4 Corrective Action

No change.

K.11.2.6 Lightning

No change. The evaluation presented in Section 8.2.6 is not affected by the addition of the NUHOMS®-61BT DSC to the NUHOMS® system.

K.11.2.7 Blockage of Air Inlet and Outlet Openings

This accident conservatively postulates the complete blockage of the HSM ventilation air inlet and outlet openings on the HSM side walls, as described in Section 8.2.7.

K.11.2.7.1 Cause of Accident

No change.

K.11.2.7.2 Accident Analysis

This event is evaluated in Section 8.2.7.2. The section below describes the additional analyses performed to demonstrate the acceptability of the system with the NUHOMS®-61BT DSC. The thermal evaluation of this event is presented in Section K.4.6. The temperatures presented in Section K.4.6 are used in the structural evaluation of this event, which is presented in Sections K.3.7.7 and K3.4.4.3.

K.11.2.7.3 Accident Dose Calculations

There are no off-site dose consequences as a result of this accident. The only significant dose increase is that related to the recovery operation. This is bounded by the evaluation of the NUHOMS® system with the 24P canister, as described in Section 8.2.7.3.

K.11.2.7.4 Corrective Action

No change.

K.11.2.8 DSC Leakage

The NUHOMS®-61BT DSC is designed as a pressure retaining containment boundary to prevent leakage of contaminated materials. The analyses of normal, off-normal, and accident conditions have shown that no credible conditions can breach the DSC shell or fail the double seal welds at each end of the DSC. The NUHOMS®-61BT DSC is designed and tested to be leak tight. Therefore DSC leakage is not considered a credible accident scenario. See Section K.7.3.

K.11.2.9 Accident Pressurization of DSC

K.11.2.9.1 Cause of Accident

The bounding internal pressurization of the NUHOMS®-61BT DSC is postulated to result from cladding failure of the spent fuel in combination with the blocked inlet and outlet vents and the consequent release of spent fuel rod fill gas and free fission gas. The evaluation conservatively assumes that 100% of the fuel rods have failed.

K.11.2.9.2 Accident Analysis

The pressure due to this case is evaluated in Section K.4.6. The maximum pressure calculated is 46 psig. The accident pressure is conservatively assumed to be 65 psig in the structural load combinations presented in Table K.3.7-15 (UL-8, HSM-5, HSM-6).

K.11.2.9.3 Accident Dose Calculations

There is no increase in dose rates as a result of this event.

K.11.2.9.4 Corrective Actions

This is a hypothetical event. Therefore no corrective actions are required. The canister is designed to withstand the pressure as a Level D condition. There will be no structural damage to the canister or leakage of radioactive material as a result of this event.

K.11.2.10 Fire and Explosion

K.11.2.10.1 Cause of the Accident

Combustible materials will not normally be stored at an ISFSI. Therefore, a credible fire would be very small and of short duration such as that due to a fire or explosion from a vehicle or portable crane.

However, a hypothetical fire accident is evaluated for the NUHOMS®-61BT system based on a fuel fire. The source of fuel is postulated to be from a ruptured fuel tank of the transfer cask transporter tow vehicle. The bounding capacity of the fuel tank is 300 gallons and the bounding hypothetical fire is an engulfing fire around the transfer cask. Direct engulfment of the HSM is

highly unlikely. Any fire within the ISFSI boundary while the DSC is in the HSM would be bounded by the fire during transfer cask movement. The HSM concrete acts as a significant insulating fire wall to protect the 61BT-DSC from the high temperatures of the fire.

K.11.2.10.2 Accident Analysis

The evaluation of the hypothetical fire event is presented in Section K.4.6.5. The fire thermal evaluation is performed primarily to demonstrate the confinement integrity and fuel retrievability of the 61BT-DSC. This is assured by demonstrating that the DSC temperatures and internal pressures will not exceed those of the blocked vent condition (see Section K.11.2.7) during the fire scenario. Peak temperatures for the NUHOMS®-61BT system components are summarized in Table K.4-6.

K.11.2.10.3 Accident Dose Calculations

The 61BT-DSC confinement boundary will not be breached as a result of the postulated fire/explosion scenario. Accordingly, no 61BT-DSC damage or release of radioactivity is postulated. Because no radioactivity is released, no resultant dose increase is associated with this event.

The fire scenario may result in the loss of cask neutron shielding should the fire occur while the 61BT-DSC is in the cask. The effect of loss of the neutron shielding due to a fire is bounded by that resulting from a cask drop scenario. See Section K.11.2.5.3 for evaluation of the dose consequences of a cask drop.

K.11.2.10.4 Corrective Actions

Evaluation of HSM or cask neutron shield damage as a result of a fire is to be performed to assess the need for temporary shielding (for HSM or cask, if fire occurs during transfer operations) and repairs to restore the transfer cask and HSM to pre-fire design conditions.

K.11.3 References

11.1 American Nuclear Society, ANSI/ANS-57.9, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), 1992.

11.2 ANSI N14.5-1997, "Leakage Tests on Packages for Shipment," February 1998.

11.3 NUREG-1536, "Standard Review Plan for dry Storage Casks, Final Report," US Nuclear Regulatory Commission, January 1997.

11.4 ISG-5, Rev. 1, Confinement Evaluation.

11.5 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, 1998 including 1999 addenda.

Table K.11-1
Comparison of Total Dose Rates for HSM with and without Adjacent HSM Shielding Effects

Distance from Nearest HSM Wall, 2x10 Array (meters)	Normal Case Dose Rate(1) (mrem/hr)	Accident Case Dose Rate(1) (mrem/hr)
10	33	66
100	0.57	1.1
500	3.8×10^{-3}	7.6×10^{-3}
600	1.2×10^{-3}	2.4×10^{-3}

(1) Air scattered plus direct radiation

Table K.11-2
Cask Accident Neutron Source

Group	Total (n/s/cc)	Total (n/s/assy)	Damaged (n/s/cc)
1	1.349E-01	1.791E+04	7.543E+02
2	1.147E+00	1.523E+05	6.413E+03
3	3.155E+00	4.188E+05	1.764E+04
4	1.573E+01	2.088E+06	8.793E+04
5	3.983E+01	5.287E+06	2.227E+05
6	5.267E+01	6.992E+06	2.945E+05
7	1.322E+02	1.755E+07	7.393E+05
8	1.082E+02	1.437E+07	6.053E+05
9	2.646E+01	3.512E+06	1.479E+05
10	1.366E+02	1.814E+07	7.639E+05
11	2.435E+02	3.232E+07	1.361E+06
12	2.159E+02	2.865E+07	1.207E+06
13	9.946E+01	1.320E+07	5.561E+05
14	4.285E-03	5.688E+02	2.396E+01
15	0.000E+00	0.000E+00	0.000E+00
16	0.000E+00	0.000E+00	0.000E+00
17	0.000E+00	0.000E+00	0.000E+00
18	0.000E+00	0.000E+00	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00

Table K.11-3
Cask Accident Gamma Source

Group	Total (g/s/assy)	Damaged (g/s/cc)
23	5.468E+04	1.788E+03
24	3.436E+05	1.123E+04
25	1.989E+06	6.504E+04
26	2.270E+06	7.421E+04
27	3.386E+09	1.107E+08
28	2.634E+10	8.611E+08
29	6.823E+11	2.231E+10
30	9.039E+11	2.955E+10
31	2.271E+13	7.423E+11
32	5.258E+13	1.719E+12
33	1.204E+14	3.936E+12
34	3.675E+14	1.201E+13
35	5.616E+14	1.836E+13
36	2.527E+13	8.262E+11
37	3.143E+13	1.028E+12
38	8.737E+13	2.856E+12
39	1.386E+14	4.532E+12
40	7.591E+14	2.482E+13

Table K.11-4
Cask Accident Dose Rate Results

	Cask Surface		
	Side (mrem/hr)	Top (mrem/hr)	Bottom (mrem/hr)
Neutron	3.70E+03	2.06E+01	7.69E+02
Gamma	4.82E+03	1.26E+02	6.70E+03
Total	6.16E+03	1.32E+02	6.82E+03
	1-Meter from Cask Surface		
	Side (mrem/hr)	Top (mrem/hr)	Bottom (mrem/hr)
Neutron	1.14E+03	6.44E+00	9.22E+01
Gamma	1.14E+03	2.06E+01	1.09E+03
Total	1.75E+03	2.53E+01	1.13E+03
	2-Meters from Cask Surface		
	Side (mrem/hr)	Top (mrem/hr)	Bottom (mrem/hr)
Neutron	5.47E+02	3.49E+00	3.30E+01
Gamma	6.29E+02	9.81E+00	6.02E+02
Total	1.05E+03	1.29E+01	6.34E+02

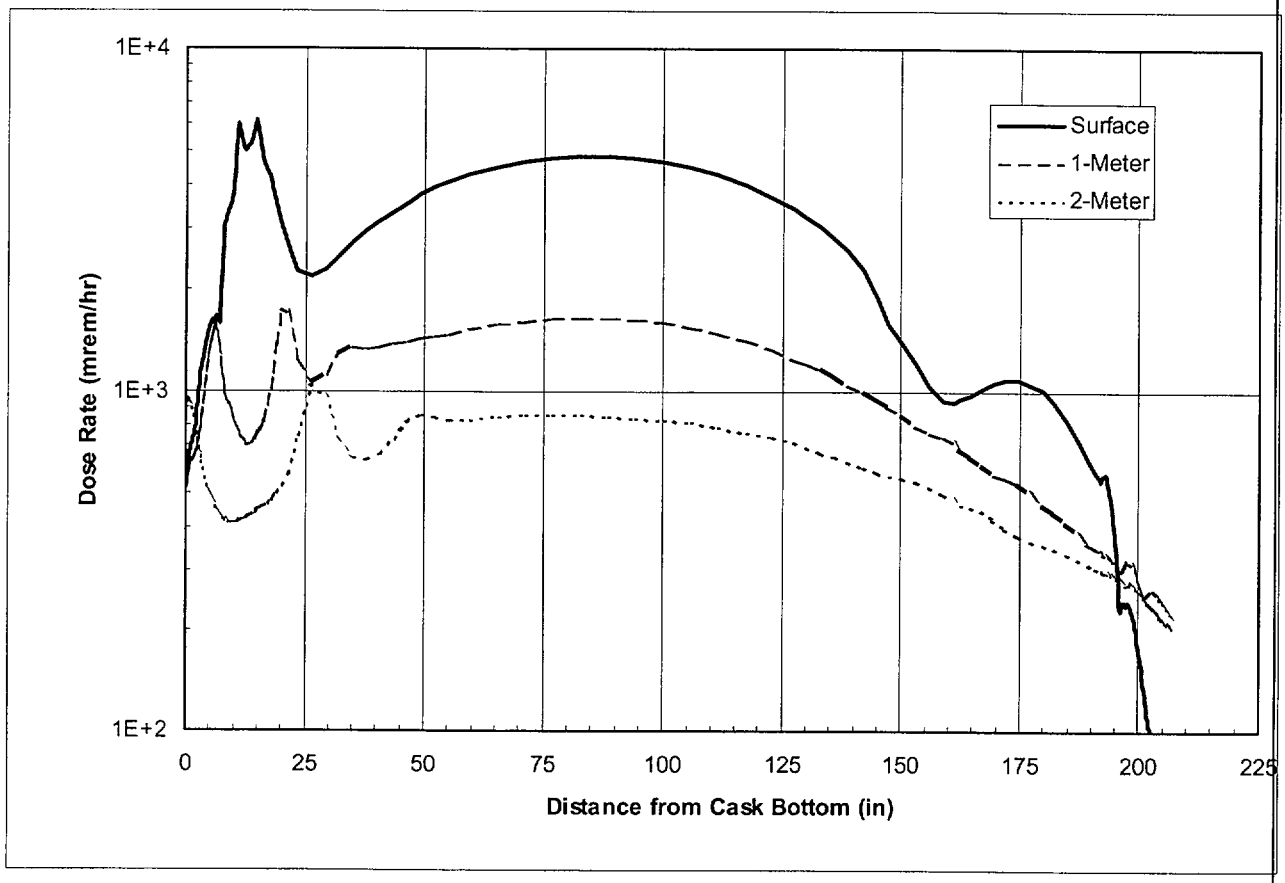


Figure K.11-1
Cask Accident Dose Rate Distribution

K.12 Conditions for Cask Use - Operating Controls and Limits or Technical Specifications

The Technical Specifications changes, due to the addition of 61BT DSC to the NUHOMS® system, are included in Attachment A to NUHOMS® CoC 1004 Amendment Number 3.

K.13 Quality Assurance

Chapter 11.0 provides a description of the Quality Assurance Program to be applied to the safety related and important to safety activities associated with the standardized NUHOMS® system. The addition of 61BT DSC to the NUHOMS® system requires the following clarification to the contents of Section 11.2:

> "In lieu of the requirements listed in paragraph A through H, Category A items may also be procured as commercial grade items and dedicated by in accordance with the guidelines of EPRI NP-5652."

K.14 Decommissioning

There is no change from the decommissioning evaluation presented in Section 9.6 due to the addition of 61BT DSC to the NUHOMS® system.

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L.1 General Discussion

Appendix L addresses the addition of the transportable 24PT2 DSC to the NUHOMS® system. The NUHOMS®-24PT2 series consists of the 24PT2S and the 24PT2L DSCs. The 24PT2S DSC has a cavity length similar to the standardized NUHOMS® 24P DSC, and is designed to store 24 PWR fuel assemblies without control components. The 24PT2L DSC has a cavity length similar to the long cavity 24P DSC and is designed to store 24 PWR fuel assemblies with or without Burnable Poison Rod Assemblies (BPRAs). The fuel assembly and BPRA types are the same as the NUHOMS® 24P DSC. The 24PT2S and 24PT2L DSCs utilize a NUHOMS® Transfer Cask (TC) for transfer operations and the NUHOMS® Horizontal Storage Module (HSM) for storage. The format of this Appendix follows the guidance provided in NRC Regulatory Guide 3.61 [1.1].

The NUHOMS®-24PT2 system provides confinement, shielding, criticality control and passive heat removal independent of any other facility structures or components. The NUHOMS®-24PT2 DSC also maintains structural integrity of the fuel during storage.

L.1.1 Introduction

The NUHOMS® system provides a modular canister based spent fuel storage and transport system. The system includes DSCs, HSMs and the TC.

This Appendix adds the 24PT2 DSCs to the NUHOMS® system. Only those features that are being revised or added to the NUHOMS® system are addressed and evaluated in this Appendix. Sections of this Appendix which are not affected by the addition of 24PT2 DSCs are indicated in this Appendix with "No Change." The HSM and TC remains unchanged.

The NUHOMS®-24PT2S and 24PT2L DSC shell assemblies are similar to the existing DSCs; however the basket assembly has the following design improvements required for transportation:

- Increase number of spacer discs (26 for the 24PT2 versus 8 for the 24P)
- Spacer disc thickness changed to 1.25" from 2.00" thick for the 24P
- Spacer disc material changed to SA 533 Grade B, Class 1 instead of SA 516 Grade 70 to accommodate the higher basket temperatures.
- The support rod assemblies design consist of pre-tensioned 2" diameter high strength stainless steel rods and 3" diameter spacer sleeves versus welded rod to spacer disc design in the 24P.
- Guide sleeves and oversleeves that support borated neutron absorber sheets.

The NUHOMS®-24PT2 DSC is designed to store 24 intact (PWR) fuel assemblies with or without BPRAs and meet the requirements of Fuel Specification 1.2.1 of NUHOMS® Certificate of Compliance (CoC) Number 1004 [1.4].

L.1.2 General Description of the NUHOMS®-24PT2 DSC

L.1.2.1 NUHOMS®-24PT2 DSC Characteristics

Each NUHOMS®-24PT2 DSC consists of a fuel basket and a canister body (shell, canister inner bottom and top cover plates and shield plugs). A sketch of the 24PT2 DSC is shown in Figure L.1-1. A set of licensing drawings is presented in Section L.1.5. Dimensions and the estimated weight of the NUHOMS®-24PT2 DSC are shown in Table L.1-1. The NUHOMS®-24PT2 DSC shell assembly including material, geometry and dimensions are nearly identical to the NUHOMS®-24P DSC design. The materials used to fabricate the DSC are shown in the Parts List on Drawings NUH-03-1070 and NUH-03-1071, included in Section L.1.5.

The NUHOMS®-24PT2 DSC basket assembly is a non-pressure retaining component housed within each DSC. The 24PT2 DSC basket assembly uses twenty-six (26) spacer discs to maintain fuel position within the DSC. Each disc has twenty-four (24) square cut-outs; one for each fuel assembly. Each cut-out is large enough to house a guide sleeve assembly that includes either two or four Boral™ poison sheets. Axial position of the discs is maintained by preloaded spacer sleeves. There are four (4) support rod/spacer sleeve locations around the periphery of each disc. The spacer sleeves are preloaded by continuous support rods which span the full length of the basket assembly within the spacer sleeves and discs.

The DSC internal basket assembly can be utilized to store various types of spent fuel assemblies. As discussed in Section 3.1.1, the physical parameters selected for this generic analysis conservatively envelops those of other fuel assembly types. The weight of each spent fuel assembly is transferred to the spacer discs by the guide sleeves for any load applied perpendicular to the DSC axis.

During dry storage of the spent fuel in the NUHOMS®-24PT2 System, no active systems are required for the removal and dissipation of the decay heat from the fuel. The NUHOMS®-24PT2 DSC is designed to transfer the decay heat from the fuel to the basket, from the basket to the canister body and ultimately to the ambient via HSM or Transfer Cask.

Each canister is identified by a Mark Number, NUHOMS®-24PT2 DSC -XX, Type Y. where XX is a sequential number corresponding to a specific canister, and Y refers to the basket type. Each canister is also marked with the patent number.

L.1.2.2 Operational Features

L.1.2.2.1 General Features

The NUHOMS®-24PT2 DSC is designed to safely store 24 standard PWR fuel assemblies with or without control components. The NUHOMS®-24PT2 DSC is designed to maintain the fuel cladding temperature below 700°F (371°C) during storage. It is also designed to maintain the fuel cladding temperature below 1058°F (570°C) during short-term accident conditions, short-term off-normal conditions and fuel transfer operations (see Section L.4).

The criticality control features of the NUHOMS®-24PT2 DSC are designed to maintain the neutron multiplication factor k-effective less than 0.95 minus benchmarking bias and modeling bias under all conditions.

L.1.2.2.2 Sequence of Operations

The sequence of operations to be performed in loading fuel into the NUHOMS®-24PT2 DSC is presented in Section L.8.

L.1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

L.1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry and by utilizing fuel pool borated water in the fuel basket. No credit under 10CFR72 [1.2] is taken for the Boral™ in the guide sleeve assembly. These features are only necessary during the loading and unloading operations that occur in the loading pool (underwater). During storage, with the DSC cavity dry and sealed from the environment, criticality control measures within the installation are not necessary because of the low reactivity of the fuel in the dry NUHOMS®-24PT2 DSC and the assurance that no water can enter the DSC cavity during storage.

L.1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the NUHOMS®-24PT2 System.

L.1.2.2.3.3 Operation Shutdown Modes

The NUHOMS®-24PT2 DSC is a totally passive system so that consideration of operation shutdown modes is unnecessary.

L.1.2.2.3.4 Instrumentation

No change.

L.1.2.2.3.5 Maintenance Techniques

No change.

L.1.2.3 Cask Contents

The NUHOMS®-24PT2 DSC is designed to store 24 standard Pressurized Water Reactor (PWR) fuel assemblies. The NUHOMS®-24PT2 DSC is designed for a maximum heat load of 24.0 kW or 1.0 kW/assembly. The fuel which may be stored in the NUHOMS®-24PT2 DSC is discussed in Section L.2.1.

Section L.5 provides the shielding analysis. Section L.6 covers the criticality safety of the NUHOMS®-24PT2 DSC and its contents, listing material densities, moderator ratios, and geometric configurations.

L.1.3 Identification of Agents and Contractors

Transnuclear West, Inc. (TNW), provides the design, analysis, licensing support and quality assurance for the NUHOMS®-24PT2 System. Fabrication of the NUHOMS®-24PT2 System cask is done by one or more qualified fabricators under TNW's quality assurance program. TNW's quality assurance program is described in Section L.13. This program is written to satisfy the requirements of Subpart G of 10CFR72, [1.2] and covers control of design, procurement, fabrication, inspection, testing, operations and corrective action. Experienced TNW operations personnel provide training to utility personnel prior to first use of the NUHOMS®-24PT2 System and prepare generic operating procedures.

Managerial and administrative controls, which are used to ensure safe operation of the casks, are provided by the host utility. NUHOMS®-24PT2 System operations and maintenance are performed by utility personnel. Decommissioning activities will be performed by utility personnel in accordance with site procedures.

Transnuclear West, Inc. provides specialized services for the nuclear fuel cycle that support transportation, storage and handling of spent nuclear fuel, radioactive waste and other radioactive materials. TNW is the holder of NUHOMS® CoC 1004 [1.4].

L.1.4 Generic Cask Arrays

No change.

L.1.5. Supplemental Data

The following Transnuclear West drawings are enclosed:

1. General License NUHOMS® 24PT2S-DSC Main Assembly, Drawing NUH-03-1070NP-SAR.

2. General License NUHOMS® 24PT2L-DSC Main Assembly, Drawing NUH-03-1071NP-SAR.

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,750,269 & 5,436,597
Transnuclear, Inc.

TRANSNUCLEAR WEST

GENERAL LICENSE
NUHOMS®24PT2S-DSC
MAIN ASSEMBLY

NUH-03-1070NP-SAR

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,439,597
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®24PT2S-DSC
MAIN ASSEMBLY

DWG. NO. NUH-03-1070NP-SAR | SCALE NONE | SHEET 2 OF 4 | REV. NO. 0

Security-Related Information Figure
Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT TRT AND ALL TOLERANCES APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994.

BREAK AND DEBURR ALL SHARP EDGES

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

SAR

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®24PT2S-DSC
MAIN ASSEMBLY

DWG NO NUH-03-107CNP-SAR | SCALE NONE | SHEET 3 OF 4 | REV NO 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS® 24PT2S-DSC
MAIN ASSEMBLY

NUH-03-1070NP-SAR

SCALE NONE | SHEET 4 OF 4 | REV. NO. 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCING APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IS ACCORDANCE WITH ASME Y14.5M-1994.

BREAK AND DEBURR ALL SHARP EDGES

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®24PT2L-DSC
MAIN ASSEMBLY

DWG. NO. NUH-03-1071NP-SAR | SCALE NONE | SHEET 1 OF 4 | REV. NO. 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AS 70°F AND ALL TOLERANCES APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994.

BREAK AND DEBURR ALL SHARP EDGES

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

TITLE: SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®-24PT2L-DSC
MAIN ASSEMBLY

DWG NO	SCALE	SHEET	REV NO
NUH-03-1071NP-SAR	NONE	2 OF 4	0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

ALL DIMENSIONS ARE APPLICABLE AT 70°F AND ALL TOLERANCES APPLIES AFTER WELDING AND FINAL MACHINING UNLESS NOTED OTHERWISE.

DIMENSIONS ARE IN INCHES AND DEGREES UNLESS NOTED OTHERWISE. DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994.

BREAK AND DEBURR ALL SHARP EDGES

3rd ANGLE PROJECTION

DO NOT SCALE DRAWING

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT

GENERAL LICENSE
NUHOMS®24PT2L-DSC
MAIN ASSEMBLY

DWG NO. NU3-4-03-1071NP-SAR | SHEET NONE | SHEET 3 OF 4 | REV 0

Security-Related Information Figure Withheld Under 10 CFR 2.390.

