**Enclosure 8 to E-60447**

# Proposed Amendment 18, Revision 0 Changes to the Standardized NUHOMS® System Updated Final Safety Analysis Report (Public Version)

1.13 U. S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, "Safety Evaluation Report for Nutech Horizontal Modular System for Irradiated Fuel Topical Report," March 28, 1986.

1.14 U. S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, "Safety Evaluation Report for a Design Change to the Transfer Cask for the Duke Power Company's Independent Spent Fuel Storage Installation," February 1990.

1.CoC-APPC CoC 1004 Appendix C, ASME Code Alternatives for the Standardized NUHOMS® Horizontal Modular Storage System, Amendment *18*.

1.TS CoC 1004 Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System, Amendment *18*.

## 3.2 Structural and Mechanical Safety Criteria

The reinforced concrete HSM and its DSC support structure, the DSC and its internal basket assembly, and the transfer cask are the NUHOMS® system components which are important to safety. Consequently, they are designed and analyzed to perform their intended functions under the extreme environmental and natural phenomena specified in 10CFR72.122 (3.6) and ANSI-57.9 (3.36). Since the NUHOMS® ISFSI is an independent, passive system, no other components or systems contribute to its safe operation.

Table 3.2-1 summarizes the design criteria for the standardized NUHOMS® system components which are important to safety. This table also summarizes the applicable codes and standards utilized for design. The extreme environmental and natural phenomena design criteria discussed below comply with the requirements of 10CFR72.122 and ANSI-57.9. A description of the structural and mechanical safety criteria for the other design loadings listed in Table 3.2-1, such as thermal loads and cask drop loads, are provided in Chapter 8. The principal design criteria for the NUHOMS®-61BT system are provided in Appendix K.

The principal design criteria for the NUHOMS® HSM Model 80 and Model 102 described in this chapter are also applicable to HSM Model 152 and HSM Model 202. See Appendix R and Appendix V, respectively, for details. See Appendix P for HSM-H design criteria and Appendix U for the high seismic design criteria for the HSM-HS.

### 3.2.1 Tornado and Wind Loadings

The NUHOMS® ISFSI is designed to be located anywhere within the contiguous United States. Consequently, the most severe tornado and wind loadings specified by NRC Regulatory Guide l.76 (3.7) and NUREG-0800, Section 3.5.1.4 (3.8) are selected as the design basis. The NUHOMS® reinforced concrete HSMs are designed to safely withstand 10CFR72.122 (b)(2) tornado missiles. Extreme wind effects are much less severe than tornado wind and missile loads or seismic effects and, therefore, are not evaluated in detail for the HSM.

Since the NUHOMS® on-site transfer cask is used infrequently and for short durations, the possibility of a tornado funnel cloud enveloping the cask/DSC during transit to the HSM is a low probability event. Nevertheless, the transfer cask is designed for the effects of tornados, in accordance with 10CFR72.122. This includes design for the effects of worst case tornado winds and missiles.

*For short term operations which are not analyzed for tornado hazards, administrative controls during ISFSI handling operations are required. Those controls, which are described in Section 5.1.1.5, coupled with the low probability of tornado events, gives confidence in weather conditions being acceptable during outdoor operations during the short durations when the system configuration was not analyzed for tornado hazards.*

3.2.1.1 Applicable Design Parameters

The design basis tornado (DBT) intensities used for the NUHOMS® transfer cask and HSM design are obtained from NRC Regulatory Guide l.76. Region I intensities are utilized since they result in the most severe loading parameters. For this region, the maximum wind speed is 160 m/sec (360 miles per hour), the rotational speed is 130 m/sec (290 miles per hour), the maximum translational speed is 31 m/sec (70 miles per hour), the radius of the maximum rotational speed is 45.7 m (150 feet), the pressure drop

28. Open the valve on the vent port and allow helium to flow into the DSC cavity to pressurize the DSC to 2.5 psig ± 2.5 psig in accordance with Technical Specification 3.1.2.a limits.

29. Close the valves on the helium source.

30. Remove the Strongback, decontaminate as necessary, and store.

5.1.1.4 DSC Sealing Operations

1. Disconnect the VDS from the DSC. Seal weld the prefabricated plugs over the vent and siphon ports and perform a dye penetrant weld examination in accordance with the CoC Appendix A Inspections, Tests, and Evaluations Item 4.3 requirements.

2. Install the automated welding machine onto the outer top cover plate and place the outer top cover plate with the automated welding system onto the DSC. Verify proper fit up of the outer top cover plate with the DSC shell.

3. Tack weld the outer top cover plate to the DSC shell. Complete the outer top cover plate weld root pass. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface in accordance with the CoC Appendix A Inspections, Tests, and Evaluations Item 4.3.

4. Remove the automated welding machine from the DSC. Rig the cask top cover plate and lower the cover plate onto the transfer cask.

5. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern. Verify that the TC radial dose rates measured at the surface of the transfer cask are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2. The configuration for determining the TC radial surface dose rates shall be in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

5.1.1.5 Transfer Cask Downending and Transfer to ISFSI

*For short term operations which are not analyzed for tornado hazards, the following administrative controls during ISFSI handling operations are required.*

*General Licensees will develop, revise, or review existing procedures to establish administrative controls that implement compensatory measures to mitigate tornado hazards during periods of ISFSI handling operations that include the following:*

*1. The local weather forecast shall be confirmed acceptable prior to starting ISFSI handling operations. The weather forecast shall indicate that there are no tornado watches, advisories, or warnings within the next eight (8) hours.*

*2. The local weather forecast shall be obtained.*

3. *Any time the above conditions cannot be met during handling operations, the storage system SSCs shall be placed in a safe and analyzed condition as soon as practicable.*

4. *A log or checklist shall be added to document that weather checks are complete prior to starting handling operations.*

5. *Staff shall be assigned to monitor weather during handling operations.*

6. *The duration of ISFSI handling operations during which ISFSI important to safety SSCs are in an unanalyzed condition shall be minimized to the extent practicable. For NUHOMS® systems, those conditions are:*
   a. *From the time a loaded transfer cask (TC) lid is removed, when the dry shielded canister is to be inserted into a horizontal storage module (HSM), until the time the HSM door is installed.*
   b. *Any other time a loaded TC lid is removed outdoors, for site configuration requirements or an HSM door is removed.*
   c. *During the time a TC is rotated from a vertical to a horizontal orientation, outdoors, for site configuration requirements.*

NOTE:

<u>Alternate Procedure for Downending of Transfer Cask</u>: Some plants have limited floor hatch openings above the cask/trailer/skid, which limit crane travel (within the hatch

2a. Perform a daily visual surveillance of the HSM air inlets and outlets (end wall and roof birdscreens) to insure that no debris is obstructing the HSM vents in accordance with Technical Specification 4.3.6.a requirements.

