APPENDIX B

32PTH Type 2 DSC and OS187H Type 2 TC

APPENDIX B.1
GENERAL INFORMATION

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.1 GENERAL INFORMATION

Appendix B to this NUHOMS® HD System updated Final Safety Analysis Report (UFSAR) documents the addition of the 32PTH Type 2 dry shielded canister (DSC) and the OS187H Type 2 transfer cask (TC) to the NUHOMS® HD System. These two components are similar but longer length versions of the 32PTH DSC and the OS187H TC described in the main body of this UFSAR.

The general information presented in Chapter 1 remains applicable for 32PTH Type 2 DSC and OS187H Type 2 TC, which are added to the NUHOMS® HD System.

The format and content of this appendix follows the format and content of the main body of this UFSAR. Generally, the same chapters and section numbers as in the main body have been kept in this appendix, preceded with a letter B. In addition, in several sections of this appendix reference is made to the corresponding section/chapter in the main body of the FSAR to avoid repetition of documentation that is also applicable to this appendix. For the sections in this appendix which have been identified as "No change," the description or analysis presented in the corresponding sections of the UFSAR for the 32PTH and OS187H or 32PTH Type 1 and OS187H Type 1 are also applicable to the 32PTH Type 2 DSC or the OS187H Type 2 transfer cask. The Tables and figures presented in the UFSAR, which remain unchanged due to the addition of the 32PTH Type 2 DSC and OS187H Type 2 TC, are not repeated in this Appendix B.

Note: References to sections or chapters within this appendix are identified with a prefix B (e.g., Section B.2.1 or Chapter B.2). References to sections or chapters of the UFSAR outside of this appendix (main body of the UFSAR) are identified with the applicable UFSAR section, chapter number or prefix A (e.g., Section 2.1, Chapter 2, Section A.2.1 or Chapter A.2).

B.1.1 Introduction

There is no change to the generic description presented in Section 1.1 of the UFSAR when the 32PTH Type 2 DSC and the OS187H Type 2 TC are used instead of the 32PTH DSC and the OS187H TC. When used with the Type 2 components, the NUHOMS® HD System consists of the 32PTH Type 2 DSC, the OS187H Type 2 TC, and the HSM-H Horizontal Storage Module. Sketches for the 32PTH Type 2 DSC and the OS187H Type 2 TC are shown in Figure B.1-1 and Figure B.1-2.

The 32PTH Type 2 DSC and the OS187H Type 2 TC are similar to, but longer length versions of, the 32PTH DSC and OS187H TC described in the main body of this UFSAR. The main design changes associated with these longer length NUHOMS® HD System components are summarized in Sections B.1.2.1.1 and B.1.2.1.3.1 for the 32PTH Type 2 DSC and OS187H Type 2 TC, respectively. The authorized contents and overall design criteria as described in the main body of this UFSAR is the same for these added components with the exception that an elastic-plastic analysis methodology is used for the accident pressure load case evaluation of the 32PTH Type 2 DSC (instead of elastic analysis methodology used for the 32PTH DSC). The application of the elastic-plastic analysis methodology to the 32PTH Type 2 DSC is similar to that used for the NUHOMS® 32P DSC in Reference [2].

B.1.2 General Description of the NUHOMS® HD System with the 32PTH Type 2 DSC and OS187H Type 2 TC

The general arrangement of NUHOMS® HD System shown in Figure 1-3 and Figure 1-4 and the general description presented in Section 1.2 remain applicable when the 32PTH Type 2 DSC and the OS187H Type 2 TC are used instead of the 32PTH DSC and OS187H TC. The confinement boundary of the 32PTH Type 2 DSC is shown in Figure B.7-1 when the standard three-piece top end assembly configuration is used. For the optional two-piece top end assembly configuration, the confinement boundary is the same as that for the 32PTH DSC as shown in Figure 7-1.

The 32PTH Type 2 DSC is identified as follows: XXX-32PTH-YYY-Z-1, where XXX, YYY, and Z are as described in Section 1.2. The basket types are the same as for the 32PTH DSC and are described in drawing 10494-72-2008-SAR.

B.1.2.1 NUHOMS® HD System Characteristics

B.1.2.1.1 Dry Shielded Canister (32PTH Type 2 DSC)

No change to the generic description for the 32PTH DSC presented in Section 1.2.1.1. Table A.1-1 summarizes the key design parameters for the 32PTH Type 2 DSC.

The major changes implemented in the 32PTH Type 2 DSC relative to the 32PTH DSC are as follows:

- The interior cavity length of the 32PTH Type 2 DSC is increased, approximately 17 in., with a corresponding increase in basket length.
- The thickness of the top shield assembly is reduced from 12.0 in. to 10.0 in. whereas the thickness of the bottom shield assembly is reduced from 8.75 in. to 6.5 in. The overall DSC length also is increased. The DSC diameter is unchanged.
- The top end assembly of the 32PTH Type 2 DSC consists of a three-part closure design (top shield plug, inner top cover, and outer top cover). This design is the same as other standardized NUHOMS® canister designs described in Reference [1]. The two-part top end closure design of the 32PTH DSC is an alternate design in the 32PTH Type 2 DSC.
- Lifting lugs are used to lift the empty 32PTH Type 2 DSC into the OS187H Type 2 TC. The lifting lugs are welded to the shell and are located at the support ring elevation, similar to other standardized NUHOMS® canister designs [1]. Lifting lugs are used in lieu of the lifting rods with welded bosses, located at the inner bottom cover plate, in the 32PTH design. The lifting lugs are non-safety components as they are used to lift the DSC prior to fuel load.

The 32PTH Type 2 DSC is shown on drawings 10494-72-2006-SAR through 10494-72-2010-SAR in Section B.1.5.2.

B.1.2.1.2 Horizontal Storage Module (HSM-H)

No change to the generic description presented in Section 1.2.1.2. Only a small (2.5 in.) increase in the overall length of the DSC support rail is required to accommodate the 32PTH Type 2 DSC. The key design parameters for the HSM-H as presented in Table 1-1 are not changed.

B.1.2.1.3 Transfer Systems

B.1.2.1.3.1 OS187H Type 2 On-Site Transfer Cask

No change to the generic description presented in Section A.1.2.1.3.1 for the OS187H Type 1 TC. Table B.1-1 summarizes the key design parameters for the OS187H Type 2 TC. The major changes incorporated into the OS187H Type 2 transfer cask are:

- In order to accommodate the longer 32PTH Type 2 DSC, the minimum internal cavity length of the TC is increased from 198.75 in. (OS187H Type 1) to 199.05 in. (OS187H Type 2). The increased cavity length is achieved by reducing the thickness of the bottom air flow wedge plate. The 70.5 in. inside diameter and the thicknesses of the top and bottom end assemblies are unchanged.
- There are no other changes (except cavity) in the OS187H Type 2 TC compared to OS187H Type 1 TC.

The OS187H Type 2 TC has a payload capacity of 120,000 lb (determined based on its evaluated capacity of 250,000 lb and its total weight of 130,000 lb).

B.1.2.1.3.2 Transfer Equipment

No change to the transfer equipment description presented in Section 1.2.1.3.2.

B.1.2.2 Operational Features

B.1.2.2.1 Dry Run Operations

No change to the dry run operations description present in Section 1.2.2.1.

B.1.2.2.2 SFA Loading Operations

No change in the primary operations (in sequence of occurrence) for the NUHOMS® HD System described in Section 1.2.2.2, except for placement of the cask spacer (if required) prior to placing the 32PTH Type 2 DSC into the TC, and, for a 32PTH Type 2 DSC with a three-part top end closure, the inner top cover plate is placed following placement of the top shield plug (Step 8) and lifting of the transfer cask from the pool (Step 9). The inner top cover is sealed in Step 10 instead of the top shield plug

B.1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

B.1.2.2.3.1 Criticality Prevention

No change in criticality prevention present in Section 1.2.2.3.1.

B.1.2.2.3.2 Chemical Safety

No change in chemical safety present in Section 1.2.2.3.2.

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B.1.2.2.3.3 Operation Shutdown Modes

The NUHOMS® HD System is a totally passive system so that consideration of operation shutdown modes is unnecessary.

B.1.2.2.3.4 Instrumentation

No change in instrumentation present in Section 1.2.2.3.4.

B.1.2.2.3.5 Maintenance and Surveillance

No change. All maintenance and surveillance tasks are described in Chapter A.9.

B.1.2.3 32PTH Type 2 DSC Contents

No change. The DSC contents described in Section 1.2.3 for the 32PTH DSC are applicable for the 32PTH Type 2 DSC.

B.1.3 Identification of Agents and Contractors

No change to identification of agents and contractors present in Section 1.3.

B.1.4 Generic Cask Arrays

No change to Generic Cask Arrays present in Section 1.4.

B.1.5 Supplemental Data

B.1.5.1 References

1. Updated Final Safety Analysis Report (UFSAR), Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NUH003.0103 Revision 14, USNRC Docket No. 72-1004.

2. USNRC Safety Evaluation Report, SNM-2505, Amendment 7, Dated 11/2/2005, Docket 72-8

B.1.5.2 Drawings

32PTH Type 2 DSC:

- 10494-72-2006-SAR, (3 sheets), (PROPRIETARY)
- 10494-72-2007-SAR, (2 sheets), (PROPRIETARY)
- 10494-72-2008-SAR, (5 sheets), (PROPRIETARY)
- 10494-72-2009-SAR, (3 sheets), (PROPRIETARY)
- 10494-72-2010-SAR, (5 sheets) (PROPRIETARY)

OS187H Type 2 TC:

- 10494-72-9004-SAR, (3 sheets), (PROPRIETARY)
- 10494-72-9005-SAR, (3 sheets), (PROPRIETARY)
- 10494-72-9006-SAR, (3 sheets) (PROPRIETARY)

Table B.1-1
Key Design Parameters of the NUHOMS® HD System Components

Dry Shielded Canister (32PTH Type 2 DSC)	
Overall length (in.)	198.50 (max)
Outside diameter (in.)	69.75 (unchanged)
Cavity length (in.)	181.38 (min)
Shell thickness (in.)	0.5 (unchanged)
Design weight of loaded 32PTH Type 2 DSC (lb)	108,000 (1)
Materials of construction	Stainless steel shell assembly and internals, carbon steel and/or stainless steel shield plugs, aluminum
Neutron absorbing material	Boral™, borated aluminum, metal matrix composite (MMC)
Internal atmosphere	Helium

Horizontal Storage Module (HSM-H)	
Overall length (without back shield wall)	20’-8”
Overall width (without end shield walls)	9’-8”
Overall height	18’ 6”
Total weight (not including 32PTH Type 2 DSC) (lbs.)	307,200(1)
Materials of construction	Reinforced concrete and structural steel
Heat removal	Conduction, convection, and radiation

On-Site Transfer Cask (OS187H Type 2)	
Overall length (in.)	210.50
Outside diameter (in.)	92.11
Cavity length (in.)	199.05
Lead thickness (in.)	3.56 (nom)
Gross weight (including 32PTH Type 1 DSC) (tons)	120.0(1)
Materials of construction	Stainless steel shell assemblies and closures with lead shielding
Internal atmosphere	Helium

Note:
(1) Rounded up values

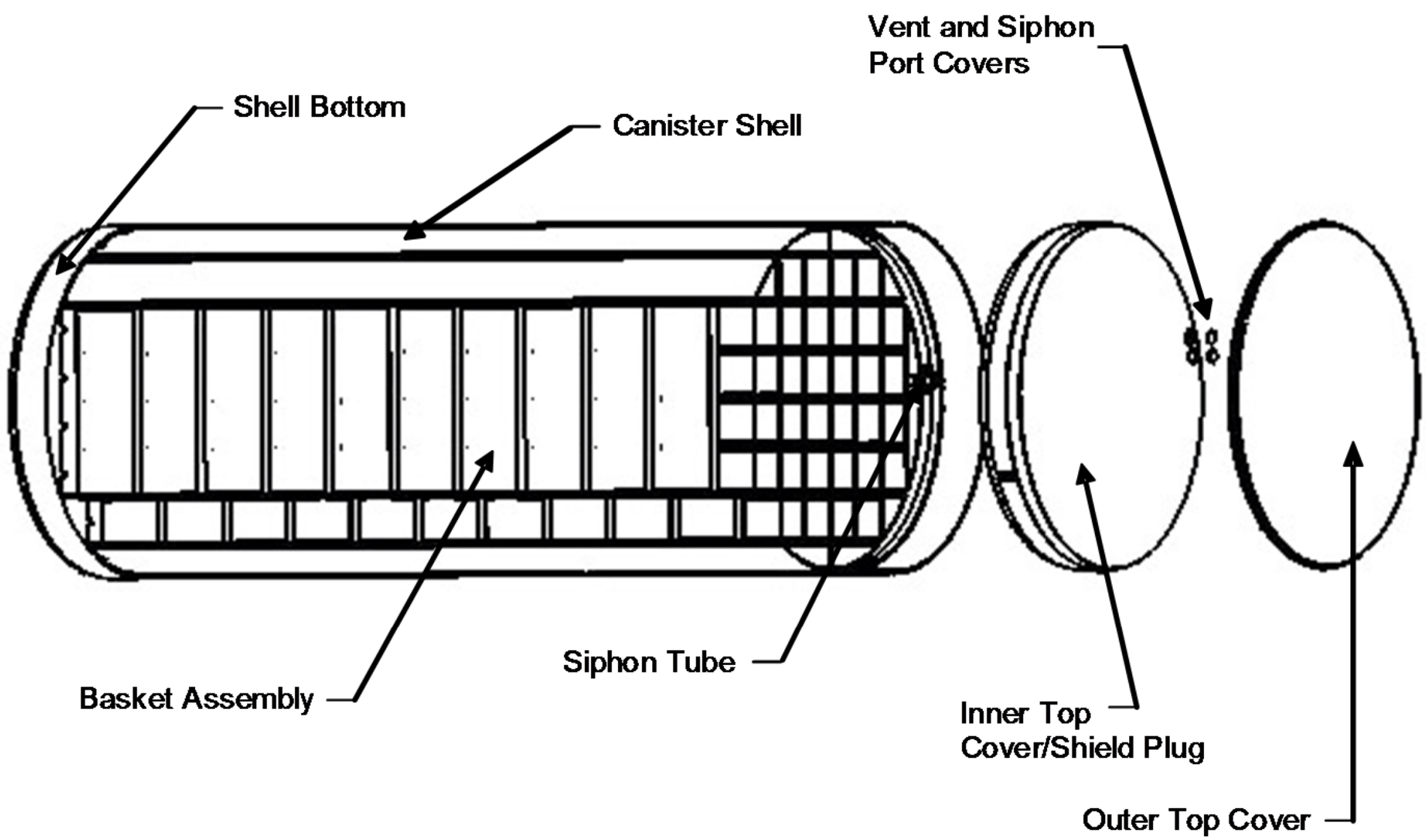

Figure B.1-1
32PTH Type 2 Dry Shielded Canister
(Optional two-part top end configuration shown)

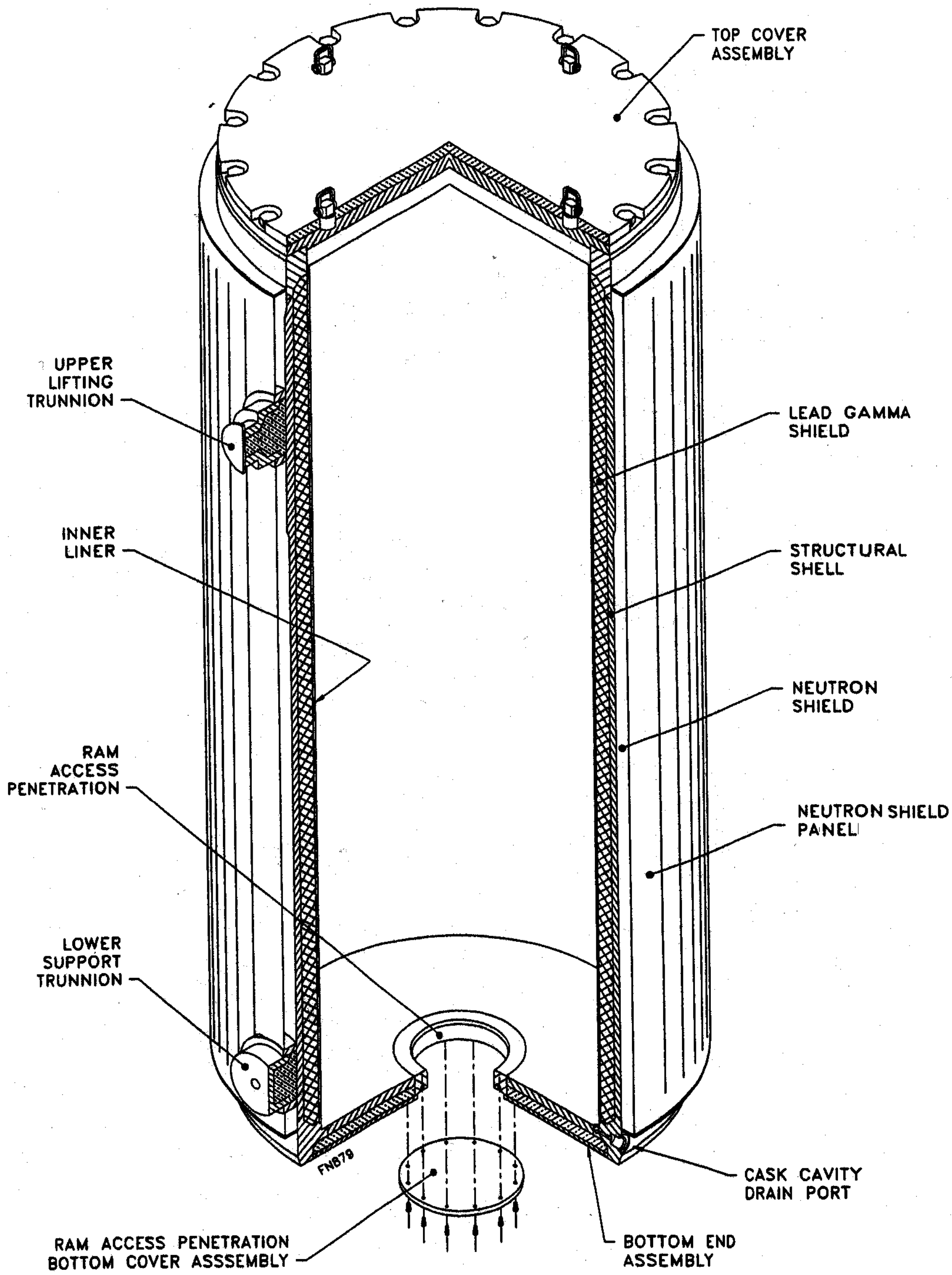

Figure B.1-2
OS187H Type 2 On-Site Transfer Cask

Proprietary and Security Related Information
for Drawing 10494-72-2006, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing 10494-72-2007, Rev. 0
Withheld Pursuant to 10 CFR 2.390

H G F E D C B A

8 7 6 5 4 3 2 1

Proprietary and Security Related Information
for Drawing 10494-72-2008, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing 10494-72-2009, Rev. 0
Withheld Pursuant to 10 CFR 2.390

H G F E D C B A

8 7 6 5 4 3 2 1

Proprietary and Security Related Information for Drawing 10494-72-2010, Rev. 0 Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information
for Drawing 10494-72-9004, Rev. 0
Withheld Pursuant to 10 CFR 2.390

8 7 6 5 4 3 2 1

H G F E D C B A

Proprietary and Security Related Information for Drawing 10494-72-9005, Rev. 0 Withheld Pursuant to 10 CFR 2.390

Proprietary and Security Related Information
for Drawing 10494-72-9006, Rev. 0
Withheld Pursuant to 10 CFR 2.390

APPENDIX B.2
PRINCIPAL DESIGN CRITERIA

No change. The design criteria described in Chapter 2 for the 32PTH DSC and OS187H transfer cask (TC) are applicable to the 32PTH Type 2 DSC and the OS187H Type 2 TC. The contents authorized for storage in the 32PTH Type 2 DSC are the same as the authorized contents for the 32PTH DSC described in Section 2.1. The number of fuel assemblies per DSC, maximum heat load per DSC and heat load configurations, basket poison types, and basket geometric configuration are not changed. Similarly, there is no change to the design criteria for environmental conditions and natural phenomena as described in Section 2.2, or to the safety protection systems as described in Section 2.3. Section 2.4 (Decommissioning Considerations), Section 2.5 (Structures, Systems and Components Important to Safety), and Section 2.6 (References) are not changed. As described in Section B.1.1, an elastic-plastic analysis methodology is used for the accident pressure load case of the 32PTH Type 2 DSC. As with the 32PTH DSC, the details of the 32PTH Type 2 DSC evaluation criteria are described in Chapter B.3.

APPENDIX B.3
STRUCTURAL EVALUATION

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.3 STRUCTURAL EVALUATION

B.3.1 Structural Design

This chapter, including its appendices, summarizes the structural evaluation of the NUHOMS® HD System Type 2 components, i.e., the 32PTH Type 2 dry shielded canister (DSC) and the OS187H Type 2 transfer cask (TC).

The 32PTH Type 2 DSC is similar to, but a longer version of, the 32PTH DSC documented in the main chapter of this UFSAR. As with the 32PTH DSC, the 32PTH Type 2 DSC is designed to accommodate up to 32 intact pressurized water reactor (PWR) fuel assemblies (or up to 16 damaged assemblies, with the remaining intact) with the same total heat load of up to 34.8 kW. The OS187H Type 2 TC is identical to OS187H Type 1 TC with the exception of a slightly longer cavity length. The cavity length is increased from the 198.75 in. of the OS187H Type 1 TC to 199.05 in. for the OS187H Type 2 TC.

The structural evaluation criteria for the 32PTH Type 2 DSC and the OS187H Type 2 TC are the same as the evaluation criteria for the 32PTH DSC and OS187H Type 1 TC described in the main chapter and Appendix A, respectively, of this UFSAR, with no exception to the analysis methodology.

B.3.1.1 Discussion

No change.

B.3.1.1.1 General Description of the 32PTH Type 2 DSC

The principal characteristics of the 32PTH Type 2 DSC are described in Chapter B.1, Section B.1.2.1, including the changes implemented in the 32PTH Type 2 DSC relative to the 32PTH DSC. The 32PTH Type 2 DSC is shown on drawings attached in Section B.1.5.

For purposes of the structural analysis, the 32PTH Type 2 DSC is divided into the 32PTH Type 2 DSC shell assembly and the internal basket assembly.

A. DSC Shell Assembly Description

The 32PTH Type 2 canister shell assembly and design details are shown on drawings in Section B1.5. As with the 32PTH DSC, the 32PTH Type 2 DSC shell assembly is a high integrity stainless steel (SA-240 Type 304 or SA-182 Type F304) welded vessel that provides confinement of radioactive materials, encapsulates the fuel in an inert atmosphere (the canister is backfilled with helium before being seal welded closed), and provides biological shielding (in axial direction).

The 32PTH Type 2 main structural components include the welded cylindrical shell and the top and bottom end assemblies. The top end assembly may be a three-piece assembly, (a solid shield plug, made of A36 carbon steel, and the inner cover and outer cover plates, both made of SA-240 Type 304 stainless steel) or, as an alternate, a two-piece assembly, consisting of a combined top shield plug/inner cover assembly, and an outer cover plate. The combined top shield plug/inner cover may be a single stainless steel piece (SA-240 Type 304 or SA-182 Type F304), or two stainless steel plates welded together, or a carbon steel shield plug encased within welded stainless steel plates. The various top end assembly optional design configurations are similar to those of the 32PTH DSC, as described in Section 3.1.1.1. Although the total thicknesses of top end assembly is reduced from 12 in. for the 32PTH DSC to 10 in. for the 32PTH Type 2 DSC. For the bottom end assembly, the four optional design configurations present in the 32PTH are kept for the 32PTH Type 2 DSC. The total thickness of the bottom end assembly is reduced from 8.75 in. for the 32PTH DSC to 6.50 in. for the 32PTH Type 2 DSC.

The remaining 32PTH Type 2 shell assembly structural components include the grapple ring assembly, the support ring and the lifting lugs (in the three-piece top end assembly design), or lifting blocks (in the two-piece alternate top end assembly design). The grapple ring assembly, which is welded to the shell bottom or outer bottom cover plate, is used to insert/extract the DSC to and from the horizontal storage module (HSM-H). The grapple ring minimum thickness is same as 32PTH DSC. The support ring, welded to the cylindrical shell, supports the shield plug. The 32PTH Type 2 DSC with the three-piece top end assembly design option incorporates four lifting lugs (welded to the shell and to the support ring) in lieu of the four lifting blocks, which are welded to the inside of the shell bottom in the alternate design. The lifting lugs/lifting blocks are used to lift the DSC into the TC prior to fuel loading operations.

The 32PTH Type 2 DSC shell assembly is designed, fabricated, examined, and tested in accordance with the same ASME Code Subsection NB [6] requirements as for the 32PTH DSC. The 32PTH Type 2 DSC top closure is designed, fabricated, and inspected using the same alternatives to the ASME code specified for 32PTH DSC. The outer top cover plate and inner top cover plate are sealed by separate, redundant closure welds. The inner top cover (or inner top cover/top shield plug in the alternate two-piece top end design) is welded to the 32PTH Type 2 DSC shell to form the confinement boundary at the top end of the 32PTH Type 2 DSC, as shown in Chapter B.7, Figure B.7-1 (or Chapter 7, Figure 7-1 for the alternate top end design). The outer top cover plate provides structural support to the confinement boundary. All closure welds are multiple layer welds. Both, the inner and outer top cover plates to shell welds are examined by multi-level liquid penetrant to effectively eliminate through wall leaks. The three-piece top end assembly incorporates a vent and siphon block welded to the shell, which is similar to that in other NUHOMS® canister designs [9]. The vent and siphon block weld to the shell and the inner top cover plate weld to the vent and siphon block are part of the confinement boundary. These welds are also multiple layer welds and receive multi-level liquid penetrant examination.

The leak test and the acceptance criterion of $1\text{x}10^{-7}$ ref. cm^3/sec as defined in ANSI N14.5 [2] of the DSC shell and bottom end assembly during fabrication and of the inner top closure weld (including vent/siphon cover welds) after loading of the fuel assemblies, have not changed from those of the 32PTH DSC.

The use of a strong back is not required during fuel loading operations when using the 32PTH Type 2 DSC.

B. Fuel Basket Assembly Description

The details of the 32PTH Type 1 basket assembly are shown in drawings provided in Section B.1.5. The overall length of the basket is increased from the 162.00 in. of the 32PTH DSC to 178.75 in. for the 32PTH Type 2 DSC. The internal canister cavity length is also increased from 164.38 in. for 32PTH DSC minimum to 181.38 in. minimum for 32PTH Type 2 DSC to allow for thermal expansion, tolerances, and access to the top of the fuel assemblies.

The description for the basket assembly presented in Section 3.1.1.1 (B) for the 32PTH basket is applicable to the 32PTH Type 2 basket assembly. Additionally, when lifting blocks are not used, the circumferential orientation of the basket is maintained by the use of a key welded to the inside diameter of the shell at two opposite azimuths, and two accompanying slots in the basket rails. The purpose of the basket key is non-safety and is intended to prevent rotation during fabrication and during shipment of the empty canister.

B.3.1.1.2 General Description of the HSM-H

The general description of the HSM-H presented in Section 3.1.1.2 is applicable when the HSM-H is loaded with a 32PTH Type 2 DSC. The spacer mounted on the support rails used to accommodate shorter length DSCs is not needed for storage of the 32PTH Type 2 DSC. Additionally, the HSM-H support rail structure length for 32PTH DSC has been increased by 2.5 in., and the thickness of the door is reduced to 2 ft.- 4 3/8 in. to accommodate the longer length 32PTH Type 2 DSC. The optional or alternate optional, square or round, doors with 3" metal plate can be used with the 32PTH Type 2 DSC. The changes to the HSM-H drawings are provided in Chapter B.1, Section B.1.5

B.3.1.1.3 General Description of the OS187H Type 2 On-Site TC

The NUHOMS® OS187H Type 2 on-site TC consists of a structural shell, gamma shielding material, and solid and liquid (water) neutron shield. The OS187H Type 2 TC is exactly similar to the OS187H Type 1 TC described in Section A.3.1.1.3 except the minimum cavity length. The minimum cavity length of the OS187H Type 2 TC is increased to 199.05 in. to accommodate the longer 32PTH Type 2 DSC. This increased cavity length is achieved by reducing the thickness of the wedge plates. Drawings for the OS187H Type 2 TC are provided in Chapter B.1, Section B.1.5.

The gross weight of the loaded TC is approximately 120 tons including a DSC payload of 54.02 tons. Section B.3.2.2 summarizes the weights of the NUHOMS® OS187H Type 2 packaging components.

The TC is fabricated and assembled in a exactly same manner as described in Section A.3.1.13 for OS187H Type 1 TC. The dimensions and design details of the OS187H Type 2 TC are provided in Chapter B.1, Section B.1.5.

The geometry and dimensions of the OS187H Type 2 TC trunnions are exactly same as that of OS187H Type 1 TC trunnions as explained in Chapter A.3, Section A.3.1.1.3.

The following sections provide physical and functional descriptions of each major component of the TC.

A. Transfer Cask Body and Structural Components

The shell or cask body cylinder assembly is an open ended (at the top) cylindrical unit with an integral closed bottom end. This assembly consists of concentric inner shell and outer shell (both SA-240 Type 304), welded to massive closure flanges (SA-182 Type F304N) at the top and bottom ends. The inner shell is 0.625 in. thick and has a 70.50 in. inside diameter. The outer shell is the primary structural shell and is 1.5 in. (lower course) to 2.38 in. thick (upper course), and has a 78.87 in. inside diameter. The annulus between the shells is filled with lead shielding. The lead gamma shielding is 3.56 in. (nominal) thick and is poured into the annulus in a molten state using a carefully controlled procedure.

The TC bottom end assembly and top cover assembly are similar to OS187H Type 1 TC with the exception that the minimum inner cavity length of the OS187H Type 2 TC is increased from 198.75 in. to 199.05 in. to accommodate longer 32PTH Type 2 DSC. This is achieved by reducing the thickness of the bottom wedge. As with the OS187H Type 1 TC, the OS187H Type 2 TC is designed to maintain a helium atmosphere in the cask cavity.

The OS187H Type 2 TC is designed, fabricated, examined, and tested in accordance with the requirements of Subsection NC [3] of the ASME code to the maximum practical extent. The alternatives to the ASME code presented in Section 3.10 for the OS187H TC are also applicable to the OS187H Type 2 TC.