U.S. Patent No. 4,780,269 & 5,438,597
Transnuclear, Inc.

TRANSNUCLEAR WEST

SAFETY ANALYSIS REPORT
GENERAL LICENSE
NUHOMS®24PT2L-DSC
MAIN ASSEMBLY

NUH-03-1071NP-SAR | NONE | 4 OF 4 | 0

L.1.6 References

1.1 US Nuclear Regulatory Commission, Regulatory Guide 3.61, Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask, February, 1989.

1.2 10CFR72, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

1.3 10CFR71, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Packaging and Transportation of Radioactive Material."

1.4 NUHOMS® Certificate of Compliance for Dry Spent Fuel Storage Casks, Certificate Number 1004, Amendment No. 3, September 2001 (Docket 72-1004).

Table L.1-1
Nominal Dimensions and Weight of the NUHOMS®-24PT2 DSC

	24PT2S	24PT2L
Overall length (with grapple, in)	189.95	189.95
Outside diameter (in)	67.19	67.19
Cavity diameter (in)	65.94	65.94
Cavity length (in)	167.0	173.0
Nominal DSC weight (kips)	84.3	82.0
Loaded on storage pad (kips)	328.0(1)	328.0(1)

Note 1: Based on a bounding weight of 85.0 kips for the DSC and 243.0 kips for the HSM.

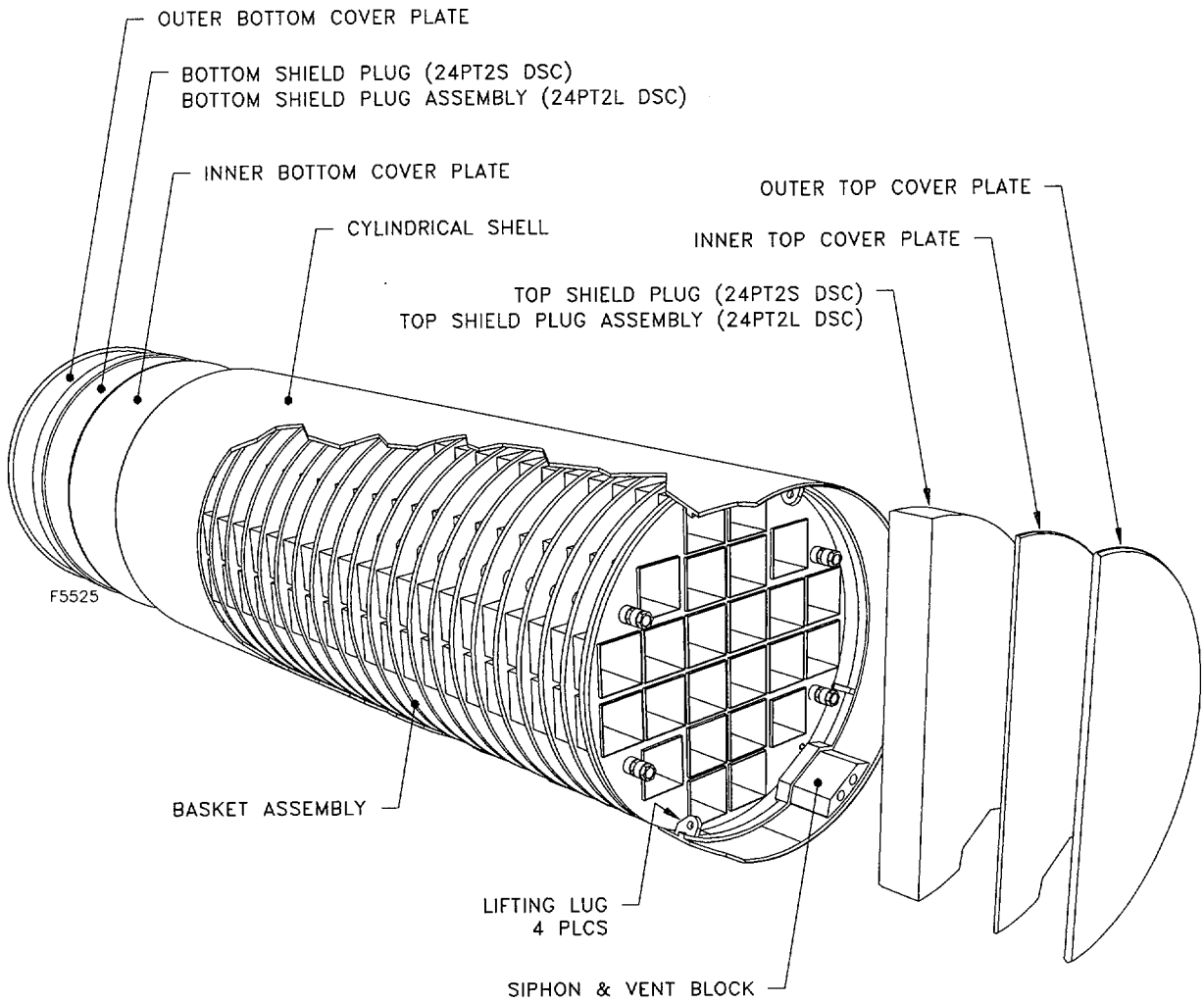

Figure L.1-1
NUHOMS®-24PT2 DSC Components

L.2 Principal Design Criteria

This section provides the principal design criteria for the NUHOMS®-24PT2 System. The NUHOMS®-24PT2 Dry Shielded Canister (DSC) is handled, transferred and stored in the same manner as the existing NUHOMS®-24P DSC. The principal design criteria for the NUHOMS®-24PT2 DSC are the same as the NUHOMS®-24P DSC as described in Chapter 3. Section L.2.1 presents a general description of the spent fuel to be stored. Section L.2.2 provides the design criteria for environmental conditions and natural phenomena. Section L.2.3 provides a description of the systems which have been designated as important to safety. Section L.2.4 discusses decommissioning considerations. Section L.2.5 summarizes the NUHOMS®-24PT2 DSC design criteria.

L.2.1 Spent Fuel To Be Stored

The NUHOMS®-24PT2S and -24PT2L DSCs are designed to store a total of 24 PWR fuel assemblies and BPRAs with the same characteristics as those described for the NUHOMS®-24P DSC in Chapter 3.

L.2.1.1 General Operating Functions

No change.

L.2.2 Design Criteria for Environmental Conditions and Natural Phenomena

The NUHOMS®-24PT2 DSC is handled and stored in the same manner as the existing NUHOMS®-24P System. The environmental conditions, natural phenomena and design criteria are the same as described for the NUHOMS®-24P DSC in Chapter 3. Design criteria for the NUHOMS® HSM and Transfer Cask remain unchanged.

L.2.2.1 Tornado Wind and Tornado Missiles

No change.

L.2.2.2 Water Level (Flood) Design

No change.

L.2.2.3 Seismic Design

No change.

L.2.2.4 Snow and Ice Loading

No change.

L.2.2.5 Combined Load Criteria

No change.

L.2.3 Safety Protection Systems

L.2.3.1 General

The NUHOMS®-24PT2 DSC is designed to provide storage of spent fuel for at least 40 years. The cask cavity pressure is always above atmospheric during the storage period as a precaution against the in-leakage of air which could be harmful to the fuel.

Safety protection systems for the NUHOMS®-24PT2 DSC are the same as those for the NUHOMS®-24P DSC as addressed in Chapter 3, except as listed below in the following sections. Components of the NUHOMS®-24PT2 DSC that are "Important to Safety" are listed in Table 3.4-1. Components of the NUHOMS®-24PT2 DSC that are "Not Important to Safety" are the same as those for the NUHOMS®-24P DSC as listed in Table 3.4-1.

L.2.3.2 Protection By Multiple Confinement Barriers and Systems

No change.

L.2.3.3 Protection By Equipment and Instrumentation Selection

No change.

L.2.3.4 Nuclear Criticality Safety

L.2.3.4.1 Control Methods for Prevention of Criticality

No change. However, one important difference between the 24PT2S/24PT2L and the 24P/long cavity 24P canister designs is the fixed poison sheets (Boral®) in the 24PT2S/24PT2L canisters. No credit is taken in the 10CFR72 (storage) criticality evaluation for the fixed poison. The poison plates are conservatively modeled as pure aluminum. This is very conservative and ensures that only canister geometry and soluble boron are credited in the criticality analysis consistent with the licensing basis for the standard 24P and the long cavity 24P DSC designs. The criticality analyses are described in Section L.6.

L.2.3.4.2 Error Contingency Criteria

No change.

L.2.3.4.3 Verification Analysis-Benchmarking

No change.

L.2.3.5 Radiological Protection

No change.

L.2.3.6 Fire and Explosion Protection

No change.

L.2.4 Decommissioning Considerations

No change.

L.2.5 Summary of NUHOMS®-24PT2 DSC Design Criteria

The principal design criteria for the NUHOMS®-24PT2 DSC are the same as those presented for the NUHOMS®-24P DSC in Chapter 3. The NUHOMS®-24PT2 DSC is designed to store the same PWR fuel assemblies and BPRAs as those for the NUHOMS®-24P DSC as described in Chapter 3.

L.3 Structural Evaluation

L.3.1 Structural Design

L.3.1.1 Discussion

This section describes the structural evaluation of the NUHOMS®-24PT2S and NUHOMS®-24PT2L system. The NUHOMS®-24PT2S and NUHOMS®–24PT2L system consists of the NUHOMS® HSM, the transfer cask, the 24PT2S and 24PT2L DSC shell assemblies and the 24PT2S and 24PT2L basket assemblies. Where the new components have an effect on the structural evaluation presented in Chapters 3 and 8, the changes are included in this section, otherwise they are identified as "No Change."

The 24PT2S and 24PT2L DSC shell assemblies are shown on drawings NUH-03-1070 and NUH-03-1071 in Section L.1.5. The 24PT2S and 24PT2L DSC shell assembly designs are essentially the same as the 24P standard length and long cavity DSC shell assemblies, respectively, which are described in Chapter 4. Materials and component geometric dimensions of the 24PT2S and 24PT2L DSC shell assemblies are identical to the 24P DSC shell assemblies. To obtain an increase in internal cavity length, the 24PT2L and 24P long cavity designs utilize shield plugs that are a composite of lead and steel. Minor but not structurally significant differences exist between the 24PT2L and 24P long cavity shield plug designs.

The NUHOMS®-24PT2S and NUHOMS®–24PT2L basket assemblies are similar to the 24P standard length and long cavity DSC basket assemblies, respectively. The 24PT2 designs differ from the 24P designs as follows:

- Increased number of spacer discs (26 vs. 8) with smaller thickness, and constructed from SA 533 Grade B, Class 1 (as compared to SA-516 Grade 70 in 24P DSC)
- Narrower spacer disc ligament widths due to the presence of Boral® poison sheets
- Support rod assemblies (with spacer sleeves) which are smaller in diameter but are constructed from higher strength steel. The nominal span length between spacer discs is reduced from 21.1 in. to 6.75 in.
- The support rod assemblies are pretensioned instead of being welded to the individual spacer discs. The pretensioned design is the same as the 52B DSC support rod assemblies.

L.3.1.2 Design Criteria

Design criteria for this section are the same as those presented for the NUHOMS®-24P DSC in Chapter 3.

L.3.1.2.1 DSC Confinement Boundary

Same as Section 3.3.2.

L.3.1.2.2 ASME Code Exceptions for the 24PT2 DSC

No change to the Code exceptions presented in Section 4.8.

L.3.2 Weights

Table L.3.2-1 and Table L.3.2-2 show the weights of the various components of the NUHOMS®-24PT2S and 24PT2L system including basket, DSC, standard HSM, standardized Transfer Cask and OS197 transfer cask. The dead weights of the components are determined based on the nominal dimensions.

Table L.3.2-1
Summary of the NUHOMS®-24PT2S System Component Weights

	Component Description	Calculated Weight (Pounds)
1.	Dry Shielded Canister Shell Assembly	15,778
2.	DSC Top Shield Plug	7,859
3.	DSC Internal Basket Assembly	18,380
4.	DSC Inner and Outer Top Cover Plates	1,934
5.	24 PWR Spent Fuel Assemblies	≤40,368(4)
6.	Weight of Water in DSC Cavity	13,110
	Total Wet DSC Loaded Weight (w/o DSC inner and outer top cover plates.)	95,495
	Total Dry DSC Loaded Weight (w/ DSC inner and outer top cover plates.)	84,319
7.	Standardized Transfer Cask Empty Weight	107,091(1)(3)
8.	Standardized Transfer Cask Max. Loaded Weight	198,099(2)(5)
9.	HSM Single Module Weight (empty)	243,000

(1) Includes weight of cask top cover plate assembly.

(2) Weight includes: DSC dry weight plus fuel, plus water in DSC and cask less DSC and cask top cover plate assemblies.

(3) The as-built empty weight for the OS197 transfer cask is 111,250 lbs, including neutron shield water.

(4) The standard design DSC fuel assembly weight of 1,682 lbs/assembly is used.

(5) The maximum loaded weight for the OS197 transfer cask without DSC and OS197 top cover plates is 203,829 lbs (199,249 lbs without neutron shield water).

Table L.3.2-2
Summary of the NUHOMS®-24PT2L System Component Weights

Component Description	Calculated Weight (Pounds)
1. Dry Shielded Canister Shell Assembly	14,720
2. DSC Top Shield Plug	6,526
3. DSC Internal Basket Assembly	18,420
4. DSC Inner and Outer Top Cover Plates	1,934
5. 24 PWR Spent Fuel Assemblies	≤40,368[4]
6. Weight of Water in DSC Cavity	13,350
Total Wet DSC Loaded Weight (w/o DSC inner and outer top cover plates.)	93,384
Total Dry DSC Loaded Weight (w/ DSC inner and outer top cover plates.)	81,968
7. Standardized Transfer Cask Empty Weight	107,091[1][3]
8. Standardized Transfer Cask Max. Loaded Weight	195,988[2][5]
9. HSM Single Module Weight (empty)	243,000

(1) Includes weight of cask top cover plate assembly.

(2) Weight includes: DSC dry weight plus fuel, plus water in DSC and cask less DSC and cask top cover plate assemblies.

(3) The as-built empty weight for the OS197 transfer cask is 111,250 lbs, including neutron shield water.

(4) The standard design DSC fuel assembly weight of 1,682 lbs/assembly is used.

(5) The maximum loaded weight for the OS197 transfer cask without DSC and OS197 top cover plates is 201,969 lbs (197,389 lbs without neutron shield water).

L.3.3 Mechanical Properties of Materials

The mechanical properties of structural materials used in the NUHOMS®-24PT2 DSC shell and basket are in accordance with ASME Code Section III, Appendix I [3.1]. The materials used in the fabrication of the 24PT2 DSC shell assemblies are identical to those used in the 24P DSC shell assemblies. The material used in the fabrication of the 24PT2 DSC support rod assemblies is the same as that used in the 52B DSC support rod assemblies. Material properties for the shell and support rod assemblies are provided in Section 8.1. The properties for material used for the 24PT2 spacer discs are presented in Table L.3.6-1. Neutron absorber sheets used in the basket assembly are not relied upon structurally.

L.3.4 General Standards for 24PT2-DSC

L.3.4.1 Chemical and Galvanic Reactions

The materials of the NUHOMS® 24PT2-DSC shell and basket assemblies have been reviewed to determine whether chemical, galvanic or other reactions among the materials, contents and environment might occur during any phase of loading, unloading, handling or storage. This review is summarized below:

The 24PT2-DSC is exposed to the following environments:

- During loading and unloading, the canister is inside of the transfer cask. Thus, the exterior of the canister will not be exposed to pool water. The annulus between the transfer cask and canister is filled with demineralized water and is covered with an inflatable seal.

- The interior surfaces of the canister, top shield plug, and the basket will be exposed to (borated) pool water. The transfer cask and canister are kept in the spent fuel pool for only a short period of time, typically about 6 hours to load or unload fuel, and 2 hours to lift the loaded transfer cask/canister out of the spent fuel pool. An additional 12 to 24 hours is typically needed to decontaminate the cask and remove the water for vacuum drying of the Spent Fuel Assemblies (SFA's).

- The canister is thoroughly dried by a vacuum drying process before storage. It is then backfilled with helium, thus providing a non-corrosive environment. During storage, the interior of the canister is exposed only to the helium environment. The helium environment does not support chemical or galvanic reactions because both moisture and oxygen must be present for a reaction to occur.

- During storage, the exterior of the canister is protected by the concrete NUHOMS® HSM. The HSM is vented, so the exterior of the canister is exposed to the atmosphere. The canister is fabricated from austenitic stainless steel which is generally resistant to corrosion.

- The support steel component of the HSM that is in contact with the 24PT2-DSC is also stainless steel.

Materials used for the NUHOMS®-24PT2S and -24PT2L DSCs are shown in the Parts List of Drawings NUH-03-1070 and -1071, provided in Section L.1.5. The canister shell material is SA-240 Type 304 stainless steel. The 24PT2S top shield plug material is A36 carbon steel plated with an electroless nickel coating. The 24PT2S bottom shield plug is sealed within the shell and inner and outer bottom cover plates and thus it does not come in contact with the external environment. The 24PT2L shield plug assemblies consist of lead encased by welded A36 carbon steel plates (top plug) and SA-240 Type 304 stainless steel plates (bottom plug).

The basket assembly consists of SA-533 Grade B Class 1 carbon steel spacer discs which are coated with electroless nickel. The guide sleeve assemblies, which consist of guide sleeves,

oversleeves, and connecting shim plates are Type 304 stainless steel. Neutron absorber plates are constructed from Boral® plates and are sandwiched between the guide sleeves and oversleeves. Each guide sleeve assembly contains either two or four neutron absorber plates depending upon its location within the basket assembly. The oversleeves are welded to the guide sleeves. The neutron poison is not welded or bolted to the guide sleeve, but is held in place by the oversleeves and the shim plates. The support rod assemblies consist of SA-564 Type 630 stainless steel rod and spacer sleeves located between the spacer discs. The basket assembly is held in position by the nominal pretension force of 80 kips applied to each support rod during assembly.

Potential sources of chemical or galvanic reactions are the interaction between the carbon steel based spacer discs, the aluminum-based neutron poison and stainless steel within the basket and the pool water, and the interaction of the stainless steel top cover plates with the top carbon steel shield plugs.

Typical water chemistry in a PWR Spent Fuel pool applicable to the NUHOMS®-24PT2 DSC is the same as the NUHOMS®-24P DSC.

L.3.4.1.1 Behavior of Austenitic Stainless Steel in Borated Water

With the exception of the shield plugs, spacer discs, and neutron poison plates (carbon steel, carbon steel, and Boral®, respectively), all parts of the 24PT2-DSC are made from stainless steel. Stainless steel does not exhibit general corrosion when immersed in borated water.

Stress corrosion cracking in the stainless steel welds is also not expected to occur, since these welds are not highly stressed during normal operations. There may be some residual fabrication stresses as a result of welding of the stainless steel guide sleeves and fusion welds between the stainless steel plates of the guide sleeves and oversleeves. Of the corrosive agents that could initiate stress corrosion cracking in the stainless steel welds, only the combination of chloride ions with dissolved oxygen occurs in spent fuel pool water. Although stress corrosion cracking can take place at very low chloride concentrations and temperatures such as those in spent fuel pools (less than 10 ppb and 160°F, respectively), the effect of low chloride concentration and low temperature is to greatly increase the initiation time, that is, the period during which the corrodent is breaking down the passive oxide film on the stainless steel surface. Below 60°C (140°F), stress corrosion cracking of austenitic stainless steel does not occur at all. At 100°C (212°F), chloride concentration on the order of 15% is required to initiate stress corrosion cracking [3.6]. Thus, the combination of low chlorides, low temperature and short time of exposure to the corrosive environment eliminates the possibility of stress corrosion cracking in the guide sleeve welds.

L.3.4.1.2 Behavior of Boral® in Borated Water

Boral® is a material that has been used for many years as a neutron absorber in PWR spent fuel pools. It has shown multi-year durability. The use of this material as a poison inside the canister, where it will see an immersion for typically less than one or two days should not pose any problems either for the Boral® or for the associated DSC components [3.10].

L.3.4.1.3 Electroless Nickel Plated Carbon Steel

The carbon steel top shield plug and the spacer discs are plated with electroless nickel. This coating is similar to the coating used on the Standard NUHOMS® 52B canister. This coating has been evaluated for a PWR fuel pool environment for potential galvanic reactions in Transnuclear West's response to NRC Bulletin 96-04 [3.9]. The reported corrosion rates are insignificant in PWR pools, and will result in a negligible rate of reaction for the 24PT2-DSC systems.

L.3.4.1.4 Hydrogen Generation

During the initial passivation state, small amounts of hydrogen gas by the Boral® may be generated in the 24PT2-DSC. The passivation stage may occur prior to submersion into the spent fuel pool. Any amounts of hydrogen generated in the canister during loading/unloading operations due to interaction of Boral® and electroless nickel coating with PWR spent fuel water, will be insignificant, and will not result in a flammable gas mixture within the canister [3.10]. No hydrogen generation will occur from the other materials (i.e. stainless steel, and ferritic stainless steel).

L.3.4.1.5 Effect of Galvanic Reactions on the Performance of the System

There are no significant galvanic reactions that could reduce the overall integrity of the canister, or its contents, during storage.

There are no reactions that would cause binding of the mechanical surfaces or the fuel to guide sleeves due to galvanic or chemical reactions.

There is no significant degradation of any safety component caused directly by the effects of the reactions, or by the effects of the reactions combined with the effects of long-term exposure of the materials to neutron or gamma radiation, high temperatures, or other possible conditions.

L.3.4.2 Positive Closure

Positive closure is provided by the redundant closure welds for the 24PT2-DSC inner and outer top cover plates and the leak-tested shell assembly.

L.3.4.3 Lifting Devices

There are no permanent lifting devices used for lifting a loaded 24PT2-DSC (the loaded 24PT2-DSC is always inside a transfer/transportation cask during handling).

L.3.4.4 Increased Temperature Behavior

L.3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the 24PT2-DSC are described in Section L.4. Section L.4.4, Section L.4.5, and Section L.4.6 describe the thermal evaluations performed for normal, off-normal, and accident conditions, respectively. Section L.4.7 describes the thermal evaluations during fuel loading/unloading operations. Table L.4-12 provides the calculated temperatures for the various components during storage, transfer and vacuum drying operations, respectively. Section L.4.4.4 provides the maximum pressures during normal, off-normal and accident conditions which are used in the evaluations presented later in this Appendix.

L.3.4.4.2 Differential Thermal Expansion

Potential interference due to differential thermal expansion between the 24PT2-DSC shell assembly and the basket assembly components is evaluated in the longitudinal and radial directions of the 24PT2-DSC.

- In the radial direction, the gaps between the spacer discs and the inside of the 24PT2-DSC shell are evaluated for possible interference due to differential thermal expansion of the materials because of the differences in their coefficients of thermal expansion. The analyses show that when including the effect of fabrication tolerances, the radial gap between the spacer disc and the inside of the shell will close, but will not impose significant stresses in the 24PT2-DSC shell or the spacer disc.

- For the following interfaces, design clearances are established to ensure that there are no thermal interferences.

  - Guide sleeve to 24PT2-DSC Cavity (Length)

  - Guide sleeve to Spacer Disc Fuel Cutout

  - Neutron Absorber (Boral®) to Oversleeve

  - Support Rod Assembly to 24PT2-DSC Cavity (Length)

- The coefficient of thermal expansion of the spacer disc material is slightly greater than the coefficient of thermal expansion of the support rod/spacer sleeve material. Thus, as the basket temperature increases, the spacer disc(s) will tend to expand faster than the rod assembly. This will increase tension in the support rod and increase compression in the spacer sleeves (similar to increasing the initial preload in the rod assembly). For a temperature rise from 70°F to 550°F, the load increase is less than 8 kips. Stresses from this load are included in the analysis of the rod assembly.