2b. Perform a temperature measurement of the thermal performance, for each HSM, on a daily basis in accordance with Technical Specification 4.3.6.b requirements.

Note: This provision, with these two alternate allowed approaches, first became effective as of CoC 1004 Amendment 8, consistent with Amendment 8 Technical Specification 1.3.

5.1.1.8 <u>DSC Retrieval from the HSM</u>

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the transfer cask, transfer trailer, and support skid for service and tow the trailer to the HSM.

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## 12.3 Aging Management Program

Aging effects that could result in the loss of in-scope SSCs' intended function(s) are managed during the extended storage period. Many aging effects are adequately managed for the extended storage period using TLAA, as discussed in Section 12.2. An AMP is used to manage those aging effects that are not managed by TLAA. The AMPs that manage each of the identified aging effects for all in-scope SSCs include the following:

1. DSC External Surfaces Aging Management Program
2. DSC Aging Management Program for the Effects of Choride-Induced Stress Corrosion Cracking (Coastal Locations, Near Salted Roads, or in the Path of Effluent Downwind from the Cooling Tower(s))
3. Horizontal Storage Module Aging Management Program for External and Internal Surfaces
4. Horizontal Storage Module Inlets and Outlets Ventilation Aging Management Program
5. Transfer Cask Aging Management Program
6. High Burnup Fuel Aging Management Program

The AMPs are summarized in Table 12.3-1 through Table 12.3-6. Additional details are available in [12.20].

*Note: Aging Management Program inspections may require short term operations that place the system in an unanalyzed condition for tornado hazards (e.g., removal of HSM door to collect a sample from the DSC). The administrative controls identified in Section 5.1.1.5 shall be in place for these types of AMP inspection activities.*

## 12.4 Retrievability

Retrievability is the ability to remove spent nuclear fuel from storage. ISG-2 Revision 1 [12.15] provides NRC staff guidance on the subject of fuel retrievability *and represents the guidance used for DSCs loaded through Amendment 17*.

The Standardized NUHOMS® System is designed to allow ready retrieval of the SFAs for further processing and disposal, in accordance with 10 CFR 72.122(1). As discussed in ISG-2, ready retrieval of the SFAs from the DSC requires: (1) the ability to transfer the DSC to a spent fuel pool (or other facility), and (2) the ability to unload the SFAs from the DSC for repackaging to allow removal from the reactor site, transportation, and ultimate disposition by the DOE.

The sliding surfaces of the DSC support rails of all the HSMs are fabricated from Nitronic® 60 austenitic stainless steel and are coated with a dry film lubricant to minimize friction during insertion and retrieval of the DSC. Graphite lubricants are suitable for very high and cryogenic temperature applications. The effect of radiation on these lubricants is minimal, since these are inorganic and consist entirely of graphite. The coefficient of friction associated with these lubricants is below 0.05, while the design basis calculations employed a coefficient of friction of 0.25. The mechanical system to be used for DSC transfer is capable of exerting an extraction force equal to the loaded weight of a DSC. Depending on the DSC type, an effective coefficient of friction ranging from 72 to 100% of the loaded DSC weight has been used for these "jammed DSC" analyses. The support structure is also designed for this loading. Therefore, loss of lubrication is not an aging effect requiring management since the dry film lubricant is not relied upon for DSC retrieval.

[12.19, Appendix 3N] presents the evaluation to demonstrate that the confinement function of the DSC is maintained and that the requirement of ready retrieval of the DSC from the HSM is met. This evaluation demonstrates that, even when conservatively assuming initial temperatures and internal pressure for normal storage conditions and an extraction force of 80 kips (about 2.5 times the expected sliding force per UFSAR, Section U.3.6.1.1 for the analyzed DSC), the DSC shell thickness could be reduced to 0.25 in. and the DSC shell stresses required to maintain confinement and to ensure retrievability are below the ASME Code Level A stress limits.

The results of the AMR, along with the AMAs, provide reasonable assurance that SFAs will be retrievable. [12.19, Appendix 3J] presents an assessment of HBU cladding stresses under normal storage conditions including the handling loads associated with retrievability of the FA from the DSC. The evaluation shows that cladding stresses due to handling of the FA are well below yield and do not impose ductility demands on the cladding. Other fuel assembly hardware (e.g., spacer grids, top and bottom nozzles, guide tubes, etc.) is less limiting. Thus, the SFAs will be capable of being retrieved by normal means. Based on the AMR results of the SFAs and the implementing AMPs for the DSC, HSM and HBU fuel, there is reasonable assurance that the SFAs will be retrievable by normal means during the period of extended operation.

*ISG-2, Revision 2 [12.21] also defines ready retrieval or retrievability of spent fuel as the ability to remove a canister loaded with spent fuel assemblies from a storage cask/overpack (Option B).*

12.17 DOE EPRI, “High Burnup Dry Storage Cask Research and Development Project - Final Test Plan,” Electric Power Research Institute, February 27, 2014.

12.18 NRC Interim Staff Guidance 24, “The Use of a Demonstration Program as a Surveillance Tool for Confirmation of Integrity for Continued Storage of High Burnup Fuel Beyond 20 Years,” Revision 0, July 11, 2014.

12.19 Enclosure 3, “Certificate of Compliance Renewal Application for the Standardized NUHOMS® System, Certificate of Compliance No. 1004 (Docket No. 72-1004), Revision 3 (Proprietary Version),” to Letter from Jayant Bondre (AREVA TN) to NRC Document Control Desk, “Response to Re-Issue of Second Request for Additional Information - AREVA Inc. Renewal Application for the Standardized NUHOMS® System - CoC 1004 (Docket No. 72-1004, CAC No. L24964),” dated September 29, 2016.