B. Gamma and Radial Neutron Shielding

The description provided in Section 3.1.1.3 (B) is applicable to the OS187H Type 2 TC except that the resin material in the top and bottom assemblies, which provides axial neutron shielding in the OS187H TC, is replaced with NS-3, a castable cementitious material. NS-3 has been used in other NUHOMS applications, e.g., the OS197 TC[9]. The radial neutron shielding provided by liquid water enclosed in a radial outer stainless steel shell welded to the structural shell is of similar design as the OS187H TC.

C. Tiedown and Lifting Devices

The description provided in Section 3.1.1.3 (C) is applicable to the OS187H Type 2 TC. The OS187H Type 2 TC trunnions are the same as the OS187H TC. The top trunnions are designed, fabricated, and tested in accordance with ANSI N14.6 [4] as single-failure-proof lifting devices. Consequently, they are designed with a factor of safety of 6 against the material yield strength and a factor of safety of 10 against the material ultimate strength.

D. Operational Features

The NUHOMS® OS187H Type 2 TC is not considered to be operationally complex and is designed to be compatible with spent fuel pool loading/unloading methods. All operational features are readily apparent from inspection of the General Arrangement Drawings provided in Chapter B.1, Section B.1.5. The sequential steps to be followed for cask loading, testing, and unloading operations are provided in Chapter B.8.

B.3.1.1.4 Discussion of NUHOMS® HD System Drop Analysis

All lifting of the TC loaded with the DSC must be done within the existing heavy loads requirements and procedures of the licensed nuclear power plant.

The TC is transported to the independent spent fuel storage installation (ISFSI) in a horizontal configuration. Therefore, the only credible drop accident during storage or transfer operations is a side drop. The TC, canister and basket assemblies and fuel cladding are analyzed for this accident in the following sections.

In addition, vertical drop or corner drop accident scenarios may need to be evaluated under 10 CFR Part 50 if the user is unable to demonstrate that this accident drop is not credible during loading operations, or during transport operations governed under 10 CFR Part 71. Similarly, the fuel cladding integrity has not been demonstrated for this accident scenario. An additional safety review by the user is required to demonstrate fuel cladding integrity under 10 CFR Part 50 or to demonstrate that the end drop accidents are not credible.

The drop analyses of the NUHOMS® HD 32PTH Type 2 DSC and OS187H Type 2 TC components are performed in the following appendices.

Appendix B.3.9.1

This appendix describes the detailed analysis of the 32PTH Type 2 DSC shell assembly and basket assembly for all the loading conditions. For the drop loads, the DSC shell assembly is analyzed for the 75g side and end drops. The basket assembly is also analyzed for the 75g side and end drops. The 75g side drop in conjunction with the 75g end drop is considered to bound the 22g corner drop.

Appendix B.3.9.2

This appendix describes the detailed analysis of the OS187H Type 2 TC for all the loading conditions. No change to the structural evaluation of the OS187H Type 2 TC for side and end drop presented in Appendix A.3.9.10.

Appendix B.3.9.3

No change to the structural evaluations of the TC top cover bolt and ram cover bolt due to corner drop presented in Appendix A.3.9.3.

Appendix B.3.9.4

Since the end and corner drops are not credible under 10 CFR Part 72, the OS187H Type 2 TC lead slump and inner shell buckling analysis for the 75g end drop load are not evaluated. Vertical drop or corner drop accident scenarios may need to be evaluated under 10 CFR Part 50 if the user is unable to demonstrate that this accident drop is not credible during loading operations, or during transport operations governed under 10 CFR Part 71.

Appendix B.3.9.8

No change to the structural evaluations of the fuel cladding presented in Appendix A.3.9.8.

Appendix B.3.9.10

No change to the drop accelerations presented in Appendix A.3.9.10.

Appendix B.3.9.11

This appendix computes the dynamic amplification factor (DAF) to be applied to the response acceleration obtained from side drop accident dynamic analysis of the TC when applying those acceleration as input to an equivalent static analysis of the 32PTH Type 2 DSC.

B.3.1.2 Design Criteria

No change. The design criteria described in Section 3.1.2 is not changed and remains applicable to the 32PTH Type 2 DSC and OS187H Type 2 TC.

B.3.2 Weights

The nominal 32PTH Type 2 DSC, HSM-H and OS187H Type 2 TC geometry is used to compute the weights of the NUHOMS® HD System components. Material densities are unchanged and are provided in Chapter 3.

B.3.2.1 32PTH Type 2 DSC Weight

The bounding weight of the loaded 32PTH Type 2 DSC is 108.03 kips (54.02 tons). The weights of the major individual subassemblies are listed in following table.

32PTH Type 2 DSC Summary of Nominal Component Weights

Component	Nominal Weight (lb x 1000)
Canister shell	6.06
Outer top cover plate	2.14
Inner top cover plate	2.15
Top shield plug and support ring	6.43
Bottom end assembly	7.20
Grapple ring	0.075
Total canister assembly	**24.05**
Fuel compartments (32)	11.09
Aluminum/poison plates	4.92
Stainless steel plates	2.36
Small support rails	3.26
Large support rails	9.37
Total Fuel Basket	**31.00**
Basket Fuel spacer	**1.46**
Total Empty DSC (Basket and Canister)	**56.51**
Fuel assembly weight (32) @ 1610 lb/assembly	51.52
Total loaded DSC weight	**108.03**

B.3.2.2 OS187H Type 2 TC Weight

The total weight of the loaded NUHOMS® OS187H Type 2 TC is 239.47 kips (119.7 tons). The weights of the major individual subassemblies are listed in following table.

OS187H Type 2 TC Summary of Nominal Component Weights

Component	Nominal Weight (lb x 1000)
Structural shell	23.73
Inner shell	7.89
Lead gamma shield	66.65
Top flange	2.63
Bottom flange	3.40
Top cover assembly	5.36
Bottom assembly	3.94
Neutron shield panel assembly	5.14
Radial neutron shield (water)	8.67
Upper trunnion pair	1.45
Lower trunnion pair	1.06
Total Empty TC Weight	**130.00**(1)
Total TC with Empty DSC Weight	**187.00**(1)
Total TC with Loaded DSC Weight (Dry)	**240.00**(1) (2)

Notes:
(1) Rounded up to the nearest 1,000 lbs.
(2) 250.0 kips is conservatively used for the trunnion analysis.

B.3.2.3 HSM-H Weight

No change. See Section 3.2.3 for details of the HSM-H weight.

B.3.3 Mechanical Properties of Materials

No change. The material properties described in Section 3.3 remain applicable to the 32PTH Type 2 DSC and the OS187H Type 2 TC.

B.3.4 General Standards for 32PTH Type 2 DSC, HSM-H, and OS187H Type 2 TC

B.3.4.1 Chemical and Galvanic Reactions

No change. The information provided in Section 3.4.1 is unchanged and applicable to the 32PTH Type 2 DSC and OS187H Type 2 TC.

B.3.4.2 Positive Closure

No change. The information provided in Section 3.4.2 is unchanged and applicable to the 32PTH Type 2 DSC and OS187H Type 2 TC.

B.3.4.3 Lifting Devices

No change. The information provided in Section 3.4.3 is unchanged and applicable to the 32PTH Type 2 DSC and OS187H Type 2 TC.

B.3.4.4 Heat

B.3.4.4.1 Summary of Pressures and Temperatures

No change. As documented in Chapter B.4, the heat transfer analyses documented in Chapter 4 for the 32PTH DSC inside the OS187H TC during transfer, and in the HSM-H during storage are bounding relative to the 32PTH Type 2 DSC in the HSM-H and in the OS187H Type 2 TC. Therefore, the pressures and temperatures used for the stress analyses of the 32PTH DSC and the OS187H TC in Chapter 3 are also applicable for the 32PTH Type 2 DSC and the OS187H Type 2 TC. As discussed in Section B.3.6 and Section B.3.7, the Chapter 4 temperature distributions are conservatively applied (considering the longer length of the 32PTH Type 2 DSC and OS187H Type 2 TC) for the structural evaluations.

Thus, the maximum and minimum temperatures for the various components for normal, off-normal, and accident conditions are the same as those summarized in Tables 4-1 to 4-6. Similarly, the maximum pressures are the same as those summarized in Table 4-10. The Table 4-10 pressures bound those used in the structural analysis of the 32PTH Type 2 DSC.

B.3.4.4.2 Differential Thermal Expansion

Potential interference due to differential thermal expansion between the 32PTH Type 2 DSC shell assembly, the basket assembly, and TC components is evaluated in Appendix B.3.9.1, Section B.3.9.1.4.

B.3.4.4.3 Stress Calculations

The stress analyses have been performed using the acceptance criteria presented in Section 3.1.2. The structural analyses for the 32PTH Type 2 DSC and OS187H Type 2 TC are summarized in Sections B.3.6 and B.3.7, for normal, off-normal, and hypothetical accident conditions, respectively.

B.3.4.5 Cold

No change. The limits on low temperature for operations that are provided in Section 3.4.5 are unchanged for the 32PTH Type 2 DSC.

B.3.5 Fuel Rods General Standards for 32PTH Type 1 DSC

No change. The fuel rod evaluations presented in Section 3.5 are unchanged for the 32PTH Type 2 DSC.

B.3.6 Normal Conditions of Storage and Transfer

This section presents the structural analyses of the 32PTH Type 2 DSC, and the OS187H Type 2 TC subjected to normal conditions of storage and transfer. The analyses performed evaluate these two major NUHOMS® HD System components for the design criteria described in Section B.3.1.2 of this appendix. The structural analyses of the HSM-H presented in Chapter 3.6 are bounding and, therefore, not changed.

The 32PTH Type 2 DSC is subjected to both storage and transfer loading conditions and the OS187H Type 2 TC is only subjected to transfer loading conditions.

Numerical analyses have been performed for the normal and accident conditions loads. In general, numerical analyses have been performed for the regulatory events. These analyses are summarized in Section A.3.6 and Section A.3.7, and described in detail in the Appendices B.3.9.1 through B.3.9.10 listed below.

The detailed structural analysis of the NUHOMS® HD System is included in the following appendices:

Appendix B.3.9.1	32PTH Type 2 DSC (Canister and Basket) Structural Analysis
Appendix B.3.9.2	OS187H Type 2 Transfer Cask Body Structural Analysis
Appendix B.3.9.3	OS187H Type 2 Transfer Cask Top Cover and Ram Access Cover Bolts Analyses
Appendix B.3.9.4	Not used (since the end and corner drops are not credible under 10CFR Part 72, the lead slump and inner shell buckling analysis of the OS187H Type 2 TC for the 75g end drop load are not documented).
Appendix B.3.9.5	OS187H Type 2 Transfer Cask Trunnion Analysis
Appendix B.3.9.6	OS187H Type 2 Transfer Cask Shield Panel Structural Analysis
Appendix B.3.9.7	Not used (See Appendix B.3.9.10)
Appendix B.3.9.8	Damaged Fuel Cladding Structural Evaluation
Appendix B.3.9.9	HSM-H Structural Analysis
Appendix B.3.9.10	OS187H Type 2 Transfer Cask Dynamic Impact Analysis
Appendix B.3.9.11	32PTH Type 2 DSC Dynamic Amplification Factors

B.3.6.1 32PTH Type 2 DSC Normal Conditions Structural Analysis

Details of the structural analysis of the 32PTH Type 2 DSC are provided in Appendix B.3.9.1. The fuel basket assembly and canister shell assembly are analyzed independently. The structural evaluation of the 32PTH Type 2 fuel basket assembly is described in Section B.3.6.1.1. The structural evaluation of the canister shell assembly is described in Section B.3.6.1.2.

B.3.6.1.1 32PTH Type 2 DSC Fuel Basket Assembly Normal Condition Structural Evaluation

No change. As described in Appendix B.3.9.1, Section B.3.9.1.2, the ANSYS models, material properties, and design criteria used for the evaluation of the fuel basket assembly are the same between the 32PTH and the 32PTH Type 2 DSCs and, therefore, the stress analysis results documented in Section 3.9.1.2 for the 32PTH fuel basket assembly are applicable to the 32PTH Type 2 fuel basket assembly. As described in Section 3.9.1.2, a 360° finite element model (FEM) of a 15-inch segment of the basket assembly is constructed for the structural evaluation of the basket assembly.

Based on the results of these analyses, the design of the 32PTH Type 2 DSC basket is structurally adequate with respect to normal condition transfer and storage loads.

B.3.6.1.2 32PTH Type 2 DSC Canister Shell Assembly Normal Condition Structural Evaluation

This section summarizes the evaluation of the structural adequacy of the 32PTH Type 2 DSC canister shell assembly under all applied normal condition loads. Detailed evaluation of the stresses generated in the canister is presented in Appendix B.3.9.1, Section B.3.9.1.3.2. The DSC canister shell buckling evaluation is presented in Appendix B.3.9.1, Section B.3.9.1.3.3.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the 32PTH Type 2 DSC canister under the transfer and storage loads. These detailed load cases are summarized in Appendix B.3.9.1, Tables B.3.9.1-3, B.3.9.1-4 and B.3.9.1-13.

The calculated stresses in the canister shell due to normal transfer loading conditions are summarized in Appendix B.3.9.1, Tables B.3.9.1-5, B.3.9.1-6, B.3.9.1-9, and B.3.9.1-10. The stresses due to normal storage loading conditions are summarized in Appendix B.3.9.1, Tables B.3.9.1-14, and B.3.9.1-15.

The 32PTH Type 2 DSC with the three-piece top end assembly configuration (separate inner cover plate, shield plug, and outer cover plate) is considered to bound the alternate design with a two-piece top end assembly (combined top shield plug/inner cover plate and outer cover plate). Similarly, the bottom end assembly configuration, consisting of separate inner bottom, shield plug and outer bottom plates is considered the bounding configuration relative to that of a DSC with the optional single or two-piece bottom end configurations. See discussion in Section B.3.9.1.3.4.

As described in Chapter B.8, Section B.8.1.1.3, Operation Steps 7 and 13, a maximum of 15.0 psig air pressure may be applied at the canister vent port to assist draining of the water. The canister is structurally evaluated for a bounding 25 psig internal pressure using the 2-D ANSYS FEM described in Appendix B.3.9.1, Section B.3.9.1.3.2. The outer cover plate of the canister is removed from the two-dimensional (2-D) model, since it is not yet installed during the application of this 25 psig air pressure. The maximum stress intensity in the canister is calculated as 14.46 ksi. The stress limit for membrane stress per ASME B&PV Code Subsection NB [6] is 24.0 ksi.

Based on the results of these analyses, the design of the 32PTH Type 2 DSC canister is structurally adequate with respect to both transfer and storage loads under the normal conditions.

B.3.6.2 HSM-H Normal Conditions Structural Analysis

No change. The DSC weight used for the structural evaluation of the HSM-H (110,000 lb) bounds the calculated weight of the 32PTH Type 2 DSC (108.03 kips). In addition, as discussed in Chapter B.4, the temperature distributions of the HSM-H loaded with a 32PTH Type 2 DSC are bounded by those of the HSM-H loaded with a 32PTH DSC documented in Chapter 4. Therefore, the structural evaluation of the HSM-H loaded with a 32PTH DSC, as documented in Section 3.6.2 and Appendix B.3.9.9 are applicable for a HSM-H loaded with the 32PTH Type 2 DSC.

B.3.6.3 OS187H Type 2 TC Normal Conditions Structural Analysis

Details of the structural analysis of the OS187H Type 2 TC are provided in Appendices B.3.9.2 through B.3.9.6. The contents of each of these appendices are as follows.

Appendix B.3.9.2	OS187H Type 2 Transfer Cask Body Structural Analysis
Appendix B.3.9.3	OS187H Type 2 Transfer Cask Lid and Ram Access Cover Bolt Analyses
Appendix B.3.9.5	OS187H Type 2 Transfer Cask Trunnion Analysis
Appendix B.3.9.6	OS187H Type 2 Transfer Cask Shield Panel Structural Analysis

B.3.6.3.1 Structural Analysis of the TC Body under Normal Conditions

The TC body evaluations documented in Appendix A.3.9.2 for OS187H Type 1 TC are applicable without change to the OS187H Type 2 TC. The details of the structural analyses of the NUHOMS® OS187H Type 1 TC body, including the cylindrical shell assembly and bottom assembly, the top cover, and the local stresses at the trunnion/cask body interface, are presented in Appendix A.3.9.2. The specific methods, models and assumptions used to analyze the cask body for the various individual loading conditions specified in 10 CFR Part 72 [1] are described in that appendix.

The NUHOMS® OS187H Type 2 on-site TC consists of a structural shell, gamma shielding material, and solid and liquid (water) neutron shield. The OS187H Type 2 TC is identical to the OS187H Type 1 TC described in Section A.3.1.1.3, with the exception of the minimum cavity length. The minimum cavity length of the OS187H Type 2 TC is increased to 199.05 in. to accommodate the longer 32PTH Type 2 DSC. This increased cavity length is achieved by reducing the thickness of the wedge plates. Detailed design drawings for the OS187H Type 2 TC are provided in Chapter B.1, Section B.1.5.

The wedge plates (Item 7, 10494-72-9004-SAR) thickness is reduced from 1.0 in. to 0.5 in. to increase the cavity. These forced air cooling wedge plates that go inside the cask cavity are not accounted for in the structural evaluation. There are no other changes made to the TC.

B.3.6.3.2 TC Top Cover and Ram Access Cover Bolt Normal Condition Analysis

No change. The TC top cover and ram cover bolt evaluations documented in Appendix A.3.9.3 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.6.3.3 TC Normal Condition Trunnion Analysis

No change. The TC trunnion evaluations documented in Appendix A.3.9.5 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.6.3.4 TC Shield Panel Structural Analysis for Normal Conditions

No change. The TC shield panel structural evaluations documented in Appendix A.3.9.5 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.7 Off-Normal and Hypothetical Accident Conditions

This section presents the structural analyses of the 32PTH Type 2 DSC, the HSM-H and the OS187H Type 2 TC subjected to off-normal and hypothetical accident conditions of storage and transfer. The analyses are summarized in Sections B.3.7.1, B.3.7.2 and B.3.7.3 of this appendix and are evaluated against the design criteria described in Section B.3.1.2 of this chapter.

The 32PTH Type 2 DSC is subjected to both storage and transfer loading conditions, while the HSM-H is only subjected to storage loading conditions and the OS187H Type 2 TC is only subjected to transfer loading conditions.

B.3.7.1 32PTH Type 2 DSC Off-Normal and Accident Conditions Structural Analysis

Details of the structural analysis of the 32PTH Type 2 DSC are provided in Appendix B.3.9.1. The fuel basket assembly and canister shell assembly are analyzed independently. The structural analysis of the fuel basket assembly is described in Appendix B.3.9.1, Section B.3.9.1.2, while the structural analysis of the canister shell assembly is described in Section B.3.9.1.3. A 360° FEM of a 15-inch segment of the basket assembly is constructed for the structural evaluation of the fuel basket assembly. Three FEMs are used for the structural evaluation of the canister shell assembly. A 2-D axisymmetric model used for the analysis of axisymmetric loads, two three-dimensional (3-D) models modeling the top and bottom halves of the shell assembly, respectively, used for the analysis of non-axisymmetric loads.

B.3.7.1.1 32PTH Type 2 DSC Fuel Basket Assembly Off-Normal and Accident Condition Structural Analysis

B.3.7.1.1.1 32PTH Type 2 Fuel Basket Off-Normal and Accident Condition Stress Analysis

The fuel basket assembly stress analyses are performed for off-normal and accident condition loads during fuel transfer and storage.

The mechanical properties of structural materials used in the basket and canister are shown in Section 3, Table 3-5, and Appendix 3.9.1, Table 3.9.1-1, as a function of temperature. All structural components of the fuel basket and support rails are constructed from SA-240, Type 304 stainless steel, with properties taken from AMSE B&PV Code [5].

The load cases used for the analyses of the 32PTH Type 2 fuel basket assembly are the same as for the 32PTH fuel basket assembly and are as summarized in Section 3.9.1.2.2.

The details of the stress analysis of the basket assembly, as presented in Appendix 3.9.1, Section 3.9.1.2.3, are applicable without change to the 32PTH Type 2 fuel basket assembly. As discussed in Section 3.9.1.2.3, the basket stress analyses are performed using a 3-D FEM of the cross section of the basket assembly. The model is a 15-inch long segment of the basket assembly and is described in detail in Appendix 3.9.1, Section 3.9.1.2.3 (A). This model is used for the analysis of the transfer side drop impact loads, storage seismic loads, and both transfer and storage thermal load cases. Hand calculations are used for the evaluation of the transfer end drop load cases.

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

The stresses calculated for the 32PTH DSC fuel basket assembly and summarized in Tables 3.9.1-4a and 3.9.1-4b for the transfer accident loads and Table 3.9.1-5 for the storage accident loads are applicable to the 32PTH Type 2 basket assembly.

The maximum shear load in the fusion welds for the 75g side drop accident loading condition is calculated in Appendix 3.9.1, Section 3.9.1.2.3.B.5. The calculated maximum shear force during side drop is 7,208 lb. The fusion weld is qualified by a pull test (shear). The minimum test load is 17.1 kips. This test load includes a safety factor of 2 and a correction for material strength for room temperature testing.

Based on the results of these analyses, the design of the 32PTH Type 2 DSC basket is structurally adequate with respect to off-normal and accident conditions of transfer and storage loads.

B.3.7.1.1.2 32PTH Type 2 DSC Fuel Basket Accident Condition Buckling Analysis

As stated in Section B.3.9.1.2.4, the details of the buckling analysis presented in detail in Appendix 3.9.1, Section 3.9.1.2.4 are applicable without change to the 32PTH Type 2 fuel basket assembly. The results for the buckling analysis are also described in Section 3.9.1.2.4.

Since the critical collapse load for the 32PTH DSC basket (83.9*g* for the 30° orientation) is greater than the maximum design acceleration of 75*g*, the basket will not fail in buckling during the accident condition events.

B.3.7.1.1.3 32PTH Type 2 DSC Fuel Basket Support Rail Accident Condition Buckling Analysis

The NUHOMS® 32PTH1 basket with stainless steel rail design provided for the standardized NUHOMS® system in CoC 1004 (see UFSAR [9]) is identical to the NUHOMS® 32PTH basket design for the NUHOMS® HD system. The buckling evaluation for the 32PTH1 basket performed in Section U.3.7.4.3.3 [9] of the CoC 1004 UFSAR is applicable also to the NUHOMS® HD system. The used pressure on the basket panel due to the final assembly load for the evaluation is 1.24 psi. However, the actual fuel assembly load calculated in Section 3.9.1.2.3, B.2 is 1.1856 psi. Therefore, the basket support rail accident condition buckling analysis is applicable to 32PTH Type 2 DSC.

B.3.7.1.2 32PTH Type 2 DSC Canister Shell Off-Normal and Accident Condition Structural Evaluation

B.3.7.1.2.1 32PTH Type 2 Canister Shell Assembly Off-Normal and Accident Condition Stress Analysis

The description of the off-normal and accident analysis for the 32PTH DSC shell assembly presented in Section 3.7.1.2.1 is applicable without change to the 32PTH Type 2 canister shell assembly.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the 32PTH Type 2 DSC shell assembly under the transfer and storage loads. These load cases are summarized in Appendix B.3.9.1, Tables B.3.9.1-3, B.3.9.1-4 and B.3.9.1-13. The accident side drop load case and the accident pressure load case are analyzed by elastic-plastic analyses and the rest by elastic analyses.

Two FEM types are used for the analysis of the 32PTH Type 2 DSC shell assembly. The first type is a 2-D axisymmetric model used for the analysis of symmetric loads (e.g., pressure, dead weight). The second type is a 3-D model of the top and bottom halves of the shell assembly and is used for the analysis of non-axisymetric loads (e.g., side drops). The 2-D model is shown in Figures B.3.9.1-1. The 3-D models are shown in Figure B.3.9.1-4 and B.3.9.1-5 for the top and bottom halves, respectively. As shown in Figure B.3.9.1-2, the three-part top end assembly is modeled (separate shield plug, inner cover, and outer cover plates). Similarly, as shown in Figure B.3.9.1-3, the design option with separate inner bottom cover plate, bottom shield plug, and outer bottom cover plate is modeled. This configuration is expected to be the bounding as the pressure load is resisted by the inner top and inner bottom plates, and supported by the outer top cover plate (at the top) and, through the stiff bottom shield plug by the outer bottom cover plate (at the bottom).

The calculated stresses in the canister shell assembly due to off-normal and accident transfer loading conditions are summarized in Appendix B.3.9.1, Tables B.3.9.1-6, 7, 8, 10, 11, and 12. The stresses due to accident storage loading conditions are summarized in Appendix B.3.9.1, Tables B.3.9.1-14, and 15.

The alternate top closure assembly of the 32PTH Type 2 DSC, which consists of the two-part combined shield plug/inner cover assembly (including the optional configurations), as well as the optional bottom end configurations, are not analyzed explicitly. The results of the 32PTH DSC for the side drop accident load case are applicable for these alternate configurations. See discussion in Section B.3.9.1.3.4.

Based on the results of these analyses, the design of the 32PTH Type 2 DSC canister is structurally adequate with respect to off-normal and accident condition transfer and storage loads.

B.3.7.1.2.2 32PTH Type 2 DSC Canister Shell Accident Condition Buckling Analysis

This section summarizes the evaluation of the 32PTH Type 2 DSC canister against buckling under a vertical end drop during transfer operations. The details of the DSC canister shell buckling analysis are provided in Appendix B.3.9.1, Section B.3.9.1.3.3. A finite element elastic-plastic analysis with large displacement option is performed to monitor occurrence of canister shell buckling under the specified loads.

The thermal evaluation presented in Chapter 4 shows that the metal temperatures of the entire canister are below 500 °F during transfer operations. The material properties of the canister at 500 °F are, therefore, conservatively used for the canister buckling analysis.

The following three hypothetical accident load cases for the canister are considered in this buckling analysis.

Buckling Load Case 1: 15 psig external pressure and 75g axial acceleration due to end drop

Buckling Load Case 2: 30 psig internal pressure and 75g axial acceleration due to end drop

Buckling Load Case 3: 0 psig internal pressure and 75g axial acceleration due to end drop

The same 2-D axisymmetric FEM used for the stress analysis of the canister shell assembly and described in Appendix B.3.9.1, Section B.3.9.1.3.2.D.2 is used for the buckling accident analysis. Since the top end of the canister is heavier than the bottom end, it is a more severe case when the canister drops on its bottom end. A bottom end drop is, therefore, chosen for analysis in this calculation.

Load Case 1 converged at 181.0g load. Load Case 2 converged at 187.7*g* load. Load Case 3 converged at a load corresponding to 195.0g. This load is much higher than the required 75*g* load in either Load Case 1 or 2. The analysis shows that the canister does not buckle up to an end drop load of 181.0*g*, which is well beyond the design 75*g* load. It is, therefore, concluded that buckling of the canister will not occur during a hypothetical accident end drop.

B.3.7.2 HSM-H Off-Normal and Accident Conditions Structural Analysis

No change. As discussed in Section 3.7.2, the HSM-H is evaluated for a DSC weight and heat loads that bound those of the 32PTH Type 2 DSC. Thus, the evaluations of the 32PTH inside the HSM-H documented in Section 3.7.2 are bounding for the 32PTH Type 2 DSC inside the HSM-H.

B.3.7.3 OS187H Type 2 TC Off-Normal and Accident Conditions Structural Analysis

B.3.7.3.1 Structural Analysis of the TC Body for Off-Normal and Accident Conditions

No change. The TC body evaluations documented in Appendix A.3.9.2 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.7.3.2 TC Top Cover and Ram Access Cover Bolt Accident Condition Analysis

No change. The TC top cover and ram cover bolt evaluations documented in Appendix A.3.9.3 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.7.3.3 TC Lead Slump Analysis

As described in Section 3.1.1.4, the only credible drop accident during storage or transfer operations is a side drop. Thus, lead slump evaluation under top or bottom end drop accident is not performed for the OS187H Type 2 TC.

B.3.7.3.4 TC Inner Containment Buckling Analysis

As described in Section 3.1.1.4, the only credible drop accident during storage or transfer operations is a side drop. Thus, inner liner buckling evaluation under top or bottom end drop accidents is not performed for the OS187H Type 2 TC.

B.3.7.3.5 TC Trunnion Analysis

No change. The TC trunnion evaluations documented in Appendix A.3.9.5 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.7.3.6 TC Shield Panel Structural Analysis for Accident Conditions

No change. The TC shield panel structural evaluations documented in Appendix A.3.9.5 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

B.3.7.3.7 TC Impact Analysis

No change. The TC impact evaluation documented in Appendix 3.9.7 is applicable to 32PTH Type 2 DSC and OS187H Type 2 TC.

B.3.8 References

1. Title 10, Code of Federal Regulations, Part 72, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation."

2. American National Standards Institute, ANSI N14.5-1997, Leakage Tests on Packages for Shipment of Radioactive Materials.

3. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Subsection NC, 1998 through 2000 addenda.

4. American National Standards Institute, ANSI N14.6, American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials, 1993.

5. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Parts A, B, C and D, 1998, through 2000 addenda.

6. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, 1998 through 2000 addenda.

7. ANSYS Users Manual, Rev. 5.6 and 6.0, 8.0, 8.1, 10A1, 14.0, 14.0.3.

8. NUREG/CR-6007 "Stress Analysis of Closure Bolts for Shipping Casks," By Mok, Fischer, and Hsu, Lawrence Livermore National Laboratory, 1992.

9. Updated Final Safety Analysis Report (UFSAR) for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, NUH003.0103 Rev. 14, USNRC Docket No. 72-1004.

B.3.9 Appendices

The detailed structural analyses of the NUHOMS® HD System Type 2 components are included in the following appendices:

Appendix B.3.9.1	32PTH Type 2 DSC (Canister and Basket) Structural Analysis
Appendix B.3.9.2	OS187H Type 2 Transfer Cask Body Structural Analysis
Appendix B.3.9.3	OS187H Type 2 Transfer Cask Top Cover and Ram Access Cover Bolts Analyses
Appendix B.3.9.4	Not used (since the end and corner drops are not credible under 10 CFR Part 72, the lead slump and inner shell buckling analysis of the OS187H Type 2 TC for the 75g end drop load are not documented).
Appendix B.3.9.5	OS187H Type 2 Transfer Cask Trunnion Analysis
Appendix B.3.9.6	OS187H Type 2 Transfer Cask Shield Panel Structural Analysis
Appendix B.3.9.7	Not used (See Appendix B.3.9.10)
Appendix B.3.9.8	Damaged Fuel Cladding Structural Evaluation
Appendix B.3.9.9	HSM-H Structural Analysis
Appendix B.3.9.10	OS187H Type 2 Transfer Cask Dynamic Impact Analysis
Appendix B.3.9.11	32PTH Type 2 DSC Dynamic Amplification Factors

B.3.10 ASME Code Alternatives

No change to the ASME Code Alternatives provided in Section 3.10.