- Differential expansion between the (carbon steel) shield plug(s) and the (Type 304) shell is addressed in the thermal stress analyses of the shell. Since the coefficient of expansion of

the shell is significantly higher than the coefficient of expansion for the enclosed plug(s), thermal interferences are minimized.

L.3.4.4.3 Stress Calculations

The stress analyses have been performed using the acceptance criteria and load combinations presented in Section L.2.5. The stress analyses for the 24PT2-DSC are summarized in Section L.3.6 for normal and off-normal conditions and in Section L.3.7 for accident conditions. Section 8.2 provides the detailed load combinations that are applicable to the 24PT2-DSC. Finite element models of the shell assembly and the spacer discs have been developed, and detailed computer analyses have been performed using the ANSYS [3.11] computer program. The guide sleeves and support rods have been analyzed using hand calculations.

24PT2-DSC Shell Assembly

As discussed in Section L.3.6, the NUHOMS® 24PT2S and 24PT2L shell assemblies are evaluated based on comparisons with the 24P standard and 24P long cavity DSC shell assemblies. Based on the comparison, all the stresses in the 24PT2-DSC confinement boundary assembly are acceptable.

Basket Assembly

The stress analyses results for the basket assembly are summarized in Table L.3.7-3, Table L.3.7-4 and Table L.3.7-5 for the controlling load combinations. Included in the tables is a summary of the controlling stress intensities in the spacer discs and the highest interaction ratios for the support rod assemblies. The controlling spacer disc stresses result from the side drop accident case. The highest support rod assembly interaction ratio results from the end drop accident case. As discussed in Section L.3.6.1.3.2, the 24PT2 guide sleeves are evaluated based on comparisons to the NUHOMS®-24P guide sleeves. Based on the comparisons, guide sleeve stresses are acceptable. The analyses presented in Sections L.3.6 and L.3.7 demonstrate that even in the extreme unlikely hypothetical accident scenarios, there is sufficient margin to ensure that the basket components perform their intended function.

L.3.4.4.4 Comparison with Allowable Stresses

The stresses for each of the major components of the 24PT2-DSC are compared to their allowables in Table L.3.7-3 through Table L.3.7-5 and are acceptable.

L.3.4.5 Low Temperature Behavior

The 24PT2S and 24PT2L DSCs have been designed for operation at a daily average ambient temperatures as low as -40°F.

The SA 240 Type 304 stainless steel along with the E308/E309 weld metal are not subject to brittle fracture for the range of operating temperatures of the 24PT2-DSC. The support rod

materials are impact-tested to confirm ductile behavior. To meet the 10CFR71 requirements, carbon steel spacer disc materials are impact-tested to demonstrate $T_{NDT} \leq -80°F$ and thus meet the requirements of NUREG/CR-1815 [3.19] for brittle fracture.

L.3.5 Fuel Rods

No change.

L.3.6 Structural Analysis (Normal and Off-Normal Operations)

In accordance with NRC Regulatory Guide 3.48 [3.13], the design events identified by ANSI/ANS 57.9-1984, [3.14] form the basis for the accident analyses performed for the standardized NUHOMS® system. Four categories of design events are defined. Design event Types I and II cover normal and off-normal events and are addressed in Section 8.1. Design event Types III and IV cover a range of postulated accident events and are addressed in Section 8.2. The purpose of this section of the Appendix is to present the structural analyses for normal and off-normal operating conditions for the NUHOMS®-24PT2 system using a format similar to the one used in Section 8.1 for analyzing the NUHOMS®-24P and -52B systems.

L.3.6.1 Normal Operation Structural Analysis

Table 8.1-1 shows the normal operating loads for which the NUHOMS® safety-related components are designed. The table also lists the individual NUHOMS® components which are affected by each loading. The magnitude and characteristics of each load are described in Section L.3.6.1.1.

The method of analysis and the analytical results for each load are described in Sections L.3.6.1.2 through L.3.6.1.9.

L.3.6.1.1 Normal Operating Loads

The normal operating loads for the NUHOMS® system components are:

1. Dead Weight Loads
2. Design Basis Internal and External Pressure Loads
3. Design Basis Thermal Loads
4. Operational Handling Loads
5. Design Basis Live Loads

These loads are described in detail in the following paragraphs.

A. Dead Weight Loads

Table L.3.2-1 and Table L.3.2-2 show the weights of various components of the NUHOMS®-24PT2S and NUHOMS®-24PT2L systems, respectively. The deadweight of the component materials is determined based on nominal component dimensions, in the same manner as for the NUHOMS®-24P and –52B DSC.

B. Design Basis Internal and External Pressure

The maximum internal pressures of the NUHOMS®-24PT2S and -24PT2L DSC for the storage and transfer mode are presented in Section L.4.4.4.

C. Design Basis Thermal Loads

The temperature distribution for the DSC shell assembly for the normal conditions is presented in Section L.4.

D. Operational Handling Loads

There are two categories of handling loads: (1) inertial loads associated with on-site handling and transporting the DSC between the fuel handling/loading area and the HSM, and (2) loads associated with loading the DSC into (and unloading the DSC from) the HSM. These handling loads are described in Section 8.1.1.1.C.

Based on the surface finish and the contact angle of the DSC support rails inside the HSM described in Chapter 4, a bounding coefficient of friction is conservatively assumed to be 0.25. Therefore, the nominal ram load required to slide the DSC under normal operating conditions is approximately 24,453 lbs, calculated as follows:

$$P = \frac{0.25\,W}{\cos\theta} = 0.29\,W = 0.29(84{,}319\text{ lbs}) = 24{,}453\text{ lbs}$$

Where:

P = Push/Pull Load

W = Loaded DSC Weight ≈ 84,319 lbs (See Table L.3.2-1 & Table L.3.2-2)

θ = 30 degrees, Angle of the Canister Support Rail

However, the DSC bottom cover plate and grapple ring assembly are designed to withstand a normal operating insertion force equal to 80,000 pounds and a normal operating extraction force equal to 60,000 pounds. To insure retrievability for a postulated jammed DSC condition, the ram is sized with a capacity for a load of 80,000 pounds, as described in Section 8.1.2. These loads bound the friction force postulated to be developed between the sliding surfaces of the DSC and transfer cask during worst case off-normal conditions.

E. Design Basis Live Loads

Same as Section 3.2.4 (no effect on the DSC).

L.3.6.1.2 DSC Shell Assembly Analysis

The NUHOMS®-24PT2S and -24PT2L DSC shell assemblies are very similar to the standard 24P and long cavity NUHOMS®-24P DSC shell assemblies. Materials and overall geometry of the 24PT2 shell assemblies are identical to the 24P shell assemblies. Some of the internal dimensions in the top and bottom shield plugs for the 24PT2L DSC have some very minor differences relative to the long cavity NUHOMS®-24P DSC. However, these differences are either bounded by the analyses of the long cavity 24P DSC shell assembly or have a negligible effect.

Load conditions applicable to the 24PT2 DSCs are the same as those presented in Section 8.1. The internal pressures calculated in Section L.4.4 for the NUHOMS®-24PT2S and -24PT2L DSCs are bounded by the internal pressures evaluated in Section 8.1 and Appendix J for the 24P standard and long cavity DSCs, respectively. Additionally, a heat load of 24kW is applicable for both the 24PT2 and 24P designs. Since the shell assemblies for the 24PT2S/24PT2L are effectively identical to the 24P standard and long cavity designs, the maximum temperatures and temperature distributions are the same as the 24P. Therefore, the 24P thermal stress analyses presented in Section 8.1 and Appendix H are directly applicable to the 24PT2S and 24PT2L DSC shell assemblies.

The weights of the 24PT2S and 24PT2L DSC shell assemblies are the same as those of the 24P standard and long cavity DSCs. However, the basket for the 24PT2S/24PT2L is heavier due to dissimilar basket design configurations (the 24PT2S/24PT2L basket design has additional spacer discs and added basket hardware). Of the normal operating load conditions, the heavier basket weight affects the deadweight and the transfer handling loads on the 24PT2S/24PT2L DSC shell assemblies.

For vertical deadweight, the higher basket weight results in a slightly greater bearing stress on the inner bottom cover plate. However, bearing stress is not a limiting or controlling condition for the DSC shell assembly. Therefore, no further evaluation is necessary. For horizontal deadweight, the increased number of spacer discs reduces the local stresses in the DSC cylindrical shell due to transverse basket loading. Therefore, the 24PT2S/24PT2L stresses are bounded by the 24P stresses for this condition.

For the transfer handling load, consideration of friction between the fuel and the guide sleeves reduces the conservative loading evaluated for the 24P DSC shell assembly. The resulting fuel/basket inertial load on the end components of the 24PT2 DSC is less than that considered in the analysis of the 24P DSC shell assembly. Therefore, the stress results presented in Section 8.1 and Appendix H bound the stresses in the 24PT2S and 24PT2L DSC shell assembly for transfer handling load.

L.3.6.1.3 DSC Basket Structural Analysis

The DSC internal basket assembly can be utilized to store various types of spent fuel assemblies. As discussed in Section 3.1.1, the physical parameters selected for this generic analysis conservatively envelope those of other fuel assembly types. The weight of each spent fuel

assembly is transferred to the spacer discs by the guide sleeves for any load applied perpendicular to the DSC axis.

L.3.6.1.3.1 Stress Analysis of the Spacer Discs

The NUHOMS®-24PT2S and -24PT2L spacer discs are similar to the spacer discs used in the NUHOMS®-24P standard and long cavity designs. The 24PT2 spacer discs are fabricated using SA-533 Grade B Class 1 carbon steel. Material properties for the spacer disc are summarized in Table L.3.6-1.

The stress analysis of the spacer disc is performed using 3-D finite element models developed using the ANSYS 5.3 and 5.6.2 programs [3.11]. Four basic model types are developed: (1) a half-symmetry (180°) model and a full symmetry (360°) model used for analyzing in-plane loads; (2) a quarter-symmetry (90°) model for analyzing out-of-plane loads; (3) a half-symmetry (180°) model for analyzing axial handling loads; and, (4) a model for analyzing thermal loads.

The spacer disc in-plane models are shown in Figure L.3.6-1 and Figure L.3.6-2. For models that address in-plane loading on the spacer discs, the 180° (half-symmetric) representation is used to analyze symmetric loads such as horizontal deadweight, 1g vertical transfer handling, and 0° side drop loads. A 360° model is used to analyze unsymmetric loads such as the 18.5° and 45° side drop loads. The spacer disc, DSC shell and cask rail are modeled with 3-D solid elements. The cask inner liner is modeled using shell elements that are fully restrained, representing the outer boundary for the system. The interaction between adjacent surfaces, (e.g. the spacer disc to the DSC shell, and the DSC shell to the rails/cask inner liner) is modeled using contact elements. Symmetry boundary conditions are placed on the mid-thickness of the spacer disc in the axial direction, so that the spacer disc is modeled as half the actual thickness. The shell is modeled with a length equal to half of the tributary span at the center of the DSC with symmetry boundary conditions at the end planes.

The spacer disc out-of-plane model is shown in Figure L.3.6-3. The 90° quarter symmetric model is used to address vertical dead weight and vertical end drops. A single spacer disc is modeled using plastic shell elements. To obtain a bounding stress on the spacer disc, analyses consider the connection between the support rod/spacer sleeve assembly to the spacer disc as both pinned and fixed. The out-of-plane model does not include fuel assembly weight because the guide sleeves are not attached to the spacer discs.

The spacer disc axial handling model addresses the effect of inertia in the axial direction due to the 1g axial load condition. This model is similar to the out-of-plane model except that it is 180° half-symmetry and it models the support rods. Inertial load from the fuel assemblies and guide sleeves is applied to the edges of the fuel assembly cut-outs, which conservatively does not account for slipping when friction is overcome. The spacer discs and support rods are modeled using shell and beam elements, respectively. The spacer disc is restrained axially at the cask rail location to model friction between the basket assembly and the DSC shell. The mid-length of the support rod assembly spans is modeled by restraining the support rod in translation in the plane of the spacer disc.

The spacer disc thermal model is a 180° half-symmetry model similar to the 180° in-plane model that includes the spacer disc only. Temperature distributions from the Section L.4 thermal analyses are imposed onto the spacer disc. Only temperature gradients in the plane of the disc are analyzed.

Linear elastic static analyses are performed for the evaluation of all normal operating loads. Stress results obtained from the analyses are linearized, as appropriate, to allow their categorization into primary membrane and primary or primary-plus-secondary membrane-plus-bending stress intensities. Stress results for the normal load conditions are included in Table L.3.6-2.

L.3.6.1.3.2 Stress Analysis of the Guide sleeve Assemblies

The NUHOMS®-24PT2S and -24PT2L guide sleeves are similar to the NUHOMS®-24P standard and long cavity guide sleeves. The 24PT2S and 24PT2L guide sleeves are fabricated from thicker plates than the 24P designs, and they support additional weight from the neutron absorber sheets and oversleeves. However, the unsupported span length of the 24PT2S/24PT2L guide sleeves is significantly shorter than that of the 24P designs because of the increased number of spacer discs. The seam and corner welds of the 24PT2S/24PT2L guide sleeves are larger than the 24P welds. Materials used in the 24PT2 and 24P guide sleeves are identical. Therefore, the analysis results presented in Chapter 8 bound the stresses applicable to the 24PT2S and 24PT2L guide sleeves.

L.3.6.1.3.3 Stress Analysis of the Support Rod Assemblies

Each NUHOMS®-24PT2S and -24PT2L support rod assembly consists of a support rod and twenty-six (26) cylindrical spacer sleeves. The spacer sleeves slide over the support rod and maintain the axial location of the spacer discs. The rod assembly is preloaded to stabilize the basket assembly. The rod assembly is similar to that used in the NUHOMS®-52B DSC basket assembly and is fabricated from the same materials.

The support rod assemblies are evaluated for the loading and stress criteria presented in Chapters 3 and 8. The rod assemblies are not affected by pressure loads or insertion/retrieval of the DSC into and out of the HSM. Based on the results of the 52B DSC support rod assembly evaluation, the 24PT2 rod assemblies are evaluated only for the controlling normal and accident load conditions which are 1g axial handling and 75g end drop. The analysis considers the effect of temperature changes which modify the effective preload in the rod assembly, due to the difference in thermal properties between the rod assembly and spacer discs.

The results of the controlling normal condition stress analysis are included in Table L.3.6-2.

L.3.6.1.4 DSC Support Structure Analysis

The DSC support structure is shown in Figures 4.2-6 and 4.2-7. The DSC support rails are supported vertically and horizontally by three moment resisting braced frames anchored to the

HSM floor and side wall. The DSC support structure design uses bolted and welded connection details. Normal operating condition loads on the DSC support structure are:

- DSC Dead weight
- DSC Support Structure Dead Weight
- DSC Operational Handling Loads.

The resulting friction loading which develops between the sliding surfaces of the DSC shell and the DSC support rails is transferred axially by the support rails to the HSM front wall.

The various components of the DSC support structure are subjected to normal operating loads including dead weight, thermal, and operational handling loads and the analysis for the NUHOMS®-24P and -52B DSCs is presented in Section 8.1.1.4. The weight of the NUHOMS®-24PT2 DSC is greater than the weight considered in the PWR HSM analysis. The DSC support structure is evaluated for the heavier 24PT2 DSC using the same methodology presented in Section 8.1.1.4. The results of this analysis are presented in Table L.3.7-1 for the governing load conditions which shows that all the limiting DSC support structure components are acceptable.

L.3.6.1.5 HSM Design Analysis

The structural analysis of an individual module provides a conservative methodology for evaluating the response of the HSM structural elements under various static and dynamic loads for any HSM array configured in accordance with Section 4.1.1. The HSM loads analysis for the NUHOMS®-24P and -52B systems is presented in Section 8.1.1.5. This analysis is applicable to NUHOMS®-24PT2 system with the exception of the increased weight of the NUHOMS®-24PT2 DSC.

The HSM is evaluated for the heavier 24PT2 DSC using the same methodology presented in Section 8.1.1.5. The results of this analysis are presented in Table L.3.7-1 for the governing load conditions which shows that the limiting HSM components are acceptable.

L.3.6.1.6 HSM Door Analyses

No change

L.3.6.1.7 HSM Heat Shield Analysis

No change

L.3.6.1.8 HSM Axial Retainer for DSC

The structural evaluation for the HSM axial retainer is addressed in Section L.3.7.3.5.

L.3.6.1.9 On-Site Transfer Cask Analysis

The on-site transfer cask is evaluated for normal operating condition loads including:

1. Dead Weight Load
2. Thermal Loads
3. Handling Loads

The on-site transfer cask is shown in Figures 1.3-6 and on the drawings contained in Appendix E. Thermal loads for the transfer casks with the NUHOMS®-24PT2 DSCs are equivalent to those for the cask with the NUHOMS®-24P DSC because a heat load of 24kW is applicable to both DSC designs.

Section L.3.7.10.3 provides the evaluation of the standardized and OS197 transfer casks when handling the heavier payload due to NUHOMS®-24PT2 DSCs.

L.3.6.2 Off-Normal Load Structural Analysis

Table 8.1-2 shows the off-normal operating loads for which the NUHOMS® safety-related components are designed. This section describes the design basis off-normal events for the NUHOMS® system and presents analyses which demonstrate the adequacy of the design safety features of a NUHOMS® system.

For an operating NUHOMS® system, off-normal events could occur during fuel loading, cask handling, trailer towing, canister transfer and other operational events. Two off-normal events are defined which bound the range of off-normal conditions. The limiting off-normal events are defined as a jammed DSC during loading or unloading from the HSM and the extreme ambient temperatures of -40°F (winter) and +125°F (summer). These events envelop the range of expected off-normal structural loads and temperatures acting on the DSC, transfer cask, and HSM. These off-normal events are described in Section 8.1.2.

L.3.6.2.1 Jammed DSC During Transfer

The interfacing dimensions of the top end of the transfer cask and the HSM access opening sleeve are specified so that docking of the transfer cask with the HSM is not possible should gross misalignments between the transfer cask and HSM exist. Furthermore, beveled lead-ins are provided on the ends of the transfer cask, DSC, and DSC support rails to minimize the possibility of a jammed DSC during transfer. Nevertheless, it is postulated that if the transfer cask is not accurately aligned with respect to the HSM, the DSC binds or becomes jammed during transfer operations.

There is no change to the outside diameter, shell thickness or material of the NUHOMS®-24PT2 DSCs as compared to NUHOMS®-24P DSCs. In addition, the interfacing dimensions and design

features of the HSM access opening, DSC Support Structure and the on-site transfer casks as described in Section 8.1.2 remain unchanged. The insertion and extraction forces applied on the NUHOMS®-24PT2 DSCs during loading and unloading operations are the same as those specified for the NUHOMS®-24P system. Hence the analysis for a jammed canister as described in Section 8.1.2 for NUHOMS®-24P remains applicable to NUHOMS®-24PT2 system.

L.3.6.2.2 Off-Normal Thermal Loads Analysis

As described in Section 8.1.2, the NUHOMS® system is designed for use at all reactor sites within the continental United States. Therefore, off-normal ambient temperatures of -40°F (extreme winter) and 125°F (extreme summer) are conservatively chosen. In addition, even though these extreme temperatures would likely occur for a short period of time, it is conservatively assumed that these temperatures occur for a sufficient duration to produce steady state temperature distributions in each of the affected NUHOMS® components. Each licensee should verify that this range of ambient temperatures envelopes the design basis ambient temperatures for the ISFSI site. The NUHOMS® system components affected by the postulated extreme ambient temperatures are the transfer cask and DSC during transfer from the plant's fuel/reactor building to the ISFSI site, and the HSM during storage of a DSC.

Section L.4.0 provides the off-normal thermal analyses for storage and transfer mode for the NUHOMS®-24PT2 DSCs. The resulting stress intensities for the NUHOMS®-24PT2 DSC are included in Table L.3.6-2.

Table L.3.6-1
Mechanical Properties of Spacer Disc Material

Material	Temperature (°F)	Stress Properties[1] (ksi)			Elastic Modulus[1] (x1.0E3 ksi) (E)	Average Coefficient of Thermal Expansion[1] ($x10^{-6}$ in./in.-°F)
		Stress Intensity (S_m)	Yield Strength (S_y)	Ultimate Strength (S_u)		
Carbon Steel ASME SA533 Grade B Class 1	-100	--	--	--	29.9	--
	-20	--	--	--	--	--
	70	26.7	50.0	80.0	29.2	--
	100	26.7	50.0	80.0	--	7.06
	200	26.7	47.5	80.0	28.5	7.25
	300	26.7	46.1	80.0	28.0	7.43
	400	26.7	45.1	80.0	27.4	7.58
	500	26.7	44.5	80.0	27.0	7.70
	600	26.7	43.8	80.0	26.4	7.83
	700	26.7	43.1	80.0	25.3	7.94
	800	26.7	41.6	80.0	23.9	8.05
	900	24.3	39.4	72.7	22.2	8.14

(1) Steel data and thermal expansion coefficients are obtained from ASME Code Case N-499-1 [3.2].

Table L.3.6-2
Maximum NUHOMS®-24PT2S & 24PT2L DSC Stresses for Normal and Off-Normal Loads

DSC Components	Stress Type	Maximum Stress Intensity(ksi)[1]			
		Dead Weight	Internal Pressure[2]	Thermal[2]	Handling[2]
DSC Shell	Primary Membrane	Same as Table 8.1-10			
	Membrane + Bending				
	Primary + Secondary				
Inner Top Cover Plate	Primary Membrane	Same as Table 8.1-10			
	Membrane + Bending				
	Primary + Secondary				
Outer Top Cover Plate	Primary Membrane	Same as Table 8.1-10			
	Membrane + Bending				
	Primary + Secondary				
Inner Bottom Cover Plate	Primary Membrane	Same as Table 8.1-10			
	Membrane + Bending				
	Primary + Secondary				
Outer Bottom Cover Plate	Primary Membrane	Same as Table 8.1-10			
	Membrane + Bending				
	Primary + Secondary				

See End of Table for Notes (next page).

Table L.3.6-2
Maximum NUHOMS®-24PT2S & 24PT2L DSC Stresses for Normal and Off-Normal Loads

(concluded)

DSC Components	Stress Type	Maximum Stress Intensity(ksi)(1)			
		Dead Weight	Internal Pressure(2)	Thermal(2)	Handling(2)
Spacer Disc	Primary Membrane	0.42	Note 5	N/A	8.3 (4)
	Membrane + Bending	1.40	Note 5	N/A	28.5 (4)
	Primary + Secondary	1.40	Note 5	97.0	96.7 (3)(4)
Support Rods	Axial	Note 6	Note 6	Note 6	29.5 (3)
	Bending	Note 6	Note 6	Note 6	4.1 (3)
Spacer Sleeves	Axial	Note 6	Note 6	Note 6	25.2 (3)
	Bending	Note 6	Note 6	Note 6	7.9 (3)

(1) Values shown are maximum irrespective of location.
(2) Envelope of Normal and Off-Normal conditions.
(3) Includes thermal loads applicable to normal and off-normal handling conditions.
(4) Includes deadweight loads.
(5) The DSC internal structures are not affected by pressure loads.
(6) Bounded by stresses due to 1g axial handling loads.