12.20 TN Americas, Calculation 67009-AMP, “CoC License Renewal Aging Management Programs - DSCs, HSMs, TCs,” Revision 1.

*12.21 Interim Staff Guidance, DSFM ISG-2, “Fuel Retrievability in Spent Fuel Storage Applications,” Revision 2, April 26, 2016.*

K.8.1.5 Transfer Cask Downending and Transfer to ISFSI

*NOTE:*
*Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

NOTE:
Alternate Procedure for Downending of Transfer Cask: Some plants have limited floor hatch openings above the cask/trailer/skid, which limit crane travel (within the hatch opening) that would be needed in order to downend the TC with the trailer/skid in a stationary position. For these situations, alternate procedures are to be developed on a plant-specific basis, with detailed steps for downending.

1. Drain the neutron shield to an acceptable location.

   CAUTION: The radiation dose rates around the surface of the transfer cask without water in the neutron shield (through step K.8.1.5.10) are expected to be high. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

2. Re-attach the transfer cask lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.

3. Move the scaffolding away from the cask as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transfer trailer.

4. The transfer trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.

5. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.

6. Move the crane forward while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.

7. Inspect the positioning of the cask to ensure that the cask and trunnion pillow blocks are properly aligned.

8. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.

9. Inspect the trunnions to ensure that they are properly seated onto the skid. Install the trunnion tower closure plates (optional for the OS197 TC and the OS197H TC).

10. Fill the neutron shield.

11. Remove the bottom ram access cover plate from the cask. Install the two-piece temporary neutron/gamma shield plug to cover the bottom ram access. Install the ram trunnion support

## K.8.2 Procedures for Unloading the Cask

### K.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the transfer cask, transfer trailer, and support skid for service and tow the trailer to the HSM. If using the OS200 TC to unload, verify that it has been fitted with an internal aluminum sleeve and a cask spacer of appropriate height (refer to Drawings NUH-08-8004-SAR and NUH-08-8005-SAR provided in Appendix U, Section U.1.5).

2. Back the trailer as close to the HSM as compatible with HSM door removal, and remove the cask top cover plate.

3. Remove the HSM door. Remove the inner tube of the DSC axial retainer.

4. Using the skid positioning system, align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.

5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install and align the hydraulic ram with the cask.

7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.

8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of 15 inches or greater.

9. Retract ram and pull the DSC into the cask.

10. Retract the ram grapple arms.

11. Disengage the ram from the cask.

1a. In accordance with Technical Specification 4.3.2, verify that the NS is filled before the draining operation in Step 2 is initiated and continually monitored during the first five minutes of the draining evolution to ensure the NS remains filled.

2. Open the cask drain port valve and remove the remaining water from the cask/DSC annulus.

3. Install the automatic welding machine onto the outer top cover plate and place the outer top cover plate with the automatic welding system onto the DSC. Verify proper fit up of the outer top cover plate with the DSC shell.

4. Tack weld the outer top cover plate to the DSC shell. Place the outer top cover plate weld root pass.

5. Helium leak test the inner top cover plate and vent/siphon port plate welds using the leak test port in the outer top cover plate in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 4.1 limits. Verify that the personnel performing the leak test are qualified in accordance with SNT-TC-1A [8.6]. Alternatively, this can be done with a test head in Step M.8.1.4.1.

6. If a leak is found, remove the outer cover plate root pass, the vent and siphon port plugs and repair the inner cover plate welds. Repeat procedure steps from M.8.1.3 step 18.

7. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface in accordance with the CoC Appendix A Inspections, Tests, and Evaluations Item 4.3 requirements.

8. Seal weld the prefabricated plug over the outer cover plate test port and perform dye penetrant weld examinations.

9. Remove the automatic welding machine from the DSC.

10. If using the OS200 TC to load, place a sleeve ring spacer at the top of the aluminum sleeve (refer to Drawing NUH-08-8004-SAR provided in Appendix U, Section U.1.5). Rig the cask top cover plate and lower the cover plate onto the TC.

11. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.

12. Verify that the TC radial dose rates measured at the surface of the Transfer Cask are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2. The configuration for determining the TC radial surface dose rates shall be in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

M.8.1.5 TC Downending and Transfer to ISFSI

*NOTE: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. If loading 32PT-S100 or 32PT-L100 DSC (qualified for 100-ton crane capacity), drain the neutron shield to an acceptable location.

   CAUTION: The radiation dose rates around the surface of the transfer cask without water in the neutron shield (through step M.8.1.5.10) are expected to be high. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

## M.8.2 Procedures for Unloading the Cask

### M.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the TC, transfer trailer, and support skid for service and tow the trailer to the HSM. If using the OS200 TC to unload, verify that it has been fitted with an internal aluminum sleeve and a cask spacer of appropriate height (refer to Drawings NUH-08-8004-SAR and NUH-08-8005-SAR provided in Section U.1.5).
2. Back the trailer as close to the HSM as compatible with HSM door removal, and remove the cask top cover plate.
3. Cut any welds from the door and remove the HSM door. Remove the DSC drop-in retainer.
4. Using the skid positioning system align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.
5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install and align the hydraulic ram with the cask.
7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.
8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of 15 inches or greater.

9. Retract ram and pull the DSC into the cask.
10. Retract the ram grapple arms.
11. Disengage the ram from the cask.
12. Remove the cask restraints.
13. Using the skid positioning system, disengage the cask from the HSM.
14. If using the OS200 TC to unload, place a sleeve ring spacer at the top of the aluminum sleeve (refer to Drawing NUH-08-8004-SAR provided in Section U.1.5).
15. Install the cask top cover plate and ready the trailer for transfer.
16. Replace the door on the HSM.

## P.1 General Discussion

This Appendix to the Updated NUHOMS® Final Safety Analysis Report (UFSAR) addresses the Important to Safety aspects of adding the NUHOMS®-24PTH system to the Standardized NUHOMS® system described in the UFSAR.