APPENDIX B.3.9.1
32PTH TYPE 2 DSC (CANISTER AND BASKET) STRUCTURAL ANALYSIS

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

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B.3.9.1 32PTH Type 2 DSC (Canister and Basket) Structural Analysis

B.3.9.1.1 Introduction

The NUHOMS® 32PTH Type 2 dry shielded canister (DSC) consists of a fuel basket assembly and a canister shell assembly. The canister shell assembly consists of a cylindrical shell, top end assembly (outer top cover plate, inner top cover plate, top shield plug), and a bottom end assembly (inner bottom cover plate, bottom shield plug, outer bottom cover plate). An alternate design for the top end assembly includes a two-part top end (combined shield plug/inner top cover and the outer cover plate). Similarly, the bottom end may consist of a single forged piece or two-piece or three-piece assembly. The primary confinement boundary for the 32PTH Type 2 DSC consists of the DSC shell, the inner top cover plate, and shell bottom or inner bottom cover plate of the shell bottom assembly.

The canister shell thickness is 0.50 in., and the top and bottom closure assemblies are 10.0 in. and 6.50 in., respectively. The canister is constructed entirely from SA-240 Type 304 stainless steel and SA-182 Type F304. The shield plugs are constructed from ASTM A-36. There are no penetrations through the confinement vessel. The draining and venting systems are covered by the port plugs, and the outer top cover plate and the inner top cover plate are welded to the cylindrical shell with multi-layer welds. The canister cavity is pressurized above atmospheric pressure with helium. The 32PTH Type 2 DSC shell assembly geometry and the materials used for its analysis and fabrication are shown on drawings 10494-72-2006-SAR to 2010-SAR included in Chapter B.1.

The basket structure consists of assemblies of stainless steel fuel compartments and support rails. The borated aluminum or boron carbide/aluminum metal matrix composite plates (neutron poison plates) provide the necessary criticality control and also provide a portion of the heat conduction paths from the fuel assemblies to the cask cavity wall. This method of construction forms a very strong structure of compartment assemblies that provide for storage of 32 PWR fuel assemblies. The open dimension of each fuel compartment is 8.70 in. × 8.70 in., which provides clearance around the fuel assemblies.

The fuel basket assembly and the canister assembly are analyzed separately. The fuel basket assembly is analyzed in Section B.3.9.1.2, and the canister shell assembly is analyzed in Section B.3.9.1.3. The full 360° three-dimensional (3-D) finite element model (FEM) of the basket assembly used for the evaluation of the 32PTH basket is applicable to the 32PTH Type 2 basket assembly. The analyses performed in Section 3.9.1.2 for the 32PTH basket are applicable for the 32PTH Type 2 basket (See Section B.3.9.1.2 for details).

Three FEMs are used for the structural evaluation of the canister shell assembly. A two-dimensional (2-D) axisymmetric model of the DSC canister shell assembly is used to evaluate axial inertial loads as well as internal pressure, external pressure, and thermal loads. Two 3-D FEMs of the DSC shell assembly are used to evaluate the effects of transverse inertial loads (e.g., side drop). These are separate models of the top half and bottom half assemblies of the 32PTH Type 2 DSC.

B.3.9.1.2 32PTH Type 2 DSC Fuel Basket Assembly Structural Evaluation

B.3.9.1.2.1 Approach

The basket design for the NUHOMS® 32PTH Type 2 DSC is identical to the 32PTH DSC except that the length of the 32PTH Type 2 basket is longer (the length of the 32PTH DSC basket is 162 in., whereas the length of the 32PTH Type 2 DSC basket is 178.75 in.) with one additional full height layer of neutron poison/thermal aluminum cross bars. In addition, the fuel compartment tubes at the top of the basket are also connected with support bars and fusion welds in the 32PTH Type 2 design. The 15-inch pitch between support bars (where the fuel compartments are connected to each other by fusion welds), which is the basis for the selection of the axial length of the analysis model, is the same for the 32PTH and 32PTH Type 2 baskets. The material properties, maximum fuel assembly weight, and the temperature profiles used in the 32PTH basket analyses (Section 3.9.1.2) have not changed. Thus, the analyses performed for the 32PTH basket assembly, documented in Section 3.9.1.2, are also applicable for the 32PTH Type 2 basket.

Therefore, the analysis results for the 32PTH basket in Section 3.9.1.2 are also applicable to the 32PTH Type 2 basket.

A. Material Properties

No change. The material properties for the 32PTH DSC in Section 3.9.1.2.1(A) are also applicable to the 32PTH Type 2 DSC.

B. Design Criteria

No change. The design criteria for the 32PTH DSC described in Section 3.9.1.2.1 (B) are also applicable to the 32PTH Type 2 DSC.

B.3.9.1.2.2 Loading Conditions

No change. The loading conditions for the 32PTH DSC described in Section 3.9.1.2.2 are also applicable to the 32PTH Type 2 DSC.

B.3.9.1.2.3 Fuel Basket Assembly Stress Analysis

No change. The 32PTH basket stress analysis model and analysis results in Section 3.9.1.2.3 are applicable to the 32PTH Type 2.

B.3.9.1.2.4 32PTH Type 2 Fuel Basket Assembly Buckling Analysis

The buckling evaluation for the 32PTH DSC performed using the full 360° 3-D model of the basket assembly documented in Section 3.9.1.2.4 (A.3) is also applicable to the 32PTH Type 2 DSC.

B.3.9.1.3 32PTH Type 2 DSC Shell Assembly Structural Evaluation

B.3.9.1.3.1 Approach

This section evaluates the structural adequacy of the 32PTH Type 2 DSC canister under all applicable normal and hypothetical accident condition loads. Evaluation of the stresses generated in the DSC is presented in Section B.3.9.1.3.2, and the DSC shell assembly buckling evaluation is presented in Section B.3.9.1.3.3.

B.3.9.1.3.2 DSC Canister Shell Assembly Stress Analysis

A. Methodology

An enveloping technique of combining various individual loads in a single analysis is used in this evaluation for several load combinations. This approach greatly reduces the number of computer runs while remaining conservative. However, for some load combinations, the stress intensities under individual loads are added to obtain resultant stress intensities for the specified combined loads. This stress addition at the stress intensity level for the combined loads, instead of at component stress level, is also a conservative way to reduce the number of analyses runs.

The ANSYS calculated stresses are the total stresses of the combined membrane, bending, and peak stresses. These total stresses are conservatively taken to be membrane stresses (P_m), as well as membrane plus bending stresses ($P_L + P_b$), and are evaluated against their corresponding ASME code stress limits. In the case where the total stresses, evaluated in this manner, exceed the ASME allowable stresses, a detailed stress linearization is performed to separate the membrane, bending, and peak stresses. The linearized stresses are then compared to their proper Code allowable stresses. ASME B&PV Code Subsection NB [8] is used for evaluation of loads under normal conditions and Appendix F [3] for evaluation of loads under hypothetical accident conditions.

The thermal stress intensities are classified as secondary stress intensities, Q, for code evaluations.

B. Canister Material Properties

Temperature dependent material properties obtained from Reference 1 for the NUHOMS® 32PTH Type 2 canister materials are summarized as follows.

Elastic Material Properties

Elastic properties are tabulated in Table 3-5 for SA-240 Type 304/SA-182 F304 (DSC shell, support ring, outer top cover, inner top cover, bottom grapple ring, inner bottom cover and outer bottom cover) and in Table B.3.9.1-1 for ASTM A-36 (top and bottom shield plugs).

Elastic-Plastic Material Properties

The ANSYS Bilinear Kinematic Hardening option of inelastic analysis is employed for Transfer Load Case 4 (120 psig internal pressure and hypothetical accident fire). Tangent modulus of 5% of elastic modulus is assumed after yield stress.

The ANSYS Multilinear Kinematic Harding material option of inelastic analysis is employed in the analyses of all canister accident side drops. A multi-linear stress-strain curve for Type 304 stainless steel at 500 °F is constructed using the yield and tensile stress values taken from Reference 1 and the elongation value from Reference [9]. The stress-strain curve used for all canister materials is as follows.

Point	1	2	3	4	5
Strain (in/in)	0.0004845	0.000768	0.001164	0.00275	0.46
Stress (psi)	12,500	14,660	17,120	19,400	63,400

C. DSC Shell Assembly Stress Criteria

Allowable stresses given in ASME B&PV Code Subsection NB [8] and Appendix F [3] are used to evaluate the calculated stresses in the canister under normal, off-normal, and accident conditions, respectively. The stress criteria are summarized in Table 3-2. The allowable stresses are summarized in Table B.3.9.1-2. The closure welds between the inner top cover to the shell and the outer top cover to the shell use a stress reduction factor of 0.8 in accordance with ISG-15 [14].

D. DSC Shell Assembly Stress Analysis for Transfer Loads

The evaluation of the stresses generated in the NUHOMS® 32PTH Type 2 canister during transfer operations is presented here. During fuel transfer, the canister is oriented horizontally inside the OS187H Type 2 Transfer Cask (TC). The OS187H Type 2 TC is mounted to the transfer skid and transferred from the fuel building to the independent spent fuel storage installation (ISFSI).

The maximum temperature in the canister under vacuum drying operation is calculated to be 522 °F in the thermal stress analysis (see Chapter 4). This temperature occurs in the shell center where stresses are low. The maximum temperature in critical stress areas (top and bottom canister regions) are below 500 °F. However, the stress evaluations are conservatively performed at 500 °F.

D.1 DSC Shell Assembly Transfer Load Cases

Elastic and elastic-plastic analyses are performed to calculate the stresses in the NUHOMS® 32PTH Type 2 canister under the transfer loads. These load cases are summarized in Table B.3.9.1-3 and Table B.3.9.1-4. The accident side drop and the accident pressure load cases are analyzed by elastic-plastic analyses and the rest by elastic analyses.

D.2 DSC Shell Assembly Finite Element Model Descriptions

DSC Temperature Distribution

The DSC metal temperatures that are calculated in Chapter 4 are extracted and directly applied as temperature loads to the 2-D stress model using ANSYS macros. Since the 32PTH Type 2 DSC is longer than the 32PTH DSC, the temperature distribution at the maximum temperature location was extended in the middle of the canister, thus maximizing thermal gradients and hence thermal stresses at the top and bottom of the canister shell.

2-D Canister Stress Models

A 2-D axisymmetric ANSYS FEM, constructed from PLANE42 elements, is used for the elastic analyses of all axisymmetrical loading on the canister. ANSYS contact elements CONTAC12 are generated by connecting the nodes of two adjacent solids along their boundary. The real constant of each contact element is defined for the initial gap at each contact element.

At the weld locations between two joined solids, the contacting nodes are coupled in all directions. These coupled-nodes are applied to the welds between the shell and the support ring and between the shell and the inner top cover plate. The larger 0.5- inch weld between the shell and the top cover is modeled with PLANE42 elements. The normal stiffness of all contact elements are calculated using guidelines in the ANSYS manual [10]. The applied boundary conditions for this 2-D model under each load case are described in the following sections. Figures B.3.9.1-1, B.3.9.1-2, and B.3.9.1-3 show the ANSYS 2-D FEM, which includes the canister shell, outer and inner top covers, support ring and outer and inner bottom covers. This model is used for analyses of all axisymmetric loads during the transfer operations of the canister.

The normal stiffness, K_N, for the contact elements ware estimated according to the ANSYS manual [10] as follows.

$$K_N \approx f\, E\, h$$

Where:

f = Factor that controls contact compatibility (ranging between 0.01 to 100), use 1
E = Young's modulus, use 25.8×10^6 psi
h = average radius where contact to occur (for 2-D axisymmetrical model), use 34 in.
K_N = $1 \times 25.8\times10^6 \times 34 = 8.8 \times10^8$ lb/in. Conservatively used $1\text{x}10^9$ lb/in.

3-D Canister Stress Model

A 3-D ANSYS stress model is created using ANSYS elements SOLID45 and CONTAC178. The 3-D model is used for the analysis of accident side drops. To help reduce the ANSYS run time and assure numerical convergence, the whole canister is split into two portions, namely, the top and the bottom end sections. These two sections are represented by two different ANSYS models. Each end model includes the canister shell at a length beyond which the un-modeled shell will have no significant impact on the stress levels at the junction between the shell and its end closures. The DSC canister top end assembly FEM is shown in Figure B.3.9.1-4 and the canister bottom end assembly model is shown in Figure B.3.9.1-5.

These 3-D models are used for analyses of side drops only. The postulated side drops will occur when the canister is resting inside the OS187H Type 2 TC during transfer. Two side drops with the impact points located at 0° (i.e., the cask drops onto a target at 180° opposite to its four canister support pads) and at 180° (i.e., the cask drops onto a target between its two bottom canister support pads) are analyzed.

Load cases 6, 7, 10, and 11 consider the side drop loads at 0° and load cases 8, 9, 12, and 13 at 180° (see Table B.3.9.1-8). Elastic-plastic analyses, using multi-linear hardening material properties, are performed for both side drops. In addition to the contact areas generated from the 2-D model, new contact elements are generated connecting the inner diameter of the cask and the outer diameter of the canister in the radial direction. The nodes of these contact elements are located either on the inner diameter of the cask or on the outer diameter of the canister at the moment when the cask hits the side drop target. The actual gaps for these contact elements are defined by their initial location in conjunction with the contact element real constants. The contact element nodes located on the inner diameter of the cask are held fixed in all directions, simulating a rigid cask on which the canister drops.

Weak link elements are added to each contact element in the model to help numerical convergence. Zero density of these link elements is used to avoid adding any non-existing weights. This model does not calculate the stress levels in the middle section of the canister shell, which are calculated and evaluated as part of the basket stress analysis in Section 3.9.1.2.3.

Only half of the canister in circumferential direction is included in the 3-D model. Symmetry boundary conditions are applied to the plane of symmetry (global Cartesian *x*-*z* plane) during a side drop. Symmetry boundary conditions are also applied to the cut-off plane at the canister shell to provide proper diametrical rigidity of the shell during side drops.

During the 75 *g* side drop, the canister internals are accounted for by applying a cosine varying pressure distribution on the inside surface of the canister shell. Assuming that the canister internals react upon a 90° arc of the inside surface, then the inertial load of the internals, $P_{(\theta)}$, which varies with angle, θ, ($\theta = 0$ is at the impact point), is governed by the following expression.

$$P_{(\theta)} = P_{max} \cos(2\theta) \qquad (0° < \theta < 45°)$$

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

Where P_{max} is the maximum pressure at the impact point ($\theta = 0$). Assuming the axial length of the applied load is L, the inside radius of the canister shell is R, and the load distribution, $P_{(\theta)}$ above, then the total inertial load generated by the internals, F, is the following.

$$F = \int_{\frac{-\pi}{4}}^{\frac{\pi}{4}} P_{\max} \cos(2\theta)\cos(\theta) LR d\theta$$

or,

$$F = \frac{P_{\max} LR}{2} \int_{\frac{-\pi}{4}}^{\frac{\pi}{4}} \cos((2+1)\theta) + \cos((2-1)\theta) d\theta$$

By integrating we get the following:

$$F = \left[\frac{P_{\max} LR}{2}\right]\left[\frac{\sin(3\theta)}{3} + \sin(\theta)\right]_{\frac{-\pi}{4}}^{\frac{\pi}{4}}$$

Therefore,

$$F = \left[\frac{P_{\max} LR}{2}\right]\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right) - \frac{\sin\left(\frac{-3\pi}{4}\right)}{3} - \sin\left(\frac{-\pi}{4}\right)\right]$$

$$F = P_{\max} LR\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]$$

The canister shell inner diameter, R = 34.375 in., the axial length of the applied load, L = 178.75 in. The total applied force, F, is equal to the inertial load of the canister internals, which is the following.

- Basket weight = 31,000 lb
- Fuel assembly weight = 51,520 lb
- Total weight of canister internals = 31,000 lb + 51,520 lb = 82,520 lb (use 85,000 lb)

Then,

$$F = 85{,}000 \times 75\ g = 6{,}375{,}000 \text{ lb.}$$

Therefore, P_{max} is the following:

$$P_{max} = \frac{6{,}375{,}000}{(178.75)(34.375)}\left[\frac{\sin\left(\frac{3\pi}{4}\right)}{3} + \sin\left(\frac{\pi}{4}\right)\right]^{-1} = 1163.93 \text{ psi.}$$

The equivalent pressure applied on the canister inside shell surface is, therefore:

$$P_{(\theta)} = 1163.93 \cos(2\theta),$$

Where, θ is the angle from the bottom ($\theta = 0$) of the horizontal canister shell to the center of the shell element, up to 45°.

D.3 DSC Shell Assembly Stress Evaluation for Transfer Loads

All analyzed load cases in this section are identified in Tables B.3.9.1-3 and B.3.9.1-4 and are described in detail in the following sections.

Transfer Load Case 1: **Deadweight + 15 psig external pressure + thermal (vacuum drying)**

The temperature profile utilized for the analysis of Transfer Load Case 1 for the 32PTH DSC described in Section 3.9.1.3.2 (D.3) was adjusted by linearly scaling to the maximum vacuum drying temperature of 522 °F, which is greater than the maximum temperature for vacuum drying 511 °F, as calculated in Chapter 4. This adjusted temperature profile is used for the analysis of Transfer Load Case 1 for the 32PTH Type 2 DSC.

The weight of the canister internals (basket and fuel assemblies) is accounted for by applying equivalent pressures on the support surfaces of the canister. The actual weights of the basket and fuel assemblies are 31,000 lb and 51,520 lb, respectively (see Section B.3.2.1). Therefore, the total weight of the canister internals is 82,520 lb. A weight of 85,000 lb is conservatively used in this analysis. The canister cavity inner radius is 34.375 in. Therefore, the pressure load equivalent to the inertial load of the internals, P_{ia}, is,

$$P_{ia} = [85{,}000 / (\pi \times 34.375^2)] = 22.90 \text{ psi}$$

An elastic analysis is performed using the ANSYS 2-D axisymmetric model. The analysis was run in two load steps. The first load step includes dead weight, 15 psig external pressure, and the temperature profile discussed above, but it does not include coefficient of thermal expansion. The second load step includes the coefficient of thermal expansion and all of the above-mentioned loads. The results from the first load step are compared against the P_m and $P_m + P_b$ allowable stresses and the results from the second load step are compared against the $P_m + P_b + Q$ allowable stresses.

The maximum primary stress intensity in the canister was calculated to be 1.95 ksi in Load Step 1. The maximum primary stress intensity in the closure welds is calculated to be 1.56 ksi.

The maximum primary plus secondary stress intensity in the canister was calculated to be 18.82 ksi in Load Step 2. These stresses are summarized in Table B.3.9.1-6. The maximum primary stress intensity in the closure welds is calculated to be 1.75 ksi.

Transfer Load Case 2: **Handling, 2 g axial + 2 g transverse + 2 g vertical + 30 psig int. pressure + thermal (115 °F ambient)**

The handling 2 *g* inertial loads applied to the canister when inside the TC in the horizontal orientation are analyzed as part of the basket model described in Section 3.9.1.2.3 (B.2) (the basket model includes a segment of the canister shell). It is judged that under the relatively light handling loads the maximum stresses in the canister will occur in the shell section and can be obtained from the results calculated in Section 3.9.1.2.3 (B.2). The maximum primary membrane stress intensity and primary membrane plus bending stress intensity in the canister shell due to the handling load of 2 *g,* calculated in Section 3.9.1.2.3 (B.2), are 880 psi and 9740 psi, respectively. These stresses are summarized in Table B.3.9.1-6.

The stress intensities calculated in Section 3.9.1.2.3 (B.2) for the canister shell due to the 2 *g* handling loads are combined with the stresses due to internal pressure of 30 psig, and the 115 °F ambient environment temperature loads resulting from the thermal analysis in Chapter 4.

The stress analysis for the 30 psig internal pressure and 115 °F thermal loads is performed using the ANSYS 2-D axisymmetric model. The stress analysis contains two load steps. Load step 1 includes the primary loads of 30 psig internal pressure. Load Step 2 includes the primary pressure load plus the secondary thermal load.

The maximum primary stress intensity in the canister was calculated to be 14.81 ksi in Load Step 1 analysis. The maximum primary stress intensity in the closure welds is calculated to be 11.72 ksi. The maximum primary plus secondary stress intensity in the canister is calculated to be 38.35 ksi under load Step 2. The maximum primary plus secondary stress intensity in the closure welds is calculated to be 15.25 ksi.

The maximum primary stress intensities in the canister shell calculated in Section 3.9.1.2.3 (B.2) are added to the maximum primary and primary plus secondary stress intensities calculated from the 2-D axisymmetric model and the combined results are evaluated against the corresponding ASME stress limits (See Table B.3.9.1-6). The direct addition of stresses at the stress intensities level, instead of at the component level, as well as the addition of the maximum stress intensities at different locations is very conservative. This enveloping technique is used to minimize the computer runs.

Transfer Load Case 3: **Handling 2 *g* axial + 2 *g* transverse + 2 *g* vertical + 15 psig ext. pressure + thermal (-20 °F ambient)**

The same methodology described for load case 2 is used in this load case.

The maximum stress intensity in the canister for the primary load of 15 psig external pressure in Load Step 1 is calculated to be 5.83 ksi. The maximum stress intensity in the closure welds is calculated to be 1.48 ksi.

The maximum stress intensity in the canister for the primary load of 15 psig external pressure plus the secondary temperature load in Load Step 2, is calculated to be 28.84 ksi. These stresses combined with the stresses due to the handling loads as well as the evaluation against the ASME stress limits are summarized in Table B.3.9.1-6. The maximum stress intensity in the closure welds is calculated to be 3.02 ksi.

Transfer Load Case 4: **120 psig internal pressure and hypothetical accident fire**

Stresses in the canister under an internal pressure of 120 psig are calculated in this load case. ASME code [3] requires only primary stresses be evaluated under accident conditions. The secondary thermal stresses are therefore not calculated. The ANSYS 2-D axisymmetric model is used for analysis of this accident pressure load. This is an elastic-plastic analysis with large deformations.

The maximum calculated stress in the entire canister for the pressure load is 23.87 ksi. This maximum stress intensity is conservatively treated both as primary membrane stress intensity and as primary membrane plus bending stress intensity and so evaluated against ASME code limits at the maximum metal temperature of the canister (See Table B.3.9.1-7).

The maximum metal temperature in the canister during fire accident is calculated to be 790 °F (see Chapter 4). Canister material properties at 800 °F are used for the ANSYS model. The maximum stress intensity in the closure welds is calculated to be 21.76 ksi.

Transfer Load Case 5: **25 psig external pressure and flood hypothetical accident**

The external pressure of 25 psig on the canister is analyzed using material properties taken at 500 °F for the entire model.

The maximum stress intensity in the canister for this load case is calculated to be 9.73 ksi. The maximum stress intensity in the closure welds is calculated to be 2.45 ksi.

Transfer Load Case 6: **Accident condition 75 *g* side drop at 0° (no rail) at ambient temperature of 115 °F (75 *g* side drop + 30 psig internal pressure)—top end portion of canister**

The canister internal pressure of 30 psig plus a side acceleration of 75 *g* is analyzed in this load case. A multi-linear elastic-plastic stress-strain curve for material 304 SS at 500 °F is applied to all materials. The stress-strain curve is obtained from Reference 9. ASME code requires only primary stresses be evaluated under accident conditions. The values of the thermal expansion coefficients for all materials are therefore set to 0 to eliminate any secondary thermal stresses in the canister.

The maximum stress intensity in the canister for this load case is calculated to be 25.31 ksi. The maximum stress intensity in the closure welds is calculated to be 21.81 ksi.

Transfer Load Case 7: **Accident condition 75 *g* side drop at 0° (no rail) at ambient temperature of 115 °F (75 *g* side drop + 30 psig internal pressure)—bottom end portion of canister**

The methodology of the analysis and stress evaluation used in this load case is the same as that described for Load Case 6.

The maximum stress intensity in the canister for this load case is calculated to be 23.96 ksi.

Transfer Load Case 8: **Accident 75 *g* side drop at 180° (drop between two TC bottom support pads) at ambient temperature of 115 °F (75 *g* side drop + 30 psig internal pressure)—top end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 6 is used for this load case except that the gaps between the canister and the rigid cask are different due to the orientation of the TC support pads.

The maximum stress intensity in the canister for this load case is calculated to be 26.89 ksi. The maximum stress intensity in the closure welds is calculated to be 23.63 ksi.

Transfer Load Case 9: **Accident 75 *g* side drop at 180° (drop between two cask bottom rails) at ambient temperature of 115 °F (75 *g* side drop + 30 psig internal pressure)—bottom end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 7 is used for this load case except that the gaps between the canister and the rigid cask are different.

The maximum stress intensity in the canister for this load case is calculated to be 24.59 ksi.

Transfer Load Case 10: **Accident 75 *g* side drop at 0° (drop at no cask rail) at ambient temperature of -20 °F (75 *g* side drop + 15 psig external pressure)—top end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 6 is used for this load case except that external pressure instead of internal pressure is applied.

The maximum stress intensity in the canister for this load case is calculated to be 25.65 ksi. The maximum stress intensity in the closure welds is calculated to be 21.27 ksi.

Transfer Load Case 11: **Accident 75 *g* side drop at 0° (drop at no cask rail) at ambient temperature of -20 °F (75 *g* side drop + 15 psig external pressure)—bottom end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 7 are used for this load case except external pressure instead of internal pressure is applied.

The maximum stress intensity in the canister for this load case is calculated to be 23.95 ksi.

Transfer Load Case 12: **Accident 75 *g* side drop at 180° (drop between two cask bottom rails) at ambient temperature of -20 °F (75 *g* side drop + 15 psig external pressure)—top end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 8 is used for this load case except that external pressure instead of internal pressure is applied.

The maximum stress intensity in the canister for this load case is calculated to be 26.86 ksi. The maximum stress intensity in the closure welds is calculated to be 23.49 ksi.

Transfer Load Case 13: **Accident 75 *g* side drop at 180° (drop between two cask bottom rails) at ambient temperature of -20 °F (75 *g* side drop + 15 psig external pressure)—bottom end portion of canister**

The same methodology of the analysis and stress evaluation used for Load Case 9 is used for this load case except that the external pressure instead of the internal pressure is applied.

The maximum stress intensity in the canister is calculated to be 24.71 ksi.

Transfer Load Case 14: **Accident 75 *g* top end drop (75 *g* + internal pressure of 30 psig)**

The top end drop is not considered credible during storage and transfer operations under 10 CFR Part 72 because the TC is always in the horizontal orientation. The top end drop evaluation documented below is performed in support of a 10 CFR Part 50 evaluation that may be performed by the user if the user cannot demonstrate that this accident drop is not credible.

The weight of the canister internals (basket and fuel assemblies) during end drop is accounted for by applying equivalent pressures on canister components that support them. The actual weights of the canister basket and fuel assemblies are 31,000 lb and 51,520 lb (see Section B.3.2.1). Therefore, the total actual weight of the canister internals is 82,520 lb. The weight of the canister internals used in this analysis is conservatively increased to 85,000 lb.

The canister cavity inner radius at the top end is 34.375 in. The pressure load equivalent to the inertial load of the internals at 75 *g* under accident condition, P_{ia}, is,

$$P_{ia} = [85{,}000 / (\pi \times 34.375^2)] \times 75\ g = 1717.30 \text{ psi}$$

The top face of the canister outer top cover is held in the axial direction in order to simulate the rigid support provided by the TC top cover. An inertial load of 75 *g* in the negative *y*-direction is applied to the model. An internal pressure of 30 psig and the metal temperatures from the 115 °F ambient condition are also included in this analysis. Temperature-dependent material properties are selected based on the temperature distribution in the canister. The values of thermal expansion coefficients for all materials are set to zero so that secondary thermal stresses, which are not required for evaluation under an accident condition per Reference 3, are not calculated.

The maximum stress intensity in the canister for this load case is calculated to be 43.19 ksi. The maximum stress intensity in the closure welds is calculated to be 10.76 ksi.

Transfer Load Case 15: **Accident 75 *g* bottom end drop (75 *g* + internal pressure of 30 psig)**

The bottom end drop is not considered credible during storage and transfer operations under 10 CFR Part 72 because the TC is always in the horizontal orientation. The bottom end drop evaluation documented below is performed in support of a 10 CFR Part 50 evaluation that may be performed by the user if the user cannot demonstrate that this accident drop is not credible.

The weight of the canister internals used in this analysis is 85,000 lb. The canister cavity inner radius at the bottom end is 34.375 in. The pressure load equivalent to the weight of the internals under the accident condition 75 *g* drop, P_{ia}, is,

$$P_{ia} = [85{,}000 / (\pi \times 34.375^2)] \times 75\ g = 1717.30 \text{ psi}$$

The bottom face of the canister is held in the axial direction in order to simulate the rigid support provided by the TC bottom. An inertial load of 75 *g* in the positive *y*-direction is applied to the model. An internal pressure of 30 psig and the metal temperatures from the 115 °F ambient condition are included in this analysis. Temperature-dependent material properties are selected based on the temperature distribution in the canister. The values of thermal expansion coefficients for all materials are set to zero so that secondary thermal stresses, which are not required for evaluation under an accident condition per Reference 3, are not calculated.

The maximum stress intensity in the canister for this load case is calculated to be 17.71 ksi. The maximum stress intensity in the closure welds is calculated to be 13.57 ksi.

Transfer Load Case 16: **Accident 75 *g* top end drop (75 *g* + external pressure of 15 psig)**

The top end drop is not considered credible during storage and transfer operations under 10 CFR Part 72 because the TC is always in the horizontal orientation. The top end drop evaluation documented below is performed in support of a 10 CFR Part 50 evaluation that may be performed by the user if the user cannot demonstrate that this accident drop is not credible.

This load case is similar to Load Case 14 with different pressure loadings and metal temperatures. An external pressure of 15 psig and material properties at 500 °F are used in this analysis. The values of thermal expansion coefficients for all materials are set to zero so that secondary thermal stresses, which are not required for evaluation under an accident condition per Reference 3, are not calculated.

The maximum stress intensity in the canister for this load case is calculated to be 59.29 ksi. The maximum stress intensity in the closure welds is calculated to be 12.22 ksi.