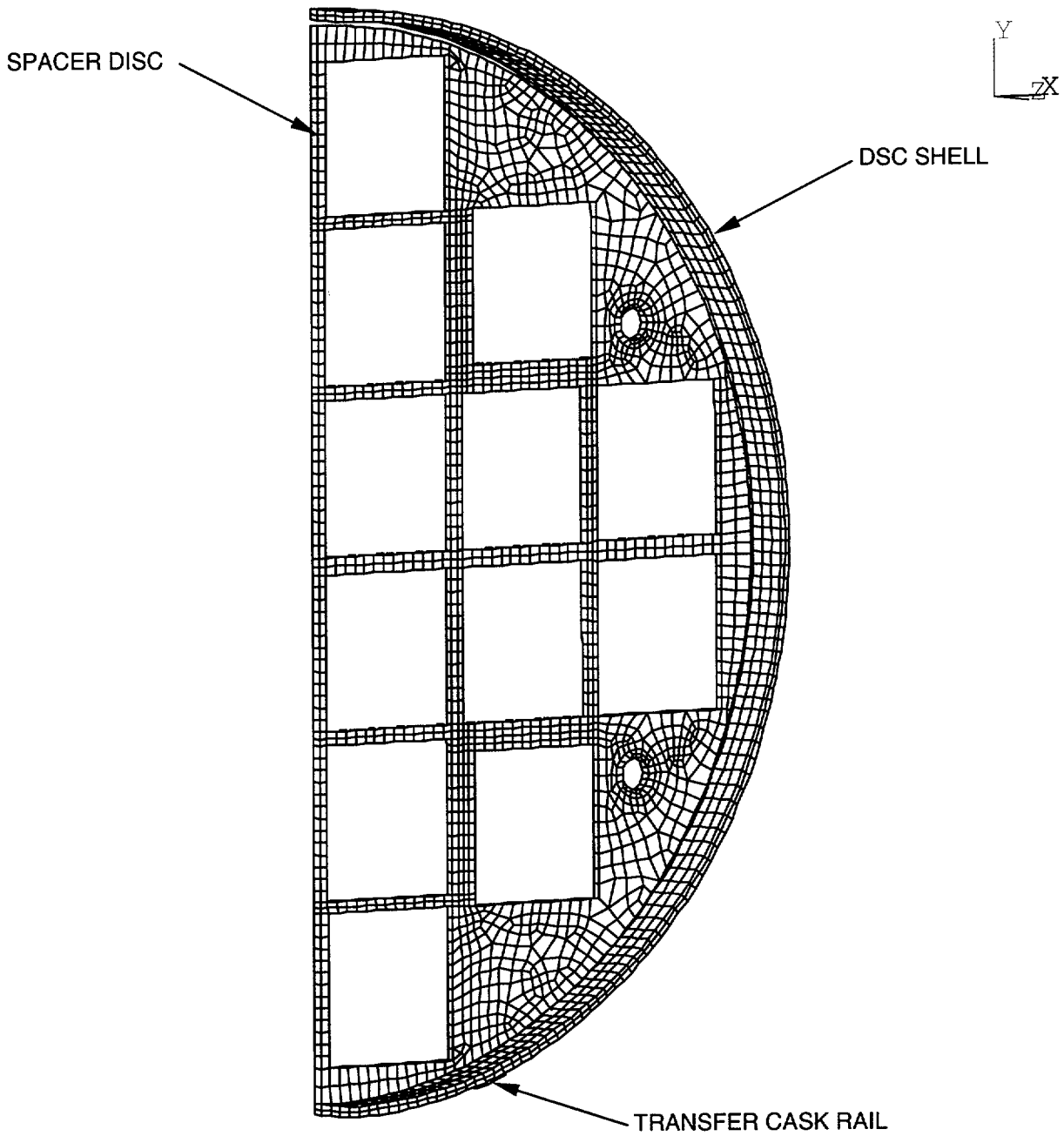

Figure L.3.6-1
NUHOMS®-24PT2 DSC Spacer Disc 180° In-Plane Analytical Model

(Cask inner liner not shown for clarity.)

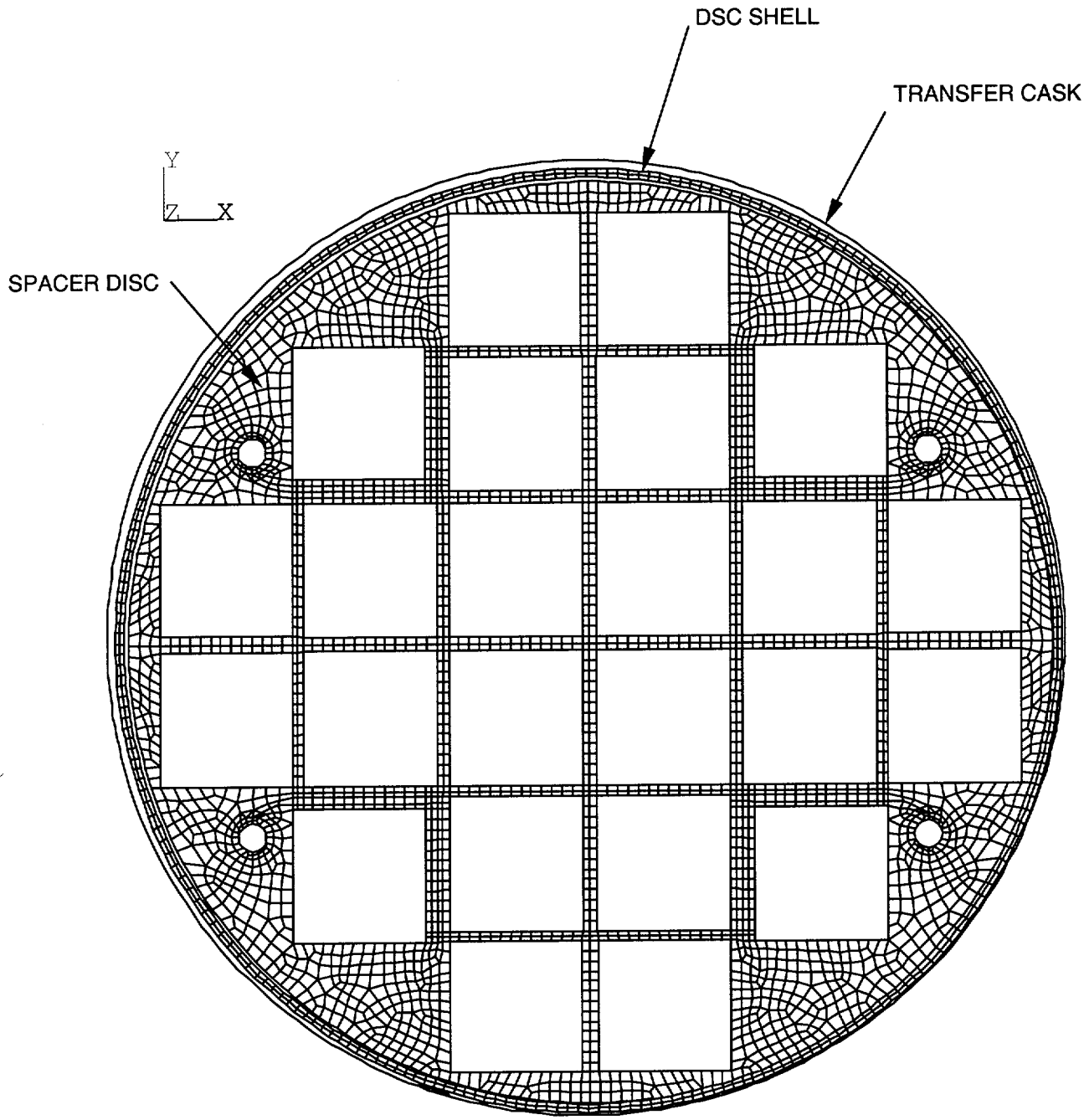

Figure L.3.6-2
NUHOMS®-24PT2 DSC Spacer Disc 360° In-Plane Analytical Model

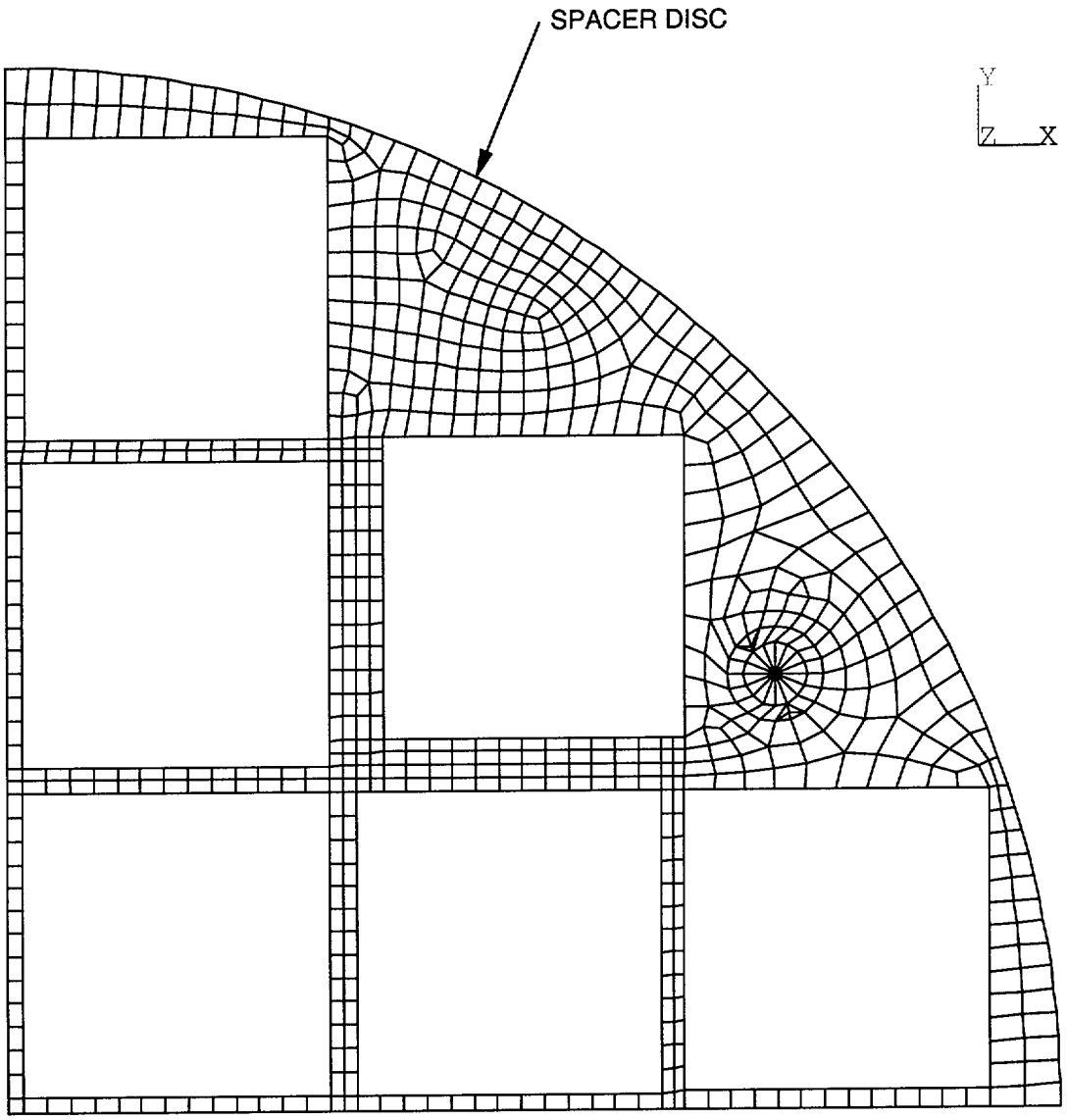

Figure L.3.6-3
NUHOMS®-24PT2 DSC Spacer Disc Out-of-Plane Analytical Model

L.3.7 Structural Analysis (Accidents)

The design basis accident events specified by ANSI/ANS 57.9-1984, and other credible accidents postulated to affect the normal safe operation of the standardized NUHOMS® system are addressed in this section. Analyses are provided for a range of hypothetical accidents, including those with the potential to result in an annual dose greater than 25 mrem outside the owner controlled area in accordance with 10CFR72. The postulated accidents considered in the analysis and the associated NUHOMS® components affected by each accident condition are shown in Table 8.2-1.

In the following sections, each accident condition is analyzed to demonstrate that the requirements of 10CFR72.122 are met and that adequate safety margins exist for the standardized NUHOMS® system design. The resulting accident condition stresses in the NUHOMS® system components are evaluated and compared with the applicable code limits set forth in Section 3.2. Where appropriate, these accident condition stresses are combined with those of normal operating loads in accordance with the load combination definitions in Tables 3.2-5, 3.2-6, and 3.2-7. Load combination results for the HSM, DSC, and transfer cask and the evaluation for fatigue effects are presented in Section L.3.7.10.

The postulated accident conditions addressed in this section include:

A. Reduced HSM air inlet and outlet shielding. (Section L.3.7.1)

B. Tornado winds and tornado generated missiles. (Section L.3.7.2)

C. Design basis earthquake. (Section L.3.7.3)

D. Design basis flood. (Section L.3.7.4)

E. Accidental transfer cask drop with loss of neutron shield. (Section L.3.7.5)

F. Lightning effects. (Section L.3.7.6)

G. Debris blockage of HSM air inlet and outlet opening. (Section L.3.7.7)

H. Postulated DSC leakage. (Section L.3.7.8)

I. Pressurization due to fuel cladding failure within the DSC. (Section L.3.7.9)

L.3.7.1 Reduced HSM Air Inlet and Outlet Shielding

No change from Section 8.2.1.

L.3.7.2 Tornado Winds/Tornado Missile

The applicable design parameters for the design basis tornado (DBT) are specified in Section 3.2.1.1. The determination of the tornado wind and tornado missile loads acting on the HSM are detailed in Section 3.2.1.2. The transfer cask is also designed for the tornado wind and tornado missile loads defined in Section 3.2.2. Stress analyses discussed in Section 8.2.2 are applicable to the NUHOMS®-24PT2 DSC.

For DBT wind and missile effects, the HSM is more stable when loaded with a heavier NUHOMS®-24PT2 DSC since the overturning moment is not a function of the DSC weight while the resisting moment increases with the increased payload. Similarly, the increased DSC weight increases the force required to slide an HSM. Therefore, the factor of safety against sliding is greater for the heavier DSC. The higher weight of the NUHOMS®-24PT2 DSC provides a similar increase in stability for wind loads on the transfer cask. Thus, the analyses presented in Section 8.2.2 for DBT winds and missile effects remain bounding for the NUHOMS®-24PT2 design.

There is no change to the HSM missile impact analysis described in Section 8.2.2.

L.3.7.3 Earthquake

As discussed in Section 3.2.3 and as shown in Figure 8.2-2, the peak horizontal ground acceleration of 0.25g and the peak vertical ground acceleration of 0.17g are utilized for the design basis seismic analysis of the NUHOMS® components. Based on NRC Reg. Guide 1.61 [3.15], a damping value of three percent is used for the DSC seismic analysis. Similarly, a damping value of seven percent for DSC support steel and concrete is utilized for the HSM. An evaluation of the frequency content of the loaded HSM is performed to determine the dynamic amplification factors associated with the design basis seismic response spectra for the NUHOMS® HSM and DSC. The dominant structural frequencies are calculated by conservatively factoring the frequencies in the Section 8 HSM analysis to account for the heavier NUHOMS®-24PT2 DSC. The resulting lateral direction frequencies are 20.7 Hz and 31.4 Hz for the DSC on the support structure and HSM concrete structure, respectively. Table 1 of NRC Regulatory Guide 1.60 requires amplification factors for these structural frequencies, which result in conservative horizontal accelerations of 0.37g and 0.26g, respectively. The dominant vertical frequencies of the loaded HSM exceed 33 Hz, corresponding to the zero period acceleration of 0.17g vertical.

The dominant frequencies of the HSM and DSC inside the HSM are determined by scaling the response spectra analysis results for an analytical model identical to that shown in Figure 8.1-22.

L.3.7.3.1 DSC Shell Assembly Seismic Evaluation

As discussed above, the maximum calculated seismic accelerations for the DSC inside the HSM are 0.37g horizontally and 0.17g vertically. The discussion below addresses the evaluation of stresses in the DSC shell due to vertical and horizontal seismic loads and the evaluation of stability of the DSC against lifting off one of the support rails during a seismic event. The DSC

basket and support structure are also subjected to the calculated DSC seismic reaction loads as discussed in Sections L.3.7.3.2 and L.3.7.3.4, respectively.

L.3.7.3.1.1 DSC Natural Frequency Calculation

Two natural frequencies, each associated with a distinct mode of vibration of the DSC are evaluated. These two modes are the DSC shell cross-sectional ovalling mode and the mode with the DSC shell bending as a beam. The NUHOMS®-24PT2S and 24PT2L DSC shells are identical to the NUHOMS®-24P standard and long cavity DSC shells. Therefore, the calculation presented in Section 8.2.3.2 is applicable to the NUHOMS®-24PT2 DSC design. The resulting maximum spectral accelerations in the horizontal and vertical directions correspond to the shell ovalling mode and are 1.0g and 0.68g, respectively.

L.3.7.3.1.2 DSC Seismic Stress Analysis

As discussed in Section 8.2.3.2.A, increase factors to account for multimode excitation and support by only one rail under horizontal seismic loading result in seismic accelerations of 3.0g horizontal and 1.0g vertical. The DSC shell stresses obtained from the analyses of vertical and horizontal seismic loads are summed absolutely. The seismic accelerations above and in Section L.3.7.3.1 are identical to those presented in Section 8.2.3.2.

As discussed in Section L.3.6.1.2, the NUHOMS®-24PT2S and 24PT2L DSC shell assemblies are essentially the same as the NUHOMS®-24P standard and long cavity DSC shell assemblies. The weights of the 24PT2S and 24PT2L DSC shell assemblies are the same as those of the 24P standard and long cavity DSCs. However, the basket for the 24PT2 DSC is heavier due to dissimilar basket design configurations (the 24PT2 basket design has additional spacer discs and added basket hardware). For transverse and vertical seismic loads, the increased number of spacer discs in the 24PT2 basket reduces the local stresses in the DSC cylindrical shell. For longitudinal seismic loading, consideration of friction along the rails reduces the conservative loading evaluated for the 24P DSC shell assembly. Therefore, the stress results presented in Section 8.2 and Appendix H bound the stresses in the 24PT2S and 24PT2L DSC shell assembly for seismic loading.

Section 8.2.3.2 evaluates the stability of the DSC against lifting off one of the support rails during a seismic event. This evaluation is applicable to the 24PT2 DSC also because the increased weight of the 24PT2 DSC increases the applied seismic moment and the stabilizing moment by the same ratio. Furthermore, the 0.37g horizontal and 0.17g vertical input accelerations applicable to the NUHOMS®-24PT2 DSC on the support structure are identical to the conservative accelerations determined in Section 8.2.3.2 for the NUHOMS®-24P DSC.

L.3.7.3.2 Basket Seismic Evaluation

As discussed in Section L.3.6.1.3, the NUHOMS®-24PT2 DSC basket is composed of spacer discs, guide sleeve assemblies and rod assemblies. The seismic accelerations are bounded by the accelerations evaluated for handling conditions documented in Section L.3.6. As discussed in Section L.3.6.1.3.2, the stress analysis results presented in Chapter 8 bound the stresses

applicable to the 24PT2 guide sleeves. As discussed in Section L.3.6.1.3.3, the support rod assemblies are evaluated only for 1g axial handling and 75g end drop, which are the controlling load conditions for the rod assemblies.

L.3.7.3.3 HSM Seismic Evaluation

To evaluate the seismic response of the HSM with the NUHOMS®-24PT2 DSC, analysis results of the HSM evaluated in Chapter 8 are adjusted to account for both increases in accelerations due to frequency shifts and increases in inertia. This is done because the NUHOMS®-24PT2S and 24PT2L DSCs are heavier than the DSCs evaluated in Chapter 8. Results for the most limiting components and the most limiting load combinations are presented in Table L.3.7-1.

An analysis is also performed to establish the worst case factor of safety against overturning and sliding for a single, free-standing module using the methodology presented in Section 8.2.3. This analysis consists of comparing the stabilizing moment produced by the weight of the HSM and DSC, reduced by 17 percent to account for the upward vertical seismic acceleration, against the overturning moment produced by applying the 0.37g load at the centroid of the HSM and DSC. For sliding of the HSM, the horizontal force of 0.37g acceleration is compared against the frictional resisting force of the foundation slab. In this manner, the factor of safety against sliding is established. The concrete coefficient of friction is taken as 0.6 as defined in Section 11.7.4.3 of ACI 318-83 [3.17].

The details of the seismic evaluation of the HSM when loaded with NUHOMS®-24PT2 DSC are described in the paragraphs that follow.

L.3.7.3.3.1 HSM Frequency Analysis

As shown in Section 8.2.3.1 paragraph B, the lowest horizontal and vertical structural frequencies calculated for a single free standing HSM are 21.7 Hz and 47.0 Hz, respectively. Based on the increased weight due to storage of the heavier NUHOMS®-24PT2 DSC, conservatively adjusted frequencies are 20.7 Hz and 44.7 Hz, respectively. The corresponding horizontal and vertical spectral accelerations are 0.37g and 0.17g.

L.3.7.3.3.2 HSM Seismic Response Spectrum Analysis

The existing HSM structural qualification evaluations provided in Sections 8.1 and 8.2 used a NUHOMS® DSC weight of 80,000 lbs. The weight of the NUHOMS®-24PT2 DSC is approximately 85,000 lbs. Stress ratios based on the heavier NUHOMS®-24PT2 DSC for the affected concrete components and the limiting support structure components are reported in Table L.3.7-1.

L.3.7.3.3.3 HSM Overturning Due to Seismic

Section 8.2.3 presents the evaluation of HSM overturning stability for seismic forces for storage of the NUHOMS®-24P DSC. The heavier weight of the NUHOMS®-24PT2 DSC has a minor effect on the center of gravity vertical height of the HSM/DSC system. The weight terms

presented in Section 8.2.3 cancel out on either side of the overturning equation. The resulting minimum factor of safety against overturning due to seismic remains unchanged at 1.24.

L.3.7.3.3.4 HSM Sliding Due to Seismic

The heavier weight of the NUHOMS®-24PT2 DSC does not have any effect on the HSM sliding stability due to seismic forces, since the HSM weight terms essentially cancel out on either side of the sliding equation presented in Section 8.2.3. Thus, the factor of safety against sliding due to seismic remains unchanged at 1.34 as evaluated in Section 8.2.3.

L.3.7.3.4 DSC Support Structure Seismic Evaluation

Using the same method discussed in Section L.3.7.3.3, Section 8 results are adjusted to account for the heavier NUHOMS®-24PT2 DSC. The evaluation includes the support frame, cross members, rails, anchor bolts, and cross member connections.

L.3.7.3.4.1 DSC Support Structure Natural Frequency

The lowest structural frequency of the DSC support structure inside the HSM is dominated by the mass of the DSC. The DSC and support structure are included in the HSM analytical model. The dominant horizontal and vertical frequencies of the DSC/DSC support structure reported in Section 8 are 21.7 Hz and 47.0 Hz, respectively. As discussed in Section L.3.7.3.3.1, a conservative frequency shift results in adjusted frequencies of 20.7 Hz and 44.7 Hz.

L.3.7.3.4.2 DSC Support Structure Seismic Response Spectra Analysis

Using the same method discussed in Section L.3.7.3.3.2, the stress ratios in the support frame columns, cross members and rails for the governing load combinations are reported in Table L.3.7-1.

L.3.7.3.5 DSC Axial Retainer Seismic Evaluation

The DSC axial retainer detail, located inside the HSM access opening, is shown on the Appendix E drawings. The retainer bears on the end of the DSC and transfers axial seismic loads to the HSM. The axial retainer is evaluated for the increased weight of the NUHOMS®-24PT2 DSC using the same methodology as presented in Section 8.2.3.2.C. The results of the evaluation are included in Table L.3.7-1.