The NUHOMS®-24PTH system is a modular canister based spent fuel storage and transfer system, similar to the Standardized NUHOMS®-24P system described in the UFSAR. The NUHOMS®-24PTH system consists of the following components:

- A dual purpose (Storage/Transportation) Dry Shielded Canister (DSC), with three alternate configurations, designated as DSC Type NUHOMS®-24PTH-S, -24PTH-L, and -24PTH-S-LC,
- A 24PTH DSC basket design, which is provided with *three* alternate options: with aluminum inserts (Type 1), without aluminum inserts (Type 2) as shown in Figure P.1-1*, and with composite plate compartments (Type 3), see Drawings NUH24PTHS-5012-SAR, NUH24PTH-L-5012-SAR, and NUH24PTH-S-LC-5012-SAR.* In addition, depending on the boron content in the basket poison plates, each basket type is designated as Type A (low B10), Type B (moderate B10), Type C*, and Type D (high B10),* which results in *seven* different basket types (Type 1A, 1B, 1C, 2A, 2B, 2C*, and 3D*),
- A modified version of the Standardized Horizontal Storage Module (HSM) Model 102 described in the UFSAR, designated as HSM-H, equipped with special design features which provide enhanced shielding and heat rejection capabilities, and
- The OS197/OS197H Transfer Cask (TC) described in the UFSAR, is provided with an optional modified top lid to allow air circulation through the TC/DSC annulus during transfer operations at certain heat loads when time limits for transfer operations cannot be satisfied. The OS197 TC with a modified top lid is designated as the OS197FC TC. The OS197H TC with a modified top lid is designated as the OS197HFC TC. Throughout this Appendix, "OS197FC" is a generic designation intended to apply to the OS197FC or OS197HFC TCs unless otherwise explicitly stated.
- An upgraded version of the HSM-H, designated as HSM-HS, is provided to allow storage of the NUHOMS®-24PTH *DSCs with Type 1 and 2 baskets* in locations where higher seismic levels exist. The HSM-HS design configuration, described in U.1, is modified to accommodate the smaller diameter of the NUHOMS®-24PTH DSC.
- The NUHOMS®-24PTH *DSCs with Type 1 and 2 baskets are* also transferred in a modified version of the OS200/OS200FC TC described in U.1. The OS200/OS200FC TC is fitted with an aluminum sleeve and a spacer to accommodate the smaller diameter and shorter length of the 24PTH DSC.

The 24PTH DSC is designed to accommodate up to 24 intact or up to 12 damaged (with up to 8 failed fuel cans loaded with failed fuel) with the remainder intact, PWR fuel assemblies with or without Control Components (CCs), with characteristics as described in Appendix P.2*, or dummy fuel, or empty slots.* The 24PTH-S and 24PTH-L are the short and long cavity configurations of the 24PTH DSC designed for a maximum heat load of 40.8 kW. They are transferred to the ISFSI for storage in the HSM-H/HSM-HS in either the OS197/OS197H/OS200 or OS197FC/OS200FC TC depending upon the heat load *and basket type*.

The 24PTH-S-LC DSC is a modified version of 24PTH-S DSC, provided with thinner top and bottom lead shield plugs instead of steel, resulting in a longer cavity length. This DSC type is designed for a maximum heat load of 24 kW per DSC and may be stored in either the currently licensed Standardized HSM Model 102, or in the new HSM-H, while the currently licensed Standardized TC (with a solid neutron shield) or OS197/OS197H TC (with a liquid neutron shield) are used for onsite transfer.

Fuel assemblies with CCs are to be stored in 24PTH-S, 24PTH-L and 24PTH-S-LC DSC Types.

These *six* alternate NUHOMS®-24PTH System configurations are summarized below:

| System Configuration | 24PTH DSC Type(1) | Basket Type | Max. Heat Load (kW) per DSC | Transfer Cask | Storage Module |
|---|---|---|---|---|---|
| 1 | 24PTH-S or 24PTH-L | 1A, 1B, or 1C(2) | 40.8 | OS197FC or OS200FC | HSM-H or HSM-HS |
| | | | 31.2 | OS197/OS197H or OS200 | HSM-H or HSM-HS |
| 2 | 24PTH-S or 24PTH-L | 2A, 2B, or 2C(3) | 31.2 | OS197FC/OS200 FC | HSM-H or HSM-HS |
| 3 | 24PTH-S-LC | 2A, 2B, or 2C(3) | 24.0 | Standardized TC (solid neutron shield)/OS197/OS 197H | HSM (Model 102 or 202) or HSM-H or HSM-HS |
| *4* | *24PTH-S or 24PTH-L(1)* | *3D* | *40.8* | *OS197FC* | *HSM-H* |
| | | | *31.2* | *OS197/ OS197H(4)* | *HSM-H* |
| *5* | *24PTH-S or 24PTH-L(1)* | *3D* | *31.2* | *OS197FC(4)* | *HSM-H* |
| *6* | *24PTH-S-LC(1)* | *3D* | *24.0* | *Standardized TC (solid neutron shield)/OS197/OS 197H* | *HSM (Model 102 or 202) or HSM-H* |

(1) Allows storage of Control Components
(2) With heat conductive aluminum inserts in the R45 basket transition rail
(3) With no heat conductive aluminum inserts in the R45 basket transition rail
*(4) For the same total heat load, transfer operations without time limits use OS197/OS197H and transfer operations with time limits require the use of OS197FC depending on the heat load zoning configurations (HLZC). Chapter P.4, Section P.4.12.2.5.3 presents the discussion on time limits for transfer operations for various HLZCs related to the Type 3 basket.*

The NUHOMS®-24PTH system provides structural integrity, confinement, shielding, criticality control and passive heat removal independent of any other facility structures or components.

The format of this Appendix follows the guidance provided in NRC Regulatory Guide 3.61 [1.1]. The analysis presented in this Appendix shows that the NUHOMS®-24PTH system meets all the requirements of 10 CFR 72 [1.2]. A separate analysis will be submitted to address the safety related aspects of transporting spent fuel in the NUHOMS®-24PTH DSC in accordance with 10 CFR 71 [1.3].

Several sections of this Appendix have been identified as "No change". For these sections, the description or analysis presented in the corresponding sections of the UFSAR for the Standardized NUHOMS® system is also applicable to the 24PTH system. In addition, Tables and Figures presented in the UFSAR which remain unchanged due to the addition of the 24PTH system to the Standardized NUHOMS® system are not repeated in this Appendix.