Transfer Load Case 17: **Accident 75 *g* bottom end drop in accident condition (75 *g* + external pressure of 15 psig)**

The bottom end drop is not considered credible during storage and transfer operations under 10 CFR Part 72 because the TC is always in the horizontal orientation. The bottom end drop evaluation documented below is performed in support of a 10 CFR Part 50 evaluation that may be performed by the user if the user cannot demonstrate that this accident drop is not credible.

This load case is similar to Load Case 15 with different pressure loadings and metal temperatures. An external pressure of 15 psig and material properties at 500 °F are used in this analysis. The values of thermal expansion coefficients for all materials are set to zero so that secondary thermal stresses, which are not required for evaluation under an accident condition per Reference 3, are not calculated.

The maximum stress intensity in the canister for this load case is calculated to be 22.63 ksi. The maximum stress intensity in the closure welds is calculated to be 14.80 ksi.

Transfer Load Case 18: **Fabrication test condition (DW + 25 psig internal pressure + 155 kips axial load)**

After the canister bottom is welded to the shell a pressure test is conducted by applying an internal pressure of 25 psig with a top seal plate being held by an axial force of 155 kips. The canister bottom may be made, as an option, of composite plates. For each of these options the bottom inner plate, which is to be first welded to the shell and tested, has a minimum thickness of 2.25 in. An ANSYS model, shown in Figure B.3.9.1-6, is generated that simulates the canister shell with the bottom inner plate for analysis of pressure and axial loads under the test condition. The deadweight load on the horizontal canister is manually analyzed using Roark's formulas [7]. The stresses calculated from both manual and ANSYS analyses are conservatively added for ASME Code stress evaluation.

1. 1g deadweight load

   It is conservatively assumed that the horizontal shell's own weight is line supported at its base.

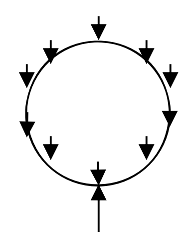
   From Case 15 of Table 9.2 in Roark's Formulas for Stress & Strains, 7th Edition :

   R (mean radius) = ½ (69.75 in. – 0.5 in.) = 34.625 in.
   t (wall thickness) = 0.5 in.
   ρ (density) = 0.29 lb/in^3

   Take unit length (L = 1 in.) of shell,

   The weight per unit length of circumference of shell, w, is,

   $$w = (2 \times \pi \times R \times t \times L \times \rho)/(2 \times \pi \times R)$$
   $$= t \times L \times \rho = 0.5 \times 1\text{in.} \times 0.29 \text{ lb/in}^3 = 0.145 \text{ lb/in}$$



   For a thin ring, $I = \dfrac{t^3}{12(1-\upsilon^2)} = 0.01145$, where $\upsilon = 0.3$

   $$K_T = 1 + \frac{I}{AR^2} \approx 1 \qquad K_2 = 1 - \alpha = 1 - \frac{I}{AR^2} \approx 1$$

   Max. $-M = -wR^2(1.6408\text{-}K_2) = -0.145 \times 34.625^2\ (1.6408 - 1) = -111.4$ in-lb/in

   or,

   Max. $+M = (3/2)\ wR^2 = 1.5 \times .145 \times 34.625^2 = 260.76$ in-lb/in
   Max. bending stress, $\sigma_b = (6M)/(t^2) = (6 \times 260.76) / (0.5^2) = 6{,}258$ psi

$N = N_A\mathrm{Cos}(x) + V_A\ \mathrm{Sin}(x) + LT_N$
$V_A = 0$
$LT_N = -\ Wr(x)(\mathrm{Sin}(x))$
$N_A = w\ R/2 = 2.51$ lb/in
$N = 2.51\ \mathrm{Cos}\ (x) - 0.145 \times 34.625 \times (x) \times \mathrm{Sin}(x)$ lb/in
$N_{max} = 2.51$ lb/in at $x = 0°$
Max. membrane stress, $\sigma_m = N_{max} / t$ = (2.51 lb/in) / (0.5 in) = 5 psi

2. 25 psig internal pressure + 155 kips axial load

   An internal pressure of 25 psig was applied while an axial force of 155 kips is applied to a seal plate on the top of the shell. The net force applied to the entire circumference of the shell at top will be 62,195 lb (155,000 lb – 25 lb/in^2 × [π/4 × 68.752] in^2 = 62,195 lb). A nodal force of 15,548.75 lb (62,195 / 4 = 15,548.75 lb) was applied at each node on the top end of the shell.

Figure B.3.9.1-6 shows the model with the applied boundary conditions.

The maximum stress intensity in the canister is calculated to be 8.0 ksi under these testing loads.

The resultant stresses calculated in (1) and (2) above are conservatively added and evaluated against ASME Code allowable stresses in Table B.3.9.1-5.

***Transfer Load Case 19:* Normal 80 kip push hydraulic load (internal pressure of 30 psig + 80 kip push + thermal load of 115 °F ambient)**

During transfer of the canister from the TC to the HSM a normal maximum push force of 80 kip is applied by a hydraulic ram over an area of 9-inch diameter on the canister bottom. A uniform pressure of 1258 psig [= 80,000 lb / ((π/4) × 9^2)] is applied over this area. The periphery of the top cover outer surface is held as boundary condition. The sustained loads of an internal pressure of 30 psig plus the equivalent push load pressure of 1,258 psi are applied in Load Step 1. The sustained loads plus the temperature load from fuel decay heat are applied in Load Step 2.

The maximum stress intensity for Load Step 1 is calculated to be 15.65 ksi. The maximum stress intensity in the closure welds is calculated to be 10.72 ksi.

The maximum stress intensity in the canister for Load Step 2 is calculated to be 31.35 ksi. The maximum stress intensity in the closure welds is calculated to be 15.21 ksi.

Transfer Load Case 20: **Normal 60 kip pull hydraulic load (internal pressure of 30 psig + 60 kip pull + thermal of 115 °F ambient)**

During retrieval of the canister from the HSM into the TC a normal maximum pull force of 60 kips is applied by a hydraulic ram over an annulus area of 12.62 in. outer diameter and 10 in. inner diameter on the inside surface of grapple ring. A uniform pressure of 1,289 psig [= 60,000 lb / $((\pi/4) \times (12.62^2 - 10^2))$] is applied over this area. The periphery of the top cover outer surface is held as boundary condition. The sustained loads of an internal pressure of 30 psig plus the equivalent pull load pressure of 1,289 psi are applied in Load Step 1. The sustained loads plus the temperature load from fuel decay heat are applied in Load Step 2.

Stresses in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are linearized in ANSYS. The membrane stress results are compared against the general membrane stress, P_m, stress limits. The membrane plus bending stress results are compared against the primary membrane plus bending, $P_m/P_L + P_B$, stress limits. The maximum stress intensity in the rest of the canister is compared against the general membrane stress, P_m, and primary membrane plus bending stress, $P_m/P_L + P_B$, stress limit.

The maximum membrane and membrane plus bending stress in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are 9.24 ksi and 25.57 ksi, respectively for Load Case 1. Maximum stress intensity in all other components is 14.81 ksi for Load Case 1. The maximum stress intensity in the closure welds is calculated to be 11.73 ksi.

The maximum stress intensity in the canister is calculated to be 38.73 ksi for Load Step 2. The maximum stress intensity in the closure welds is calculated to be 15.25 ksi.

Transfer Load Case 21: **Off-normal 80 kip push hydraulic load (internal pressure of 30 psig + 80 kip push + thermal load of 115 °F ambient)**

The same 80 kip push hydraulic load analyzed in Load Case 19 is also designated as an off-normal condition. Evaluation of this load in Load Case 19 as normal condition covers this off-normal condition.

Transfer Load Case 22: **Off-normal 80 kip pull hydraulic load (internal pressure of 30 psig + 80 kip pull + thermal of 115 °F ambient)**

During retrieval, the canister from the HSM into the TC a normal maximum pull force of 80 kips is applied by a hydraulic ram over an annulus area of 12.62 in. outer diameter, and 10-inch inner diameter on the inside surface of grapple ring. A uniform pressure of 1,719 psig [= 80,000 lb / $((\pi/4) \times (12.62^2 - 10^2))$] is applied over this area. The periphery of the top cover outer surface is held as boundary condition. The sustained loads of an internal pressure of 30 psig plus the equivalent pull load pressure of 1,719 psi are applied as the loading. The ASME code requires only primary stresses to be evaluated under off-normal condition Service Level C; therefore, the secondary thermal stresses are not evaluated.

Stresses in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are linearized in ANSYS. The membrane stress results are compared against the general membrane stress, P_m, stress limits. The membrane plus bending stress results are compared against the primary membrane plus bending, $P_m/P_L + P_B$, stress limits. The maximum stress intensity in the rest of the canister is compared against the general membrane stress, P_m, and primary membrane plus bending stress, $P_m/P_L + P_B$, stress limit.

The maximum membrane and membrane plus bending stress in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are 12.32 ksi and 34.13 ksi, respectively. The maximum stress intensity in all other components is 14.81 ksi. The maximum stress intensity in the closure welds is calculated to be 11.72 ksi.

Transfer Load Case 23: **Accident 110 kip push hydraulic load (internal pressure of 30 psig + 110 kip push)**

The maximum accident hydraulic force applied by the ram to push the canister from its TC to the HSM is set at 110 kips. The load will be applied over an area with a 9-inch diameter on the canister bottom. A uniform pressure of 1,729.1 psig [= 110,000 lb / $((\pi/4) \times 9^2)$] is applied over this area in the 2-D ANSYS canister model. The periphery of the canister top cover outer surface is held as boundary condition. The sustained loads of an internal pressure of 30 psig plus the equivalent push force pressure of 1,729 psi are applied as the loading. The secondary temperature load is not required by ASME code for an accident condition analysis.

The maximum stress intensity in the canister for this load case is calculated to be 16.25 ksi. The maximum stress intensity in the closure welds is calculated to be 10.45 ksi.

Transfer Load Case 24: **Accident 110 kip pull hydraulic load (internal pressure of 30 psig + 110 kip pull)**

The maximum accident condition hydraulic force applied by the ram to pull the canister out of the HSM into the TC is set at 110 kips. This pull force is applied over an annulus area of 12.62 in. outer diameter and 10 in. inner diameter on the inside surface of grapple ring. A uniform pressure of 2,363 psig [=110,000 lb / $((\pi/4) \times (12.62^2 - 10^2))$] is applied over this area in the 2-D ANSYS canister model. The periphery of the top cover outer surface is held as a boundary condition. The sustained loads of an internal pressure of 30 psig plus the equivalent pull force pressure of 2,363 psi are applied as loading. The secondary temperature load is not required by ASME code for an accident condition analysis.

Stresses in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are linearized in ANSYS. The membrane stress results are compared against the general membrane stress, P_m, stress limits. The membrane plus bending stress results are compared against the primary membrane plus bending, $P_m/P_L + P_B$, stress limits. The maximum stress intensity in the rest of the canister is compared against the general membrane stress, P_m, and primary membrane plus bending stress, $P_m/P_L + P_B$, stress limit.

The maximum membrane and membrane plus bending stress in the grapple ring, outer bottom cover plate, and the bottom 2 in. of the canister shell are 16.96 ksi and 46.98 ksi, respectively. The maximum stress intensity in all other components is 14.81 ksi. The maximum stress intensity in the closure welds is calculated to be 11.72 ksi.

***Transfer Load Case 25:* Canister lifting**

Three-Piece Top End Assembly Design

For the three-piece top end assembly design, four lifting lugs are used for lifting the empty canister into the TC. The lifting lugs, support ring, reinforcing pad, connecting welds, and local stresses in the canister shell are evaluated using an empty DSC bounding weight and a dynamic load factor of 1.15.

Since lifting using internal lugs is an infrequent event (normally the DSC would be lifted for placement into the cask only once prior to fuel loading and will never occur after the DSC is in service), Service Level B allowable stresses are applied. Level B allowables are identical to Level A allowables for the components (shell, support ring, and lug). However, for the welds, Level B allowables are 33% greater than Level A values.

The evaluation is performed using a combination of hand calculations and ANSYS finite element analyses. Hand calculations are used to evaluate the local stresses in the lifting lugs near the pin-hole; finite element analyses are used to determine loads and/or stresses in all other components.

The shell, support ring and lug components are modeled using ANSYS solid elements and welds are modeled by coupling the translational degrees of freedom for the coincident nodes.

Results of the stress evaluation are calculated for different lifting configurations. The maximum stress ratio is 0.909 for the spreader bar assembly, 8-foot sling, and 10-foot sling lifting configurations. Therefore, the lug design and required welds are acceptable for the 32PTH Type 2 DSC.

Alternate Two-piece Top End Assembly Design

For the alternate two-piece top end assembly design, the evaluations performed for the 32PTH DSC are bounding.

Canister Corner Drop Analysis

As stated in [16], the end and corner drops are generally not considered credible during storage and transfer operations because the TC will always be in horizontal orientation. Thus, corner drop load cases are not evaluated.

D.4 Summary of Results for DSC Shell Assembly Stress Evaluation for Transfer Loads

The calculated maximum stress intensities in the DSC shell assembly components are summarized in Tables B.3.9.1-5 through B.3.9.1-8. These tables also show that the stress intensity results are below the ASME code stress intensity allowables.

The stresses in the closure welds are summarized in Tables B.3.9.1-9 through B.3.9.1-12. These tables also show that the stress results are below the ASME code stress allowables.

Based on the results of these analyses, the design of the 32PTH Type 2 DSC shell assembly is structurally adequate under transfer loads of testing, normal (Service Level A), and accident (Level D) conditions.

E. DSC Shell Assembly Stress Evaluation for Storage Loads

This section evaluates the structural adequacy of the 32PTH Type 2 DSC shell assembly when it is in the horizontal storage position within an HSM-H. This section considers storage loads on the canister under both normal and hypothetical accident conditions.

The evaluation of the stresses in the canister for storage loads employs an ANSYS 2-D axisymmetrical model to analyze three thermal conditions specified for the canister during storage. This 2-D model is the same model described in Section B.3.9.1.3.2 (D.2) used to compute stresses due to axisymmetric transfer loads. The analyses of axisymmetric loads, such as internal and external pressure loads for transfer conditions, are also valid for a horizontal storage canister. Their results are, therefore, used in this section for stress combinations and evaluations.

The fuel basket stress analysis for storage loads (Section 3.9.1.2.3 (C)) uses an ANSYS 3-D model, which includes the DSC canister shell, to calculate the non-axisymmetrical seismic and deadweight loads. The calculated stress intensities in the canister under the seismic and deadweight loads from Section 3.9.1.2.3 (C) are used in this section for stress combinations and evaluations.

The temperatures in the canister under 115 °F and -20 °F ambient conditions of and under HSM-H blocked vent conditions for 34 hours are computed in Chapter 4. These temperatures are imposed on the stress model in this evaluation for thermal stress calculations.

E.1 DSC Shell Assembly Storage Load Cases

The storage load cases considered in this section are summarized in Table B.3.9.1-13.

E.2 DSC Shell Assembly Finite Element Model Descriptions

The 2-D axisymmetrical stress models described in Section B.3.9.1.3.2 (D.2) for the transfer load analysis are also used for the storage load analysis. Figures B.3.9.1-1, B.3.9.1-2 and B.3.9.1-3 show this model. This model is used to evaluate the three specified thermal cases for storage, which are the -20 °F and 115 °F ambient conditions, and the blocked vent hypothetical accident condition. The temperature profiles in the canister for the three storage thermal cases are calculated in Chapter 4.

E.3 DSC Shell Assembly Stress Analysis for Storage Loads

All individual load cases specified in Table B.3.9.1-13 are described in detail in the following sections.

Storage Load Case 1: **Deadweight (1*g* down)**

The canister shell and fuel basket containing the fuel assemblies, resting horizontally on the rails of an HSM-H is analyzed in Section 3.9.1.2.3 (C) for storage loads. The maximum primary membrane and membrane plus bending stress intensities in the canister shell due to the deadweight load are calculated to be 0.4 ksi, and 4.05 ksi, respectively (see Table 3.9.1-14). These stress intensities are also used as maximum stress intensities at closures welds (see Table B.3.9.1-15).

Storage Load Case 2: **Internal pressure of 30 psig**

The internal pressure of 30 psig applied on the canister is analyzed in Load Step 1 of Transfer Load Case 2 in Section B.3.9.1.3.2 (D). The maximum membrane plus bending stress intensities in the canister, calculated in Section B.3.9.1.3.2.D is 14.97 ksi. The maximum stress intensity in the closure welds is calculated to be 11.75 ksi calculated in section B.3.9.1.3.2 (D).

Storage Load Case 3: **Seismic loads (0.65*g* axial + 0.65*g* transverse + 1.3*g* vertical down)**

The seismic loads on the canister, containing the basket and the fuel assemblies and resting on the rails of an HSM-H, are analyzed in Section 3.9.1.2.3 (C). The maximum primary membrane and membrane plus bending stress intensities are calculated in Section 3.9.1.2.3 (C) to be 0.63 ksi, and 6.08 ksi, respectively (see Table 3.9.1-14). This specified seismic load includes a 1*g* deadweight load.

Storage Load Case 4: **Thermal load at -20 °F ambient**

The maximum temperature in the canister for this thermal case is calculated in Chapter 4 to be 318 °F. The temperatures in the canister calculated in Chapter 4 are applied to the stress model in order to compute the thermal stress intensities in the canister. The maximum secondary thermal stress intensity is calculated to be 20.91 ksi. The 20.91 ksi stress is calculated based on canister maximum temperature of 324 °F. Since the revised temperature of 318 °F is less than 324 °F, 20.91 ksi is conservatively used for load combination and compared with the allowables. The maximum stress intensity in the closure welds is calculated to be 3.67 ksi.

Storage Load Case 5: **Thermal load at 115 °F ambient**

The thermal load case with the canister stored in the HSM-H with fins, described in Chapter 4, is selected for this evaluation. The maximum temperature in the canister for this thermal case is calculated in Chapter 4 to be 407 °F. The same procedure used for calculating the thermal stress intensities for the Load Case 4 is repeated for the 115 °F ambient thermal load. The secondary thermal stress intensity is calculated to be 18.95 ksi. The 18.95 ksi stress is calculated based on canister maximum temperature of 434 °F. Since the revised temperature of 407 °F is less than 434 °F, 18.95 ksi is conservatively used for load combination and compare with the allowables. The maximum stress intensity in the closure welds is calculated to be 3.62 ksi.

Storage Load Case 6: **Blocked vent thermal accident condition**

The thermal evaluation presented in Chapter 4 reports four thermal cases for the canister stored in the HSM with blocked vent. The maximum temperature of 600 °F in the 24-hour canister is reached after 34 hours of complete vent blockage in an HSM with fins. The 34-hour vent blockage is a conservative scenario, since the vent is visually checked at least every 24 hours. However, this case is reported in the thermal evaluation and is therefore selected for analysis in this section. The same procedure used for obtaining the thermal load in Load Case 4 is used in this load case. The secondary thermal stress intensity is calculated to be 18.48 ksi. The maximum stress intensity in the closure welds is calculated to be 8.19 ksi.

Storage Load Case 7: **Accident internal pressure of 70 psig (in the event of blocked vent)**

The internal pressure of 70 psig in the canister is analyzed for enveloping the accident condition internal pressures during the blocked vent scenario. The maximum primary membrane plus bending stress intensity in the canister is calculated to be 34.56 ksi. The maximum stress intensity in the closure welds is calculated to be 27.38 ksi.

Storage Load Case 8: **Accident flood load (enveloped by external pressure of 30 psig)**

The hypothetical accident condition flood load is enveloped by an external pressure of 30 psig. The maximum primary membrane plus bending stress intensity in canister is calculated to be 11.67 ksi. The maximum stress intensity in the closure welds is calculated to be 2.94 ksi.

E.4 Summary of the Stress Calculation Results for All Storage Load Cases

Tables B.3.9.1-14 and B.3.9.1-15 summarize the calculated stresses in the entire canister and their corresponding ASME code evaluations.

Based on the results of this calculation, the 32PTH Type 2 DSC canister is structurally adequate under all normal (Service Level A), off-normal (Service Level C), and hypothetical accident (Service Level D) conditions during storage.

B.3.9.1.3.3 DSC Shell Buckling Evaluation

This section evaluates the structural adequacy of the 32PTH Type 2 DSC canister against buckling during a vertical end drop during transfer operations.

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

For the NUHOMS HD® System, the vertical end drops are not considered credible during storage and transfer operations under 10 CFR Part 72 because the TC is always in the horizontal orientation. The vertical end drop buckling evaluation documented below is performed in support of a 10 CFR Part 50 evaluation that may be performed by the user if the user cannot demonstrate that this accident drop is not credible.

A. Approach

A finite element plastic analysis with large displacement option is performed to monitor occurrence of canister shell buckling under the specified loads.

The thermal evaluation presented in Chapter 4 shows that the metal temperatures of the entire canister are below 500 °F during the transfer operations. The material properties of canister at 500 °F are, therefore, conservatively used in this calculation.

B. Material Properties used for Canister Buckling Evaluation

The material properties of the canister materials, SA-240 Type 304 stainless steel, at 500 °F are as follows.

Property	@ 500 °F
S_m (ksi)	17.5
S_y (ksi)	19.4
S_u (ksi)	63.4
E (psi)	25.8×10^6

For the elastic-plastic finite element analysis, bilinear kinematic hardening material properties are used. Tangent modulus of 5% of elastic modulus is assumed after yield stress.

The material properties for the top and bottom shield plug, A-36, at 500 °F are as follows:

Property	@ 500 °F
S_m (ksi)	19.3
S_y (ksi)	29.3
S_u (ksi)	58.0
E (psi)	27.3×10^6

C. Finite Element Buckling Analysis

The following three hypothetical accident load cases for the canister are considered in this buckling analysis.

Buckling Load Case 1: End drop + 15 psig external pressure

Buckling Load Case 2: End drop + 30 psig internal pressure

Buckling Load Case 3: End drop + 0 psig internal pressure

The 2-D axisymmetric FEM of the canister described in Appendix B.3.9.1, Section B.3.9.1.3.2 (D.2) for the DSC canister stress analysis is used for this analysis.

The gap element real constants, node couplings and displacement boundary conditions are also the same as those used in Section B.3.9.1.3.2 (D.2). The weight of the canister's outer and inner top cover plus the top shield plug and its support ring is 10,720 lb, and the bottom shield plug is 7,200 lb (see Section B.3.2.1). Since the top end of the canister is heavier than the bottom end, it is a more severe case when the canister drops on its bottom end. A drop on the bottom end is, therefore, chosen for analysis in this calculation.

For load case with external pressure or internal pressure, a quasi-static plastic analysis consisting of two load steps is performed to monitor buckling of the canister. The first load step applies external pressure or internal pressure alone. A subsequent inertial load of 300*g* is added in the second load step. The outer surface of the canister bottom is held in order to simulate the case that the canister drops on a rigid cask bottom face.

In the Load Step 1, the stepped external or internal pressure is applied as a static load.

In the Load Step 2, the weight of the canister internals (basket and fuel assemblies) is accounted for by applying an equivalent internal pressure on the canister bottom. The actual total weight of the canister internals is 82,520 lb (basket 31,000 lb + fuel assemblies 51,520 lb) (Chapter B.3, Section B.3.2.1). A total weight of 85,000 lb for the canister internals is conservatively used in this analysis. This inertial load is uniformly distributed over the bottom surface of the canister cavity with a radius of 34.375 in. This equivalent uniform pressure, P_{in}, exerted on the canister bottom by the weight of the internals under a 1*g* load is calculated as follows.

$$P_{in} = [85{,}000 / (\pi \times 34.375^2)] = 22.8972 \text{ psi}$$

An equivalent pressure of 6870.0 psig on the canister bottom corresponding to the 300*g* load (P_{in} = 300 × 22.8972 = 6870.0 psi) is, therefore, applied to the canister bottom along with the 300*g* acceleration load in the Load Step 2.

A bilinear stress-strain relationship (with kinematic hardening) is used to obtain stresses and deflections beyond the elastic limit of the material. The large displacement option in ANSYS is activated to monitor the buckling response.

D. Summary Canister Buckling Analysis Results

The following table summarizes the last converged load for the three load cases:

Load Case	Last Converged Load (*g*)	*g* Load Used for Basket Structural Analysis	Factor of Safety
1	181.0	75	2.41
2	187.7	75	2.50
3	195.0	75	2.60

The analysis shows that the critical buckling load for the canister end drop is 181.0*g*, which is well beyond the design 75*g* load. Therefore, it is concluded that buckling of the canister will not occur during a hypothetical accident end drop.

B.3.9.1.3.4 Evaluation of Alternate DSC Top and Bottom Closure Assembly Design

The alternate top closure assembly of the 32PTH Type 2 DSC, which consists of the two-part combined shield plug /inner cover assembly (including the optional configurations), as well as the optional bottom end configurations (consisting of two-plate or single forging bottom assembly), are not analyzed explicitly.

The evaluations for the 32PTH Type 2 DSC consider a DSC with a three-part top end configuration (with separate inner cover plate, shield plug, and outer cover plate) and a three-part bottom end configuration (with separate inner bottom cover, bottom shield plug, outer bottom cover plate). The results from these evaluations are documented in Sections B.3.9.1.3.2 and B.3.9.1.3.3, and are considered to be bounding relative to those for a DSC with the alternate two-part top end assembly or the optional bottom end configurations for cases involving internal pressure and handling loads. For side drop accident loads, the results of the 32PTH DSC for the side drop accident load case are also applicable for the alternate top end and the optional bottom end configurations of the 32PTH Type 2 DSC. This is justified because the side drop analyses are performed using two separate 3-D models, which model the top and the bottom regions of the DSC shell assembly, respectively. These models include a segment of the DSC shell and are intended to capture the maximum stresses that occur near the transition between the shell and the stiffer top and bottom ends and, therefore, are not sensitive to the length differences between the 32PTH and 32PTH Type 2 DSCs. Furthermore, the loaded canister weight used in the 32PTH DSC analysis bounds the 32PTH Type 2 analyses.

B.3.9.1.4 32PTH Type 2 DSC and OS187H Type 2 TC Thermal Expansion Evaluation

B.3.9.1.4.1 Introduction

The purpose of this section is to determine the thermal growths among fuel assembly, basket, canister, and TC in the 32PTH Type 2 DSC and OS187H Type 2 TC. This thermal expansion calculation covers events of vacuum drying, transfer, storage, and storage with blocked vent.

B.3.9.1.4.2 Approach

The temperatures of the fuel cladding, basket, canister, and TC under various events calculated in the thermal analyses of Chapter 4 are applicable for the 32PTH Type 2 DSC and OS187H Type 2 TC. Transient thermal analyses are conducted for the vacuum drying and blocked vent events. Steady-state thermal analyses are conducted for the normal and off-normal conditions during transfer and storage. This section evaluates the thermal expansions at the steady-state temperatures in the events of transfer and storage.

In the vacuum drying load case, the profiles of transient temperature versus time computed in Chapter 4 are studied for selection of the critical time points at which the corresponding component temperatures would generate a minimum clearance between two nested components. For the blocked vent load case, the maximum temperatures from Chapter 4 are used in this evaluation.

The cold dimensions of each pair of nested components are so determined, based on design tolerances, which generates a minimum cold clearance between the two components.

Unless otherwise stated, nominal dimensions of basket, canister, and cask are used for the thermal expansion calculations.

B.3.9.1.4.3 Mechanical Properties of Materials

The coefficient of thermal expansion of structural materials used for the fuel basket, canister shell, and TC are provided in Table 3.9.1-6 as a function of temperature. The properties of SA-240 Type 304 and the zircaloy are taken from References 1 and 4 listed in Section 3.9.1.5.

B.3.9.1.4.4 Thermal Expansion Computation

A. Thermal Expansion between the Length of Fuel Assembly and DSC Cavity

The maximum length of fuel assemblies in 32PTH Type 2 DSC is 170.0 in and the minimum cavity length of the 32PTH Type 2 DSC is 181.38 in. The clearance between the fuel assembly and the 32PTH Type 2 DSC cavity is calculated using the same methodology and data as described in Appendix 3.9.1, Section 3.9.1.4.4.A.

An irradiation growth of 1.25 in. is considered in Appendix 3.9.1, Section 3.9.1.4.4.A for the fuel assemblies with a maximum length of 162.4 in. with a maximum burnup of 60 GWd/MTU. The fuel assemblies in 32PTH Type 2 DSC have a maximum length of 170.0 in. with the same maximum burnup of 60 GWd/MTU. Since the irradiation growth is proportional to the fuel assembly length for a given burnup, an irradiation growth of 1.31 in is considered for the fuel assemblies in the 32PTH Type 2 DSC as calculated below.

$$\Delta L_{irrad} = \frac{170.0''}{162.4''} \times 1.25'' = 1.31''$$

The calculated clearances between the fuel assembly and the DSC cavity for 32PTH Type 2 DSC are summarized below using the same nomenclature as used in Appendix 3.9.1, Section 3.9.1.4.4.A.

Event	T_F (°F)	α_Z (in/in-°F)	α_S (in/in-°F)	T_C (°F)	α_C (in/in-°F)	L_F (in)	$L_{F, irrad}$ (in)	L_{CH} (in)	L_{CH} - L_{FHT} (in)
Vacuum Drying	760	3.01E-06	10.0E-06	210	8.94E-06	170.48	171.79	181.61	9.82
Transfer	730	3.00E-06	10.0E-06	390	9.46E-06	170.46	171.77	181.93	10.16
Storage, Off-Normal	700	3.00E-06	10.0E-06	280	9.16E-06	170.44	171.75	181.73	9.98
Storage Accident	830	3.01E-06	10.1E-06	590	9.80E-06	170.53	171.84	182.30	10.46

As shown in the above table, the minimum clearance between the fuel assemblies and the 32PTH Type 2 DSC cavity is 9.82 in. Fuel space is required to minimize the axial fuel gap while maintain the adequate clearance to permit free thermal expansion of the fuel assemblies in the 32PTH Type 2 DSC.

B. Thermal Expansion between the Outer Diameter of the Basket and the Inner Diameter of the DSC Cavity

The diametrical gap between the outer diameter of the basket and the inner diameter of the canister remains the same as for the 32PTH DSC. With the same radial temperature profile, the thermal expansion values calculated in Section 3.9.1.4.4.B are applicable for the 32PTH Type 2 DSC. These calculations show that the gap will allow free thermal expansion.

C. Thermal Expansion between the Length of Basket and DSC Cavity

The maximum length of the 32PTH Type 2 basket and the minimum cavity length of the 32PTH Type 2 DSC are 178.75 in. and 181.38 in., respectively, at room temperature. The clearance between the basket and the DSC cavity for 32PTH Type 2 DSC is calculated using the same methodology and data as described in Appendix 3.9.1, Section 3.9.1.4.4.C.