L.3.7.3.6 Transfer Cask Seismic Evaluation

The effects of a seismic event occurring when a loaded NUHOMS®-24P or -52B DSC is resting inside the transfer cask are described in Section 8.2.3 paragraph D. The stabilizing moment to prevent overturning of the cask/trailer assembly due to the 0.25g horizontal and 0.17g vertical seismic ground accelerations is calculated and compared to the dead weight stabilizing moment. The results of this analysis show that there is a factor of safety of at least 2.0 against overturning

that ensures that the cask/trailer assembly has sufficient margin for the design basis seismic loading. This factor of safety against overturning due to seismic remains bounding for the NUHOMS®-24PT2 DSC as discussed above for the HSM in Section L.3.7.3.3.3.

As discussed in Section 8.2.3 paragraph D, the seismic accelerations on the transfer casks are bounded by accelerations evaluated for normal transfer.

L.3.7.4 Flood

Since the source of flooding is site specific, the exact source, or quantity of flood water, should be established by the licensee. However, for this generic evaluation of the DSC and HSM, bounding flooding conditions are specified that envelop those that are postulated for most plant sites. As described in Section 3.2, the design basis flooding load is specified as a 50 foot static head of water and a maximum flow velocity of 15 feet per second. Each licensee should confirm that this represents a bounding design basis for their specific ISFSI site.

L.3.7.4.1 HSM Flooding Analysis

For flooding effects, the HSM is more stable when loaded with the heavier NUHOMS®-24PT2 DSC since the overturning moment is not a function of the DSC weight while the resisting moment increases with the increased payload. Similarly, the sliding force is not a function of the DSC weight while the resistance to sliding increases with the increased payload. Thus, the analyses presented in Section 8.2.4 for flooding effects remains bounding.

L.3.7.4.2 DSC Flooding Analyses

As discussed in Section L.3.6.1.2, the NUHOMS®-24PT2S and 24PT2L DSC shell assemblies are essentially the same as the NUHOMS®-24P standard and long cavity DSC shell assemblies. The pressure load due to flooding is identical to that considered in Section 8.2.4. Therefore, the stress results presented in Section 8.2 and Appendix H bound the stresses in the 24PT2S and 24PT2L DSC shell assembly for flood loading. DSC internal components are unaffected by the flood pressure.

L.3.7.5 Accidental Cask Drop

This section addresses the structural integrity of the standardized NUHOMS® on-site transfer cask, the DSC and its internal basket assembly when subjected to postulated cask drop accident conditions.

Cask drop evaluations include the following:

- DSC Shell Assembly (Section L.3.7.5.2),
- Basket Assembly (Section L.3.7.5.3),
- On-Site Transfer Cask (Section L.3.7.5.4), and

- Loss of the Transfer Cask Neutron Shield (Section L.3.7.5.4).

The DSC shell assembly, transfer cask, and loss of neutron shield evaluations are based on the approaches and results presented in Section 8.2.

A short discussion of the effect of the NUHOMS®-24PT2 DSC on the transfer operation, accident scenario and load definition is presented in Section L.3.7.5.1.

L.3.7.5.1 General Discussion

A. Cask Handling and Transfer Operation

No change.

B. Cask Drop Accident Scenarios

In spite of the incredible nature of any scenario that could lead to a drop accident for the transfer cask, a conservative range of drop scenarios are developed and evaluated. These bounding scenarios assure that the integrity of the DSC and spent fuel cladding is not compromised. Analyses of these scenarios demonstrate that the transfer cask will maintain the structural integrity of the DSC pressure containment boundary. Therefore, there is no potential for a release of radioactive materials to the environment due to a cask drop. The range of drop scenarios conservatively selected for design are:

1. A horizontal side drop or slap down from a height of 80 inches.

2. A vertical end drop from a height of 80 inches onto the top or bottom of the transfer cask (two cases).

3. An oblique corner drop from a height of 80 inches at an angle of 30° to the horizontal, onto the top or bottom corner of the transfer cask. This case is not specifically evaluated. The side drop and end drop cases envelope the corner drop.

C. Cask Drop Accident Load Definitions

The NUHOMS®-24PT2 DSCs are heavier than the NUHOMS®-24P & -52B DSCs. Therefore, the expected g loads for the postulated drop accidents would be lower. However, the conservative g loads used for the NUHOMS®-24P & -52B analyses are also used for the NUHOMS®-24PT2 DSC analyses. See Section 8.2.5.

D. Cask Drop Surface Conditions

No change.

L.3.7.5.2 DSC Shell Assembly Drop Evaluation

As discussed in Section L.3.6.1.2 the NUHOMS®-24PT2S and 24PT2L DSC shell assemblies are essentially the same as the NUHOMS®-24P standard and long cavity DSC shell assemblies. The weights of the 24PT2S and 24PT2L DSC shell assemblies are the same as those of the 24P standard and long cavity DSCs. However, the basket for the 24PT2 DSC is heavier due to dissimilar basket design configurations (the 24PT2 basket design has additional spacer discs and added basket hardware).

The 75g top end drop evaluation does not involve the basket assembly weight except for bearing stress on the top shield plug. However, bearing stress is not limited for Level D conditions. Similarly, increased bearing stresses on the inner bottom cover plate due to a 75g bottom end drop do not need to be evaluated.

For the 75g side drop, the increased number of spacer discs in the 24PT2 basket reduces the load per disc applied to the shell, resulting in reduced local stresses in the DSC cylindrical shell. Therefore, the stress results presented in Section 8.2 and Appendix H bound the stresses in the 24PT2S and 24PT2L DSC shell assembly for cask drop loading.

L.3.7.5.3 Basket Assembly Drop Evaluation

As discussed in Section L.3.6.1.3, the NUHOMS®-24PT2 DSC basket is composed of spacer discs, guide sleeve assemblies and rod assemblies. The spacer discs are evaluated for side drop and end drop loading using the finite element models documented in Section L.3.6.1.3.

The most heavily loaded NUHOMS®-24PT2 spacer disc is evaluated for the 75g side drop condition to demonstrate structural adequacy. For the side drop condition, the spacer discs support the weight of the fuel assemblies, guide sleeve assemblies, and support rod assemblies, as well as their own self-weight. The spacer discs are supported by the canister shell in the region of impact and the canister shell is supported by the transfer cask inner liner. Side drop analyses are performed for 0°, 18.5° and 45° orientations. The finite element model for one half (180°) of a typical DSC spacer disc, is developed to analyze the spacer disc for the 0° orientation postulated horizontal 75g side drop. Full (360°) spacer disc models are developed for analyses of the 18.5° and 45° drop orientations. The 0° drop orientation corresponds to the drop on the 180° azimuth of the spacer disc such that at the point of impact, the load is equally distributed on the two rails. The 18.5° drop orientation corresponds to the drop on the 161.5° azimuth of the spacer disc, such that the impact point is directly on one cask rail. The 45° drop orientation corresponds to the drop on the 135° azimuth of the spacer disc and is intended to apply maximum bending loads to the spacer disc ligaments. The masses of the PWR fuel assemblies and guide sleeves are applied to the spacer disc ligaments.

Elastic-plastic analyses of the spacer disc side drop models are performed to account for local yielding of the spacer disc during the side drop events. Classical bilinear plasticity with a tangent modulus equal to 5% of the elastic modulus is used to represent the elastic-plastic material properties of the carbon steel spacer disc and stainless steel DSC shell.

Stress results obtained from the ANSYS analyses are linearized, as appropriate, to allow their categorization into primary membrane and membrane plus bending stress intensities. The stress results for the side drop conditions are summarized in Table L.3.7-2.

In addition, an ANSYS bifurcation buckling analysis of the entire spacer disc is performed to evaluate the global buckling behavior and stability of the spacer disc. The spacer disc model is based on the 24PT2 side drop model documented in Section L.3.6.1.3. with all but the spacer disc elements removed. Elastic shell elements are used to model the disc and support rod assemblies are added using beam elements. The spacer disc analytical model permits out-of-plane deformations, and is assumed to be supported both in-plane at the perimeter of the spacer disc that is in contact with the DSC shell, and out-of-plane at the four support rod locations. In addition to the 75g side drop loads, the worst case thermal loads are applied to the spacer disc model. Using the stresses from the side drop and thermal loads analyses, a subspace eigenvalue buckling analysis is performed for the drop. A factor of safety of 1.70 against collapse of the spacer disc is calculated for the postulated 75g horizontal drop.

The NUHOMS®-24PT2 DSC spacer discs are analyzed for the vertical end drop using the quarter symmetry finite element model described in Section L.3.6.1.3. A quarter symmetry model is used since the spacer discs exhibit symmetry along two horizontal axes. As discussed in Section L.3.6.1.3, both pinned and fixed conditions are considered at the support rod locations. Only the spacer disc self weight is considered because the guide sleeves are not attached to the spacer disc. As with the side drop model, elastic-plastic material properties are used. The stress results for the end drop condition are summarized in Table L.3.7-2.

As discussed in Section L.3.6.1.3.2, the stress analysis results presented in Chapter 8 bound the stresses applicable to the 24PT2 guide sleeves. The support rod assemblies are evaluated only for the end drop, which controls for the rod assembly. This conclusion is based on the results of the NUHOMS®-52B support rod evaluation, which is for a design similar to the NUHOMS®-24PT2 DSC support rod assemblies. The stress results for the end drop condition are summarized in Table L.3.7-2.

L.3.7.5.4 On-site Transfer Cask Horizontal and Vertical Drop Evaluation

An analysis has been performed [Section 8.2.5.2] to evaluate the transfer cask when loaded with the NUHOMS®-24P or -52B DSC for postulated horizontal and vertical drop accidents with a static equivalent deceleration of 75g's.

The bounding weight of the NUHOMS®-24PT2 DSC is 85,000 lbs compared to the 80,000 lbs used for the NUHOMS®-24P/52B DSC. The maximum stress ratio for the OS197 transport of the NUHOMS®-24P/52B DSC analysis for this accident has been scaled by a conservative factor of 1.105 (actual load ratio is 85,000/80,000 = 1.063) to establish the maximum stress ratio applicable to the NUHOMS®-24PT2 DSC. Similarly, the standardized Transfer Cask results are scaled based on increased weight from the NUHOMS®-24PT2 DSC. See Section L.3.7.10.3.

Section 8.2.5.3 conservatively postulates a loss of neutron shield in the OS197 transfer cask. The transfer of the NUHOMS®-24PT2 DSC has no affect on the evaluation since the thermal decay heat load is identical to the NUHOMS®-24P DSC.

L.3.7.6 Lightning

No change.

L.3.7.7 Blockage of Air Inlet and Outlet Openings

The thermal effects of this accident for the NUHOMS®-24PT2 DSC are bounded by the storage of 24P DSC which has the same heat load of 24 kW as described in Section L.4. Therefore, the evaluation presented in Section 8.2.7.2 is applicable to storage of the 24PT2 DSC also.

L.3.7.8 DSC Leakage

Same as Section 8.2.8.

L.3.7.9 Accident Pressurization of DSC

This accident addresses the consequences of accidental pressurization of the DSC.

See Section L.11.2.9 for this analysis.

L.3.7.10 Load Combinations

The load categories associated with normal operating conditions, off-normal conditions and postulated accident conditions are described and analyzed in previous sections. The load combination results for the NUHOMS® components important to safety are presented in this section. Fatigue effects on the transfer cask and the DSC are also addressed in this section.

L.3.7.10.1 DSC Load Combination Evaluation

As described in Section 3.2, the stress intensities in the DSC at various critical locations for the appropriate normal operating condition loads are combined with the stress intensities experienced by the DSC during postulated accident conditions. It is assumed that only one postulated accident event occurs at any one time. The DSC load combinations summarized in Table 3.2-6 are expanded in Table 8.2-24. Since the postulated cask drop accidents are by far the most critical, the load combinations for these events envelope all other accident event combinations. Table L.3.7-3 through Table L.3.7-5 tabulate the maximum stress intensity for each component of the DSC (shell and basket assemblies) calculated for the enveloping normal operating, off-normal, and accident load combinations. For comparison, the appropriate ASME Code allowables are also presented in these tables.

L.3.7.10.2 DSC Fatigue Evaluation

The range of pressure fluctuations due to seasonal temperature changes are essentially the same as those evaluated for the NUHOMS®-24P DSC. Similarly, the normal and off-normal temperature fluctuations for the NUHOMS®-24PT2 DSC due to seasonal fluctuations are essentially the same as those calculated for the NUHOMS®-24P DSC. Therefore, the fatigue evaluation presented in Section 8.2.10.2 remains applicable to the NUHOMS®-24PT2 DSC.

L.3.7.10.3 Transfer Cask Load Combination Evaluation

The standardized Transfer Cask evaluation is documented in Sections 8.1 and 8.2 for transfer of loaded NUHOMS®-24P and –52B DSCs. The weight of the NUHOMS®-24PT2S DSC is greater, due to a heavier basket assembly design. The maximum stresses in the standardized Transfer Cask shown in Table 8.2-21 are scaled based on the increase in DSC weight, and the resulting maximum stress ratio is 0.97.

The standardized Cask lifting trunnions were evaluated for a loaded cask weight of 200 kips. The increased load due to the NUHOMS®-24PT2S DSC basket results in an additional 7 kips of weight (conservative). Therefore, the maximum stress associated with lift at the trunnions is increased by 3.5%, resulting in a conservative stress ratio of 0.87 (weld).

Similarly, the OS197 Cask stresses are increased for the heavier NUHOMS®-24PT2 DSC. The limiting stress ratio for membrane plus bending stress intensity in the cask bottom support ring under the dead weight plus thermal plus earthquake load combination is scaled to reflect a conservative increased deadweight of 88,390 lbs (actual bounding weight is 85,000 lbs per Table L.3.2-1 and Table L.3.2-2) for the NUHOMS®-24PT2 DSC. 80,000 lbs was considered in the evaluation for the NUHOMS®-24P and –52B DSCs. This updated limiting stress ratio is conservatively established as 0.82. Hence, the resulting stresses for the OS197 Transfer Cask when handling the NUHOMS®-24PT2 DSC remain well below the code allowables.

The cask trunnions have been evaluated for an OS197 loaded cask weight of at least 240,000/1.15 = 208,696 lbs (see Section 8.1.1.9). The maximum weight of the lifted OS197 cask with the 24PT2 DSC is 203,829 lbs (see Table L.3.2-1 and Table L.3.2-2), which is less than the evaluated weight. Therefore, the trunnions are acceptable for lifting the OS197 with the 24PT2 DSC.

L.3.7.10.4 Transfer Cask Fatigue Evaluation

No change.

L.3.7.10.5 HSM Load Combination Evaluation

The existing HSM structural qualification evaluations provided in Sections 8.1 and 8.2 include a NUHOMS® DSC weight 80,000 lbs used for the NUHOMS®-24P and -52B DSCs. The bounding weight of the NUHOMS®-24PT2S DSC, 85,000 lbs (see Table L.3.2-1 and Table L.3.2-2), is 6.3% greater than 80,000 lbs. The HSM is evaluated for the effects of the increased

weight and corresponding frequency shifts as discussed in Section L.3.7.3.3. Table L.3.7-1 shows that all the limiting HSM structural components are acceptable.

L.3.7.10.6 Thermal Cycling of the HSM

No change.

L.3.7.10.7 DSC Support Structure Load Combination Evaluation

See Section L.3.7.10.5 above.

Table L.3.7-1
HSM Limiting Component Evaluation – Storage of NUHOMS®-24PT2 DSC

Component	Stress Ratio or Demand/Capacity (1)
HSM Concrete Floor	0.78
HSM Concrete Side Wall	0.76
HSM Concrete Front Wall	0.71
HSM Concrete Rear Wall	0.64
DSC Support Steel Column	0.96
DSC Support Steel Wall Attachment Bolt	0.88
DSC Support Steel Rail Extension Plates	0.98
DSC Support Steel Wall Attachment Angle	0.98
DSC Support Steel Rail Stiffener Weld	0.93
DSC Support Steel Stop Plate Stiffener Weld	0.86
DSC Support Steel Beam Flange to Stiffener Weld	0.97
HSM Concrete Floor Embedment	0.91
DSC Axial Retainer	0.92

Notes:
1. Accident thermal and HSM binding load conditions/combinations are not included because the DSC weight has essentially no effect on these results.

Table L.3.7-2
Maximum NUHOMS®-24PT2 DSC Stresses for Drop Accident Loads

DSC Components	Stress Type	Calculated Stress (ksi)	
		Vertical	Horizontal
DSC Shell	Primary Membrane	Same as Table 8.2-7	
	Membrane + Bending		
Inner Top Cover Plate	Primary Membrane	Same as Table 8.2-7	
	Membrane + Bending		
Outer Top Cover Plate	Primary Membrane	Same as Table 8.2-7	
	Membrane + Bending		
Inner Bottom Cover Plate	Primary Membrane	Same as Table 8.2-7	
	Membrane + Bending		
Outer Bottom Cover Plate	Primary Membrane	Same as Table 8.2-7	
	Membrane + Bending		
Spacer Discs	Primary Membrane	20.2	52.4
	Local Membrane	N/A	58.1
	Membrane + Bending	61.6	72.07
Support Rods	Axial	45.1	Note 3
	Bending	16.9	Note 3
Spacer Sleeves	Axial	71.6	Note 3
	Bending	25.4	Note 3
Guide Sleeves	Axial	Same as Table 8.2-7	
	Bending		
Top Cover Plate Weld(4)	Primary	Same as Table 8.2-7	
Bottom Cover Plate Weld(4)	Primary	Same as Table 8.2-7	

(1) Values shown are maximums irrespective of location.
(2) DSC was also included in corner drop analysis for cask, however, stresses for above cases are enveloping.
(3) End drop controls for the support rod assembly based on comparison to the 52B results.
(4) Envelope of inner and outer cover plate weld. Stress values include 10 psig internal pressure.

Table L.3.7-3
NUHOMS®-24PT2 DSC Enveloping Load Combination Results for Normal and Off-Normal Loads (ASME Service Levels A and B)

DSC Components	Stress Type	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable (2)
DSC Shell	Primary Membrane	Same as Table 8.2-11		
	Membrane + Bending			
	Primary + Secondary			
Inner Bottom Cover Plate	Primary Membrane	Same as Table 8.2-11		
	Membrane + Bending			
	Primary + Secondary			
Outer Bottom Cover Plate	Primary Membrane	Same as Table 8.2-11		
	Membrane + Bending			
	Primary + Secondary			
Inner Top Cover Plate	Primary Membrane	Same as Table 8.2-11		
	Membrane + Bending			
	Primary + Secondary			
Outer Top Cover Plate	Primary Membrane	Same as Table 8.2-11		
	Membrane + Bending			
	Primary + Secondary			
Spacer Disc	Primary Membrane	TR-1, TR-5	8.3	26.7
	Membrane + Bending	TR-4, TR-8	28.5	28.5
	Primary + Secondary	DD-2	97.0	Note 5
Support Rods (4)	Axial + Bending Stress Interaction Ratio	TR-1, TR-5	0.59	1.0
Spacer Sleeves (4)	Axial + Bending Stress Interaction Ratio	TR-1, TR-5	0.66	1.0

See Table L.3.7-6 for notes.

Table L.3.7-4
NUHOMS®-24PT2 DSC Enveloping Load Combination Results for Accident Loads (ASME Service Level C)

DSC Components	Stress Type	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable (2)
DSC Shell	Primary Membrane	Same as Table 8.2-13		
	Membrane + Bending			
Inner Bottom Cover Plate	Primary Membrane	Same as Table 8.2-13		
	Membrane + Bending			
Outer Bottom Cover Plate	Primary Membrane	Same as Table 8.2-13		
	Membrane + Bending			
Inner Top Cover Plate	Primary Membrane	Same as Table 8.2-13		
	Membrane + Bending			
Outer Top Cover Plate	Primary Membrane	Same as Table 8.2-13		
	Membrane + Bending			
Spacer Disc	Primary Membrane	HSM-7, HSM-8	Note 6	Note 6
	Membrane + Bending	HSM-7, HSM-8	Note 6	Note 6
Support Rods (4)	Axial + Bending Stress Interaction Ratio	HSM-7, HSM-8	Note 6	Note 6
Spacer Sleeves (4)	Axial + Bending Stress Interaction Ratio	HSM-7, HSM-8	Note 6	Note 6

See Table L.3.7-6 for notes.

Table L.3.7-5
NUHOMS®-24PT2 DSC Enveloping Load Combination Results for Accident Loads (ASME Service Level D)

DSC Components	Stress Type (3)	Controlling Load Combination (1)	Stress (ksi)	
			Calculated	Allowable (2)
DSC Shell	Primary Membrane	Same as Table 8.2-15		
	Membrane + Bending			
Inner Bottom Cover Plate	Primary Membrane	Same as Table 8.2-15		
	Membrane + Bending			
Outer Bottom Cover Plate	Primary Membrane	Same as Table 8.2-15		
	Membrane + Bending			
Inner Top Cover Plate	Primary Membrane	Same as Table 8.2-15		
	Membrane + Bending			
Outer Top Cover Plate	Primary Membrane	Same as Table 8.2-15		
	Membrane + Bending			
Spacer Disc	Primary Membrane	TR-11	52.4	56.0
	Local Membrane	TR-11	58.1	72.0
	Membrane + Bending	TR-11	72.07 (7)	72.0
Support Rods (4)	Axial + Bending Stress Interaction Ratio	TR-9, TR-10	0.26	1.0
Spacer Sleeves (4)	Axial + Bending Stress Interaction Ratio	TR-9, TR-10	0.99	1.0
Guide Sleeves	Bending Stress	Same as Table 8.2-15		
Top Cover Plate Welds	Primary	Same as Table 8.2-15		
Bottom Cover Plate Welds	Primary	Same as Table 8.2-15		

See Table L.3.7-6 for notes.

Table L.3.7-6
DSC Enveloping Load Combination Table Notes

(1) See Tables 3.2-6 and 8.2-24 for load combination nomenclature.

(2) See Table 3.2-9 for allowable stress criteria. Material properties were obtained from Table 8.1-3 and from Table L.3.6-1 at a design temperature of 500°F or as noted in the supporting calculations.

(3) In accordance with the ASME Code, thermal stresses need not be included in Service Level D load combinations.

(4) Allowable stresses in the support rods and spacer sleeves are based upon the criteria specified in Subsection NF and Appendix F of the ASME Code.

(5) Qualification of primary + secondary stresses for the spacer disc are based on the simplified elastic-plastic analysis methodology of NB-3228.5. The evaluation uses the creep/fatigue criteria of Code Case N-499-1 and ASME Section III, Subsection NH.

(6) The only Service Level C load combinations applicable to primary stresses in the spacer discs are HSM-7 and HSM-8 (earthquake loading), which is bounded by the Service Level A/B handling load combinations.

(7) This stress occurs in the bottom spacer disc where the tributary length is the longest. In the middle of the basket assembly, where the spacer discs are supporting the active fuel region, the membrane + bending stress intensity is 66.6 ksi.

L.3.8 References

3.1 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Subsections NB, NC, NF, NG, and Appendices, 1983 Edition with Winter 1985 Addenda.

3.2 American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Code Case N-499-1, "Use of SA-533 Grade B, Class 1 Plate and SA-508 Class 3 Forgings and their Weldment for Limited Elevated Temperature Service Section III, Division 1," Approval Date December 12, 1994.