**Note:** References to sections or chapters within this Appendix are identified with a prefix P (e.g., Section P.2.3 or Appendix P.2 or Chapter P.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 or chapter number (e.g., Section 2.3 or Chapter 2). The references used in this appendix are identified as [X.X] (e.g., [1.1] is reference 1.1 at the end of Section P.1).

<u>Aging Management Program Requirements</u>

*Aging Management Program (*AMP*)* requirements for use of the 24PTH System during the period of extended storage operations are contained in Section 12.3. Applicable TLAAs performed for the initial CoC 1004 renewal application are provided in Section 12.2.

### P.1.1 Introduction

The NUHOMS®-24PTH system is designed to store up to 24 intact (including reconstituted) B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, and WE 14x14 class PWR fuel assemblies. WE 15x15 Partial Length Shield Assemblies (PLSAs) are also authorized to be stored in the 24PTH system. The fuel to be stored is limited to a maximum assembly average initial enrichment of 5.0 wt. %, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 2.0 years. The 24PTH-S, 24PTH-L and 24PTH-S-LC DSC types are also designed to store up to 24 Control Components (CCs) which include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs) and Neutron Sources. Furthermore, materials that are positioned or operated within the envelope of the fuel assembly during reactor operation are also considered as CCs. The design characteristics, including physical and radiological parameters of the payload, are described in Appendix P.2.

Reconstituted assemblies containing up to 10 replacement stainless steel rods per assembly or unlimited number of lower enrichment $UO_2$ rods instead of Zircaloy clad enriched $UO_2$ rods are acceptable for storage in 24PTH DSC as intact fuel assemblies. The maximum number of irradiated stainless steel rods in reconstituted assemblies per DSC is 40.

Fuel assemblies containing up to 10 stainless steel rods irradiated throughout the irradiation cycles are allowed for loading under the requirements of reconstituted fuels with irradiated stainless steel rods.

Provisions have been made for storage of up to 12 damaged fuel assemblies in lieu of an equal number of intact assemblies in cells located at the outer edge of the 24PTH basket. Damaged PWR fuel assemblies are assemblies containing missing or partial fuel rods, fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. The extent of damage in the fuel assembly, including non-cladding damage, is to be limited such that a fuel assembly is able to be handled by normal means and the retrievability is ensured following normal and off-normal conditions. *The fuel compartment and the top and bottom end cap together form the "acceptable alternative," per NUREG-2215 Revision 1 for confinement of damaged fuel. If fuel particles are released from the damaged assembly, the top and bottom end caps provide for the confinement of gross fuel particles to a known volume. Similarly, the FFC provides confinement of the FFC contents to a known volume, and has lifting features to allow the ability to unload the FFC. Additionally, consistent with ISG-2, Revision 2, ready retrieval of the damaged and failed fuel as well as intact fuel is based on the ability to remove a canister from the HSM.*

Provisions have also been made for storage of up to 8 failed fuel assemblies in lieu of an equal number of intact and/or damaged assemblies in cells located at the outer edge of the 24PTH basket as described in Appendix P.2.

The NUHOMS®-24PTH system consists of the following components:

- A 24PTH DSC, with *six* alternate configurations, described in detail in Section P.1.2, provides confinement, an inert environment, structural support, and criticality control for the 24 PWR fuel assemblies,

- An HSM-H module, described in Section P.1.2, or an HSM-HS module (described in Appendix U.1, Section U.1.2) is provided for environmental protection, shielding and heat rejection during storage, and
- OS197-FC or OS200FC transfer cask for onsite transfer of the 24PTH-S and 24PTH-L DSCs. The NUHOMS®-24PTH-S and 24PTH-L DSCs with Types 1A, 1B, 1C baskets can also be transferred in the OS197 or OS197H or OS200 TCs if the total heat load is 31.2 kW or less.

In addition to these new or modified components listed above, the 24PTH-S-LC DSC requires the use of the existing Standardized HSM Model 102 or the new HSM-H for storage and the Standardized Transfer Cask or OS197/OS197H TC for transfer.

The NUHOMS®-24PTH system requires the use of non-safety related auxiliary transfer equipment described in Chapter 1, Section 1.3.2.2 of the UFSAR. There is no change to any of these items except for the cask support skid. The cask support skid is modified by adding two industrial grade motor driven redundant blowers with associated ductwork for connecting to the TC ram cover plate opening. This modification provides a reliable source of external air circulation for the OS197FC TC.

Approval of the NUHOMS®-24PTH system components described in Section P.1.2 is sought under the provisions of 10 CFR 72, Subpart L for use under the general license provisions of 10 CFR 72, Subpart K. The 24PTH system components are intended for storage on a reinforced concrete pad.

## P.1.2 General Description of the NUHOMS®-24PTH System

### P.1.2.1 NUHOMS®-24PTH System Characteristics

#### P.1.2.1.1 NUHOMS®-24PTH DSC

Each NUHOMS®-24PTH DSC consists of a DSC shell assembly (cylindrical shell, canister bottom and top cover plates and shield plugs or shield plug assemblies) and a basket assembly. A sketch of the NUHOMS®-24PTH DSC components is shown in Figure P.1-1.

The 24PTH DSC is provided with three alternate configurations depending on the DSC shell assembly length and DSC cavity length shown in Table P.1-1.

These three DSC design configurations allow flexibility to accommodate the payload fuel types and control components described in Section P.2, and are compatible with the lifting capacity of most of the fuel handling cranes in the United States. The key design parameters and estimated weights of the NUHOMS®-24PTH DSC are listed in Table P.1-1.

The 24PTH DSC shell assembly geometry and the materials used for its fabrication are shown on drawings NUH-24PTH-1001-SAR and NUH-24PTH-1002-SAR included in Section P.1.5.

The primary confinement boundary for the NUHOMS®-24PTH DSC consists of the DSC shell, the top and bottom inner cover plates, (or the top and bottom inner cover plates of the shield plug assemblies for the 24PTH-S-LC), the siphon and vent block, the siphon and vent port cover plates, and the associated welds. Figure P.3.1-1 and Figure P.3.1-2 provide a pictorial representation of the confinement boundary for the 24PTH DSC. The outer top cover plate and associated welds form the redundant confinement boundary.