The calculated clearances between the basket and the 32PTH Type 2 DSC cavity are summarized below using the same nomenclature as used in Appendix 3.9.1, Section 3.9.1.4.4.C.

Event	Case	T_{CNH} (°F)	α_{CN} (in/in-°F)	T_{BKH} (°F)	α_{BK} (in/in-°F)	L_{CNH} (in)	L_{BKH} (in)	$L_{CNH} - L_{BKH}$ (in)
Vacuum Drying	TC Backfill	500	9.70E-06	550	9.80E-06	182.137	179.591	2.546
Transfer	115 °F Amb. Basket Type I, Conf. # 1	460	9.62E-06	640	9.88E-06	182.061	179.757	2.304
	115 °F Amb. Basket Type I, Conf. # 2	460	9.62E-06	625	9.85E-06	182.061	179.727	2.334
	115 °F Amb. Basket Type I, Conf. # 3	460	9.62E-06	630	9.86E-06	182.061	179.737	2.324
	115 °F Amb. Basket Type I, Conf. # 4	460	9.62E-06	640	9.88E-06	182.061	179.757	2.304
	-20 °F Amb. Basket Type I, Conf. # 1	390	9.46E-06	570	9.80E-06	181.929	179.626	2.303
	115 °F Amb. Basket Type II, Conf. # 1	460	9.62E-06	640	9.88E-06	182.061	179.757	2.304
Storage	115 °F Amb. HSM-H w/ Finned Side Shield	400	9.50E-06	600	9.80E-06	181.949	179.678	2.271
	-20°F Amb. HSM-H w/ Finned Side Shield	280	9.16E-06	505	9.71E-06	181.729	179.505	2.224
	34 hours after Blockage HSM-H w/ Finned Side Shield	590	9.80E-06	740	10.0E-06	182.304	179.948	2.356

As shown in the above table, adequate clearance has been provided to permit free thermal expansion of the basket within 32PTH Type 2 DSC cavity.

D. Thermal Expansion between the Outer Diameter of the DSC and the Inner Diameter of the TC

The diametrical gap between the outer diameter of the canister and the inner diameter of the cask remains the same as for the 32PTH DSC and OS187H TC. With the same radial temperature profile, the thermal expansion values calculated in Section 3.9.1.4.4.D are applicable for the 32PTH Type 2 DSC and OS187H Type 2 TC. These values show that the current gap will allow free thermal expansion.

E. Thermal Expansion between the Length of the DSC and the TC Cavity

The maximum length of the 32PTH Type 2 DSC and the minimum cavity length of the OS187H Type 2 TC are 198.50 in. and 199.05 in., respectively, at room temperature. The clearance between the DSC and the TC cavity for 32PTH Type 2 DSC is calculated using the same methodology and data as described in Appendix 3.9.1, Section 3.9.1.4.4.E.

The calculated clearances between the 32PTH Type 2 DSC and OS187H Type 2 TC cavity are summarized below using the same nomenclature as used in Appendix 3.9.1, Section 3.9.1.4.4.E.

Event	Case	T_{CKH} (°F)	α_{CK} (in/in-°F)	T_{CNH} (°F)	α_{CN} (in/in-°F)	L_{CKH} (in)	L_{CNH} (in)	$L_{CKH} - L_{CNH}$ (in)
Vacuum Drying	TC Backfill	265	9.13E-06	525	9.75E-06	199.404	193.381	0.023
Transfer	115°F Amb.	330	9.26E-06	485	9.67E-06	199.529	199.297	0.232
	-20°F Amb.	240	9.06E-06	500	9.70E-06	199.357	199.328	0.029

As seen in the above table, an adequate clearance has been provided to permit free thermal expansion of the 32PTH Type 2 DSC within the OS187H Type 2 TC.

B.3.9.1.4.5 Thermal Expansion Analysis Conclusions

This evaluation demonstrates that adequate clearance is provided between the 32PTH Type 2 DSC fuel basket and canister shell, and between the 32PTH Type 2 DSC canister and the OS187H Type 2 TC to permit free thermal expansions among these components due to all specified design and service conditions.

B.3.9.1.5 References

1. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part D, 1998, through 2000 addenda.

2. Not used.

3. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Appendix F, 1998 through 2000 addenda.

4. NUREG/CR-0497-Rev 2, MATPRO-Version 11 (Revision 2), A handbook of materials properties for use in the analysis of light water reactor fuel rod behavior.

5. Not used.

6. Manual of Steel Construction, Ninth Edition, American Institute of Steel Construction, Inc., 1989.

7. Roark, Formulas for Stress and Strain, Seventh Edition.

8. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NB, 1998, through 2000 addenda.

9. NUREG/CR-0481 SAND77-1872 R-7, "An Assessment of Stress-Strain Data Suitable for Finite-Element Elastic-Plastic Analysis of Shipping Containers," September 1978.

10. ANSYS Users Manual, Release 8.0 and 10.0A1 and 14.0

11. Not used.

12. Not used.

13. Not used.

14. USNRC Spent Fuel Project Office, Interim Staff Guidance – 15, "Materials Evaluation."

15. Roark, Formulas for Stress and Strain, Sixth Edition.

16. Safety Evaluation Report, Transnuclear, Inc., NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear fuel, Docket No. 72-1030.

Table B.3.9.1-1
Temperature Dependent Material Properties for ASTM A-36

Temp (°F)	E (10^3 ksi)	S_m (ksi)	S_y (ksi)	S_u (ksi)	α_{INST} (10^{-6} °F^{-1})	α_{AVG} (10^{-6} °F^{-1})
70	29.5	19.3	36.0	58.0	6.4	6.4
200	28.8	19.3	33.0	58.0	6.9	6.7
300	28.3	19.3	31.8	58.0	7.3	6.9
400	27.7	19.3	30.8	58.0	7.7	7.1
500	27.3	19.3	29.3	58.0	8.0	7.3
600	26.7	17.7	27.6	58.0	8.4	7.4
700	25.5	17.3	25.8	58.0	8.6	7.6

Table B.3.9.1-2
Material Stress Limits for 32PTH Type 2 DSC
SA-240/SA-479 304 & SA-182 F304

Temp	Level A			Level C		Level D			
						Elastic		Elastic-Plastic	
(°F)	P_m	$P_m + P_b$	$P_m + P_b + Q$	P_m	$P_m + P_b$	P_m	$P_m + P_b$	Pm	$P_m + P_b$
70	20.0	30.0	60.0	30.0	45.0	48.0	72.0	52.5	67.5
200	20.0	30.0	60.0	25.0	37.5	48.0	71.0	49.7	63.9
300	20.0	30.0	60.0	24.0	36.0	46.3	66.2	46.3	59.6
400	18.7	28.1	56.1	22.4	33.7	44.8	64.0	44.8	57.6
500	17.5	26.3	52.5	21.0	31.5	42.0	63.0	44.4	57.1
600	16.4	24.6	49.2	19.7	29.5	39.4	59.0	44.4	57.1
700	16.0	24.0	48.0	19.2	28.8	38.4	57.6	44.4	57.1
800	15.2	22.8	45.6	18.2	27.4	36.5	54.7	44.0	56.5

Table B.3.9.1-3
32PTH Type 2 DSC Canister Load Combinations during Transfer

Loading	Canister w/TC Orientation	Service Level	Load for Analysis	Load Combinations	Analyzed Load Case No.	ANSYS Model
Dead weight	Vertical(1)	A	1g down (axial)	1g down + 15 psig ext. press. + thermal (vacuum dry)	1	2-D
External pressure	Vertical(1)	A	15 psig			
Thermal	Vertical(1)	A	Vacuum dry			
Dead weight	Horizontal(2)	A	2g axial + 2g trans. + 2g vertical	A = 2g axial + 2g trans. + 2g vertical A+ 30 psig int. pressure + thermal (115 °F)	2	2-D
Handling load in TC	Horizontal(2)	A		A+ 15 psig ext. pressure + thermal (-20 °F)	3	2-D
Internal pressure	Horizontal(2)	A	30 psig(6)	Pressure stress	[2](5)	2-D
External pressure	Horizontal(2)	A	15 psig	Pressure stress	[3](5)	2-D
Thermal	Horizontal(2)	A	Thermal stress (-20 °F Ambient)	Thermal stress	[3](5)	2-D
Thermal	Horizontal(2)	A	Thermal stress (115 °F ambient)	Thermal stress	[2](5)	2-D
Internal pressure	Horizontal	D	120 psig(3)	Pressure stress	4	2-D
External pressure	Horizontal	D	25 psig(4)	Pressure stress	5	2-D
Side drop	Horizontal	D	75g multiple orientations (0°, 30°, 45°, impact on two rails, impact on one rail) Drop angles are enveloped by 0° (no rail) and 180° (two rails)	75g side drop at 0° (no rail) + 30 psig int. press. of top/bottom ends	6/7	3-D
				75g side drop at 180° (two rails) + 30 psig int. press. of top/bottom ends	8/9	3-D
				75g side drop at 0° (no rail) + 15 psig ext. press. of top/bottom ends	10/11	3-D
				75g side drop at 180° (two rails) + 15 psig ext. press. of top/bottom ends	12/13	3-D
Corner drop	Horizontal	D	Enveloped by 75 g Side Drop and 75 g End Drop			
End drop	Vertical	D	75g End Drop	75g top/bottom + 30 psig int. pressure	14/15	2-D
				75g top/bottom + 15 psig ext. pressure	16/17	2-D

Notes:
(1) TC supported at the bottom.
(2) TC supported at 4 trunnion location.
(3) Under accident fire condition.
(4) Under accident flood condition.
(5) [#] indicates this individual load case is enveloped in the analyzed load case No.
(6) From Chapter 4, Table 4-10, the maximum normal operating pressure is 6.4 psig during transfer operation. However, a design pressure of 15 psig is used. Conservatively, 30 psig is used for structural evaluation of the canister.

Table B.3.9.1-4
32PTH Type 2 DSC Canister Load Combinations during Lifting, Testing, and Hydraulic Loads

Loading	Canister w/TC Orientation	Service Level	Load for Analysis	Load Combinations	Analyzed Load Case No.	ANSYS Model
Dead weight	Horizontal	A	$1g$	$1g$ + 25 psig int. pressure + 155 kips axial loads	18	2-D
Test pressure	Horizontal	A	25 psig[3]			
Seal plate axial load	Horizontal	A	155 kips			
Hydraulic loads[1,2] (push/pull)	Horizontal	A	80/60 kips	30 psig int. pressure + 80 kips push/60 kips pull + thermal (115 °F)	19/20	2-D
Hydraulic loads[1,2] (push/pull)	Horizontal	C	80/80 kips	30 psig int. pressure + 80 kips + thermal (115 °F)	21/22	2-D
Hydraulic loads[1,2] (push/pull)	Horizontal	D	110/110 kips	30 psig int. pressure + 110 kips	23/24	2-D
Lifting	Vertical	A	$1g$	$1g$	25	3-D

Notes:
(1) The hydraulic push loads are applied at the canister bottom surface within the grapple ring support.
(2) The hydraulic pull loads are applied at the inner surface of the grapple ring.
(3) From Chapter 4, Table 4-10, the maximum normal operating pressure is 6.4 psig during transfer operation. The canister is conservatively evaluated at higher test pressures.

Table B.3.9.1-5
Summary of Calculated Stresses for Testing Condition Loads

Load Case	Combination of Loads	Canister Orientation	Service Level	Component	Stress Category	Stress (ksi)	Stress Limit (ksi)
T8(a)	DW + 25 psig int. press. + 155 kip axial load	Horizontal	A	All(1)	P_m	8.0(2)	24(4)
					$P_m + P_b$	14.26 ksi(3)	40.5(5)

Notes:
(1) Yield stress, S_y = 30,000 psi, is taken at test temperature of 100 °F for both material SA-240 GR.304 and SA-182 F304
(2) P_m = 8.0 ksi + 0.005 ksi (dead weight, in load case 18) = 8 ksi
(3) $P_m + P_b$ = 8 ksi + 6.26 ksi (dead weight, in load case 18) = 14.26 ksi
(4) $P_m < 0.8\ S_y$ = 24 ksi
(5) $P_m + P_b < 1.35\ S_y$ = 40.5 ksi

Table B.3.9.1-6
Summary of Calculated Stress for Normal and Off-Normal Condition Transfer Loads

Load Case	Combination of Loads	Canister Orientation	Service Level	Components	Stress Category	Stress(3) (ksi)	Stress Limit (ksi)
T1	1*g* down + 15 psig ext. press. + vacuum drying thermal	Vertical	A	All(2)	P_m	1.95	17.5
					$P_m + P_b$	1.95	26.3
					$P_m + P_b + Q$	18.82	52.5
T2	Handling 2*g* + 30 psig int. press. + thermal (115 °F)	Horizontal	A	All(2)	P_m	14.81+0.88 = 15.69	17.5
					$P_m + P_b$	14.81+9.74 = 24.55	26.3
					$P_m + P_b + Q$	38.35+9.74 = 48.09	52.5
T3	Handling 2*g* + 15 psig ext. press. + thermal (-20 °F)	Horizontal	A	All(2)	P_m	5.83+0.88 = 6.71	17.5
					$P_m + P_b$	5.83+9.74 = 15.57	26.3
					$P_m + P_b + Q$	28.84+9.74 = 38.58	52.5
T9	30 psig int. press + 80 kips push + thermal (115 °F)	Horizontal	A	All(2)	P_m	15.65	17.5
					$P_m + P_b$	15.65	26.3
					$P_m + P_b + Q$	31.35	52.5
T10	30 psig int. press + 60 kips pull + thermal (115 °F)	Horizontal	A	GR, BOCP, and bottom 2" CS(1)	P_m	9.24	20.0
					$P_m + P_b$	25.57	30.0
					$P_m + P_b + Q$	27.23	60.0
				All except GR, BOCP, and bottom 2" CS(3)	P_m	14.81	17.5
					$P_m + P_b$	14.81	26.3
					$P_m + P_b + Q$	38.73	52.5
T11	30 psig int. press + 80 kips push + thermal (115 °F)	Horizontal	C	All(2)	P_m	15.65	21.0
					$P_m + P_b$	15.65	31.5
					$P_m + P_b + Q$	-	-
T12	30 psig int. press + 80 kips pull + thermal (115 °F)	Horizontal	C	GR, BOCP, and bottom 2" CS(1)	P_m	12.32	24.0
					$P_m + P_b$	34.13	36.0
					$P_m + P_b + Q$	-	-
				All except GR, BOCP, and bottom 2" CS(3)	P_m	14.81	21.0
					$P_m + P_b$	14.81	31.5
					$P_m + P_b + Q$	-	-

Notes:
(1) GR–grapple ring; BOCP–bottom outer cover plate; CS–canister shell. Except for the vacuum drying and fire accident load cases, the temperature in the grapple ring, the bottom outer cover plate and the bottom 2 in. of the canister shell do not exceed 300 °F. Conservatively stress limits at 300 °F are used.
(2) Conservatively the stress limits at 500 °F are used.
(3) Conservatively the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses except for grapple pull load cases, 20 and 22, where the stresses were linearized in the grapple ring, bottom outer cover plate and bottom 2 in. of the canister shell.

Table B.3.9.1-7
Summary of Calculated Stress for Accident Condition Transfer Loads (Axisymmetric Loads)

Load Case	Combination of Loads	Canister Orientation	Service Level	Components	Stress Category	Stress[4] (ksi)	Stress Limit (ksi)
T4	120 psig int. press. under fire accident	Horizontal	D	All[2]	P_m	23.87	44.0
					$P_m + P_b$	23.87	56.5
T5	25 psig ext. press. under flood accident	Horizontal	D	All[3]	P_m	9.73	42.0
					$P_m + P_b$	9.73	63.0
T6	75 *g* top end drop + 30 psig int. press.	Vertical	D	All[3]	P_m	6.39	42.0
					$P_m + P_b$	43.19	63.0
T7	75 *g* bottom end drop + 30 psig int. press.	Vertical	D	All[3]	P_m	17.71	42.0
					$P_m + P_b$	17.71	63.0
T16	75 *g* top end drop + 15 psig ext. press.	Vertical	D	All[3]	P_m	8.90	42.0
					$P_m + P_b$	59.29	63.0
T15	75 *g* bottom end drop + 15 psig ext. press.	Vertical	D	All[3]	P_m	22.63	42.0
					$P_m + P_n$	22.63	63.0
T13	30 psig int. press. + 110 kips push	Horizontal	D	All[3]	P_m	16.25	42.0
					$P_m + P_b$	16.25	63.0
T14	30 psig int. press. + 110 kips pull	Horizontal	D	GR, BOCP, and bottom 2" CS[1]	P_m	16.96	46.3
					$P_m + P_b$	46.98	66.2
				All except GR, BOCP, and bottom 2" CS[3]	P_m	14.81	42.0
					$P_m + P_b$	14.81	63.0

Notes:
(1) GR–grapple ring; BOCP–bottom outer cover plate; CS–canister shell. Except for the vacuum drying and fire accident load cases, the temperature in the grapple ring, the bottom outer cover plate, and bottom 2 in. of the canister shell do not exceed 300 °F. Conservatively stress limits at 300 °F are used for elastic analysis.
(2) Conservatively the stress limits at 800 °F are used for elastic-plastic analysis.
(3) Conservatively the stress limits at 500 °F are used for elastic analysis.
(4) Conservatively the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses except for grapple pull load cases, 23, where the stresses were linearized in the grapple ring, bottom outer cover plate and bottom 2 in. of the canister shell.

Table B.3.9.1-8
Summary of Stresses for Accident Condition Transfer Loads (3-D Inertial Loads)

Load Case	Load Combination	Canister	Maximum Stress Intensity[1] [ksi]	Stress Limits	
				P_m	P_m+P_b
SD1	Side drop 75*g* + 30 psig internal pressure	Top end, no rails (orientation 0°)	25.31	44.4 ksi	57.1 ksi
SD2	Side drop 75*g* + 30 psig internal pressure	Bottom end, no rails (orientation 0°)	23.96	44.4 ksi	57.1 ksi
SD3	Side drop 75*g* + 30 psig internal pressure	Top end, rails (orientation 180°)	26.89	44.4 ksi	57.1 ksi
SD4	Side drop 75*g* + 30 psig internal pressure	Bottom end, rails (orientation 180°)	24.59	44.4 ksi	57.1 ksi
SD5	Side drop 75*g* + 15 psig external pressure	Top end, no rails (orientation 0°)	25.65	44.4 ksi	57.1 ksi
SD6	Side drop 75*g* + 15 psig external pressure	Bottom end, no rails (orientation 0°)	23.95	44.4 ksi	57.1 ksi
SD7	Side drop 75*g* + 15 psig external pressure	Top end, rails (orientation 180°)	26.86	44.4 ksi	57.1 ksi
SD8	Side drop 75*g* + 15 psig external pressure	Bottom end, rails (orientation 180°)	24.71	44.4 ksi	57.1 ksi

Note:
(1) Shield plug component excluded in stress evaluation.

Table B.3.9.1-9
Summary of Calculated Stress at End Closure Welds for Testing Condition Loads

Load Case	Combination of Loads	Canister Orientation	Service Level	Stress Category	Stress[(1)] (ksi)	Stress Limit (ksi)
18	DW + 25 psig int. press. + 155 kip axial load	Horizontal	A	P_m	-	-
				$P_m + P_b$	-	-

Note:
(1) There are no closure welds during pressure test.

Table B.3.9.1-10
Summary of Calculated Stress at the End Closure Welds for Normal and Off-Normal Condition Transfer Loads

Load Case	Combination of Loads	Canister Orientation	Service Level	Stress Category	Stress(2) (ksi)	Stress Limit(1) (ksi)
T1	1*g* down + 15 psig ext. press. + vacc. dry thermal	Vertical	A	P_m	1.56	16
				$P_m + P_b$	1.56	24
				$P_m + P_b + Q$	1.75	48
T2	Handling 2*g* + 30 psig int. press. + thermal (115 °F)	Horizontal	A	P_m	11.72+0.88 = 12.60	16
				$P_m + P_b$	11.72+9.74 = 21.46	24
				$P_m + P_b + Q$	15.25+9.74 = 24.99	48
T3	Handling 2*g* + 15 psig ext. press. + thermal (-20 °F)	Horizontal	A	P_m	1.48+0.88 = 2.36	16
				$P_m + P_b$	1.48+9.74 = 11.22	24
				$P_m + P_b + Q$	3.02+9.74 = 12.76	48
T9	30 psig int. press + 80 kips push + thermal (115 °F)	Horizontal	A	P_m	10.72	16
				$P_m + P_b$	10.72	24
				$P_m + P_b + Q$	15.21	48
T10	30 psig int. press + 60 kips pull + thermal (115 °F)	Horizontal	A	P_m	11.73	16
				$P_m + P_b$	11.73	24
				$P_m + P_b + Q$	15.25	48
T11	30 psig int. press + 80 kips push + thermal (115 °F)	Horizontal	C	P_m	10.72	19.2
				$P_m + P_b$	10.72	28.8
				$P_m + P_b + Q$	-	-
T12	30 psig int. press + 80 kips pull + thermal (115 °F)	Horizontal	C	P_m	11.72	19.2
				$P_m + P_b$	11.72	28.8
				$P_m + P_b + Q$	-	-

Notes:
(1) Since the temperatures at the closure welds do not exceed 300 °F, the allowable stresses at 300 °F are used.
(2) Conservatively, the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses.

Table B.3.9.1-11
Summary of Calculated Stresses at End Closure Welds for Accident Condition Transfer Loads (Axisymmetric Loads)

Load Case	Combination of Loads	Canister Orientation	Service Level	Stress Category	Stress(2) (ksi)	Stress Limit(1) (ksi)
T4	120 psig int. press. under fire accident	Horizontal	D	P_m	21.76	37.04
				$P_m + P_b$	21.76	47.68
T5	25 psig ext. press. under flood accident	Horizontal	D	P_m	2.45	37.04
				$P_m + P_b$	2.45	52.96
T6	75*g* top end drop + 30 psig int. press.	Vertical	D	P_m	10.76	37.04
				$P_m + P_b$	10.76	52.96
T7	75*g* bottom end drop + 30 psig int. press.	Vertical	D	P_m	13.57	37.04
				$P_m + P_b$	13.57	52.96
T16	75*g* top end drop + 15 psig ext. press.	Vertical	D	P_m	12.22	37.04
				$P_m + P_b$	12.22	52.96
T15	75*g* bottom end drop + 15 psig ext. press.	Vertical	D	P_m	14.80	37.04
				$P_m + P_b$	14.80	52.96
T13	30 psig int. press. + 110 kips push	Horizontal	D	P_m	10.45	37.04
				$P_m + P_b$	10.45	52.96
T14	30 psig int. press. + 110 kips pull	Horizontal	D	P_m	11.72	37.04
				$P_m + P_b$	11.72	52.96

Notes:
(1) Since the temperatures at the closure welds do not exceed 300 °F, the allowable stresses at 300 °F are used.
(2) Conservatively, the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses.

Table B.3.9.1-12
Summary of Calculated Stresses at End Closure Welds for Accident Condition Transfer Loads (3-D Inertial Loads)

Load Case	Load Combination	Canister	Maximum Stress Intensity (ksi)	Stress Limits
SD1	Side drop 75*g* + 30 psig internal pressure	Top end, no rails (orientation 0°)	21.81	35.52 ksi
SD3	Side drop 75*g* + 30 psig internal pressure	Top end, rails (orientation 180°)	23.63	35.52 ksi
SD5	Side drop 75*g* + 15 psig external pressure	Top end, no rails (orientation 0°)	21.27	35.52 ksi
SD7	Side drop 75*g* + 15 psig external pressure	Top end, rails (orientation 180°)	23.49	35.52 ksi

Table B.3.9.1-13
32PTH Type 2 DSC Canister Load Combinations during Storage

Loading	Canister Orientation	Service Level	Load	Enveloped Load for Analysis	Load Combinations
Dead weight	Horizontal[1]	A	1g down	0.65g axial + 0.65 g trans. + 1.3 g vertical	0.65g axial + 0.65g trans. + 1.3g vertical down
Seismic loads	Horizontal[1]	C[2]	0.43g axial + 0.43g trans. +0.20g vertical		0.65g axial + 0.65g trans. + 1.3 g vertical down + 30 psig + thermal (115 °F)
					0.65g axial + 0.65g trans. + 1.3 g vertical down + 30 psig + thermal (-20 °F)
Internal pressure	Horizontal[1]	A	15 psig	30 psig	Pressure
Thermal	Horizontal[1]	A	Thermal (-20 °F ambient)	Thermal (-20 °F ambient)	Thermal
Thermal	Horizontal[1]	A	Thermal (115 °F ambient)	Thermal (115 °F ambient)	Thermal
Thermal	Horizontal[1]	D	Blocked vent	Blocked vent	1g down + 70 psig int. pressure + thermal (blocked vent)
Internal pressure	Horizontal[1]	D	< 67 psig due to blocked vent	Enveloped by 70 psig internal pressure	
Flood	Horizontal[1]	D(	50 ft water (≈22 psig)	Enveloped by 30 psig external pressure design	

Notes:
(1) Canister supported at HSM rails and axial restrained by the seismic restraint devices.
(2) Levels C loads are conservatively treated as Level A loads and evaluated as such.

Table B.3.9.1-14
Summary of Calculated Stresses for Normal and Accident Condition Loads (canister in horizontal position)

Load Case	Combination of Loads	Canister Orientation	Service Level	Components	Stress Category	Stress (ksi)	Stress Limit (ksi)
S1	Dead weight (1g down)	Horizontal	A	All(2)	P_m	0.40	17.5
					$P_m + P_b$	4.05	26.3
S2	30 psig internal pressure	Horizontal	A	All(2)	P_m(3)	14.97	17.5
					$P_m + P_b$(3)	14.97	26.3
S3	Seismic (0.65g axial + 0.65 trans. + 1.3 vert. down)	Horizontal	A(1)	All(2)	P_m	0.63	17.5
					$P_m + P_b$	6.08	26.3
S4	Thermal (-20 °F amb.)	Horizontal	A	All(2)	Q	20.91	52.5
S5	Thermal (115 °F amb.)	Horizontal	A	All(2)	Q	18.95	52.5
S6	Thermal (blocked vent)	Horizontal	D	All(4)	Q	18.48	63.0
S7	Accident 70 psig internal pressure	Horizontal	D	All(2)	P_m(3)	34.56	42.0
					$P_m + P_b$(3)	34.56	63.0
S8	Accident flood (enveloped by 30 psig ext. pressure)	Horizontal	D	All(2)	P_m(3)	11.67	42.0
					$P_m + P_b$(3)	11.67	63.0
SC1	S2 + S3 + S4	Horizontal	A(1)	All(2)	P_m	15.56	17.5
					$P_m + P_b$	21.05	26.3
					$P_m + P_b + Q$	41.96	52.5
SC2	S2 + S3 + S5	Horizontal	A(1)	All(2)	P_m	15.60	17.5
					$P_m + P_b$	21.05	26.3
					$P_m + P_b + Q$	40.0	52.5
SC3	S1 + S7 + S6	Horizontal	D	All(4)	P_m	34.96	42.0
					$P_m + P_b$	38.61	63.0
					$P_m + P_b + Q$	57.09	63.0
SC4	S1 + S8	Horizontal	D	All(2)	P_m	12.07	42.0
					$P_m + P_b$	15.72	63.0

Notes:
(1) Seismic loads are conservatively treated as Level A loads.
(3) Conservatively the stress limits at 500 °F are used.
(3) Conservatively the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses.
(4) ASME code requires only primary stresses be evaluated under accident conditions, conservatively secondary stresses were evaluated and compared against the $P_m + P_b$ stress limits. The peak stresses occur at the top and bottom of the canister where the maximum temperature is lower than 500 °F. The stress limits at 500 °F are used.

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

Table B.3.9.1-15
Summary of Calculated Stresses at the End Closure Welds for Normal and Accident Condition Storage Loads

Load Case	Combination of Loads	Canister Orientation	Service Level	Stress Category	Stress (ksi)	Stress Limit[2] (ksi)
S1	Dead weight (1g down)	Horizontal	A	P_m	0.40	16
				$P_m + P_b$	4.05	24
S2	30 psig internal pressure	Horizontal	A	P_m[3]	11.75	16
				$P_m + P_b$[3]	11.75	24
S3	Seismic (0.65 g axial + 0.65 trans. + 1.3 vert. down)	Horizontal	A[1]	P_m	0.63	16
				$P_m + P_b$	6.08	24
S4	Thermal (-20 °F amb.)	Horizontal	A	Q	3.67	48
S5	Thermal (115 °F amb.)	Horizontal	A	Q	3.62	48
S6	Thermal (blocked vent)	Horizontal	D	Q[4]	8.19	52.96
S7	Accident 70 psig internal pressure	Horizontal	D	P_m[3]	27.38	37.04
				$P_m + P_b$[3]	27.38	52.96
S8	Accident flood (enveloped by 30 psig ext. pressure)	Horizontal	D	P_m[3]	2.94	37.04
				$P_m + P_b$[3]	2.94	52.96
SC1	S2 + S3 + S4	Horizontal	A[1]	P_m	12.38	16
				$P_m + P_b$	17.83	24
				$P_m + P_b + Q$	21.50	48
SC2	S2 + S3 + S5	Horizontal	A[1]	P_m	12.38	16
				$P_m + P_b$	17.83	24
				$P_m + P_b + Q$	21.45	48
SC3	S1 + S7 + S6	Horizontal	D	P_m	27.78	37.04
				$P_m + P_b$	31.43	52.96
				$P_m + P_b + Q$[4]	39.62	52.96
SC4	S1 + S8	Horizontal	D	P_m	3.34	37.04
				$P_m + P_b$	6.99	52.96

Notes:
(1) Seismic loads are conservatively treated as Level A loads.
(2) Since the temperatures at the closure welds do not exceed 300 °F, the stress limits at 300 °F are used.
(3) Conservatively, the maximum stress intensity was used for both P_m and $P_m + P_b$ stresses for all analyses.
(4) ASME code requires only primary stresses be evaluated under accident conditions, conservatively secondary stresses were also included and compared against the $P_m + P_b$ stress limits.