3.3 Not used.

3.4 Brooks and Perkins, "Boral® Product Performance Report 624."

3.5 Pacific Northwest Laboratory Annual Report – FY 1979, "Spent Fuel and Fuel Pool Component Integrity," May 1980.

3.6 G. Wranglen, "An Introduction to Corrosion and Protection of Metals," Chapman and Hall, 1985, pp. 109-112.

3.7 A.J. McEvily, Jr., ed., "Atlas of Stress Corrosion and Corrosion Fatigue Curves," ASM Int'l, 1995, p. 185.

3.8 Not used.

3.9 TNW letter 31-B9604-97-003 dated December 19, 1997 from Dave Dawson to Tim McGinty, NRC.

3.10 "Safety Analysis Report for the NUHOMS®-MP187 Multipurpose Cask," NUH-05-151, Revision 10, November 2000 [Docket 71-9255].

3.11 ANSYS Engineering Analysis System, Users Manual for ANSYS Revisions 5.3 and 5.6.2, Swanson Analysis Systems, Inc., Houston, PA.

3.12 Roark, 4th Edition, "Formulas for Stress and Strain".

3.13 U.S. Nuclear Regulatory Commission (U.S. NRC), "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation (Dry Storage)," Regulatory Guide 3.48 (Task FP-029-4), (October 1981).

3.14 American National Standard, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," ANSI/ANS 57.9-1984, American Nuclear Society, La Grange Park, Illinois (1984).

3.15 U.S. Atomic Energy Commission, "Damping Values for Seismic Design of Nuclear Power Plants," Regulatory Guide 1.61, (October 1973).

3.16 R. D. Blevins, "Formulas for Natural Frequency and Mode Shape," Van Nostrand Reinhold Co., New York, N.Y., (1979).

3.17 American Concrete Institute, Building Code Requirements for Reinforced Concrete (ACI 318-83) ACI, Detroit, MI (1983).

3.18 American Institute of Steel Construction, Manual of Steel Construction, 8th Edition, 1980.

3.19 NUREG/CR-1815, "Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers up to Four Inches Thick," Lawrence Livermore National Laboratory, August 1981.

L.4 Thermal Evaluation

L.4.1 Discussion

The thermal analysis is documented in Section 8.1.3 and Appendix J for the 24P and long cavity 24P designs with and without Burnable Poison Rod Assemblies (BPRAs). The thermal evaluation described herein demonstrates that the 24PT2S and 24PT2L canister designs meet all the thermal criteria of the 24P and long cavity 24P designs. The payload considered is identical to the standardized NUHOMS® PWR system.

The heat load that is considered for this analysis is the bounding heat load for the 24P DSC of 1.0 kW per assembly, 24 kW total heat load in the canister. Therefore, the thermal analyses of the transfer cask and the HSM loaded with a 24PT2S or 24PT2L canister are not affected. The analyses presented in Section 8.1.3 for the transfer cask and HSM with the NUHOMS®-24P DSC are also applicable to the 24PT2S and 24PT2L DSCs.

The thermal analysis for the 24PT2S and 24PT2L-DSC canisters for normal, off-normal and accident operating conditions are documented below. The maximum temperatures of the fuel cladding are computed and compared against its limits. The maximum temperatures of the basket structural components are computed. Also the pressure within the 24PT2S and 24PT2L DSC cavity is calculated for normal, off-normal and accident conditions. The approach in the thermal evaluation for the 24PT2S/24PT2L canisters is to bound the fuel cladding temperature results presented in Chapter 8 for 24P DSC. The fuel cladding temperature limits given in Chapter 3 for the PWR fuel can then be conservatively applied to the storage of the same fuel payload in the 24PT2S and 24PT2L canisters.

The thermal evaluation concludes that NUHOMS®-24PT2S and -24PT2L DSC designs satisfy all the thermal design criteria given in Chapter 3 and Chapter 8.

L.4.2 Summary of Thermal Properties of Materials

The thermal properties of the material used in the thermal evaluation are the same for the materials that are the same as Section 8.1.3. The 24PT2S and 24PT2L DSCs use Boral®, and SA-564, Type 630 for the support rods as additional materials. Table L.4-1 lists the material properties for these additional materials. The emissivity of electroless nickel coating on the spacer disc material is assumed to be 0.15 [4.4].

Table L.4-1
Thermal Properties for SA-564 Type 630 and Boral®

Temperature (°F)	K (Btu/min/in/°F)	ρ (lb_m/in^3)	C_p (Btu/lb_m)
SA-564, Type 630 [4.2]			
70	0.0138	0.285	0.107
100	0.0140		0.109
150	0.0144		0.112
200	0.0147		0.114
300	0.0156		0.120
400	0.0163		0.124
500	0.0169		0.130
600	0.0176		0.136
650	0.0181		0.140
Boral® [4.3]			
100	0.0689	0.0896	0.220
500	0.0617		0.268

L.4.2.1 Fuel Axial Conductivity Calculation

L.4.2.1.1 Helium Filled Cases

The axial conductivity of the fuel is derived using a parallel resistance method [4.5], taking no credit for the presence of the fuel pellet and no credit for the presence of guide tubes or control components. The zircaloy and helium are weighted by their areas according to the following formula:

$$R_{tot} = \frac{1}{\left(1/R_{Hel} + 1/R_{zirc} \right)}$$

$$\frac{L}{k_{eff} \cdot A_{tot}} = \frac{1}{\left(k_{hel} \cdot A_{hel}/L + k_{zirc} \cdot A_{zirc}/L \right)}$$

$$k_{eff} = \frac{\left(k_{hel} \cdot A_{hel} + k_{zirc} \cdot A_{zirc} \right)}{A_{tot}}$$

where A_{tot} is the total area, conservatively including the area inside the fuel rods.

The conductivities of zircaloy and helium are given in References 4.6 and 4.7, respectively. The effective conductivities are found by interpolating these conductivities and using the equation given above. The results are presented in Table L.4-2.

Table L.4-2
Fuel Region Axial Conductivities With Helium Fill

Temperature (°F)	K_{eff} (Btu/min/in/°F)
400	1.048e-3
500	1.113e-3
600	1.194e-3
700	1.295e-3
800	1.329e-3

L.4.2.1.2 Vacuum Drying Case

For the vacuum drying analysis, air conductivity at atmospheric pressure is assumed. Thermal conductivity of gases do not change significantly with pressure down to 3 mm Hg [4.14]. During the transient process, the DSC cavity is pressurized with a cover gas while the DSC is drained of water. Then a vacuum is applied. During the vacuum drying, evaporation of water droplets on the metal surfaces occur and the cover gas is a mixture of air and water vapor. Water vapor has a comparable conductivity to air at higher temperatures as can be seen in Table L.4-3. The evaporation of the water droplets also provide a significant cooling mechanism because of the high latent heat of vaporization for water. However no credit is taken for the presence of water

during blow down or for evaporative cooling effects during the pump down. Since the conductivity does not significantly depend on pressure, the conductivity of dry air alone is used in the analysis of the DSC basket during vacuum drying.

Table L.4-3
Comparison of Water Vapor and Air Conductivities

Temperature (°F)	k_{air} Btu/min/in/°F	k_{wv} Btu/min/in/°F	[Ref]
620	3.74e-5	3.73e-5	[4.9]
728	4.02e-5	4.29e-5	[4.9]

The procedure for determining the effective conductivities for fuel region with air is identical to the helium case above. The helium conductivities are replaced with air conductivities from Section 8.1-3 in determining the axial fuel effective conductivities. The results are given in Table L.4-4.

Table L.4-4
Fuel Region Axial Conductivities With Air Fill

Temperature (°F)	K_{eff} (Btu/min/in/°F)
200	9.750e-4
300	1.004e-3
400	1.034e-3
500	1.071e-3
600	1.112e-3
700	1.160e-3
800	1.217e-3

L.4.2.2 Guide Sleeve Assembly Effective Properties

The top and right surfaces of the peripheral guide sleeves are solid stainless steel, SA-240, Type 304. These guide sleeve surfaces around the outer periphery are therefore assigned the conductivity of stainless steel, SA-240, Type 304. The conductivity of the interior guide sleeves is different through the thickness and along the length. Therefore, the conductivities will be derived separately and anisotropic conductivities will be defined in ANSYS. A sampling of the guide sleeve assemblies is shown in Figure L.4-1.

Material 7 is SA-240, Type 304. Material 2 has high conductivity in the 'y' direction and low conductivity in the 'x' direction according to the results derived below. Material 6 has high conductivity in the 'x' direction and low conductivity in the 'y' direction according to the results derived below.

L.4.2.2.1 Helium Filled Cases

The interior guide sleeves consist of stainless steel guide sleeves and oversleeves and Boral® inserts. The effective conductivity through the thickness of the guide sleeve assembly is based on a series resistance method [4.5] given in the equation below.

$$k_{eff} = \frac{t_{tot}}{\frac{t_{st}}{k_{st}} + \frac{t_{boral}}{k_{boral}} + \frac{t_{He}}{k_{He}}}$$

The effective conductivities as a function of temperature are given in Table L.4-5.

Table L.4-5
Through-Wall Effective Conductivities of Guide Sleeve Assemblies with Helium

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min/in/°F)
200	2.267e-3
300	2.473e-3
400	2.693e-3
500	2.933e-3
600	3.166e-3
700	3.383e-3
800	3.583e-3

Along the length of the guide sleeve assemblies, a parallel resistance method [4.5] is used to model conduction.

$$k_{eff} = \frac{k_{st} \cdot t_{st} + k_{boral} \cdot t_{boral} + k_{He} \cdot t_{He}}{t_{tot}}$$

The effective conductivities as a function of temperature are given in Table L.4-6.

Table L.4-6
Effective Conductivities of Guide Sleeve Assemblies Along Length with Helium

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min/in/°F)
200	3.180e-2
300	3.155e-2
400	3.137e-2
500	3.113e-2
600	3.083e-2
700	3.059e-2
800	3.023e-2

L.4.2.2.2 Vacuum Cases

For the vacuum cases, the conductivity of air replaces the conductivity of helium in the equations above. The results are given in Table L.4-7 and Table L.4-8.

Table L.4-7
Through-Wall Effective Conductivities of Guide Sleeve Assemblies with Air

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min/in/°F)
200	4.542e-4
300	5.083e-4
400	5.602e-4
500	6.103e-4
600	6.588e-4
700	7.062e-4
800	7.523e-4

Table L.4-8
Effective Conductivities of Guide Sleeve Assemblies Along Length with Air

Temperature (°F)	K_{eff}, Guide Sleeve (Btu/min/in/°F)
200	3.179e-2
300	3.155e-2
400	3.136e-2
500	3.112e-2
600	3.082e-2
700	3.058e-2
800	3.022e-2

L.4.3 Specifications for Components

The fuel cladding temperature limits and material temperature limits for the Boral® materials are given below. The material specification for the other materials are the same as described in Section 8.1.3.

Table L.4-9
Fuel Cladding Temperature Limits

Condition	Temp Limit (°F)
Long Term Average	700[1]
Short Term	1058

(1) The fuel cladding temperature limit given in Chapter 8 is higher than 700°F used here. The purpose of the thermal analysis presented here was to conservatively show that the maximum calculated cladding temperatures are below the cladding temperatures calculated in Section 8.1.3.

The Boral® material also has temperature limits from the manufacturer which are given in Reference 4.3.

Table L.4-10
DSC Non-Fuel Material Temperature Limits

Component	Material	Normal Limit (°F)	Off-Normal/Accident Limit (°F)
Boral® Sheets [4.3]	Boral®	850	1000

L.4.4 Thermal Evaluation for Normal Conditions of Storage (NCS) and Transfer (NCT)

The normal conditions of storage are used for the determination of the maximum fuel cladding temperature, component temperatures, internal pressure and thermal stresses for the NUHOMS®-24PT2S and -24PT2L DSC. The ambient conditions and solar insolation are the same as Section 8.1.3.

L.4.4.1 NUHOMS®-24PT2 DSC Thermal Models

The NUHOMS®-24PT2 DSC finite element models are developed using the ANSYS computer code [4.10]. ANSYS is a comprehensive thermal, structural and fluid flow analysis package. It is a finite element analysis code capable of solving steady state and transient thermal analysis problems in one, two or three dimensions. Heat transfer via a combination of conduction, radiation and convection can be modeled by ANSYS.

The metal components, fuel and cover gas are modeled with three-dimensional, brick elements (ANSYS element solid70). Figures L.4-2 through L.4-7 show the ANSYS models created. The conduction link elements (link33 elements) were used to model conduction over the 0.19" gap between the basket internals and the DSC shell. The temperature gradients in the helium regions near the spacer disc are quite large in the axial direction. In order to address these gradients, the axial gridlines were concentrated near the two spacer discs, as shown in Figure L.4-3. These steps ensured that the solution is independent of the mesh. The areas of the conduction link elements are defined in ANSYS as real constants. The total area for heat transfer is conserved.

Radiation is modeled in ANSYS by using the AUX12 module. Surface elements (two-dimensional shell57) are overlaid over the top of the following basket components: the guide sleeve assemblies, spacer discs and the DSC shell. The view factors from each element to the other elements in the matrix are calculated by ANSYS. The hidden method is used to assure that blocking surfaces are accounted for. A radiation substructure matrix is used which depends only on the geometry and specific meshing of the model. The surface elements are shown in Figure L.4-7.

A portion of the thermal radiation was modeled using radiation link elements (link31). Radiation between the spacer discs and the DSC shell and radiation between the guide sleeves and the spacer discs were modeled by this method. For these link elements, the area, view factor, emissivity, and Stefan Boltzman constant are defined as real constants. A view factor of unity is assumed because of the close proximity of the components.

Boundary Conditions, Storage

The ambient temperature and solar insolation boundary conditions used in the analysis are the same as Section 8.1.3. Since the NUHOMS®-24P DSC was analyzed for 24 kW heat load in Section 8.1.3, the shell temperatures calculated for the DSC in the HSM storage cases from Section 8.1.3 are applicable for the shell analyses of the 24PT2S and 24PT2L DSCs. These DSC

shell temperatures are used in the ANSYS models of the 24PT2 DSCs as a constant temperature boundary condition. Linear interpolation is used to calculate DSC shell temperatures at node points along the DSC shell.

Boundary Conditions, Transfer

The ambient temperature and solar insolation boundary conditions used in the analysis are the same as Section 8.1.3. Since the NUHOMS®-24P DSC was analyzed for 24 kW heat load in Section 8.1.3, the shell temperatures calculated for the DSC in the transfer cask cases during transfer from Section 8.1.3 are applicable for the shell analyses of the 24PT2S and 24PT2L DSCs. These DSC shell temperatures are used in the ANSYS models of the 24PT2 DSCs as a constant temperature boundary condition. Linear interpolation is used to calculate DSC shell temperatures at node points along the DSC shell. For the vacuum drying condition, saturated water conditions on the surface of the DSC shell are assumed based on saturation temperature of water in the annulus and taking credit for enhanced heat transfer at the DSC outer surface and annulus water. Therefore DSC shell temperature of 215 °F is used as the boundary condition on the DSC shell surface.

Maximum Fuel Cladding Temperature

The ANSYS models described above were used to calculate the maximum fuel cladding and basket material temperatures. The fuel cladding and basket material temperatures calculated for the various conditions of storage and transfer are listed in Tables L.4-11, L.4-12 and L.4-13. Figures L.4-8 through L.4-11 show the contour plots extracted from the ANSYS results.

L.5 Shielding Evaluation

The radiation shielding evaluation for the Standardized NUHOMS® System (during loading, transfer and storage) for the 24P and 52B canisters is discussed in Sections 3.3.5, 7.0, 8.0 and Appendix J. The following radiation shielding evaluation discussion specifically addresses the 24PT2S and 24PT2L canister designs. The 24PT2S and 24PT2L canister designs (less the basket) are identical from a shielding point of view. The 24PT2S and 24PT2L baskets include internal design features that result in increased shielding as compared to the standard 24P and the long cavity 24P DSC designs. This increased shielding is in the form of additional, albeit thinner spacer discs, poison material and the stainless steel wrappers. Since the same fuel assembly types and source terms are applicable to the 24PT2S/24PT2L as those applicable to the standard 24P and long cavity 24P there is no adverse change in the shielding performance of the system. Therefore, the shielding analysis presented in Sections 3.3.5, 7.0, 8.0 and Appendix J for the standard 24P and long cavity 24P bound the 24PT2S and 24PT2L canister designs.

L.6 Criticality Evaluation

The criticality analysis is documented in Section 3.3.4 and Appendix J.6 for the 24P and long cavity 24P designs with and without Burnable Poison Rod Assemblies (BPRAs). The criticality evaluation described herein demonstrates that the 24PT2S and 24PT2L canister designs are less reactive than the 24P and long cavity 24P designs. Therefore, the criticality analysis presented in Section 3.3.4 and Appendix J.6 bounds the 24PT2S and 24PT2L canister designs. This evaluation is performed using KENO-5A [6.2] and the H-R 16 group cross section set used for the 52B canister. Soluble boron credit criticality analyses are performed to qualify the 24PT2S and the 24PT2L Dry Shielded Canisters. This approach is consistent with the licensing basis analysis performed in the NUHOMS®-24P Topical Report [6.2].

L.6.1 Discussion and Results

The important difference between the 24PT2S/24PT2L and the 24P/long cavity 24P canister designs is the fixed poison sheets (Boral®) in the 24PT2S/24PT2L canisters. No credit is taken in this criticality evaluation presented herein for the fixed poison. The poison plates are modeled as pure aluminum. This is very conservative, however it ensures that only canister geometry and soluble boron are credited in the criticality analysis consistent with the licensing basis for the standard 24P and the long cavity 24P DSC designs.

Two sets of models were prepared to determine if the 24PT2S and 24PT2L systems are inherently less reactive, or equivalent to, the standardized 24P and long cavity 24P canister designs.

The 24PT2L DSC is designed with a longer internal cavity length to accommodate fuel control components as compared to the 24PT2S. The 24PT2L is identical to the 24PT2S for the purpose of criticality analysis since the DSC is conservatively modeled with spectral boundary conditions in the axial direction (i.e. fuel and basket is infinite in the axial directions). Therefore, only the 24PT2S is referenced in the balance of the evaluation, however, the analysis also applies to the 24PT2L.

The results of the calculation show that the 24PT2S/24PT2L are qualified for storage in the NUHOMS® system because the canisters are less reactive than the standardized 24P and long cavity 24P used for the NUHOMS® system criticality analysis.

The models include the fuel assemblies, guide sleeves, neutron absorber sheets (no credit taken for boron in the poison sheet), spacer discs, support rods, and shell. The first model is a quasi-3-D base case model, using the bounding B&W fuel assembly with the nominal dimensions of the standardized DSC. The second model is a quasi-3D model of the 24PT2S. The results from the second model are compared to the results of the base case model.

A set of parametric studies for unirradiated fuel assemblies in borated water were also performed as described below. The only parameter included in this study is fuel design. As demonstrated by the results of the analysis, the B&W 15x15 Mark B fuel assembly remains the bounding

assembly type, and thus all assembly designs currently acceptable for storage in the 24P and long cavity 24P are also acceptable for storage in the 24PT2S/24PT2L. Therefore, the criticality analyses presented in Section 3.3.4 for the standard 24P and in Appendix J for long cavity 24P, bound the 24PT2S and 24PT2L designs, respectively.

L.6.1.1 24PT2S Compared to Standardized 24P

For nominal conditions, the standardized 24P and long cavity 24P designs are more reactive by 0.5% Δk/k than the 24PT2S and 24PT2L designs. Other considerations effecting reactivity in Section 3.3.4.1.3.G are listed below:

- Method Bias (B-method),
- Bias accounting for non-uniform axial burnup in PWR fuel assemblies (B-axial),
- Bias accounting for worst-case moderator density conditions (B-mod),
- Bias accounting for worst-case metal reflector positioning (B-ref),
- 95/95 uncertainty in the nominal case k_{eff} value (ks-nominal),
- 95/95 uncertainty in method bias (ks-method),
- 95/95 uncertainty in the non-uniform axial burnup bias (ks-axial),
- 95/95 uncertainty resulting from material and construction tolerances and positioning uncertainties (ks-mechanical),
- 95/95 uncertainty in the bias accounting for worst case metal reflector model assumptions (ks-reflector),
- Uncertainty in the equivalencing method results (ks-burnup), and
- 95/95 uncertainty in the moderator density effects bias (ks-mod).

(B-method) – As stated in Section 3.3.4.2.2 KENO-5A/HR-16/PN-HET slightly over-predicts k_{eff} and that no significant biases are present due to system parameters such as fuel enrichment, absorber characteristics, fuel/moderator volume ratios, soluble boron content, etc. In addition since this is a parametric study, the method bias does not effect the conclusions of the calculation.

(B-axial) – The calculations for both DSC designs are for fresh (unburned) 4.0 wt. % U235 fuel. Therefore the axial bias (burnup) does not effect the conclusions of the calculation.

(B-mod) – The nominal cases assume the moderator is borated water at a density of 0.9982 g/cc. The two DSC designs are very similar, therefore, the moderator density variation effects on reactivity are considered to effect both DSC designs in an equivalent manner. No additional bias must be accounted for in the 24PT2S calculations.

(B-ref) – The two DSC designs are very similar with similar tolerances, therefore, the effect of worst case positioning of the metal reflectors will have an equivalent effect on each system. No additional bias must be accounted for in the 24PT2S calculations.

(ks-nominal) – As shown in Table L.6-4 the 1 sigma uncertainty for both calculations are virtually the same (0.0120 and 0.0128). Therefore, no additional uncertainty must be accounted for in the 24PT2S calculation.

(ks-method) – See B-method above.

(ks-axial) – See B-axial above.

(ks-mechanical) – The two DSC designs have similar tolerances, therefore, the effect of worst case tolerance stack up is expected to have an equivalent effect on each system. No additional uncertainty must be accounted for in the 24PT2S calculations.

(ks-reflector) – See B-ref above.

(ks-burnup) – See B-axial above.

(ks-mod) – See B-mod above.

L.6.1.2 Qualified Fuel Designs

The list of fuels qualified for storage in the 24P and long cavity 24P canisters includes the following designs and any identical reload fuel designed by another manufacturer. Fuels which are known to exceed NUHOMS®-24PT mechanical design parameters, such as assembly length, have been omitted.

- B&W 15x15 Mark B
- B&W 15x15 St. Steel
- CE 14x14 Fort Calhoun
- CE 15x15 Palisades
- CE 14x14 Standard/Generic
- Exxon/ANF 14x14 Westinghouse
- Exxon/ANF 15x15 CE
- Exxon/ANF 15x15 Westinghouse
- Westinghouse 14x14 Std/SC
- Westinghouse 14x14 Std/ZCA
- Westinghouse 14x14 Std/ZCB
- Westinghouse 15x15 Std/ZC
- Westinghouse 17x17 OFA
- Westinghouse 17x17 Vantage 5
- Westinghouse 17x17 Standard

The criticality analysis presented in the Topical Report [6.2] established that the B&W 15x15 Mark B assembly type represents the most reactive fuel type of the above listed fuel types. These same fuel designs were also found to be less reactive than the B&W 15x15 Mark B in the 24PT2S and 24PT2L designs, thus verifying that the B&W 15x15 Mark B fuel is the most reactive PWR fuel. The next most reactive fuel is Westinghouse 17x17 Standard, which is 1.5% $\Delta k/k$ lower than the Mark B design.

L.6.2 Package Fuel Loading

There is no change to the package fuel loading as the 24PT2S and 24PT2L canister designs are capable of transferring and storing the same standard PWR fuel assemblies with or without BPRAs as the 24P and long cavity 24P canisters.

L.6.3 Model Specification

The first two models used in this evaluation are prepared to determine if the 24PT2S and 24PT2L canister designs are inherently less reactive, or equivalent to, the standardized DSC basket design.