The cylindrical shell and the inner bottom cover plate boundary welds are fully compliant to Subsection NB of the ASME Code [1.4] and are made during fabrication. The top closure confinement welds are multi-layer welds applied after fuel loading and comply with the requirements of the alternative ASME Code Case N-595-2. The outer top cover plate is welded to the shell subsequent to the leak testing of the confinement boundary to the leak-tight criteria of ANSI N14.5-1997 [1.5]. There are no credible accidents which could breach the confinement boundary of the 24PTH DSC as documented in Chapter P.11.

The 24PTH *Types 1 and 2* DSC basket structure, shown schematically in Figure P.1-2, consists of 24 stainless steel fuel tubes with the space between adjacent tubes sandwiched by aluminum and neutron poison plates. *Each fuel tube is welded together at selected elevations along the axial length of the basket through stainless steel insert plates, which separate the aluminum and poison plates arranged in an egg crate configuration. The 24PTH Type 3 basket structure consists of composite plates of steel, neutron poison, and aluminum plates that fit together to form the grid structure. The Type 3 basket is based on the EOS-37PTH basket design and methodology that is approved in CoC 1042 [1-6].*

The poison plates are made of either Borated aluminum or Metal Matrix Composites (MMCs) or Boral® that provide the necessary criticality control. The aluminum plates, together with the poison plates, provide a heat conduction path from the fuel assemblies to the canister shell. The transition rails provide the transition between the rectangular basket structure *and* the cylindrical DSC shell. There are four R90 solid aluminum rails located at 0°, 90°, 180°, and 270° and eight R45 transition rails located on both sides of 45°, 135°, 225°, and 275° locations inside the DSC cavity. *There are three types of R45 transition rail versions. The 24PTH Type 1 basket utilizes an open steel frame running axially down the length of the DSC with aluminum inserts installed to increase heat conduction. The 24PTH Type 2 basket utilizes the steel frame as described for the Type 1 without the aluminum inserts. The 24PTH Type 3 basket uses extruded aluminum rails open sections, reinforced with internal steel angles to provide structural strength.* The transition rails support the fuel tubes and transfer mechanical loads to the DSC shell. They also provide the thermal conduction path from the basket assembly to the canister shell wall, making the basket assembly efficient in rejecting heat from its payload. The nominal clear dimension of each fuel tube opening is sized to accommodate the limiting assembly with sufficient clearance around the fuel assembly.

The 24PTH DSC basket geometry and the materials used for its fabrication are shown on *Drawings* NUH24PTH-1003-SAR, NUH24PTH-1004-SAR, *NUH24PTH-S-5012-SAR, NUH24PTH-L-5012-SAR, and NUH24PTH-S-LC-5012-SAR* included in Section P.1.5.

The failed fuel assemblies are to be placed in individual Failed Fuel Cans (FFCs). Each FFC is constructed of sheet metal and is provided with a welded bottom closure and a removable top closure which allows lifting of the FFC with the enclosed damaged assembly/debris. The FFC is provided with screens at the bottom and top to contain fuel debris and allow fill/drainage of water from the FFC during loading operations. The FFC is protected by the fuel compartment tubes and its only function is to confine the failed fuel.

The FFC geometry and the materials used for its fabrication are shown on drawing NUH24PTH-72-1008 *for basket Types 1 and 2 and NUH24PTH-5014-SAR for the Type 3 basket,* included in Section P.1.5. The geometry and materials used in the fabrication of a 24PTH *Type 1 and 2* basket assembly with FFCs is shown on drawing NUH24PTH-72-1009 *for Type 1 and 2 basket assemblies and NUH24PTH-L-5012-SAR, NUH24PTH-S-5012-SAR, and NUH24PTH-S-LC-5012-SAR for Type 3 basket assemblies* included in Section P.1.5.

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

Each canister is identified by a Mark Number, **W-24PTH-X-Y-Z**, where:

**W** is user specific designations;

**X** refers to the DSC Type as described previously (X = S or L or S-LC);

**Y** refers to the basket type (1A, 2A, 1B, 2B, 1C*, 2C, or 3D*) and

**Z** is a number corresponding to a specific canister.

P.1.2.1.2 NUHOMS®-HSM-H Module

*As shown in the Systems Configuration tables in the introduction to P.1, the NUHOMS®-24PTH DSC variations may be stored in either the HSM-H, HSM-HS, HSM-102, or HSM-202.*

The Standardized HSM Model 102 is described in Chapter 1 and in the drawings included in Appendix E of the UFSAR. *The HSM Model 202 is described in Chapter V.1 and drawings are included in Section V.1.5 of the UFSAR.*

The modifications made to the HSM-HS design configuration to accommodate the smaller diameter and shorter length of the NUHOMS®-24PTH DSC are described in Appendix U.1, Section U.1.2 and are not discussed further in this section.

The HSM-H module design is similar to the design of HSM Model 102 with the following features provided to improve the heat rejection and shielding capabilities:

- Use of a thicker roof with no uniform gap between the adjacent modules,

Figure P.1-4 shows these features in a cross sectional view of the HSM-H. The key design parameters and estimated weights of the HSM-H module are shown in Table P.1-1. The geometry and materials used to fabricate the HSM-H module are shown in the Parts List on Drawings NUH-03-7001-SAR included in Section P.1.5.

#### P.1.2.1.3 NUHOMS®-OS197FC Transfer Cask

The modifications made to the OS200/OS200FC transfer cask design configuration to accommodate the smaller diameter and shorter length of the NUHOMS®-24PTH DSC are described in Appendix U.1, Section U.1.2 and are not discussed further in this section.

The OS197FC TC is a modified version of the OS 197/OS197H TC described in the UFSAR and in the drawings included in Appendix E of the UFSAR.

The top lid of the OS197/OS197H TC is scalloped out at sixteen locations on the lid underside (See Figure P.1-5) to provide slots that provide an exit path for air circulation through the TC/DSC annulus. This external air circulation feature is needed *for 24PTH-S or 24PTH-L DSCs* during the transfer mode *for all basket types based on the HLZC. Chapter P.4 presents additional details on the various time limits for transfer operations*.