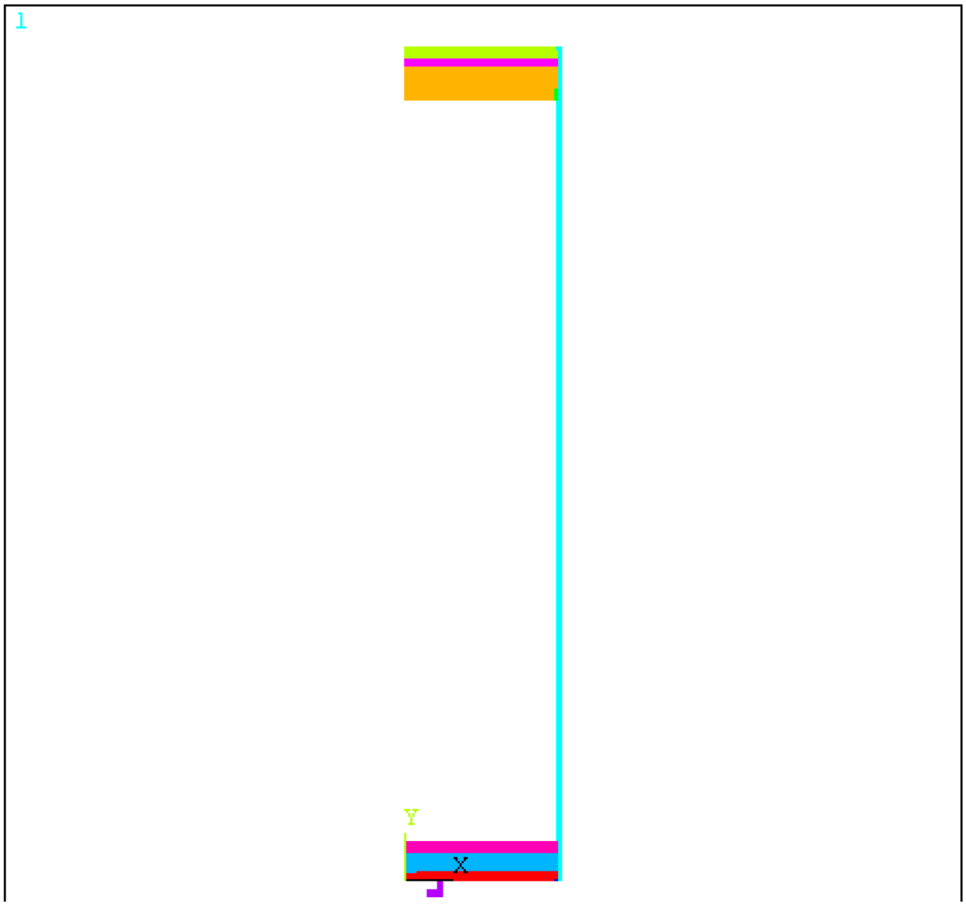


Figure B.3.9.1-1
2-D Canister Axisymmetrical Thermal and Stress Finite Element Model

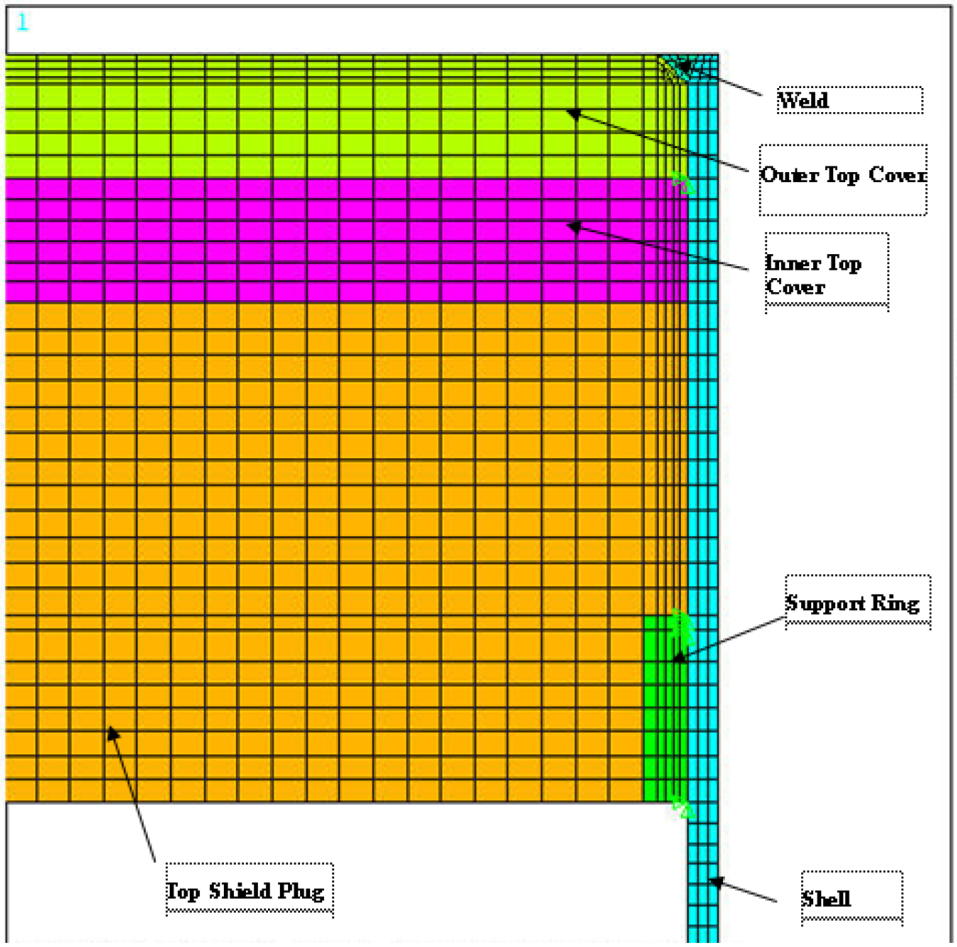


Figure B.3.9.1-2
Top End of the 2-D Axisymmetrical Canister Model

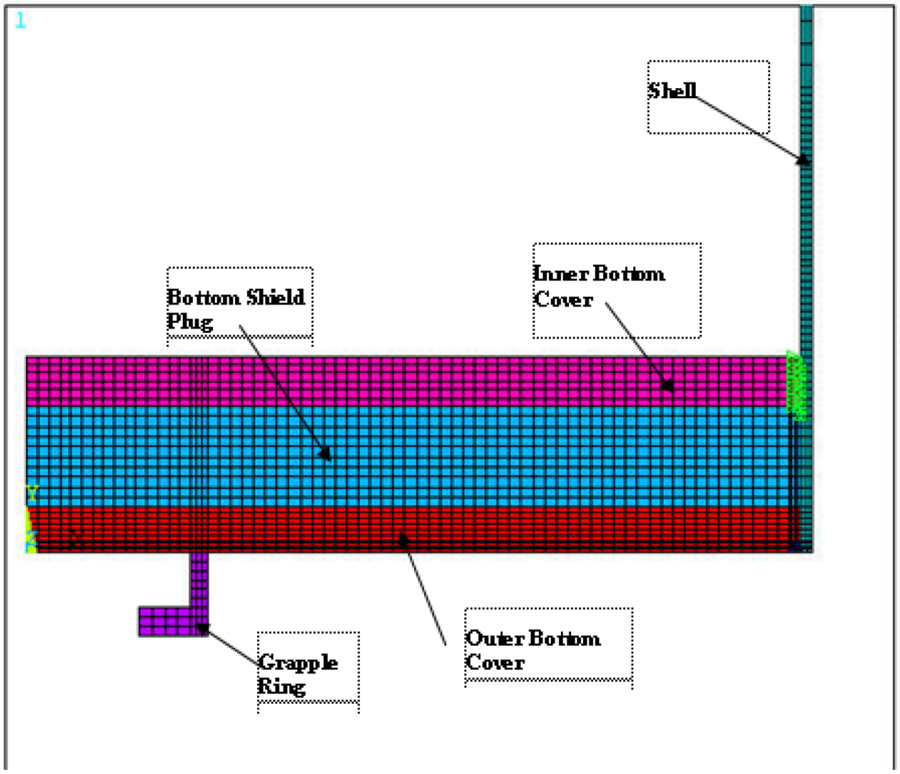


Figure B.3.9.1-3
Bottom End of the 2-D Axisymmetrical Canister Model

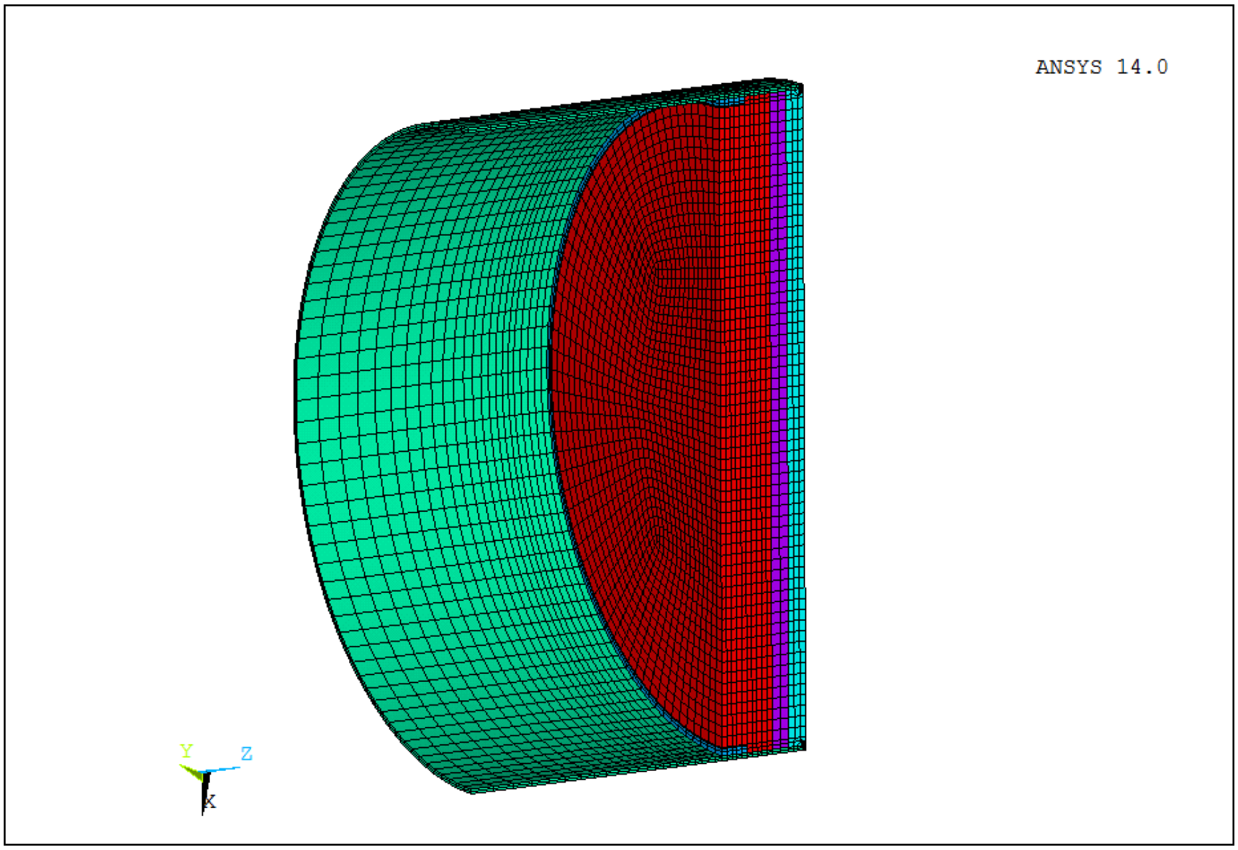


Figure B.3.9.1-4
3-D DSC Canister Top End Assembly Finite Element Model

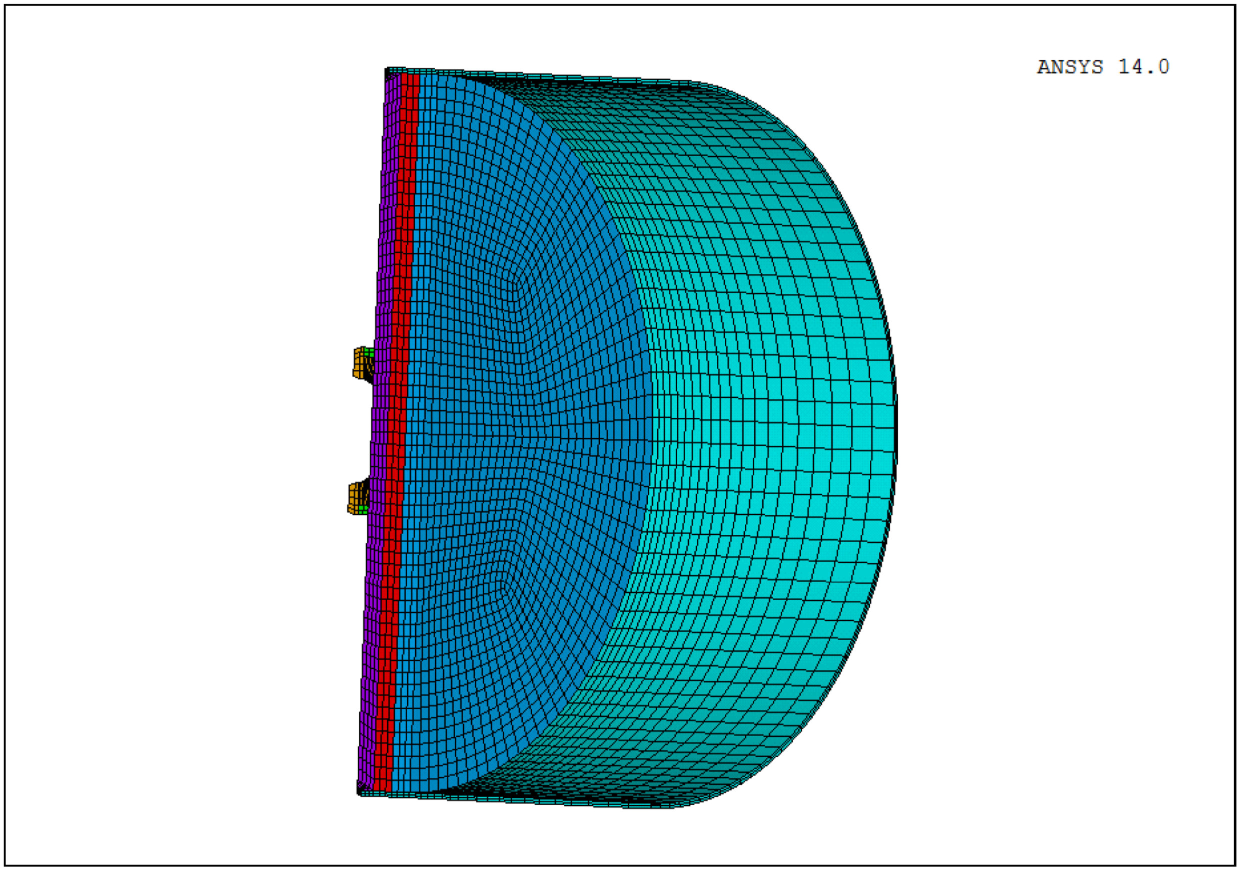


Figure B.3.9.1-5
3-D DSC Canister Bottom End Assembly Finite Element Model

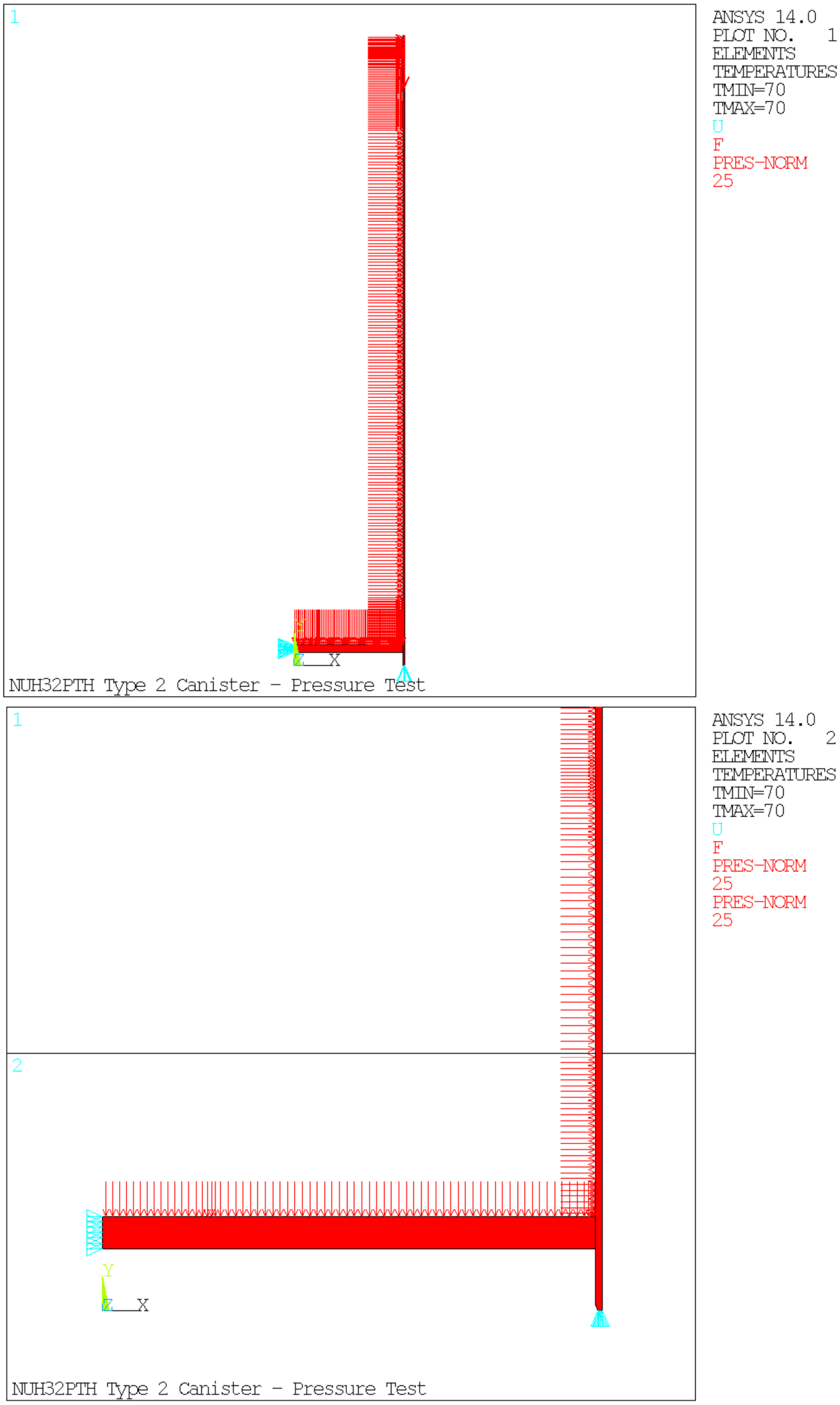


Figure B.3.9.1-6
32PTH Type 2 DSC Canister Finite Element Model used for Pressure Test Analysis

Appendix B.3.9.2
OS187H Type 2 Transfer Cask Body Structural Analysis

No change. The clearance to permit free thermal expansion of the 32PTH Type 2 DSC within the OS187H Type 2 transfer cask (TC) requires a minimum cavity length of 199.05 in. The air flow wedge thickness is reduced to 0.5 in. to achieve this cavity length. There is no structural credit taken for these wedges. There are no other changes made to the TC. The TC evaluations documented in Appendix A.3.9.2 for OS187H TYPE 1 TC are applicable without change to the OS187H TYPE 2 TC.

Appendix B.3.9.3
OS187H Type 2 Transfer Cask Top Cover and Ram Cover Bolt Analyses

No change. There are no changes to the transfer cask (TC) top cover or ram bolts. The TC Top Cover and Ram Cover Bolt evaluations documented in Appendix A.3.9.3 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

Appendix B.3.9.4
OS187H Type 2 Transfer Cask Lead Slump and Inner Shell Buckling Analysis

In accordance with the NUHOMS® HD System Safety Evaluation Report (SER), the top and bottom end accident drops and the corner accident drop are not credible under 10 CFR Part 72 because the OS187H Type 2 transfer cask (TC) is always in the horizontal orientation. Therefore, the OS187H Type 2 TC lead slump and shell buckling analysis are not evaluated and, thus, this appendix has been deleted. These analyses may need to be evaluated under 10 CFR Part 50 should the user not be able to demonstrate that the top and bottom end and the corner drops are not credible during loading operations, or during transport operations governed under 10 CFR Part 71.

Appendix B.3.9.5
OS187H Type 2 Transfer Cask Trunnion Analysis

No change. There are no changes to the transfer cask (TC) trunnion. The TC Trunnion evaluations documented in Appendix A.3.9.5 for OS187H Type 1 are applicable without change to the OS187H Type 2 TC.

Appendix B.3.9.6
OS187H TYPE 2 Transfer Cask Shield Panel Structural Analysis

No change. There are no changes to the transfer cask (TC) shield panel. The TC Shield Panel structural evaluations documented in Appendix A.3.9.5 for the OS187H Type 1 TC are applicable without change to the OS187H Type 2 TC.

Appendix B.3.9.7
OS187H Type 2 Transfer Cask Impact Analysis

Appendix 3.9.7 describes the evaluations originally performed to substantiate the 75g accident drop decelerations used for the structural evaluation of the NUHOMS® HD System components. During the licensing of the 32PTH System and as part of the request for additional information response process, TN performed an accident drop analysis of the OS187H TC using the LS-DYNA computer code. This LS-DYNA evaluation is documented in Appendix 3.9.10 and forms the basis for the acceleration values used for evaluation of the NUHOMS® HD System components. The justification for applicability of the Appendix 3.9.7 to the 32PTH Type 2 DSC and OS187H Type 2 TC is provided in Appendix B.3.9.10. Therefore, Appendix B.3.9.7 is deleted.

Appendix B.3.9.8
Damaged Fuel Cladding Structural Evaluation

No change. The damaged fuel cladding evaluations documented in Appendix 3.9.8 are applicable without change to the 32PTH Type 2 DSC.

Appendix B.3.9.9
HSM-H Structural Analysis

The structural evaluation of the HSM-H documented in Appendix 3.9.9 remains applicable when the HSM-H is loaded with a 32PTH Type 2 DSC. The HSM-H evaluation in Appendix 3.9.9 is based on a dry shielded canister (DSC) weight of 110 kips, which bounds the weight of the loaded 32PTH Type 2 DSC of 108.03 kips. Also, as documented in Chapter 4, the HSM-H design is based on temperature distributions resulting from thermal analysis using a bounding heat load of 40.8 kW, which is higher than the 32PTH Type 2 DSC maximum heat load of 34.8 kW. As documented in Chapter A.4, the longer 32PTH Type 2 DSC is not expected to change significantly the HSM-H temperature distributions documented in Chapter 4 for the HSM-H loaded with a 32PTH DSC.

Two minor design modifications are made to the HSM-H to accommodate the 32PTH Type 2 DSC. These consist of a small (2.5 in.) increase in the length of the support rail structure, and, to accommodate the rail length increase, an alternate design of the DSC stop plate at the rear of the rail support structure is implemented (the 1-inch thick stiffened canister stop plate assembly is replaced with a single 2-inch thick plate welded to the top flange of the support rail structure). These design modifications are shown in drawings provided in Chapter B.1, Section B.1.5. These modifications do not affect the overall structural qualification of the HSM-H as documented in Appendix 3.9.9. The increased length provides additional bearing area for the support rail structure on its concrete support on the rear wall of the module and, thus, has no effect on the structural qualification of the rail support structure. The alternate DSC stop plate is evaluated using the same loads and allowables as the original stop plate design and is shown to meet the same stress allowable criteria. The maximum bending and shear stresses are on the order of 13.0 ksi and 2.5 ksi, respectively, versus allowable stresses of 18.9 ksi and 12.5 ksi, respectively. The weld between the stop plate and the top flange of the rail is conservatively specified as a full penetration weld.

Therefore, the HSM-H as evaluated in Appendix 3.9.9 with the minor design modifications described above is qualified to store a 32PTH Type 2 DSC.

Appendix B.3.9.10
OS187H Type 2 Transfer Cask Dynamic Impact Analysis

No change. There are no changes to the transfer cask (TC) top design except change in the cavity length. The Transfer Cask Dynamic Impact assessment documented in Appendix A.3.9.10 for the OS187H Type 1 TC is applicable without change to the OS187H Type 2 TC.

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

APPENDIX B.3.9.11
NUHOMS® 32PTH TYPE 2 DSC DYNAMIC AMPLIFICATION FACTOR ANALYSIS

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.3.9.11 NUHOMS® 32PTH Type 2 DSC Dynamic Amplification Factor Analysis

B.3.9.11.1 Introduction

This appendix computes the dynamic amplification factor (DAF) to be applied to the response accelerations obtained from the drop accident dynamic analysis of the OS187H Type 2 transfer cask (TC) when applying those accelerations as input to an equivalent static analysis of the 32PTH Type 2 DSC of the same postulated drop accident event.

The DAF is computed for the loaded 32PTH Type 2 DSC in the horizontal orientation. Vertical and corner drop accidents are not credible events since the TC is always in the horizontal configuration.

B.3.9.11.2 Side Drop Modal Analysis

A. Canister Shell

The fundamental natural frequency of the 32PTH Type 2 DSC shell corresponding to an ovalling (radial-axial) mode is determined assuming the cylindrical shell is simply supported without axial constraint. The natural frequency of the cylindrical shell ovalling mode is given by the following [1, p. 305, Table 12-2, Frame 5]:

$$f_{ij} = \frac{\lambda_{ij}}{2\pi R}\left(\frac{E}{\mu(1-\nu^2)}\right)^{1/2}$$

$$\lambda_{ij} = \frac{\left\{(1-\nu^2)(j\pi R/L)^4 + (h^2/12R^2)\left[i^2+(j\pi R/L)^2\right]^4\right\}^{1/2}}{(j\pi R/L)^2 + i^2}$$

Where L is taken to be the length between the top and bottom shield plugs, which is roughly 181.38 in., $E = 25.8\times10^6$ psi (for SA-240 Type 304 stainless steel at 500 °F [2]), R is the average shell radius, 34.625 in., ν is Poisson's ratio, which is 0.305 for stainless steel [3, page 5-6], μ = 0.29/386.4 = 0.000751 lbm. in^{-3}, and thickness h = 0.5 in.

For the fundamental mode, i = 2 and j = 1.

$$\lambda_{ij} = \frac{\left\{(1-.305^2)(\pi\times34.625/171.63)^4 + (0.5^2/12\times34.625^2)\left[2^2+(\pi34.625/171.63)^2\right]^4\right\}^{1/2}}{(\pi34.625/181.38)^2 + 2^2}$$

$$= 0.081$$

$$f_{21} = \frac{0.081}{2\pi\times34.625}\left(\frac{25.8\times10^6}{0.000751(1-0.305^2)}\right)^{1/2} = 72.46 \text{ Hz}$$

B. Basket with Fuel Assemblies

The basket for the 32PTH Type 2 DSC is identical to the 32PTH DSC, except that the length of the basket is 15 in. longer in the 32PTH Type 2 DSC with one additional full height layer of neutron poison/thermal aluminum cross bars and the fuel tubes at the top of the basket are also connected with crossbars and fusion welds. The length of the 32PTH DSC basket is 162 in. and the length of the 32PTH Type 2 DSC is 178.75 in. The weight of the fuel remains the same. As discussed in Appendix B.3.9.1, the axial length of the finite element model of the 32PTH basket assembly is based on a 15-inch segment, which corresponds to the pitch of the cross bars where the compartment tubes are welded together. This basket model and analysis results are also applicable to the 32PTH Type 2 basket. Thus, the DAF for the 32PTH DSC basket assembly computed in Appendix 3.9.11 are also applicable to the 32PTH Type 2 basket assembly.

B.3.9.11.3 Dynamic Load Factor Calculations

The natural frequency of the 32PTH Type 2 canister (72.46 Hz) is lower than the 32PTH canister (86.0 Hz) in the horizontal orientation. It is concluded from the results in Section 3.9.11.5 and the amplification factor results for a half sine wave [4, Figure 2.15] that frequencies lower than 86 Hz will result in a lower DAF than 1.03. Thus the DAF calculated for the 32PTH canister side drop bounds the DAF for the 32PTH Type 1 canister.

Since the natural frequencies of the NUHOMS® 32PTH Type 2 basket are the same as the NUHOMS® 32PTH basket, the DAF for the NUHOMS® 32PTH Type 2 will also be the same as the DAF for the NUHOMS® 32PTH basket, which is 1.18.

B.3.9.11.4 Summary of g-Loads for 32PTH Type 2 DSC Impact Analyses

Appendix A.3.9.10 summarizes the maximum g-loads computed for the OS187H Type 1 transfer cask (TC) during an 80-inch side drop is applicable without change to the OS187H Type 2 TC.

B.3.9.11.5 References

1. Blevins, R. D., "Formulas for Natural Frequency and Mode Shape," Krieger Publishing Company, 1995.

2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Part D, 1998 through 2000 addenda.

3. Baumeister, T. and L. S. Marks, "Standard Handbook for Mechanical Engineers," Seventh Edition, McGraw-Hill Book Company, December 1967.

4. Nelson, T. A. and R. C. Chun, "Methods for Impact Analysis of Shipping Containers," NUREG/CR-3966, UCID-20639, Lawrence Livermore National Lab (LLNL), CA, 1987.

APPENDIX B.4
THERMAL EVALUATION

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B.4 THERMAL EVALUATION

B.4.1 Discussion

The NUHOMS® 32PTH Type 2 DSC is designed to passively reject decay heat during storage and transfer for normal, off-normal, and accident conditions while maintaining temperatures and dry shielded canister (DSC) internal pressures within specified limits.

In general, the thermal evaluations and results documented in Chapter 4 for the 32PTH DSC inside the HSM-H and OS187H TC are bounding for the 32PTH Type 2 DSC inside the HSM-H and the OS187H Type 2 TC.

As shown in Table B.1-1, the main differences between the 32PTH DSC and the 32PTH Type 2 DSC consist of a longer overall DSC length and a corresponding longer internal cavity length to accommodate an increased basket length. The effect of these differences is addressed in this chapter and shows a negligible effect on the overall thermal performance of the 32PTH Type 2 DSC compared to the 32PTH DSC.

The longer length of the 32PTH Type 2 DSC affects the HSM-H air flow evaluation, and the longer cavity length affects the decay heat flux and heat generation rate used for thermal evaluation of the 32PTH Type 2 DSC.

B.4.1.1 Air Flow Evaluation for 32PTH Type 2 DSC in HSM-H

The mass flow rates, exit and average air temperatures, and total loss coefficients for the 32PTH Type 2 DSC in the HSM-H are calculated for the bounding off-normal conditions using the same methodology used for the 32PTH DSC described in Chapter 4. Table B.4-1 shows the results of the air flow calculations for 32PTH Type 2 DSC in comparison to those for the 32PTH DSC.