The KENO-5A models used in this evaluation include the fuel assembly, guide sleeves, neutron absorber sheets (no credit for boron), spacer discs, support rods, and shell. To model these features a quasi-3-D (infinite extent) model is used for the evaluation. A quasi-3-D base case model is developed, using the bounding B&W fuel assembly with nominal dimensions of the standardized 24P canister. A second quasi-3D model of the 24PT2S is developed and compared to the results of the base case model.

The second set of calculations is a parametric study of unirradiated fuel assemblies in borated water. The purpose of this study is to demonstrate that the B&W 15x15 Mark B fuel assembly is the most reactive fuel assembly in the 24PT2S and 24PT2L as in the standardized 24P. The only parameter included in this study is fuel design.

L.6.3.1 24PT2S Dimensions

The following tables summarize the 24PT2S dimensions used in the KENO model:

Guide Sleeve Dimensions (Nominal)

	inches	cm
Guide sleeve inside dimension	8.9	22.606
Guide sleeve outside dimension	9.14	23.2156
Guide sleeve thickness	0.120	0.30481

Boral® Panel Dimensions (Nominal)

	inches	cm
Boral® panel width	8.50	21.590
Boral® panel thickness	0.085	0.2159
Over sleeve thickness	0.0178	0.045212

Support Rod Dimensions (Nominal)

	inches	cm
Support rod radius	1.5	3.81
X coordinate	24.00	60.96
Y coordinate	13.67	34.7218

Spacer Disc Dimensions (Nominal)

	inches	cm
Spacer disc thickness	1.25	3.175
"Type A" cutout dimensions	9.45	24.003
"Type B" cutout dimensions	9.55	24.257
Spacer disc pitch	(See Figure L.6-1)	

Figure L.6-2 shows the radial 24PT2S dimensions used in the model.

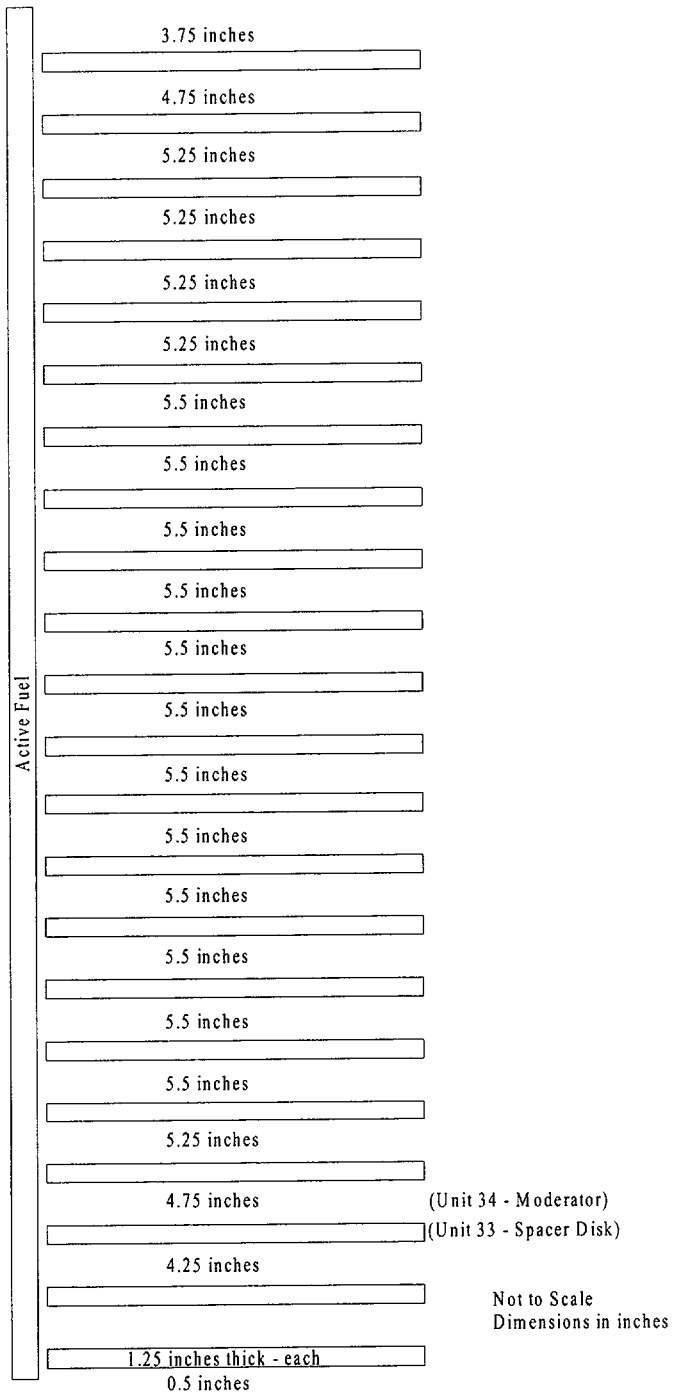

Figure L.6-1
NUHOMS®-24PT2S DSC Spacer Disc Model Layout

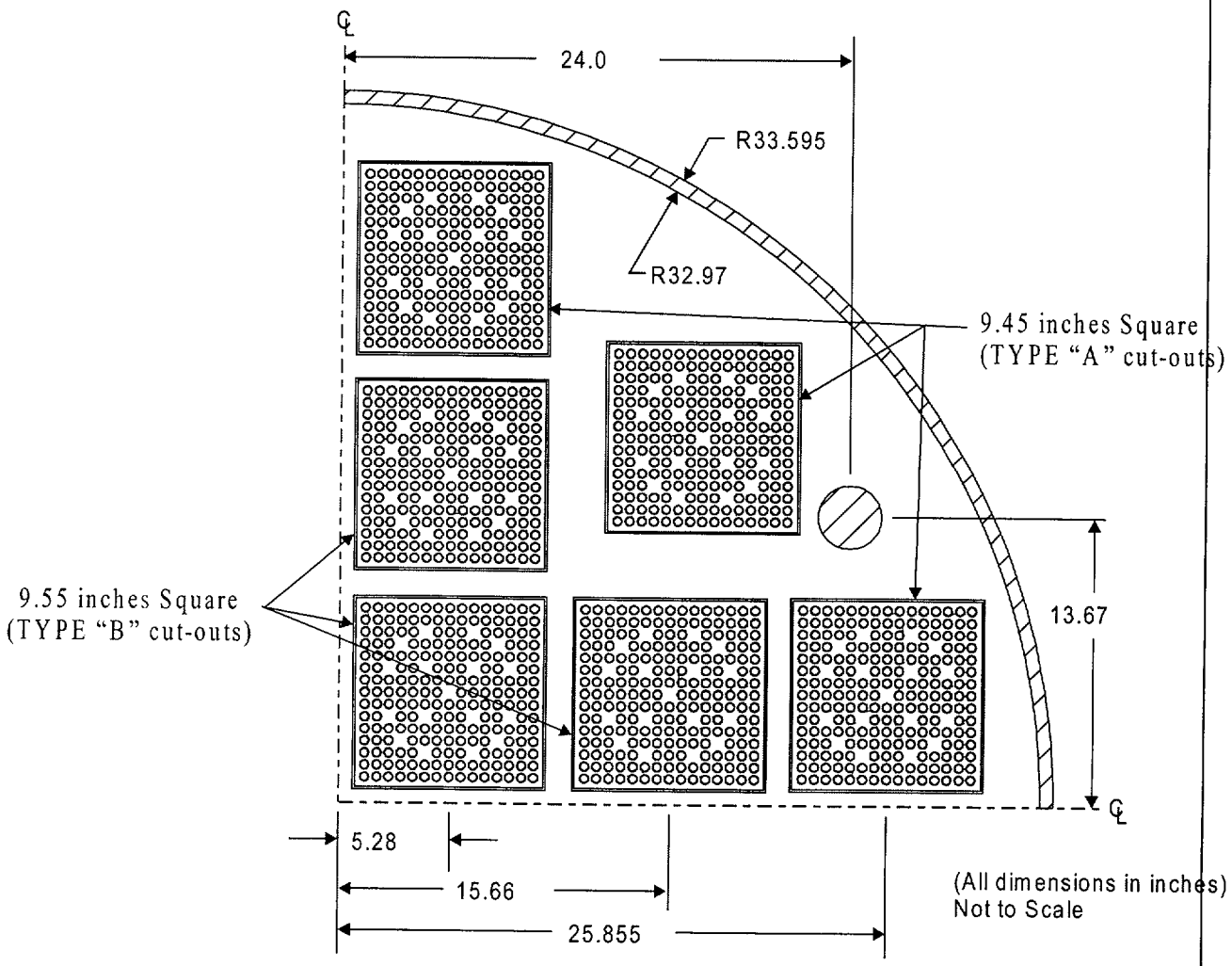

Figure L.6-2
NUHOMS®-24PT2S DSC Radial Geometry

L.6.3.2 Standardized DSC Dimensions

The following table summarizes the standardized 24P DSC dimensions used in the KENO model.

Guide Sleeve Dimensions (Nominal)

	inches	cm
Guide sleeve inside dimension	8.9	22.606
Guide sleeve outside dimension	9.14	23.2156
Guide sleeve thickness	0.1046	0.265684

Support Rod Dimensions (Nominal)

	inches	cm
Support rod radius	1.5	3.81
X coordinate	23.95	60.833
Y coordinate	13.67	34.7218

Spacer Disc Dimensions (Nominal)

	inches	cm
Spacer disc thickness	2.00	5.08
Cutout dimensions	9.28	23.5712
Spacer disc pitch	(See Figure L.6-3)	

Figure L.6-4 shows the radial standardized DSC dimensions used in the model.

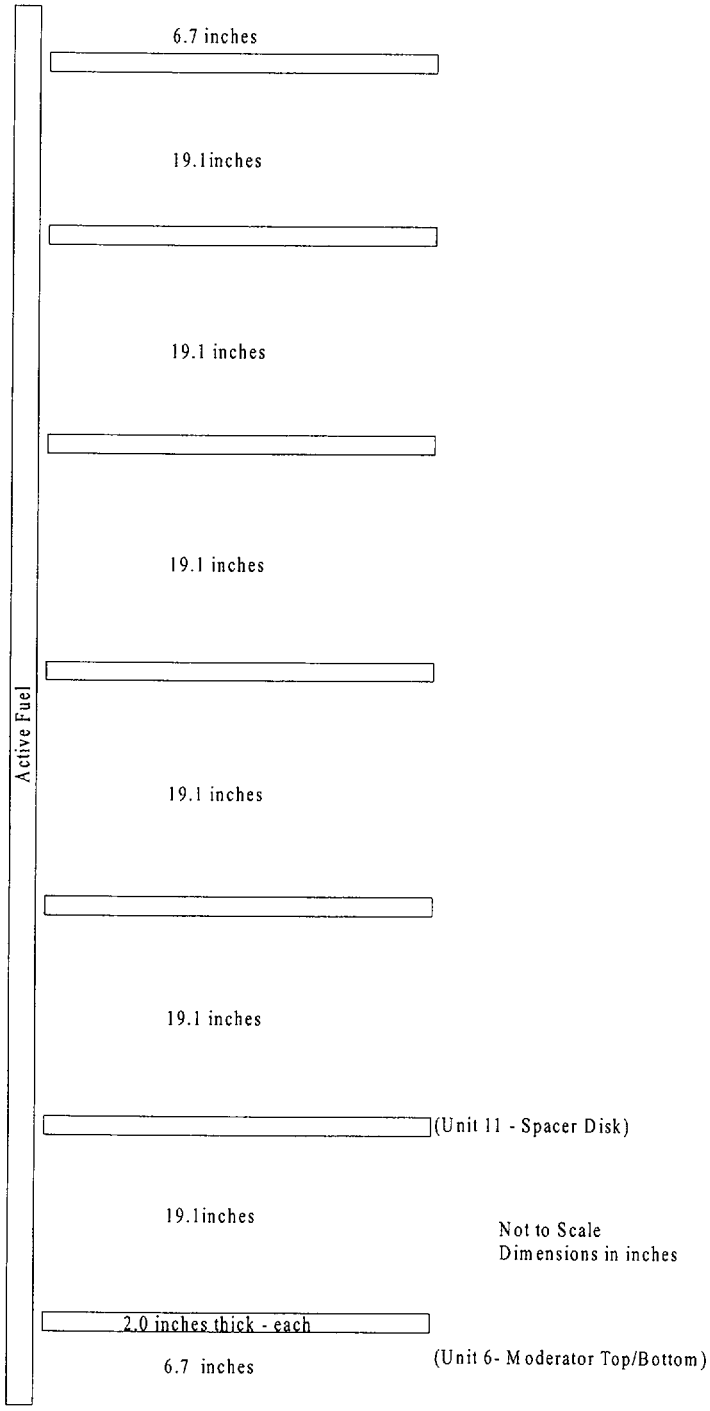

Figure L.6-3
NUHOMS®-24P DSC Spacer Disc Model Layout

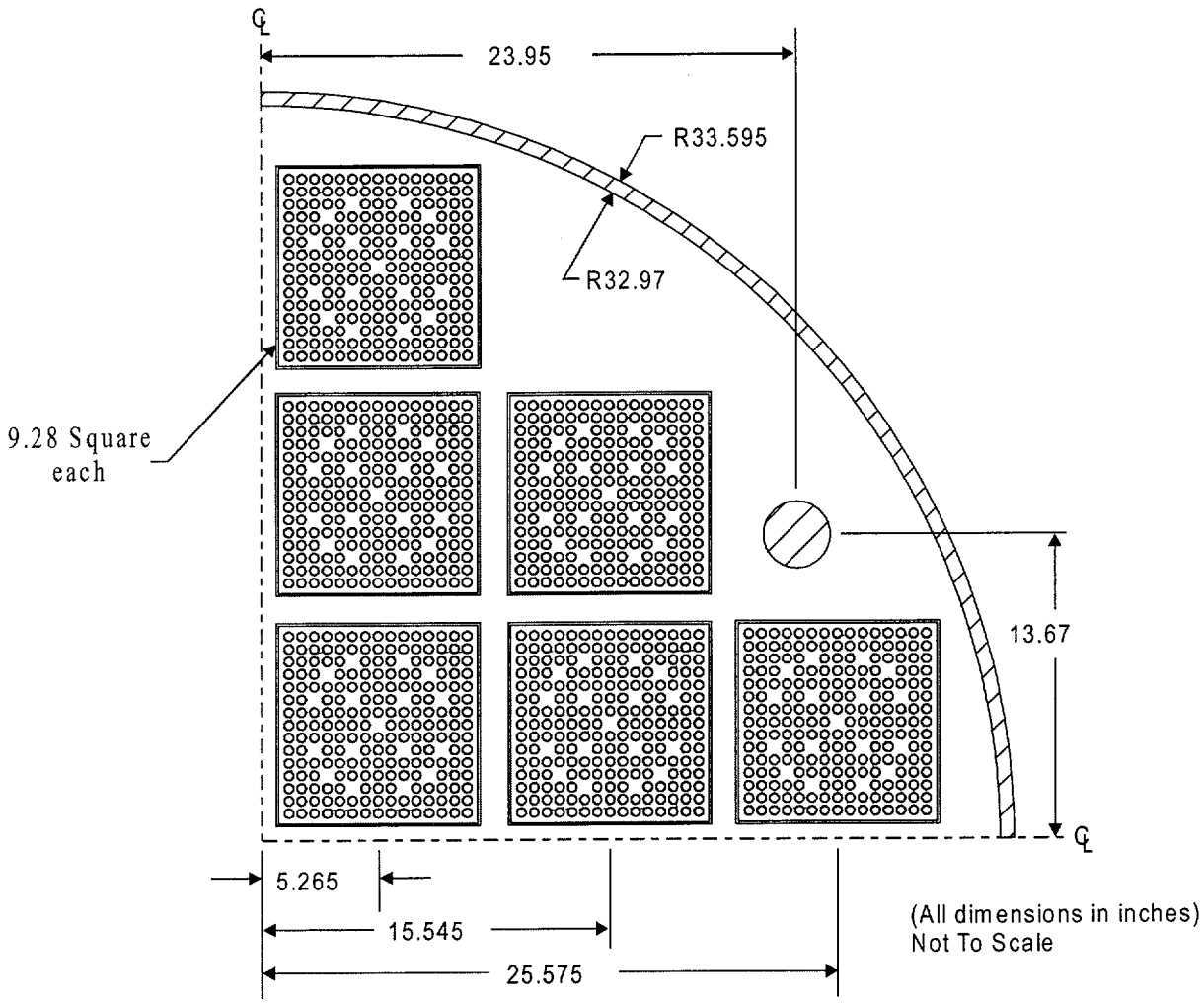

Figure L.6-4
NUHOMS®-24P DSC Radial Geometry

L.6.3.3 24PT2S Infinite Array Calculations

The following dimensional data were used for the infinite array KENO models.

	inches	cm
Guide sleeve inside dimension	8.9	22.606
Guide sleeve thickness	0.2228	0.565912
Guide sleeve outside dimension	9.3456	23.737824
Guide sleeve pitch	10.38	26.3652

L.6.4 Criticality Calculation

L.6.4.1 Calculational Method

L.6.4.1.1 Computer Codes

All calculations are performed using the microcomputer application KENO-5A [6.2] and the Hansen-Roach 16-group (HR-16) cross section working library.

Resonance and heterogeneous effects corrections are performed using the Transnuclear West (TNW) proprietary program PN-HET. PN-HET is used to calculate σ_{peff}, the effective resonance cross section, for each fuel, using the following procedure:

- Calculate σ_{peff} for U235 and U238 in the fuel rods.
- Select H-R library nuclides with σ_{peff} above and below the calculated value.
- Perform a weighted average to accurately represent the resonance nuclide using a mixture of the two selected nuclides.

The benchmark calculations validating this methodology and these codes are documented in Section 3.3.4.2.2.

L.6.4.1.2 Physical and Nuclear Data

The physical and nuclear data required for the criticality analysis are described in Sections L.6.4.1.3 and L.6.4.1.4.

L.6.4.1.3 Fuel Design Parameters

Table L.6-1 summarizes the B&W 15x15 Mark B fuel (most reactive fuel) characteristics used in the criticality analysis.

Table L.6-1
B&W 15x15 Mark B Fuel Characteristics

Fuel assembly design Shorthand description	**B&W 15x15 Mark B** BW15MB	
Parameter	Value	
Maximum number of fueled rods	208	
Fuel density, % theoretical	95%	
Quantity of guide tubes	16	
Quantity instrument tubes	1	
Parameter	inches	cm
Pellet diameter	0.3686	0.9362
Active fuel length	141.8	360.1720
Cladding thickness	0.0265	0.0673
Fuel rod OD	0.43	1.0922
Fuel rod pitch	0.568	1.4427
Guide tube OD	0.53	1.3462
Guide tube thickness	0.016	0.0406
Instrument tube OD	0.493	1.2522
Instrument tube thickness	0.026	0.0660

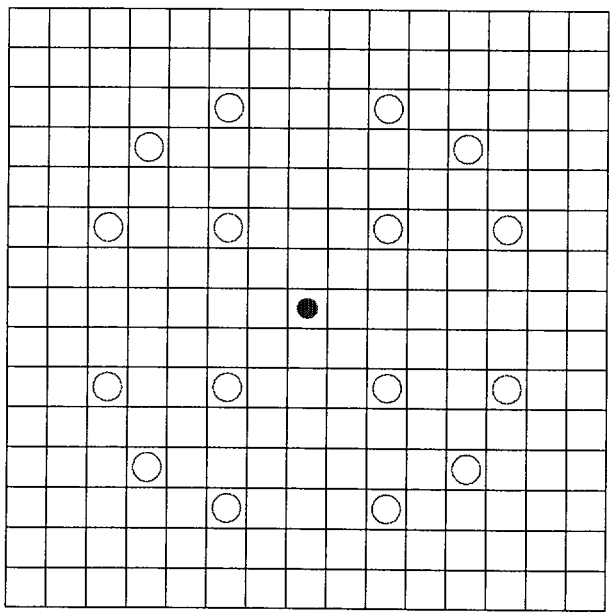

Figure L.6-5
B&W 15x15 Mark B Fuel Assembly

L.6.4.1.4 Atom Density Calculations

The fuel atom densities are based in 95% theoretical density UO_2 fuel enriches to 4.0 wt. % U-235. The resultant atom densities are:

Oxygen atom density, #/b-cm	4.6550E-02
U-235 atom density, #/b-cm	9.3102E-04
U-238 atom density, #/b-cm	2.2345E-02

The moderator atom densities are based on water at a density of 0.99823 g/cm^3. The resultant atom densities are:

Hydrogen atom density, #/b-cm	6.6736E-02
Oxygen atom density, #/b-cm	3.3368E-02
Natural boron atom density, #/b-cm	1.0064E-04

The atom densities used in these calculations for zircaloy, stainless steel, carbon steel and the Boral® are given in Table L.6-2 and Table L.6-3.

Table L.6-2
Zircaloy and Steel Atom Densities

	Density, g/cc	6.4900		7.8500	
	Material	ZIRCALOY-4		Stainless Steel	
Element	atomic mass	mass %	atom density, atoms/b-cm	mass %	atom density, atoms/b-cm
CARBON	12.0112			0.015%	5.9036e-05
CHROMIUM	51.996	0.100%	7.5166e-05	19.000%	1.7274e-02
IRON	55.847	0.135%	9.4476e-05	69.485%	5.8817e-02
MANGANESE	54.938			1.000%	8.6048e-04
NICKEL	58.71	0.055%	3.6613e-05	10.000%	8.0520e-03
SILICON	28.086			0.500%	8.4158e-04
ZIRCONIUM	91.22	99.710%	4.2721e-02		
	Total	1		1	

Table L.6-3
Carbon Steel and Neutron Absorber Atom Densities

	Density, g/cc	7.85		2.549835	
	Material	Carbon Steel		Neutron Absorber	
Element	atomic mass	mass %	atom density, atoms/b-cm	mass %	atom density, atoms/b-cm
IRON	55.847	99.00%	8.3801e-02		
MANGANESE	54.938	1.00%	8.6048e-04		
ALUMINUM	26.9815			69.00%	3.9268e-02
CARBON	12.0112			6.00%	7.6705e-03
BORON	NA			0.00%	0.0
	Total	1		0.75	(No Boron)

The criticality analysis uses the Hansen-Roach 16-group (HR-16) cross section working library. Resonance and heterogeneous effects corrections are preformed with PH-HET as described in Section L.6.4.1.1.

L.6.4.1.5 Bases and Assumptions

It is assumed that a number of PWR fuels can also be qualified for storage in the 24PT2S and 24PT2L system if they can be demonstrated to be less reactive than the design basis fuel used for the generic system criticality analysis.

It is assumed that an infinite array modeling approach is appropriate since the 24PT2S is large (reflection/leakage effects do not dominate the problem). The 24PT2S does not have a uniform assembly pitch in both the x and y axes (fuel/moderator ratio is not the same everywhere). The infinite array is modeled using the minimum pitch, as this will allow the maximum interaction between the fuel assemblies.

L.6.4.1.6 Determination of k_{eff}.

The criticality calculations were performed with KENO-5A [6.2]. The Monte Carlo calculations performed with KENO-5A used a flat neutron starting distribution. The total number of histories traced for each calculation was approximately 61,500. This number of histories was sufficient to converge the source and produce standard deviations of less than 0.3% in k_{eff}. The maximum k_{eff} for the calculation was determined with the following formula:

$$k_{eff} = k_{KENO} + 2\sigma_{KENO.}$$

L.6.4.2 Fuel Loading Optimization

A. 24PT2S Compared to Standardized DSC

The 24P standardized model was generated to serve as the base case to determine if the 24PT2S is less reactive by comparing the reactivity to that of the standardized DSC analyzed in the NUHOMS® Topical Report [6.1]

Table L.6-4 lists the calculated reactivity for each case. The 24PT2S is less reactive as compared to the 24P standardized DSC; the difference being about -0.5% Δk/k. Therefore, the results show that the 24PT2S and 24PT2L are bounded by the standardized DSC design.