To achieve this air circulation, the NUHOMS® TC support skid is modified by the addition of two motor-driven redundant industrial grade blowers and associated hoses (See Figure P.1-6) which are connected via a cone adapter to the ram access opening. The TC spacer inside the TC cavity also requires minor modifications to ensure distribution of the airflow to the perimeter region of the TC. The air circulation system is sized to provide a minimum capacity of 450 cfm.

The modifications necessary to convert OS197/OS197H TC into a OS197FC TC are shown on Drawings NUH-03-8000-SAR, included in Appendix E.3, and NUH-03-8006-SAR, included in Section P.1.5.

### P.1.2.2 Operational Features

#### P.1.2.2.1 General Features

The NUHOMS®-24PTH DSC is designed to safely store 24 intact standard PWR fuel assemblies or up to 12 damaged, with up to 8 failed fuel cans loaded with failed fuel with the remainder intact PWR fuel assemblies with or without CCs. The NUHOMS®-24PTH DSC is designed to maintain the fuel cladding temperature below allowable limits during normal storage, short-term accident conditions, short-term off-normal conditions and fuel loading/transfer operations.
The criticality control features of the NUHOMS®-24PTH DSC are designed to maintain the neutron multiplication factor k-effective less than the upper subcritical limit equal to 0.95 minus benchmarking bias and modeling bias under all conditions.

P.1.2.2.2 Sequence of Operations

The sequence of operations to be performed in loading fuel into the NUHOMS®-24PTH DSCs is presented in Appendix P.8.

P.1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

P.1.2.2.3.1 Criticality Prevention

Criticality is controlled by geometry, soluble boron in spent fuel pool and by utilizing fixed neutron poison material in the fuel basket. During storage, with the DSC cavity dry and sealed from the environment, criticality control measures within the installation are not necessary because of the low reactivity of the fuel in the dry NUHOMS®-24PTH DSC and the assurance that no water can enter the DSC cavity during storage.

P.1.2.2.3.2 Chemical Safety

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

P.1.2.2.3.3 Operation Shutdown Modes

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

P.1.2.2.3.4 Instrumentation

No change to Chapter 3, Section 3.3.3.2 and Chapter 4, Section 4.3.12.

P.1.2.2.3.5 Maintenance Techniques

No change to Chapter 4, Section 4.3.9.

P.1.2.3 Cask Contents

The NUHOMS®-24PTH DSC system is designed to store 24 intact or up to 12 damaged, with up to 8 failed fuel cans loaded with failed fuel with the remainder intact PWR fuel assemblies with or without control components. The fuel that may be stored in the NUHOMS®-24PTH DSC is presented in Appendix P.2.

Appendix P.3 provides the structural analysis. Appendix P.4 includes the thermal analysis. Appendix P.5 provides the shielding analysis. Appendix P.6 covers the criticality safety of the NUHOMS®-24PTH DSC system and its contents, listing material densities, moderator ratios, and geometric configurations.

### P.1.3 Identification of Agents and Contractors

*TN Americas, LLC* (TN) provides the design, analysis, licensing support and quality assurance for the NUHOMS®-24PTH system. Fabrication of the NUHOMS®-24PTH system cask is done by one or more fabricators qualified under TN's quality assurance program described in Chapter P.13. This program is written to satisfy the requirements of 10 CFR 72, Subpart G and covers control of design, procurement, fabrication, inspection, testing, operations and corrective action. Experienced TN operations personnel provide training to utility personnel prior to first use of the NUHOMS®-24PTH system and prepare generic operating procedures.

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

TN provides specialized services for the nuclear fuel cycle that support transportation, storage and handling of spent nuclear fuel, radioactive waste and other radioactive materials. TN is the holder of Certificate of Compliance 1004.

### P.1.5 Supplemental Data

The following *TN* drawings are enclosed:

***DSC***

- NUHOMS®-24PTH Transportable Storage DSC, for PWR Fuel, Main Assembly NUH24PTH-1001-SAR.
- NUHOMS®-24PTH Transportable Storage DSC, for PWR Fuel, Shell Assembly, NUH24PTH-1002-SAR.
- NUHOMS®-24PTH Transportable Storage DSC, for PWR Fuel Basket Assembly, NUH24PTH-1003-SAR.
- NUHOMS®-24PTH Transportable Storage DSC, for PWR Fuel, Transition Rails, NUH24PTH-1004-SAR.
- *NUHOMS® Transportable Canister 24PTH Type 3 Basket Damaged Fuel End Caps, NUH24PTH-5013-SAR.*
- *NUHOMS® Transportable Canister 24PTH Type 3 Basket Failed Fuel Canister, NUH24PTH-5014-SAR.*
- NUHOMS®-24PTHF Transportable Canister for PWR Fuel, Failed Fuel Can, NUH24PTH-72-1008.
- NUHOMS®-24PTHF Transportable Canister for PWR Fuel, Basket Assembly, NUH24PTH-72-1009.
- *NUHOMS® Transportable Canister 24PTH-S Type 3 Basket Transition Rails, NUH24PTH-S-5011-SAR.*
- *NUHOMS® Transportable Canister 24PTH-S Type 3 Basket Assembly, NUH24PTH-S-5012-SAR.*
- *NUHOMS® Transportable Canister 24PTH-L Type 3 Basket Transition Rails, NUH24PTH-L-5011-SAR.*
- *NUHOMS® Transportable Canister 24PTH-L Type 3 Basket Assembly, NUH24PTH-L-5012-SAR.*
- *NUHOMS® Transportable Canister 24PTH-S-LC Type 3 Basket Transition Rails, NUH24PTH-S-LC-5011-SAR.*
- *NUHOMS® Transportable Canister 24PTH-S-LC Type 3 Basket Assembly, NUH24PTH-S-LC-5012-SAR.*

***TC***

- General License NUHOMS® ISFSI OS197FC Onsite Transfer Cask Main Assembly, NUH-03-8006-SAR.

***HSM***

- Standardized NUHOMS® ISFSI HSM-H, Main Assembly, NUH-03-7001-SAR.
- Standardized NUHOMS® ISFSI, HSM-H/HSM-HS Dose Reduction Hardware, NUH-03-7004-SAR.