As shown in Table B.4-1, the differences in the air flow calculation results for HSM-H loaded with 32PTH Type 2 DSC or 32PTH DSC are insignificant. The exit air temperatures for 32PTH Type 2 DSC are bounded by those of the 32PTH DSC due to the longer DSC length, which results in a lower decay heat flux at the DSC surface and a larger heat transfer surface. The reduced air temperature difference from the exit to the inlet of the HSM-H results in increasing air mass flow rate through the HSM-H cavity. Thus, the air flow calculation results used for the thermal evaluation of the 32PTH DSC in the HSM-H can be conservatively used for thermal evaluation of the 32PTH Type 2 DSC in the HSM-H.

B.4.1.2 Thermal Evaluation of 32PTH Type 2 DSC in HSM-H

The main design differences between the 32PTH DSC and the 32PTH Type 2 DSC listed in Table B.1-1 only affect applied decay heat load used for normal and off-normal conditions and heat generation rate within the DSC used for blocked vent accident conditions. Table B.4-2 summarizes the applied decay heat load and heat generation rate for 32PTH DSC and 32PTH Type 2 DSC in the HSM-H.

As shown in Table B.4-2, both the decay heat flux and the heat generation rate for the 32PTH Type 2 DSC are bounded by those used for 32PTH DSC in HSM-H. The 32PTH Type 2 DSC is longer, which provides larger heat transfer surface for DSC outer shell than 32PTH DSC. The added length of the 32PTH Type 2 DSC basket increases the heat rejection capacity of the basket. Therefore, the temperatures of 32PTH Type 2 DSC in HSM-H for storage conditions are bounded by those calculated for 32PTH DSC in Chapter 4.

Due to the longer length of the 32PTH Type 2 DSC, the HSM-H is exposed to a lower heat flux/heat generation rate than the 32PTH DSC. Thus, the temperature distribution in the HSM-H concrete structure and steel support structure will correspondingly decrease with the lower heat flux/heat generation rate. Therefore, the thermal analysis results of the 32PTH DSC in HSM-H as calculated in Chapter 4 (see Table 4-2, Table 4-4 and Table 4-6) are bounding.

B.4.1.3 Thermal Evaluation of 32PTH Type 2 DSC in OS187H Type 2 TC

To accommodate the longer length of the 32PTH Type 2 DSC in the OS187H Type 2 TC, the air flow wedge in the TC is reduced from 1.0 in. to 0.5 in. to increase TC cavity length. The wedges support forced air cooling option, which is not used for the OS187H Type 2 TC. However, the overall TC length does not change. So, this change has no impact on TC thermal performance.

Since the 32PTH Type 2 DSC cavity and OS187H Type 2 TC cavity are longer than that of 32PTH DSC and OS187H TC, the total decay heat load (34.8 kW) would be distributed over a larger radial inner surface of the DSC cavity than the one considered in the Chapter 4 thermal analysis for transfer conditions. This means the applied heat fluxes and heat generation rates considered in Chapter 4 bound those for the 32PTH Type 2 DSC and OS187H Type 2 TC. Furthermore, the longer DSC/TC length provide large heat transfer surface for heat rejection from the DSC to the ambient. The maximum DSC/TC component temperatures decrease with a lower heat flux/heat generation rate and a larger DSC/TC heat transfer surface and, therefore, the thermal analysis results of the 32PTH DSC in OS187H TC (see Table 4-1, Table 4-3 and Table 4-5) bound those for the 32PTH Type 2 DSC and OS187H Type 2 TC.

B.4.1.4 Maximum 32PTH Type 2 DSC Internal Pressure for Storage and Transfer Conditions

The 32PTH Type 2 DSC has a longer cavity length in comparison to 32PTH DSC, which provides an additional 10.3% of cavity volume. The overall 32PTH Type 2 DSC cavity gas volume with the increased basket length is still higher than that of 32PTH DSC. Furthermore, the authorized fuel assembly types and decay heat loads are the same for both 32PTH DSC and 32PTH Type 2 DSC. Therefore, the volumes of fission and fill gas calculated for 32PTH DSC are unchanged for 32PTH Type 2 DSC. As discussed in Sections B.4.1.2 and B.4.1.3, the average cavity gas temperatures for 32PTH Type 2 DSC for both storage and transfer conditions are bounded by those for the 32PTH DSC. Therefore, the maximum internal pressures within the 32PTH Type 2 DSC are bounded by those for 32PTH DSC design (see Table 4-10) and the pressure design criteria are satisfied for the 32PTH Type 2 DSC.

Table B.4-1
Airflow Calculation Results for HSM-H Loaded with 32PTH Type 2 DSC

Parameter	32PTH DSC	32PTH Type 2 DSC	32PTH DSC	32PTH Type 2 DSC
Ambient temperature, T_{amb}, (°F)	-20		115*	
Exit air temperature, T_{Exit}, (°F)	46.2	46.0	191.9	191.7
Average air temperature, T_{aver}, (°F)	13.1	13.0	148.4	148.4
Total loss coefficient, ΣK, (ft^{-4})	0.0988	0.0982	0.1016	0.1009
Mass flow rate, (lbm/s)	2.073	2.078	1.574	1.578

*24-hour average of 105 °F used

Table B.4-2
Applied Decay Heat Load and Heat Generation Rate within 32PTH DSC and 32PTH Type 2 DSC in HSM-H

Parameter	**32PTH DSC**	**32PTH Type 2 DSC**
Total decay heat load, Q	118748 Btu/hr (34.8 kW)	
DSC inner diameter, D_i, (in)	68.75	
DSC cavity length, L, (in)	164.5	181.38
Decay heat flux = $Q/(\pi D_i L)$, (Btu/hr-in^2)	3.3422	3.0312
Heat generation rate = $Q/(\pi D_i^2 L/4)$, (Btu/hr-in^3)	0.1945	0.1764

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

APPENDIX B.5
SHIELDING EVALUATION

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.5 SHIELDING EVALUATION

The NUHOMS® 32PTH Type 2 DSC and the OS187H Type 2 transfer cask (TC) are designed to be comparable to the NUHOMS® 32PTH DSC and the OS187H TC from a shielding standpoint for all conditions of loading and transfer. The shielding evaluation documented in Chapter 5 for the 32PTH DSC and OS187H TC is applicable but not bounding for the 32PTH Type 2 DSC and OS187H Type 2 TC for loading and transfer conditions. Additional analysis is evaluated herein for the 32PTH Type 2 DSC and OS187H Type 2 TC for loading and transfer conditions.

The NUHOMS® 32PTH Type 2 DSC and the HSM-H using the 32PTH Type 2 HSM-H optional or alternate optional (square or round) door are designed to be comparable to the NUHOMS® 32PTH DSC and the HSM-H using the 32PTH and 32PTH Type 1 HSM-H original door from a shielding standpoint for all conditions of storage. In general, the shielding evaluation documented in Chapter 5 for the 32PTH DSC and the HSM-H using the 32PTH and 32PTH Type 1 HSM-H original door is applicable and bounding for the 32PTH optional or alternate optional (square or round) DSC and the HSM-H using the 32PTH Type 2 HSM-H door for storage conditions.

DSC, TC, and HSM Physics Parameters

The effect on shielding due to the changes in the geometry and material design of the 32PTH Type 2 DSC, the OS187H Type 2 TC, and the HSM-H using the 32PTH Type 2 HSM-H optional or alternate optional (square or round) door with 3 inch inner steel plate is evaluated herein. The 32PTH Type 2 DSC and OS187H Type 2 TC are designed to be longer than the 32PTH DSC and OS187H TC with thickness reductions incorporated into the top shield plug and bottom lid of 32PTH Type 2 DSC. The 32PTH Type 2 HSM-H optional or alternate optional (square or round) door is designed to be thinner than the 32PTH and 32PTH Type 1 HSM-H original door. Since there is no change in the authorized fuel contents of the NUHOMS® HD System, all the source terms and fuel qualification tables determined in Chapter 5 remain unchanged.

DSC and TC Geometry and Material Design Changes

The computational models of the DSC inside the TC for loading and transfer described in Chapter 5 are impacted by the reduction in thickness of the DSC top shield plug and bottom lid. Therefore, the shielding evaluations for the 32PTH DSC inside the OS187H TC documented in Section 5.4.8.2 are reevaluated for the 32PTH Type 2 DSC inside the OS187H Type 2 TC. The differences between the 32PTH and 32PTH Type 2 DSCs, and the OS187H and the OS187H Type 2 TCs, respectively, that are relevant to the calculation of dose rates during loading and transfer are evaluated and discussed below:

- The OS187H Type 2 TC inner liner thickness is increased from the OS187H TC 0.50 in. to 0.625 in. This change results in a small reduction in radial dose rates and is an improvement in the shielding design.

- The OS187H Type 2 TC lead shielding thickness is reduced from the OS187H TC 3.60 in. to 3.56 in. The shielding calculations documented in Chapter 5 utilize a lead shield thickness of 3.56 in. and, therefore, the results from the Chapter 5 radial dose rate calculations are applicable for the Type 2 TC.
- The Type 2 TC water (radial) neutron shield is extended to mate with the upper trunnion. This design change is an improvement over the OS187H TC and results in a reduction in the neutron dose rates below the upper trunnion as there are no pocket-to-neutron shield gaps.
- The Type 2 TC trunnions utilize a monolithic forging (solid steel) with removal of the solid neutron shield resin inside the trunnions. This is an improvement in design over the OS187H TC since it results in a significant reduction in the gamma dose rates around the trunnions. The slight increase in the neutron dose rates due to the removal of the solid neutron shield resin inside the trunnions is more than compensated by the increase in the gamma shielding due to the stainless steel. Note that the dose rates around the TC are mostly due to contribution from gamma sources.
- The solid neutron shielding material (resin) at the top and bottom of the OS187H Type 2 TC is changed from TN Proprietary Polyester Resin of the OS187H TC to NS-3. The material composition of the TN Proprietary Polyester Resin material is shown in Table 5-17. The material composition of the NS-3 material is shown in Table B.5.1. The shielding characteristics of these materials are similar and do not result in a substantial change in the dose rate magnitude and distribution at the top and bottom of the TC.

  A shielding evaluation with the Monte Carlo N-Particle (MCNP) computer code (described in Chapter 5, Section 5.4) is performed to determine the effect of the change of the solid neutron shield material for the OS187H Type 2 TC and the reduction of shielding materials at both ends. The results of this evaluation are shown in Table B.5-2. A comparison of the dose rates at the top and bottom ends of the Type 2 TC with those shown in Table 5-4 and Table 5-5 for the OS187H TC indicates that the differences in dose rates vary from 1.5 times at the surface top end to about three times at the bottom end. The dose rate increase at the top end and bottom end of the OS187H Type 2 TC is due to the use of NS-3 as the solid neutron shielding material and the reduction of the shielding material.

- The 32PTH Type 2 DSC top shielding design includes a two-piece assembly, consisting of a separate top shield plug and inner top cover plate. This configuration is similar to, but 2 in. less thick than the single piece top shield plug/inner top cover plate assembly modeled in the Chapter 5 shielding calculations. During some steps in the decontamination process, the 32PTH Type 2 DSC top shielding configuration consists of the shield plug only which results in a reduction of the amount of steel at the top of the DSC (during decontamination operations) by 4 in. compared to the 32PTH DSC. During additional steps in decontamination, the 32PTH Type 2 DSC top shielding configuration consists of the shield plug and the inner top cover plate, which results in a reduction of the amount of steel at the top of the DSC by 4 in. compared to the 32PTH DSC. The shielding models for decontamination are described in Chapter 5, Section 5.3.1.2.

Due to the two-piece top shield plug and inner top cover plate assembly design, it is not necessary to decontaminate the top surface of the shield plug (as opposed to the single piece design where it is required). Therefore, top dose rates during this stage of operation do not significantly impact total occupational exposure. The radial dose results are used for these operations steps for the 32PTH Type 2 DSC and OS187H Type 2 TC.

An additional welding configuration model is introduced for the Type 2 TC, which calculates dose rates during the welding operations of the outer top cover plate. This second configuration reduces the top dose rates further by modelling the shield plug and both top cover plates during several steps in decontamination.

- The 32PTH Type 2 DSC bottom shielding design is 2.25 in. less thick than the 32PTH DSC modeled in the Chapter 5 shielding calculations. All transfer process steps that place personnel at the bottom of the 32PTH Type 2 DSC will be exposed to higher dose rates when compared to either the 32PTH DSC or 32PTH Type 1 DSC.

The modeling differences discussed for the 32PTH Type 2 DSC in the OS187H Type 2 TC are illustrated in Figure B.5-1.

<u>DSC and HSM Geometry and Material Design Changes</u>

The computational model of the 32PTH DSC inside the HSM-H using the original shield door documented in Section 5.4.8.1 contains significant conservatism in how the HSM-H base unit shielding concrete is modeled, especially around the lower cavity and inlet vents. It would be expected that the reduction in thickness of the 32PTH Type 2 DSC top shield plug and bottom lid, and the reduction in thickness of the HSM-H shield door would result in an increase in dose rates calculated at the HSM surfaces. However, the shielding models used for the 32PTH Type 2 DSC inside the HSM-H using the optional or alternate optional (square or round) shield door incorporate improvements to the modeling details of the HSM-H base unit, which results in noticeably lower HSM surface dose rates. With the modeling improvements incorporated into the Type 2 system analysis, the resulting dose rates including the thickness reductions in the DSC shield plug, bottom lid, and the HSM shield door, Table B.5-3, are bounded by the storage system dose rate analysis documented in Table 5-21.

The differences between the 32PTH and 32PTH Type 2 DSCs detailed in the DSC and TC section are also applicable to the DSC and HSM evaluation. The differences between the HSM-H 32PTH Type 1 with the original shield door and the HSM-H 32PTH Type 2 with the optional or alternate optional (square or round) shield door that are relevant to the calculation of dose rates during long term storage are evaluated and discussed below:

- Both shield doors for the HSM-H consist of a 3-inch thick (square or round) steel plate fastened to the front concrete wall, and both have a stepped circular reinforced concrete block at the rear of the 3-inch thick steel plate. The reinforced concrete block for both shield doors consists of a block at the front which is 6-7/8-inch thick. However, the rear block for the 32PTH Type 1 original door is 1-foot-10 ½-in. thick and rear block for the 32PTH Type 2 optional or alternate optional (square or round) door is 1-foot-6 ½ in. thick. This reduction in thickness of 4 in. of concrete will have an impact on storage system dose rates.

In summary, the shielding evaluation documented in Chapter 5 for the 32PTH DSC and OS187H TC is applicable but not bounding for the 32PTH Type 2 DSC and OS187H Type 2 TC for all conditions of loading and transfer. The occupational dose for pool-to-pad operations with the Type 2 system is estimated to be 3.6 rem comparing to 2.2 rem for the 32PTH system. Improvements such as using additional temporary shielding or performing evolutions at different locations or remotely would yield significant exposure dose improvements. The shielding evaluation documented in Chapter 5 for the 32PTH DSC and the HSM-H using the original shield door is applicable and bounding for the 32PTH Type 2 DSC and the HSM-H using the shield door for all conditions of storage.

Table B.5-1
Material Composition of NS-3 Neutron Shielding Resin

Element	Weight %
Hydrogen	4.85
Carbon	9.35
Calcium	5.61
Oxygen	57.05
Silicon	3.36
Aluminum	17.89
Iron	0.56
Trace[(1)]	1.33
Density (g/cm^3)	1.76

Note:
(1) Trace elements were modeled as oxygen in the shielding analysis

Table B.5-2
32PTH Type 2 Transfer Cask Top and Bottom Dose Rate Summary
During Transfer Operations

Location	Dose Rate mrem/hr	On Outside Surface		1.5 Feet from Surface		Three Feet from Surface	
		Gamma	Neutron	Gamma	Neutron	Gamma	Neutron
Top end	Average surface	**13.51**	**16.83**	**9.98**	**9.69**	**7.48**	**6.87**

Location	Dose Rate mrem/hr	On Outside Surface		1.5 Feet from Surface		Three Feet from Surface	
		Gamma	Neutron	Gamma	Neutron	Gamma	Neutron
Bottom end	Average surface	**287.51**	**171.50**	**243.82**	**112.65**	**194.66**	**76.25**

Table B.5-3
32PTH Type 2 DSC in HSM, Maximum and Average Dose Rates

Dose Rate Location	Total Maximum Dose Rates (mrem/hour)
HSM-H End (Side) Shield Wall Surface	0.93
HSM-H Door Exterior Surface (centerline)	1.42
HSM-H Front Bird Screen	318.64
Dose Rate Location	**Total Average Dose Rates (mrem/hour)**
HSM-H End (Side) Shield Wall Surface	0.32
HSM-H Front	10.17
HSM-H Back Shield Wall Surface	0.07

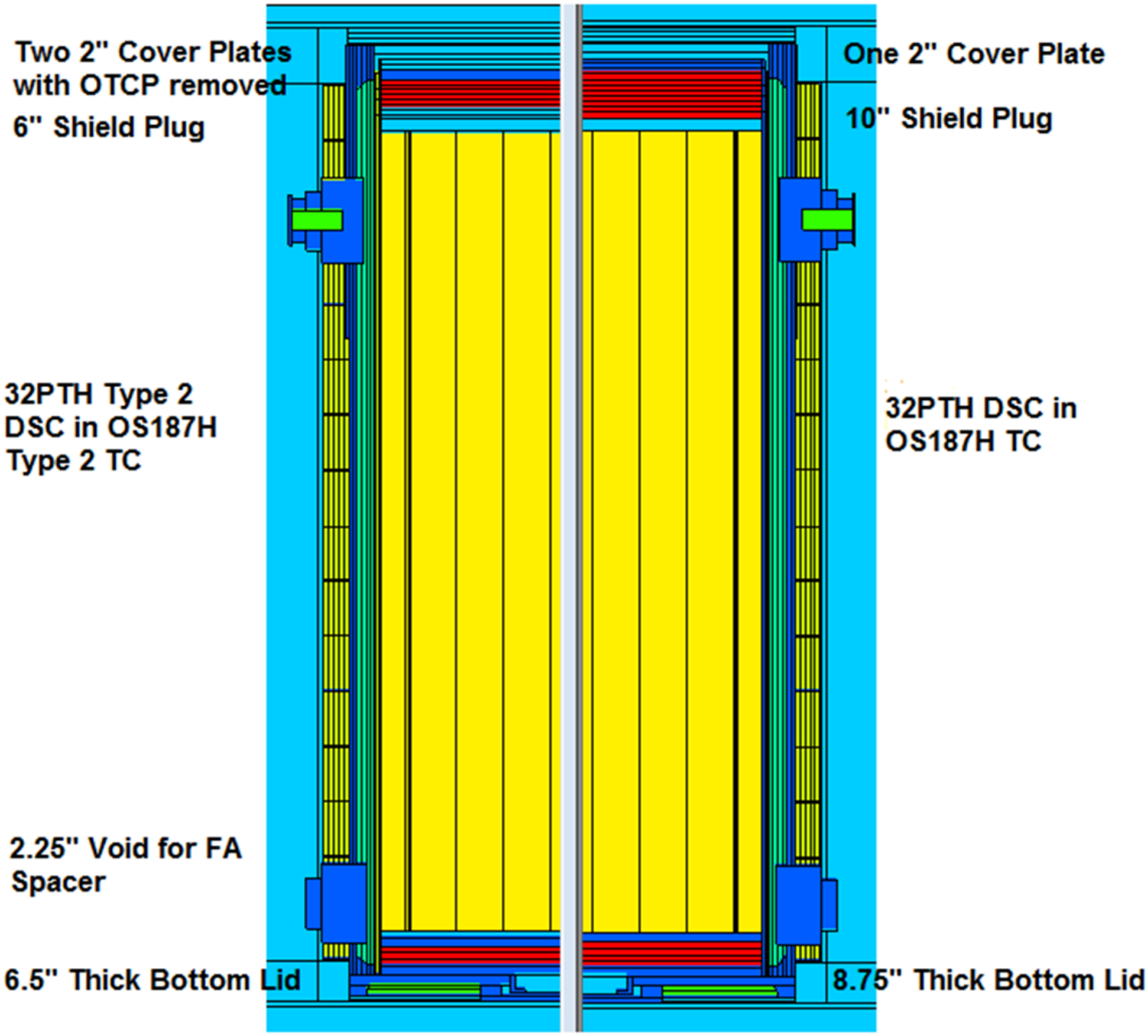

Figure B.5-1
Geometry Comparison for 32PTH DSC in OS187H TC and 32PTH Type 2 DSC in OS187H Type 2 TC

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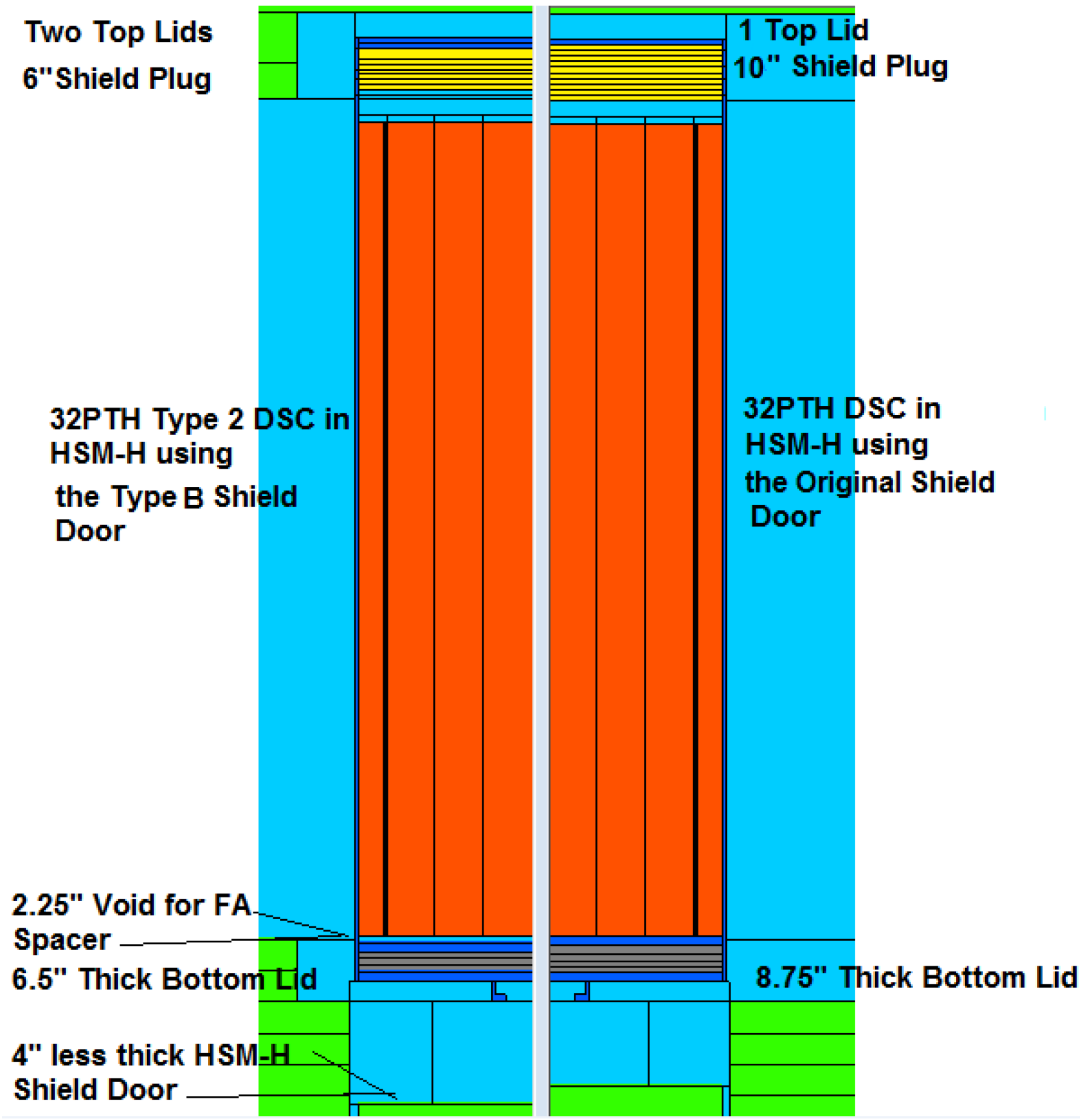

Figure B.5-2
Geometry Comparison of 32PTH DSC in HSM-H Using the Original Shield Door and 32PTH Type 2 DSC in HSM-H Using the Optional or Alternate Optional (Square or Round) Shield Door

APPENDIX B.6
CRITICALITY EVALUATION

The NUHOMS® 32PTH Type 2 dry shielded canister (DSC) and the OS187H Type 2 transfer cask (TC) are designed to be identical to the NUHOMS® 32PTH DSC and OS187H TC from a criticality standpoint for all conditions of loading, storage, and transfer. In general, the criticality analysis documented in Chapter 6 for the 32PTH DSC in the OS187H TC is applicable and bounding for the 32PTH Type 2 DSC in the OS187H Type 2 TC.

The effect on criticality due to the small changes in the geometry of the Type 2 DSC and Type 2 TC is determined by investigating the effect due to the geometry modeling employed in the criticality calculations documented in Chapter 6. These considerations are listed below:

- The height of the individual egg-crate sections in the active fuel region of the basket of the 32PTH Type 2 DSC does not change. The increase in overall height of the 32PTH Type 2 DSC is due to an increase in the number of egg-crate sections. Though the height of the top egg-crate section of the Type 2 DSC is different from that of the 32PTH DSC, the top section of the Type 2 DSC contains more neutron poison than that of the 32PTH DSC. Therefore, the criticality analysis model in Chapter 6, that considers an infinite axial array of egg-crate sections, is applicable, conservatively, to the Type 2 DSC. Note that the gap between the top of the neutron poison sheets and the bottom of the top shield plug is decreased for the 32PTH Type 2 DSC.
- The Type 2 DSC is 12.75 in. longer than the 32PTH DSC and has 17 more inches of basket and poison plates. The top layer of basket plates in the Type 2 DSC contain integral neutron poison material whereas the top layer of basket plates in the 32PTH DSC do not.

In summary, the criticality analysis documented in Chapter 6 for the 32PTH DSC in the OS187H TC is applicable and bounding for the 32PTH Type 2 DSC in the OS187H Type 2 TC for all conditions of loading, storage, and transfer.

APPENDIX B.7
CONFINEMENT

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B.7 CONFINEMENT

B.7.1 Confinement Boundary

No change. Section 7.1 applies in its entirety to the 32PTH Type 2 DSC. The 32PTH DSC confinement boundary described in Section 7.1 and shown in Figure 7-1 is applicable without change to the 32PTH Type 2 DSC design when the optional two-part top end closure assembly is used. In addition, as described in Chapter B.1, the 32PTH Type 2 DSC also features a three-part top end closure assembly, consisting of separate top shield plug, inner top cover and outer top cover plates. This three-part closure design is the same as that used in other NUHOMS® canister designs [1] and includes a vent and siphon block which is welded to the shell during fabrication.

The confinement boundary for the three-part closure consists of the DSC cylindrical shell, the inner top cover plate, the siphon and vent block, the inner bottom cover plate, and the associated welds. At the top, the inner top cover plate, the siphon and vent block, and the DSC shell are welded to each other using partial penetration welds, which are subject to multi-level penetrant testing (PT) examination. The vent and siphon block contains two ports, which are used for draining, vacuum drying, and backfilling. These ports are closed with welded cover plates, which are also subject to multi-level PT. Along the shell and at the bottom end of the DSC, the confinement boundary is the same as for the 32PTH DSC. The 32PTH Type 2 DSC top shield design is 2 in. thinner than the 32PTH DSC. The Type 2 DSC bottom lid is also 2.25 in. thinner than that of the 32PTH DSC

The confinement boundary for the three-part top end closure configuration is shown in Figure B.7-1.

B.7.2 Requirements for Normal Conditions of Storage

No change.

B.7.3 Confinement Requirements for Hypothetical Accident Conditions

No change.

B.7.4 Supplemental Data

B.7.4.1 Confinement Monitoring Capability

No change.

B.7.5 References

1. Updated Final Safety Analysis Report, "Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Revision 14, August 2014, U.S. Nuclear Regulatory Commission, Docket No. 72-1004.

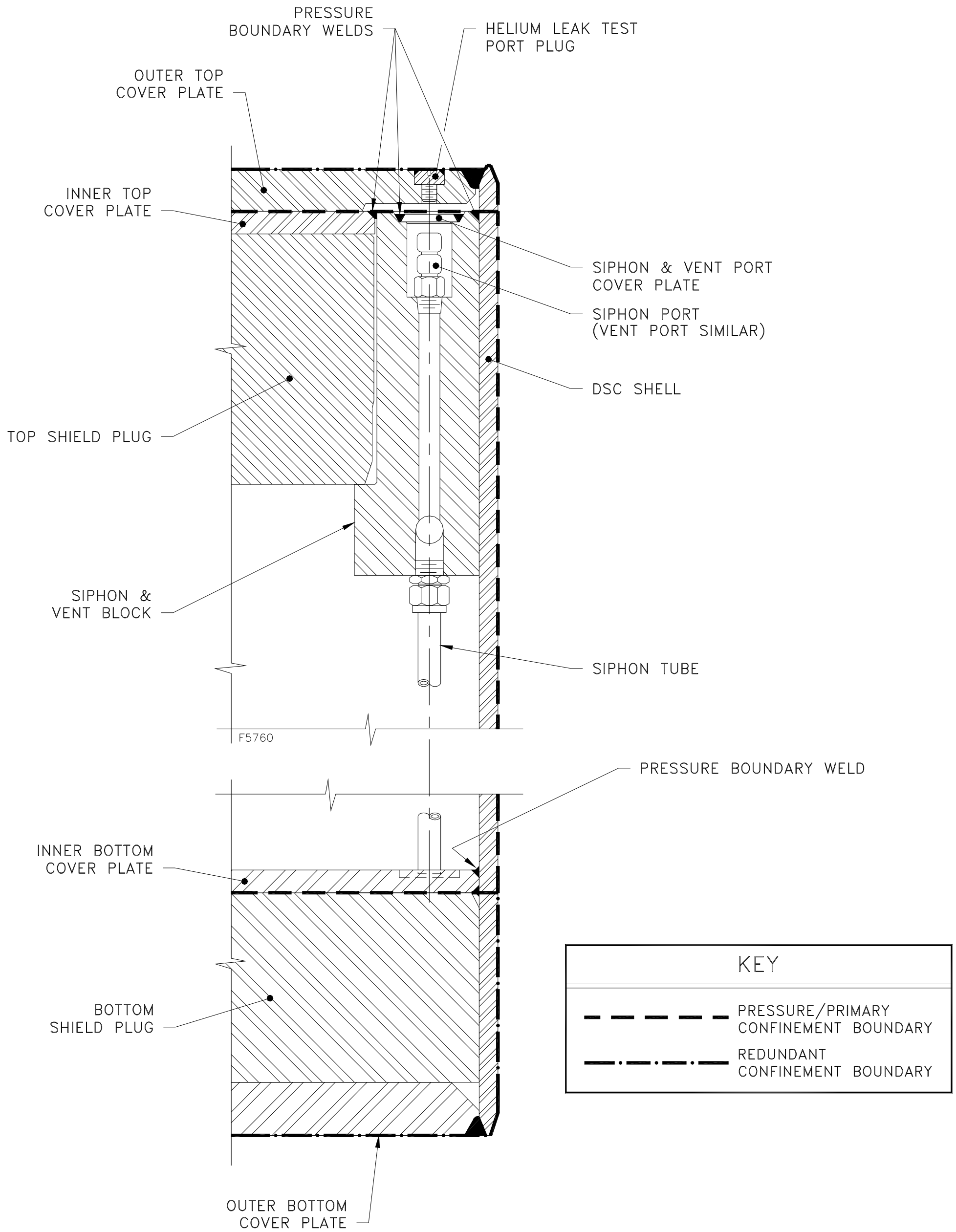

Figure B.7-1
32PTH Type 2 DSC Confinement Boundaries and Welds for Three-Part Top End Configuration

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

APPENDIX B.8
OPERATION PROCEDURES

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.8 OPERATION PROCEDURES

Chapter 8 applies in its entirety and without change to the 32PTH Type 2 DSC when the optional two-part top end closure assembly (which is similar to the 32PTH DSC) is used. In addition, as described in Chapter B.1, the 32PTH Type 2 DSC also features a three-part top end closure assembly, consisting of separate top shield plug, inner top cover, and outer top covers. The modifications to the operating procedures described in this chapter apply to the three-part closure design and are based on the similar three-part closure used in other NUHOMS® canister designs [3].