Table L.6-4
24PT2S-DSC vs Standardized DSC

Case	k_{KENO}	$1\ \sigma_{KENO}$
24P	0.88402	0.00120
24PT2S	0.87995	0.00128

B. Demonstration of the Most Reactive Fuel Lattice

Table L.6-5 lists the calculated reactivity for each fuel design placed in an infinite array of 0.2228" guide sleeves at the minimum cell pitch of 10.38 inches found in the 24PT2S.

B&W 15x15 Mark B fuel has the highest calculated k_{KENO} reactivity of any fuel design analyzed. The nearest fuel design, Westinghouse 17x17 Standard, is 1.5% Δk/k less reactive than the Mark B fuel.

Table L.6-5
Fuel Design Study Results

Assembly Type	k_{KENO}	$1\ \sigma_{KENO}$	k_{eff}
B&W 15x15 Mark B	0.90926	0.00246	0.91418
B&W 15x15 St. Steel	0.86016	0.00226	0.86468
CE 14x14 Fort Calhoun	0.83533	0.00239	0.84011
CE 14x14 Standard/Generic	0.82443	0.00227	0.82897
CE 15x15 Palisades	0.87133	0.00256	0.87645
CE 15x15 Palisades	0.78324	0.00234	0.78792
Exxon/ANF 15x15 CE	0.8619	0.00261	0.86712
Exxon/ANF 15x15 Westinghouse	0.8766	0.00249	0.88158
Westinghouse 14x14 Std/SC	0.78213	0.00239	0.78691
Westinghouse 14x14 Std/ZCA	0.79942	0.00251	0.80444
Westinghouse 14x14 Std/ZCB	0.80602	0.00266	0.81134
Westinghouse 15x15 Std/ZC	0.89008	0.00252	0.89512
Westinghouse 17x17 OFA/Vantage 5	0.88054	0.00246	0.88546
Westinghouse 17x17 Standard	0.89599	0.00227	0.90053

L.6.4.3 Criticality Results

The results provided in Table L.6-4 demonstrate that the 24PT2S and 24PT2L canister designs are less reactive than the 24P. These results are very conservative as the B-10 poison material in the 24PT2S and 24PT2L designs are not modeled. The results provided in Table L.6-5 also demonstrate that the design basis B&W 15x15 Mark B assembly continues to be the most reactive fuel assembly.

L.6.5 Critical Benchmark Experiments

All calculations are performed using the microcomputer application KENO-5A [6.2] and the Hansen-Roach 16-group (HR-16) cross section working library

An extensive verification and validation of KENO-5A, the HR-16 working cross section library, and the resonance/heterogeneous effects calculation program PN-HET has been performed. This benchmark analysis is documented in Section 3.3.4.2.2. It was concluded that KENO-5A/HR-16/PN-HET slightly over-predicts k_{eff} and that no significant biases are present due to system parameters such as fuel enrichment, absorber characteristics, fuel/moderator volume ratios, soluble boron content, etc. Since this is a parametric study, and since no significant bias correlations were determined, further discussion of calculational bias is not required.

L.6.6 References

6.1 "Topical Report for the NUTECH Horizontal Modular Storage System for Irradiated Nuclear Fuel," Pacific Nuclear Fuel Services, Revision 2A, NUH-002, 1991.

6.2 "KENO-5A-PC, Monte Carlo Criticality Program with Supergrouping," CCC-548, Oak Ridge National Laboratory, File Number QA040.214.0002, June 1990.

L.7 Confinement

The design features and operating procedures applicable to the 24PT2S/24PT2L DSCs required for confinement are identical to the standard 24P and long cavity 24P DSC. Therefore, the confinement evaluation for the 24P and long cavity 24P DSCs bound the 24PT2S/24PT2L DSC designs.

L.8 Operating Systems

The operating procedures for the standardized NUHOMS®-24PT2 system described in previous chapters of Appendix L and shown on the drawings in Section L.1.5 include preparation of the DSC and fuel loading, closure of the DSC, transport to the ISFSI, DSC transfer into the HSM, monitoring operations, and DSC retrieval from the HSM. The standardized NUHOMS® transfer equipment, and the existing plant systems and equipment are used to accomplish these operations.

Chapter 5 provides a description as to how these operations are to be performed for the standardized 24P and 52B NUHOMS® system. In general, these operational steps are also applicable to the NUHOMS®-24PT2 system. This chapter only lists significant variations, if any, for the NUHOMS®-24PT2 system.

The generic NUHOMS® procedures described in Chapter 5 have been developed to minimize the amount of time required to complete the subject operations, to minimize personnel exposure, and to assure that all operations required for DSC loading, closure, transfer, and storage are performed safely. Plant specific ISFSI procedures are to be developed by each licensee in accordance with the requirements of 10CFR72.24 (h) and the guidance of Regulatory Guide 3.61 [8.1]. These generic procedures are provided as a guide for the preparation of plant specific procedures and serve to point out how the NUHOMS® system operations are to be accomplished. They are not intended to be limiting in that the licensee may judge that alternate acceptable means are available to accomplish the same operational objective.

L.8.1 Procedures for Loading the Cask

Process flow diagrams for loading and retrieval of the 24PT2 system are identical to those presented in Figures 5.1-1 and 5.1-2 respectively of Chapter 5.

L.8.1.1 Preparation of the Transfer Cask and DSC

No change relative to Chapter 5, except that for plants with a 100 ton crane capacity, the transfer cask neutron shield water may need to be removed. If this option is used, the neutron shield needs to be filled with water once the cask is downended on the transfer trailer in Section 0.

L.8.1.2 DSC Fuel Loading

No change.

L.8.1.3 DSC Drying and Backfilling

No change.

L.8.1.4 DSC Sealing Operations

No change.

L.8.1.5 Transfer Cask Downending and Transport to ISFSI

No change.

L.8.1.6 DSC Transfer to the HSM

No change.

L.8.1.7 Monitoring Operations

No change.

L.8.2 Procedures for Unloading the Cask

L.8.2.1 DSC Retrieval from the HSM

No change.

L.8.2.2 Removal of Fuel from the DSC

No change.

L.8.3 Identification of Subjects for Safety Analysis

No change.

L.8.4 Fuel Handling Systems

No change.

L.8.5 Other Operating Systems

No change.

L.8.6 Operation Support System

No change.

L.8.7 Control Room and/or Control Areas

No change.

L.8.8 Analytical Sampling

No change.

L.8.9 References

8.1 U.S. Nuclear Regulatory Commission, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask," Regulatory Guide 3.61 (Task 306-4), February 1989.

L.9 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

L.9.1 Acceptance Tests

The addition of 24PT2 DSC to the standardized NUHOMS® system does not result in any change to the Pre-Operational Tests described in Section 9.2 since the transfer cask and HSM involved are not changed and the 24PT2 DSC is very similar to the 24P DSC from an operations perspective.

Prior to operation of the ISFSI for a particular plant, the licensee should perform functional tests of the in-plant operations, the on-site transfer operations, and 24PT2 DSC insertion and retrieval (operations at the ISFSI). These tests are intended to verify that the storage system components (e.g., 24PT2 DSC, HSM, transfer cask, transfer equipment, etc.) operate safely and effectively. Such a program has been successfully completed for the NUHOMS® ISFSIs at Duke Power Company's Oconee Nuclear Station, Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant, Toledo Edison's Davis Besse Nuclear Station and Pennsylvania Power and Light's Susquehanna Nuclear Station.

L.9.1.1 Visual Inspection

Visual inspections are performed at the fabricator's facility to ensure that the 24PT2 DSC and the HSM conform to the drawings and specifications. The visual inspections include verifying dimensions and the application of specified coatings and that the 24PT2 DSC is clean and free of defects. Visual inspections are performed in accordance with the requirements and acceptance criteria specified by the codes applicable to the associated components.

Upon arrival at the site, the 24PT2 DSCs are again inspected to ensure that they have not been damaged during shipment. Conditions which are not in conformance with the drawings and specifications will be repaired or evaluated, in accordance with 10CFR 72.48, for the effect of the condition on the safety function of the components.

L.9.1.2 Structural

All welding is performed using qualified processes and qualified personnel according to the applicable code requirements (e.g., ASME, AWS). NDE requirements for welds are specified on the drawings provided in Section L.1. Weld-related NDE is performed in accordance with written and approved procedures.

The confinement welds on the 24PT2 DSC are designed, fabricated, tested and inspected in accordance with ASME B&PV Code Subsection NB [9.1] as modified by Code Case N-595-1 as discussed in Sections L.3 and L.7.

24PT2 DSC non-confinement welds are inspected to the NDE acceptance criteria of ASME B&PV Code Subsection NG or NF, based on the applicable code for the components welded.

24PT2 DSC lifting lugs are provided for empty DSC handling operations only. These operations are performed away from plant safety related equipment; therefore these lifting lugs are not subject to load testing requirements of ANSI N14.6 [9.2] for heavy loads.

L.9.1.3 Leak Tests and Pressure Tests

24PT2 DSC leakage tests are performed on the confinement system at the fabricator's facility and during 24PT2 DSC closure operations in accordance with ANSI N14.5 [9.3].

The 24PT2 DSC shell is pressure tested in accordance with ASME Code Case N-595-1. This pressure test is performed following installation of the inner bottom cover plate at a minimum pressure of 12 psig.

L.9.1.4 Components

No change associated with the addition of 24PT2 DSC.

L.9.1.5 Shielding Integrity

The gamma and neutron shielding materials used are limited to the carbon steel and lead shield plugs in the 24PT2S and 24PT2L DSC, respectively. The integrity of these shielding materials is ensured by the control of their fabrication in accordance with the appropriate ASME or ASTM criteria.

External dose rate surveys are performed at loading to ensure that Technical Specification radiation dose limits are not exceeded for each 24PT2 DSC.

L.9.1.6 Thermal Acceptance

The thermal analysis performed for the 24PT2 DSC is discussed in Section L.4. This analysis demonstrates that the system will provide adequate thermal performance during storage. Thermal acceptance will be confirmed by monitoring HSM thermal performance throughout the service life of the HSM. This is performed in accordance with the associated Technical Specification requirements.

L.9.1.7 Neutron Absorber Tests

This section describes the tests, process controls, and measurements relied upon to demonstrate proper fabrication and effectiveness of the neutron absorber sheets.

During fabrication, the neutron absorber sheets used in the 24PT2 DSC are verified to have their minimum total B10 per unit area (areal density) of the sandwiched material as specified on the drawings in Section L.1.5.

Samples from each sheet of the neutron absorber are retained for testing and record purposes. The minimum B10 content per unit area and the uniformity of dispersion within a sheet are verified by chemical analysis and/or neutron attenuation testing. All material certifications, lot control records, and test records are maintained to assure material traceability and are part of the maintenance records discussed in Section L.9.2.1.

Chemical (destructive) testing is the preferred method because the B10 areal density, which is the primary requirement for the material, can be directly measured. This is done by taking two one inch square samples from each end of the rolled product. The size of the one square inch sample is small compared to the finished sheet size, 1300 in^2, so that non-uniformities in B10 areal density would be readily apparent between the samples. The material on the ends of the rolled product is known to be thinner than the rest of the sheet because of the rolling process. This characteristic of the finished product is confirmed by examination of thickness in four locations on 100% of the sheets. The thinnest of these samples is used for destructive chemical determination of the amount of boron in the sample using written, approved procedures and standard laboratory processes and equipment. Using the area of the sample, and the mass of boron in the sample, the areal boron density may be calculated. Once the areal boron density is known, the areal B10 density is calculated using the isotopic assay of the B_4C powder used to manufacture the product. The sample frequency is determined using standard statistical procedures to assure that minimum B10 areal densities are achieved with a 95/95 confidence level. This assures that the minimum safety requirements for the neutron absorber sheets are met. The neutron absorber sheets are capable of performing their function throughout the service life of the 24PT2 DSC as discussed in Section L.6.

Neutron attenuation testing may be performed to augment or replace chemical (destructive) testing as required to demonstrate acceptable minimum areal B10 loading of the neutron absorber sheets. Neutron transmission measurements may be performed on samples, or completed sheets, using a neutron diffractometer. If used, the neutron transmission measurements shall be performed using written, approved procedures in accordance with applicable portions of ASTM E94 [9.4], "Recommended Practice for Radiographic Testing", ASTM E142 [9.5], "Controlling Quality of Radiographic Testing", and ASTM E545 [9.6], "Standard Method for Determining Image Quality in Thermal Radiographic Testing." Since this type of testing does not measure directly the B10 areal density of the sheets, the results of neutron attenuation tests shall be demonstrated by calculation to show that the minimum specified B10 areal densities are achieved with a 95/95 confidence level.

L.9.2 Maintenance Program

The NUHOMS® system is designed to be totally passive with minimal maintenance requirements. The 24PT2 DSC does not require any maintenance once it is loaded into the HSM.

L.9.2.1 Maintenance of Records

No change.

L.9.2.2 Maintenance of Thermal Monitoring System

No change.

L.9.3 Training Program

No change.

L.9.4 References

9.1 ASME Boiler and Pressure Vessel Code, Section III, 1992 Edition with 1994 Addenda as modified by Code Case N-595-1.

9.2 ANSI N14.6, "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials," New York, 1996.

9.3 ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials", February 1998.

9.4 ASTM E94, "Guide for Radiographic Testing", 1993.

9.5 ASTM E142, "Method for Controlling Quality of Radiographic Testing", 1992.

9.6 ASTM E545, "Method for Determining Image Quality in Direct Thermal Neutron Radiographic Examination", 1991.

L.10 Radiation Protection

Section 7.4.1 and Appendix J discuss the anticipated cumulative dose exposure to site personnel during the fuel handling and transfer activities associated with utilizing one NUHOMS® HSM for storage of one 24P, long cavity 24P, or 52B canister. Chapter 5 describes in detail the NUHOMS® operational procedures, several of which involve potential exposure to personnel. As discussed in Section L.5 "Shielding," the dose rates on and around the transfer cask or HSM loaded with the 24PT2S and 24PT2L canisters are bounded by the 24P or long cavity 24P canister designs. Also, no operational changes are required. Therefore, the anticipated cumulative dose exposures to site personnel during fuel handling and transfer activities utilizing the 24PT2S and 24PT2L canister designs are bounded by the 24P and long cavity 24P canisters because the operating procedures are identical.

The site dose evaluations presented in Section 7.4.2 and Appendix J also bound the 24PT2S and 24PT2L canister designs because the dose rates on and around the HSM are bounded by the 24P and long cavity 24P canister designs.

L.11.2 Postulated Accidents

L.11.2.1 Reduced HSM Air Inlet and Outlet Shielding

This event is described in Section 8.2.1.

L.11.2.1.1 Cause of Accident

No change.

L.11.2.1.2 Accident Analysis

No change.

L.11.2.1.3 Accident Dose Calculations

No change. As discussed in Section L.5, the standard 24P and long cavity 24P shielding analyses bound the 24PT2S and 24PT2L canister designs. Therefore, the analysis presented in Section 8.2.1.3 bounds the 24PT2S and 24PT2L canister designs.

L.11.2.1.4 Corrective Actions

No change.

L.11.2.2 Earthquake

This event is described in Section 8.2.3.

L.11.2.2.1 Cause of Accident

No change.

L.11.2.2.2 Accident Analysis

Section 8.2.3.2 describes the analyses performed to demonstrate that the NUHOMS® system will withstand the design basis seismic event. Section L.3.7.3 presents the changes to this analysis resulting from the addition of NUHOMS®-24PT2 DSC. There are no changes to the design of the HSM or the transfer casks. Therefore, only those analyses affected by the DSC weight have been modified. The analysis of the NUHOMS®-24PT2 DSC is presented in Section L.3.7. The results of this analysis show that the structural integrity of the canister is not compromised. No damage to the HSM is postulated. The basket stresses are also within acceptable limits and do not result in deformations that would prevent fuel from being unloaded from the canister.

L.11.2.2.3 Accident Dose Calculations

No change.

L.11.2.2.4 Corrective Actions

No change.

L.11.2.3 Extreme Wind and Tornado Missiles

This event is described in Section 8.2.2.

L.11.2.3.1 Cause of Accident

No change.

L.11.2.3.2 Accident Analysis

An evaluation of the HSM and transfer cask with respect to tornado winds and tornado missiles is presented in Section 8.2.2. Changes to this analysis, as a result of the addition of the NUHOMS®-24PT2 DSC, are presented in Section L.3.7.2. The analysis presented in Section 8.2.2 is bounding.

L.11.2.3.3 Accident Dose Calculations

No change.

L.11.2.3.4 Corrective Actions

No change.

L.11.2.4 Flood

This event is described in Section 8.2.4.

L.11.2.4.1 Cause of Accident

No change.

L.11.2.4.2 Accident Analysis

The HSM is evaluated for flooding in Section 8.2.4. This evaluation is bounding for the NUHOMS®-24PT2 DSC as described in Section L.3.7.4.1. The evaluation of the NUHOMS®-24PT2 DSC due to the design basis flood is presented in Section L.3.7.4.2. Per

Section L.3.7.4.2, the stress results presented in Section 8.2 and in Appendix H bound the stresses in the 24PT2 DSC.

L.11.2.4.3 Accident Dose Calculations

No change.

L.11.2.4.4 Corrective Actions

No change.

L.11.2.5 Accidental Transfer Cask Drop

This event is described in Section 8.2.5.

L.11.2.5.1 Cause of Accident

No change.

L.11.2.5.2 Accident Analysis

The evaluation of the DSC, basket and the transfer cask is presented in Section L.3.7.5. As shown in Section L.3.7.5, the DSC, basket and transfer cask stress intensities are within the appropriate ASME Code Service Level D allowable limits and maintain their structural integrity.

The evaluation for loss of neutron shield provided in Section 8.2.5.3 is also applicable to the NUHOMS®-24PT2 DSC.

L.11.2.5.3 Accident Dose Calculations for Loss of Neutron Shield

No change.

L.11.2.5.4 Corrective Action

No change.

L.11.2.6 Lightning

No change. The evaluation presented in Section 8.2.6 is not affected by the addition of the NUHOMS®-24PT2 DSC to the NUHOMS® system.

L.11.2.7 Blockage of Air Inlet and Outlet Openings

This event is described in Section 8.2.7.

L.11.2.7.1 Cause of Accident

No change.

L.11.2.7.2 Accident Analysis

The thermal evaluation of this event for the 24PT2 DSC is presented in Section L.4.6. The temperatures presented in Section L.4.6 are used in the structural evaluation of this event, which is presented in Sections L.3.7.7 and L.3.4.4.3.

L.11.2.7.3 Accident Dose Calculations

No change.

L.11.2.7.4 Corrective Action

No change.

L.11.2.8 DSC Leakage

No change to the cause of the accident, accident analysis and accident dose calculations presented in Section 8.2.8 due to the addition of 24PT2 DSC.

L.11.2.9 Accident Pressurization of DSC

L.11.2.9.1 Cause of Accident

The bounding internal pressurization of the NUHOMS®-24PT2 DSC is postulated to result from cladding failure of the spent fuel in combination with the blocked inlet and outlet vents and the consequent release of spent fuel rod fill gas and free fission gas. The evaluation conservatively assumes that 100% of the fuel rods have a cladding failure. It is further assumed that 30% of the fission gasses are released.

L.11.2.9.2 Accident Analysis

The pressure due to this case is evaluated in Section L.4.6. The maximum pressure calculated is 57.2 psig. The accident pressure is conservatively assumed to be 60 psig in the structural load combinations presented in Table 8.2-24 (UL-8, HSM-5, HSM-6). This pressure is applied to the outer pressure boundary in the same manner as the NUHOMS®-24P DSC.

L.11.2.9.3 Accident Dose Calculations

No change.

L.11.2.9.4 Corrective Actions

This is a hypothetical event. Therefore no corrective actions are required. The canister is designed to withstand the pressure as a Level D condition. There will be no structural damage to the canister or leakage of radioactive material as a result of this event.

L.11.2.10 Fire and Explosion

This evaluation presented in Section 3.3.6 is not affected by the addition of NUHOMS®-24PT2 DSC.

L.11.3 References

11.1 American Nuclear Society, ANSI/ANS-57.9, Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type), 1992.

11.2 NUHOMS® Certificate of Compliance for Dry Spent Fuel Storage Casks, Certificate Number 1004, January 1995 (Docket 72-1004).

L.11 Accident Analyses

This section describes the postulated off-normal and accident events that could occur during transfer and storage of the NUHOMS®-24PT2 DSC. Sections which do not affect the evaluation presented in Chapter 8 are identified as "No change." Detailed analysis of the events are provided in other sections and referenced herein.

L.11.1 Off-Normal Operations

Off-normal operations are design events of the second type (Design Event II) as defined in ANSI/ANS 57.9 [11.1]. Off-normal conditions consist of that set of events that, although not occurring regularly, can be expected to occur with moderate frequency or on the order of once during a calendar year of ISFSI operation.

The off-normal conditions considered for the NUHOMS®-24PT2 DSC are off-normal transfer loads and extreme temperatures.

L.11.1.1 Off-Normal Transfer Loads

No change. The limiting off-normal event is the jammed DSC during loading or unloading from the HSM. This event is described in Section 8.1.2.

L.11.1.1.1 Postulated Cause of Event

No change relative to Section 8.1.2. The probability of a jammed DSC does not increase with the NUHOMS®-24PT2 DSC, since the outside diameter and length of the DSC is the same as the NUHOMS®-24P DSC.

L.11.1.1.2 Detection of Event

No change.

L.11.1.1.3 Analysis of Effects and Consequences

No change.

L.11.1.1.4 Corrective Actions

No change.

L.11.1.2 Extreme Temperatures

No change.

L.11.1.2.1 Postulated Cause of Event

No change.

L.11.1.2.2 Detection of Event

No change.

L.11.1.2.3 Analysis of Effects and Consequences

The thermal evaluation of the NUHOMS®-24PT2 system for off-normal conditions is presented in Section L.4.5. The 100°F normal condition with solar insolation bounds the 125°F case without solar insolation for the DSC in the transfer cask. Therefore, the normal condition maximum temperatures are bounding.

The structural evaluation of the HSM's, NUHOMS®-24PT2 DSC and the OS-197 and Standardized transfer casks for the off-normal temperature conditions are presented in Section L.3.6.2.2. The structural evaluation of the basket due to off-normal thermal conditions is presented in Section L.3.6.2.2.

L.11.1.2.4 Corrective Actions

Restrictions for onsite handling of the transfer cask with a loaded DSC under extreme temperature conditions are presented in NUHOMS® Technical Specifications 1.2.13 and 1.2.14 [11.2]. There is no change to this requirement as a result of addition of the NUHOMS®-24PT2 DSC.

L.12 Operating Controls and Limits

The addition of 24PT2 DSC to the standardized NUHOMS® system does not result in any change to the Technical Specifications, Functional and Operating of NUHOMS® CoC 1004, Amendment 3.

L.13 Quality Assurance

Chapter 11 provides a description of the Quality Assurance Program to be applied to the safety related and important to safety activities associated with the Standardized NUHOMS® system. The addition of the 24PT2 DSC to the NUHOMS® system also requires the same following clarification as the 24P and 52B DSCs to the contents of Section 11.2:

"In lieu of the requirements listed in paragraph A through H, Category A items may also be procured as commercial grade items and dedicated by in accordance with the guidelines of EPRI NP-5652."

L.14 Decommissioning

There is no change from the decommissioning evaluation presented in Section 9.6 due to the addition of 24PT2 DSC to the NUHOMS® system.