B.8.1 Procedures for Loading the DSC and Transfer to the HSM-H

B.8.1.1 Narrative Description

The following steps describe the recommended modifications to the generic operating procedures described in Sections 8.1 and 8.2, and are applicable when the standard three-part top end closure assembly is implemented in the 32PTH Type 2 DSC. For purposes of completeness of presentation, the entire sequence of operational steps is presented whenever a modification has been introduced in any particular operation. When no changes are made to a section, "No Change" is indicated and a reference is listed to the applicable section in Chapter 8.

B.8.1.1.1 Transfer Cask and DSC Preparation

1. Verify by plant records or other means that candidate fuel assemblies meet the physical, thermal and radiological criteria specified in the Technical Specifications.
2. Clean or decontaminate the transfer cask as necessary to meet licensee pool and ALARA requirements, and to minimize transfer of contamination from the cask cavity to the DSC exterior.
3. Examine the transfer cask cavity for any physical damage.
4. Verify specified lubrication of the transfer cask rails.
5. Examine the DSC for any physical damage and for cleanliness. Verify that bottom fuel spacers or damaged fuel bottom end caps, if required, are present in all fuel compartments. Remove damaged fuel top end caps if they are in place. Record the DSC serial number, which is located on the grappling ring. Verify the basket type by identifying the "Z" character in the XXX- 32PTH-YYY-Z-1 serial number.
6. Lift the DSC into the cask cavity and rotate the DSC to match the transfer cask alignment marks.
7. Fill the transfer cask/DSC annulus with clean water.
8. Seal the top of the annulus, using for example an inflatable seal.
9. A tank filled with clean water, and kept above the pool surface may be connected to the top vent port of the transfer cask via a hose to provide a positive pressure in the annulus. This is an optional arrangement, which provides additional assurance that contaminated water from the fuel pool will not enter the annulus. Do not pressurize this tank, nor raise it sufficiently high to float the DSC. For the 32PTH Type 2 DSC with a 69.75-inch OD, and an empty weight of 46,000 lb, a differential pressure of 11.7 psi, equivalent to 27.1 ft of pure water, would be sufficient to lift the DSC.
10. If the DSC top covers were trial fitted, they must be removed prior to filling the DSC with water. The vent port quick connect fitting in the inner top cover may be removed to facilitate hydrogen monitoring later. The drain port fitting may be either left in place or removed – water may be pumped from the DSC either with or without the fitting.

11. The licensee shall develop procedures to verify that the boron content of the water added to the DSC conforms to the Technical Specifications. Fill the DSC with water from the fuel pool or an equivalent source meeting the minimum boron concentration required by the Technical Specifications. Optionally, this may be done at the time of immersing the cask in the pool. If the pool water is allowed flow over the transfer cask lip and into the DSC, provision must be made to protect the annulus seal from being dislodged by the water running over it.

12a. Optionally, secure a sheet of suitable material to the bottom of the cask to minimize the potential for ground-in contamination. This step may be done at any convenient time prior to immersion.

12b. Drain or fill the transfer cask liquid neutron shield, as required by licensee ALARA requirements and crane weight limits. This step may be done at any convenient time prior to immersion.

13. Prior to the cask being lifted into the fuel pool, the water level in the pool should be adjusted as necessary to accommodate the transfer cask and DSC volume. If the water placed in the DSC cavity was obtained from the fuel pool, a level adjustment may not be necessary.

B.8.1.1.2 DSC Fuel Loading

1. Verify proper engagement of the lifting yoke with the transfer cask lifting trunnions.
2. Lift the transfer cask / DSC and position them over the cask loading area of the spent fuel pool.
3. Lower the cask into the fuel pool until the bottom of the cask is at the height of the fuel pool surface. As the cask is lowered into the pool, spray the exterior surface of the cask with clean water to minimize surface adhesion of contamination.
4. Place the cask in the location of the fuel pool designated as the cask loading area.
5. Disengage the lifting yoke from the transfer cask lifting trunnions and move the yoke clear of the cask. Spray the lifting yoke with clean water if it is raised out of the fuel pool.
6. Load pre-selected spent fuel assemblies into the DSC basket compartments. The licensee shall develop procedures to verify that the boron content of the water conforms to the Technical Specifications, and that fuel identifications are verified and documented. The loading plan must be developed according to Figure 2-1 for the orientation of the fuel assemblies. Damaged fuel must be loaded only in designated compartments fitted with a damaged fuel bottom end cap.
7. After all the fuel assemblies have been placed into the DSC and their identities verified, install damaged fuel top end caps into designated compartments containing damaged fuel.
8. Lower the top shield plug into the DSC.
9. Visually verify that the inner top cover/shield plug is properly seated in the DSC. Reseat if necessary.
10. Position the lifting yoke and verify that it is properly engaged with the transfer cask trunnions.

11. Lift the transfer cask to the pool surface and spray the exposed portion of the cask with clean water.
12. Drain any water from above the inner top cover/shield plug back to the spent fuel pool. Up to 1300 gallons of water may be removed from the DSC prior to lifting the transfer cask clear of the pool surface. Up to 15 psig of helium may only be used to assist the removal of water. The DSC shall be backfilled only with helium after drainage of bulk water.
13. Lift the cask from the fuel pool, continuing to spray the cask with clean water.
14. Move the cask with loaded DSC to the area designated for DSC draining and closure operations. The set-down area should be level, or if slightly sloped, the transfer cask and DSC should be placed with the slope down toward the DSC drain/siphon tube.

B.8.1.1.3 DSC Closing, Drying, and Backfilling

1. Fill the transfer cask liquid neutron shield if it was drained for weight reduction during preceding operations.
2. Decontaminate the transfer cask exterior.
3. Disengage the rigging from the top shield plug, and remove the eyebolts. Disengage the lifting yoke from the trunnions.
4. Disconnect the annulus overpressure tank if one was used, decontaminate the exposed surfaces of the DSC shell perimeter, remove any remaining water from the top of the annulus seal, and remove the seal.
5. Open the cask cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top of the DSC shell. Take swipes around the outer surface of the DSC shell to verify conformance with Technical Specification limits.
6. Cover the transfer cask / DSC annulus to prevent debris and weld splatter from entering the annulus.
7. If water was not drained from the DSC earlier, connect a pump to the DSC drain port and remove up to 1300 gallons of water. Consistent with ISG-22 [4] guidance and Technical Specification 3.1.1, helium at 1-3 psig is used to backfill the DSC with an inert gas (helium) as water is being removed from the DSC. This lowers the water sufficiently to allow welding of the inner top cover/shield plug. Up to 15 psig of helium gas may be applied at the vent port to assist the water pump down.

   CAUTION: Verify that no inadvertent draining of the TC Neutron Shield water has occurred.

   CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

7a. Monitor TC/DSC annulus water level to be approximately twelve inches below the top of the DSC shell and replenish as necessary until drained.

8. Install the automated welding machine onto the inner top cover and place the inner top cover with the automatic welding machine onto the DSC. Optionally, the inner top cover and the automatic welding machine can be place separately. Verify proper fit up of the inner top cover with the DSC shell.

9. Hydrogen monitoring is required prior to commencing and continuously during the welding of the inner top cover / shield plug per Technical Specification 5.6. Install hydrogen monitoring equipment that samples the atmosphere below the shield plug.

10. Verify that the hydrogen concentration does not exceed 2.4% [1]. If this limit is exceeded, stop all welding operations and purge the DSC cavity with helium to reduce hydrogen concentration safely below the 2.4% limit before resuming welding operations.

11. Complete the inner top cover/shield plug welding and perform the non-destructive examinations as required by the Technical Specifications. The weld must be made in at least two layers.

12. Remove the automated welding machine.

13. Pump remaining water from the DSC. Remove as much free standing water as possible to shorten vacuum drying time. Use of helium is required per Technical Specification 3.1.1. Up to 15 psig of helium gas may be applied at the vent port to assist the water pump down. All helium used in backfilling operations shall be at least 99.99% pure (this may be done as part of Step 15).

    NOTE: Proceed cautiously when evacuating the DSC to avoid freezing consequences.

14. Connect a vacuum pump / helium backfill manifold to the vent port or to both the vent and drain ports. The quick connect fittings may be removed and replaced with stainless steel pipe nipple / vacuum hose adapters to improve vacuum conductance. Make provision to prevent icing, for example by avoiding traps (low sections) in the vacuum line. Provide appropriate measures as required to control any airborne radionuclides in the vacuum pump exhaust. Purge air from the helium backfill manifold.

    Optionally, leak test the manifold and the connections to the DSC. The DSC may be pressurized to no more than 15 psig for leak testing.

    CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

    CAUTION: During the vacuum drying evolution, personnel should be in the area of loading operations, or in nearby low dose areas, in order to take proper action in the event of a malfunction.

15. Connect a vacuum pump / helium backfill manifold to the vent port or to both the vent and drain ports. The quick connect fittings may be removed and replaced with stainless steel pipe nipple / vacuum hose adapters to improve vacuum conductance. Make provision to prevent icing, for example by avoiding traps (low sections) in the vacuum line. Provide appropriate measures as required to control any airborne radionuclides in the vacuum pump exhaust. Purge air from the helium backfill manifold.

Optionally, leak test the manifold and the connections to the DSC. The DSC may be pressurized to no more than 15 psig for leak testing.

CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

CAUTION: During the vacuum drying evolution, personnel should be in the area of loading operations, or in nearby low dose areas, in order to take proper action in the event of a malfunction.

16. Evacuate the DSC to the pressure required by the Technical Specification for vacuum drying, and isolate the vacuum pump. The isolation valve should be as near to the DSC as practicable, with a pressure gauge on the DSC side of the valve. Prior to performing the vacuum hold for 30 minutes as required by the Technical Specification, the vacuum pump must be turned off; or if the pump is not turned off, provide a tee and valve (or other means) to open the line to atmosphere between the pump and the DSC isolation valve.

    NOTE: The user shall ensure that the vacuum pump is isolated from the DSC cavity when demonstrating compliance with Technical Specification 3.1.1 requirements. Simply closing the valve between the DSC and the vacuum pump is not sufficient, as a faulty valve allows the vacuum pump to continue to draws a vacuum on the DSC. Turning off the pump, or opening the suction side of the pump to atmosphere are examples of ways to ensure that the pump is not continuing to draw a vacuum on the DSC.

17. If the Technical Specification is satisfied, i.e., if the pressure remains below the specified limit for the required duration with the pump isolated, continue to the next step. If not, repeat Step 16.
18. Purge air from the backfill manifold, open the isolation valve, and backfill the DSC cavity with helium to 16.5 to 18 psig and hold for 10 minutes.
19. Reduce the DSC cavity pressure to atmospheric pressure, or slightly over.
20. If the quick connect fittings were removed for vacuum drying, remove the vacuum line adapters from the ports, and re-install the quick connect fittings using suitable pipe thread sealant.

    CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

21. Evacuate the DSC through the vent port quick connect fitting to a pressure 100 mbar or less.

    NOTE: The user shall ensure that the vacuum pump is isolated from the DSC cavity when demonstrating compliance with Technical Specification 3.1.1 requirements. Simply closing the valve between the DSC and the vacuum pump is not sufficient, as a faulty valve allows the vacuum pump to continue to draws a vacuum on the DSC. Turning off the pump, or opening the suction side of the pump to atmosphere are examples of ways to assure that the pump is not continuing to draw a vacuum on the DSC.

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22. Backfill the DSC with helium to the pressure specified in the Technical Specifications, and disconnect the vacuum / backfill manifold from the DSC.
23. Weld the covers over the vent and drain ports, performing non-destructive examination as required by the Technical Specifications. The welds shall have at least two layers.
24. Install a temporary test head fixture (or any other alternative means). Perform a leak test of the inner top cover/shield plug to the DSC shell welds and siphon/vent cover welds in accordance with the Technical Specification limits. Verify that the personnel performing the leak test are qualified in accordance with SNT-TC-1A.
25. Place the outer top cover plate onto the DSC and verify correct rotational alignment of the cover and the DSC shell. Install the automated welding machine onto the outer top cover plate. As an option, the welding machine may be mounted onto the cover plate and then placed together on the DSC.
26. Complete the outer top cover welding and perform the non-destructive examinations as required by the Technical Specifications. The weld must be made in at least two layers.
27. Remove everything except the DSC from the transfer cask cavity: welding machine, protective covering from the transfer cask / DSC annulus, temporary shielding, etc., and drain the water from the transfer cask/DSC annulus.
28. Install the transfer cask lid and bolt it.
29. Evacuate the transfer cask cavity to below 100 mbar, and backfill the transfer cask annulus with helium in accordance with the Technical Specifications pressure tolerance and time limit.

    CAUTION: Monitor the applicable time limits of the Technical specifications for transfer cask annulus helium backfill.

B.8.1.1.4 Transfer Cask Downending and Transport to ISFSI

1. The transfer trailer should be positioned so that the cask support skid is accessible to the crane with the trailer supported on its vertical jacks. If required due to space limitations, the crane may remain in a stationary position while the cask support skid and trailer translate underneath the cask as it is downended, (the trailer cannot be supported on the vertical jacks.)
2. Engage the lifting yoke and lift the transfer cask over the cask support skid onto the transfer trailer.
3. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.
4. Move the crane while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks. Alternatively, if the crane is to remain stationary as identified above, slowly move the trailer and support skid as the cask is lowered until the upper trunnions are just above the support skid upper trunnion pillow blocks.
5. Verify that the cask and trunnion pillow blocks are properly aligned.
6. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.

7. Verify the trunnions are properly seated onto the skid. Install the trunnion tower closure plates (optional).

B.8.1.1.5 DSC Transfer to the HSM-H

1. The maximum lifting height and ambient temperature requirements of the Technical Specifications must be met during transfer from the fuel building to the HSM-H.
2. Prior to loading the DSC into the HSM-H, verify that there is no debris in the HSM-H, the air inlet and outlets are not blocked, the air inlet and outlet screens are not damaged, and the rails are lubricated as specified.

   CAUTION: The insides of empty modules have the potential for high dose rates due to adjacent loaded modules. Proper ALARA practices should be followed for operations inside these modules and in the areas outside these modules whenever the door from the empty HSM has been removed.

3. Tow the transfer trailer with the loaded cask to the ISFSI.
4. Position the transfer trailer to within a few feet of the HSM-H to maintain doses ALARA when the cask lid is removed.
5. Verify that the centerline of the HSM-H and cask approximately coincide. Reposition the trailer as necessary following appropriate ALARA practices.
6. Using a portable crane, unbolt and remove the cask lid.
7. Back the trailer to within a few inches of the HSM-H, set the trailer brakes and disengage the tractor. Drive the tractor clear of the trailer and extend the transfer trailer vertical jacks.
8. Remove the skid tie-down bracket fasteners and use the hydraulic skid positioning system to bring the cask into approximate vertical and horizontal alignment with the HSM-H. Using optical survey equipment and the alignment marks on the cask and the HSM-H, adjust the position of the cask until it is aligned with the HSM-H.
9. Using the skid positioning system, fully insert the cask into the HSM-H access opening docking collar.
10. Secure the cask to the front wall embedments of the HSM-H using the cask restraints.
11. Verify the alignment of the transfer cask is within specified tolerance using the optical survey equipment.
12. Remove the bottom ram access cover plate from the transfer cask. Extend the ram through the bottom cask opening into the DSC grapple ring.
13. Activate the hydraulic cylinder on the ram grapple and engage the grapple arms with the grapple ring.
14. Activate the hydraulic ram to initiate insertion of the DSC into the HSM-H. Stop the ram when the DSC reaches the support rail stops at the back of the module.
15. Disengage the ram grapple mechanism from the DDC grapple ring, and retract the hydraulic ram system from the transfer cask.

16. Remove the cask restraints from the HSM-H. Replace the bottom ram access cover plate. Optionally, a temporary cover may be used to cover the ram access opening.
17. Using the skid positioning system, disengage the cask from the HSM-H access opening.
18. Install the DSC seismic restraint.
19. Secure the skid to the trailer, retract the vertical jacks. Tow the trailer and cask a few feet to provide access for door installation.
20. Install the HSM-H door and secure it in place.
21. Replace the transfer cask lid.
22. Tow the trailer and cask from the ISFSI.

B.8.1.1.6 Monitoring Operations

1. Perform routine security surveillance in accordance with the licensee's ISFSI security plan.
2. Perform a daily visual surveillance of the HSM-H air inlets and outlets (bird screens) to verify that no debris is obstructing the HSM-H vents in accordance with Technical Specification requirements.
3. Perform a temperature measurement for each HSM-H in accordance with Technical Specification requirements.

B.8.2 Procedures for Unloading the DSC

The following section outlines the procedures for retrieving the DSC from the HSM-H and for removing the fuel assemblies from the DSC.

B.8.2.1 DSC Retrieval from the HSM-H

1. The maximum lifting height and ambient temperature requirements of the Technical Specifications must be met during transfer from the HSM-H to the fuel building.
2. Ready the transfer cask, transfer trailer, and support skid for service and tow the trailer to the HSM-H. Fill the transfer cask liquid neutron shield and remove the bottom access plate from the transfer cask.
3. Remove HSM-H door and seismic restraint. Remove the transfer cask lid. Back the trailer to within a few inches of the HSM-H.
4. Using the skid positioning system, align the transfer cask with the HSM-H and position the skid until the transfer cask is docked with the HSM-H access opening.
5. Using optical survey equipment, verify alignment of the transfer cask with respect to the HSM-H within specified tolerance. Install the transfer cask restraints.
6. Install and align the hydraulic ram with the transfer cask.
7. Extend the ram through the transfer cask into the HSM-H until it is inserted in the DSC grapple ring.
8. Activate the arms on the ram grapple mechanism to engage the grapple ring.
9. Retract the ram and pull the DSC into the transfer cask.
10. Disengage the ram grapple arms.
11. Retract the ram from the transfer cask.
12. Replace the cask ram access cover plate and remove the transfer cask restraints.
13. Using the skid positioning system, disengage the transfer cask from the HSM-H.
14. Install the transfer cask top cover plate and ready the trailer for transfer/transport.
15. Evacuate the transfer cask cavity to below 100 mbar, and backfill with helium in accordance with the Technical Specifications pressure tolerance and time limit, if using a transfer cask. If using a transportation cask, follow applicable requirements for the transportation cask.
16. Replace the door and seismic restraint on the HSM-H.

B.8.2.2 Removal of Fuel from the DSC

If it is necessary to remove fuel from the DSC, it can be removed in dry transfer facility or the initial fuel loading sequence can be reversed and the plant's spent fuel pool utilized.

Procedures for wet unloading of the DSC are presented here. Dry unloading procedures are essentially identical up to the removal of the DSC vent and drain port covers.

1. Tow the trailer with the loaded cask to the cask handling area inside the plant's fuel handling building. Drain the transfer cask liquid neutron shield as required by licensee ALARA requirements and crane weight limits.
2. Position and ready the trailer for access by the crane.
3. Engage the lifting yoke with the trunnions of the transfer cask.
4. Verify that the yoke lifting hooks are properly aligned and engaged onto the transfer cask trunnions.
5. Lift the transfer cask approximately one inch off the trunnion supports. Verify that the yoke lifting hooks are properly positioned on the trunnions.
6. Move the crane in a horizontal motion while simultaneously raising the crane hook vertically and lift the transfer cask off the trailer. Move the transfer cask to the cask decontamination area.
7. Lower the transfer cask into the cask staging area in the vertical position.
8. Unbolt the transfer cask lid and remove it.
9. Install temporary shielding to reduce personnel exposure as required. Fill the transfer cask/DSC annulus with clean water and seal the top of the annulus, using, for example, an inflatable seal.
10. Locate the drain and vent port using the indications on the outer top cover plate. Place a portable drill press on the top of the DSC. Align the drill over the drain port.
11. Cut or drill a hole through the top cover plate to expose the drain port on the inner top cover. Remove the drain port cover plate with an annular hole cutter. Repeat for the vent port.

    CAUTION: Radiation dose rates are expected to be high at the vent and siphon port locations. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

12. Obtain a sample of the DSC atmosphere. Confirm acceptable hydrogen concentration and check for presence of fission gas indicative of degraded fuel cladding.
13. If degraded fuel is suspected, additional measures appropriate for the specific conditions are to be planned, reviewed, and implemented to minimize exposures to workers and radiological releases to the environment.
14. Verify that the boron content of the fill water conforms to the Technical Specifications. Fill the DSC with water from the fuel pool or equivalent source through the drain port with the vent port open. The vented cavity gas may include steam, water, and radioactive material, and should be routed accordingly. Monitor the vent pressure and regulate the water fill rate to ensure that the pressure does not exceed 15 psig.
15. Provide for continuous hydrogen monitoring of the DSC cavity atmosphere during all subsequent cutting operations to ensure that hydrogen concentration does not exceed 2.4%. Purge with helium as necessary to maintain the hydrogen concentration below this limit.
16. Provide suitable protection for the transfer cask during cutting operations.

17. Using a suitable method, such as mechanical cutting, remove the weld of the outer top cover plate to the DSC shell.
18. Remove the outer top cover plate.
19. Remove the weld of the inner top cover/shield plug to the shell in the same manner as the outer cover plate. Do not remove the inner top cover/shield plug at this time unless the removal is being done remotely in a dry transfer system.
20. Remove any remaining excess material on the inside shell surface by grinding.
21. Clean the transfer cask surface of dirt and any debris that may be on the transfer cask surface as a result of the weld removal operation.
22. Engage the yoke onto the trunnions, install eyebolts or other lifting attachment(s) into the inner top cover/shield plug, and connect the rigging cables to the eyebolts/lifting attachment(s).
23. Verify that the lifting hooks of the yoke are properly positioned on the trunnions.
24. Lift the transfer cask just far enough to allow the weight of the transfer cask to be distributed onto the yoke lifting hooks. Verify that the lifting hooks are properly positioned on the trunnions.
25. Optionally, install suitable protective material onto the bottom of the transfer cask to minimize cask contamination. Move the transfer cask to the spent fuel pool.
26. Prior to lowering the transfer cask into the pool, adjust the pool water level, if necessary, to accommodate the volume of water that will be displaced by the transfer cask during the operation.
27. Position the transfer cask over the cask loading area in the spent fuel pool.
28. Lower the transfer cask into the pool. As the transfer cask is being lowered, the exterior surface of the transfer cask should be sprayed with clean water.
29. Disengage the lifting yoke from the transfer cask and lift the inner top cover/shield plug from the DSC.
30. Remove any failed fuel top end caps.
31. Remove the fuel from the DSC.

B.8.3 Supplemental Information

No change. See Section 8.3.

B.8.4 References

1. U.S. Nuclear Regulatory Commission, Office of the Nuclear Material Safety and Safeguards, “Safety Evaluation of VECTRA Technologies’ Response to Nuclear Regulatory Commission Bulletin 96-04 for NUHOMS®-24P and NUHOMS® 7P Dry Spent Fuel Storage System,” November 1997 (Dockets 72-1004, 72-3, 72-4, 72-8, and 72-14).

2. NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants,” U.S. Nuclear Regulatory Commission, July 1980.

3. Transnuclear, Inc., Updated Final Safety Analysis Report, “Standardized NUHOMS® Horizontal Modular Storage Systems for Irradiated Nuclear Fuel,” Revision 14, Docket 72-1004.

4. U.S. Nuclear Regulatory Commission, Interim Staff Guidance (ISG-22), “Potential Rod Splitting due to Exposures to an Oxidizing Atmosphere during Short-term Cask Loading Operations in LWR of Other Uranium Oxide Based Fuel.”

APPENDIX B.9
ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.9 ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

Chapter 9 applies in its entirety to this chapter, except for the leakage tests described in Section 9.1.3. The 32PTH Type 2 DSC design contains an inner and outer top cover, and a separate top shield plug; therefore, the leakage test procedure has been revised to reflect this geometry. This three-part closure design is the same as that is used in other NUHOMS® DSC canister designs.

B.9.1 Acceptance Criteria

B.9.1.1 Visual Inspection and Non-Destructive Examination (NDE)

No change from Chapter 9, Section 9.1.1.

B.9.1.2 Structural and Pressure Tests

No change from Chapter 9, Section 9.1.2.

B.9.1.3 Leak Tests

No change from Chapter 9, Section 9.1.3.

B.9.1.4 Components

No change from Chapter 9, Section 9.1.4.

B.9.1.5 Shielding Integrity

No change from Chapter 9, Section 9.1.5.

B.9.1.6 Thermal Acceptance

No change from Chapter 9, Section 9.1.6.

B.9.1.7 Neutron Absorber Tests

No change from Chapter 9, Section 9.1.7.

B.9.2 Maintenance Program

No change from Chapter 9, Section 9.2.

B.9.3 Marking

No change from Chapter 9, Section 9.3.

B.9.4 Pre-Operational Testing and Training Exercise

No change from Chapter 9, Section 9.4.

B.9.5 Specification for Neutron Absorbers

No change from Chapter 9, Section 9.5.

B.9.6 References

1. American Society for Nondestructive Testing, "Personnel Qualification and Certification in Nondestructive Testing," SNT-TC-1A, 1992.

APPENDIX B.10
RADIATION PROTECTION

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.10 RADIATION PROTECTION

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

No change.

B.10.2 Radiation Protection Design Features

The estimates of off-site dose rates in and around an independent spent fuel storage installation containing arrays (two generic arrays – 2x10 back-to-back array and 2-1x10 front-to-front array) of loaded HSM-Hs (each HSM-H containing a 32PTH DSC fully loaded with design basis fuel) during long term storage are presented in Section 10.2 of Chapter 10. As described in Chapter B.5, the authorized fuel content has not changed. The top and bottom canister shielding thicknesses, including the HSM-H door, have decreased; however the average HSM-H surface dose rates remain bounded by those around the HSM-H loaded with a 32PTH DSC. Therefore, the off-site dose estimates presented in Chapter 10 are applicable to the 32PTH Type 2 DSC.

B.10.3 Estimated Onsite Collective Dose Assessment

The estimates of occupational dose during the loading of a 32PTH DSC fully loaded with design basis fuel for long term storage in an HSM-H using an OS187H TC during transfer are presented in Section 10.3 of Chapter 10. As described in Chapter B.5, the differences in the design of the 32PTH Type 2 DSC and the OS187H Type 2 TC result in an increase about 49% in the dose rates at the surface top end. Some of the design changes result in a reduction in these near field dose rates. For the top end design option with separate shield plug and inner cover plate, the occupational exposure during decontamination operations is expected to be lower because the DSC top shield plug is not required to be decontaminated. Overall, the occupational exposure estimate presented in Chapter 10 is expected to increase by 60% when loading Type 2 DSC and Type 2 TC; temporary shielding and ALARA practices (distances, duration and number of workers) could be employed to minimize the occupational exposure.

APPENDIX B.11
ACCIDENT ANALYSIS

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Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

B.11 ACCIDENT ANALYSIS

B.11.1 Introduction

No change from Chapter 11, Section 11.1.

B.11.2 Off-Normal Operation

No change from Chapter 11, Section 11.2.

B.11.3 Postulated Accident

No change from Chapter 11, Section 11.3.

B.11.3.1 Cask Drop

No change from Chapter 11, Section 11.3.1.

B.11.3.2 Earthquake

No change from Chapter 11, Section 11.3.2.

B.11.3.3 Tornado Wind and Tornado Missiles Effect on HSM-H

No change from Chapter 11, Section 11.3.3.

B.11.3.4 Tornado Wind and Tornado Missiles Effect on Transfer Cask

No change from Chapter A.11, Section A.11.3.4.

B.11.3.4.1 Penetration Resistance

No change from Chapter 11, Section 11.3.4.1.

B.11.3.4.2 Impact Stress Analysis

No change from Chapter A.11, Section A.11.3.4.2.

B.11.3.4.3 Accident Dose Calculation

No change from Chapter A.11, Section A.11.3.4.3.

B.11.3.4.4 Corrective Action

No change from Chapter A.11, Section A.11.3.4.4.

B.11.3.5 Flood

No change from Chapter 11, Section 11.3.5.

B.11.3.6 Blockage of HSM-H Air Inlet and Outlet Openings

No change from Chapter 11, Section 11.3.6.

B.11.3.7 Lightning

No change from Chapter 11, Section 11.3.7.

B.11.3.8 Fire/Explosion

No change from Chapter 11, Section 11.3.8.

B.11.4 References

No change from Chapter 11, Section 11.4.

APPENDIX B.12
OPERATING CONTROLS AND LIMITS

No change from Chapter 12.

APPENDIX B.13
QUALITY ASSURANCE

No change from Chapter 13.

Appendix B is newly added in Revision 6 pursuant to the 10 CFR 72.48 process.

APPENDIX B.14
DECOMMISSIONING

No change from Chapter 14.