## P.1.6 References

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

1.2 10 CFR 72, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste."

1.3 10 CFR 71, Rules and Regulations, Title 10, Chapter 1, Code of Federal Regulations - Energy, U.S. Nuclear Regulatory Commission, Washington, D.C., "Packaging and Transportation of Radioactive Material."

1.4 American Society of Mechanical Engineers, ASME Boiler And Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG and NF, 1998 edition including 2000 Addenda.

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

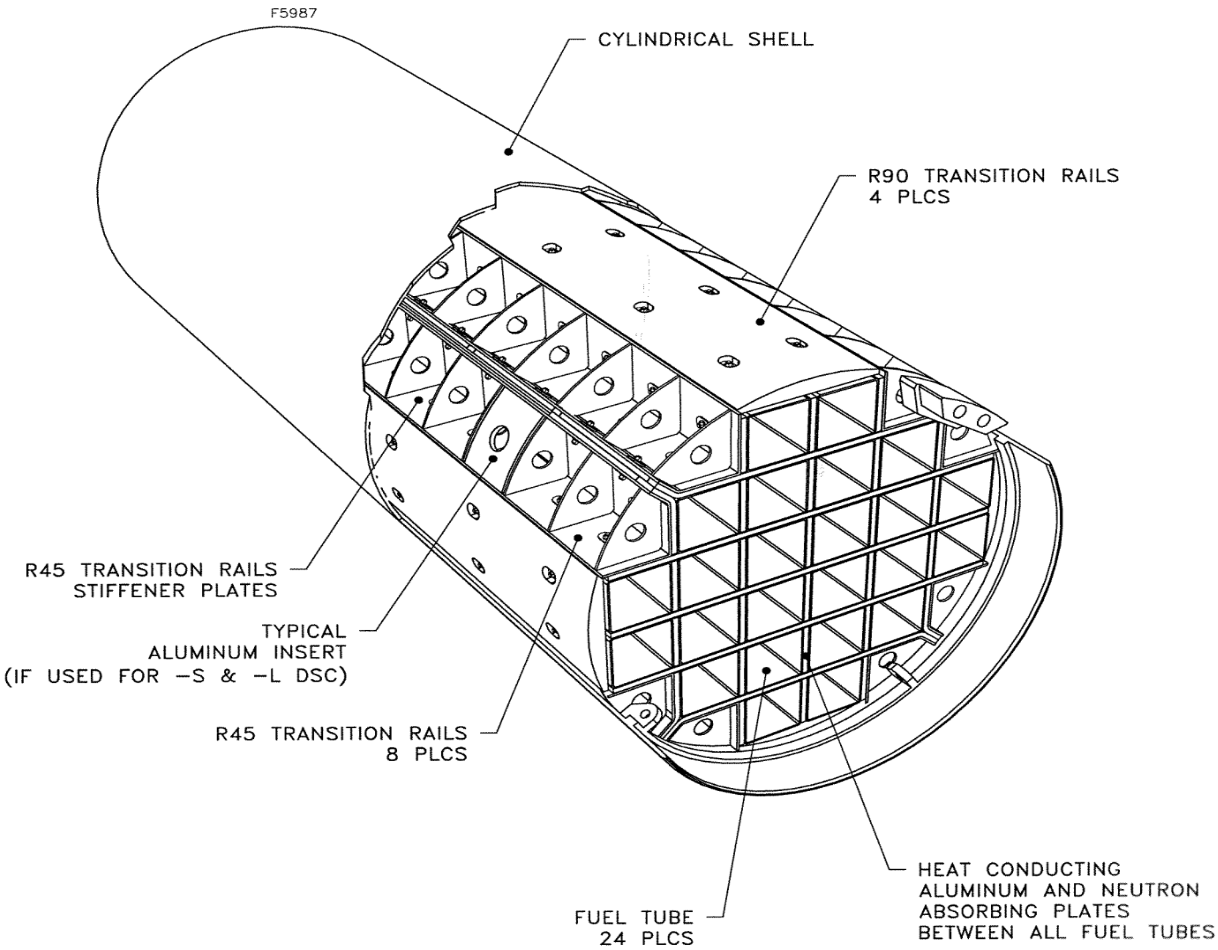
*1.6 CoC 1042 Updated Final Safety Analysis Report (UFSAR) for the NUHOMS® EOS System, Revision 3, June 2020.*

**Table P.1-1**
**Key Design Parameters of the NUHOMS®-24PTH System(2)**

| Parameter | 24PTH DSC Type | | |
|---|---|---|---|
| | **24PTH-S** | **24PTH-L** | **24PTH-S-LC** |
| DSC Length (in.) | 186.55 (Maximum) | 192.55 (Maximum) | 186.67 (Maximum) |
| DSC Outside Diameter (in) | 67.19 | 67.19 | 67.19 |
| DSC Cavity Length (in.) | 169.6 | *175.1* | 173.28 |
| DSC Shell Thickness (in) | 0.5 | 0.5 | 0.5 |
| DSC Loaded Weight, Dry(1) (kips) | 92.4/89.0/*86.1* | 93.7/90.1/*87.1* | *NA*/89.5/*86.6* |
| DSC Loaded Weight, Wet(1) (kips) | 96.6/93.2/*90.9* | 98.4/94.8/*92.4* | *NA*/95.1/*91.6* |
| HSM-H Single Module Weight, Empty (kips) | 306.1 | | |
| HSM-H Single Module Weight, Loaded (kips) | 398.5 | 399.8 | 395.6 |
| HSM Model 102 Weight, Empty (kips) | NA | NA | 263.0 |
| HSM Model 102 Weight, Loaded (kips) | NA | NA | 352.5 |

| HSM-H | |
|---|---|
| Overall Length (without shield walls), in | 248 |
| Overall Width (without shield walls), in | 116 |
| Overall Height, in | 222 |

Notes: (1) *The weights are provided for Type 1/Type 2/Type 3 baskets where applicable.*
(2) Unless stated otherwise, nominal values are provided.




**Note:** *Type 1 basket is shown.* The DSC top and bottom shield plugs and cover plates are not shown for clarity.

**Figure P.1-1**
**NUHOMS®-24PTH DSC Components**

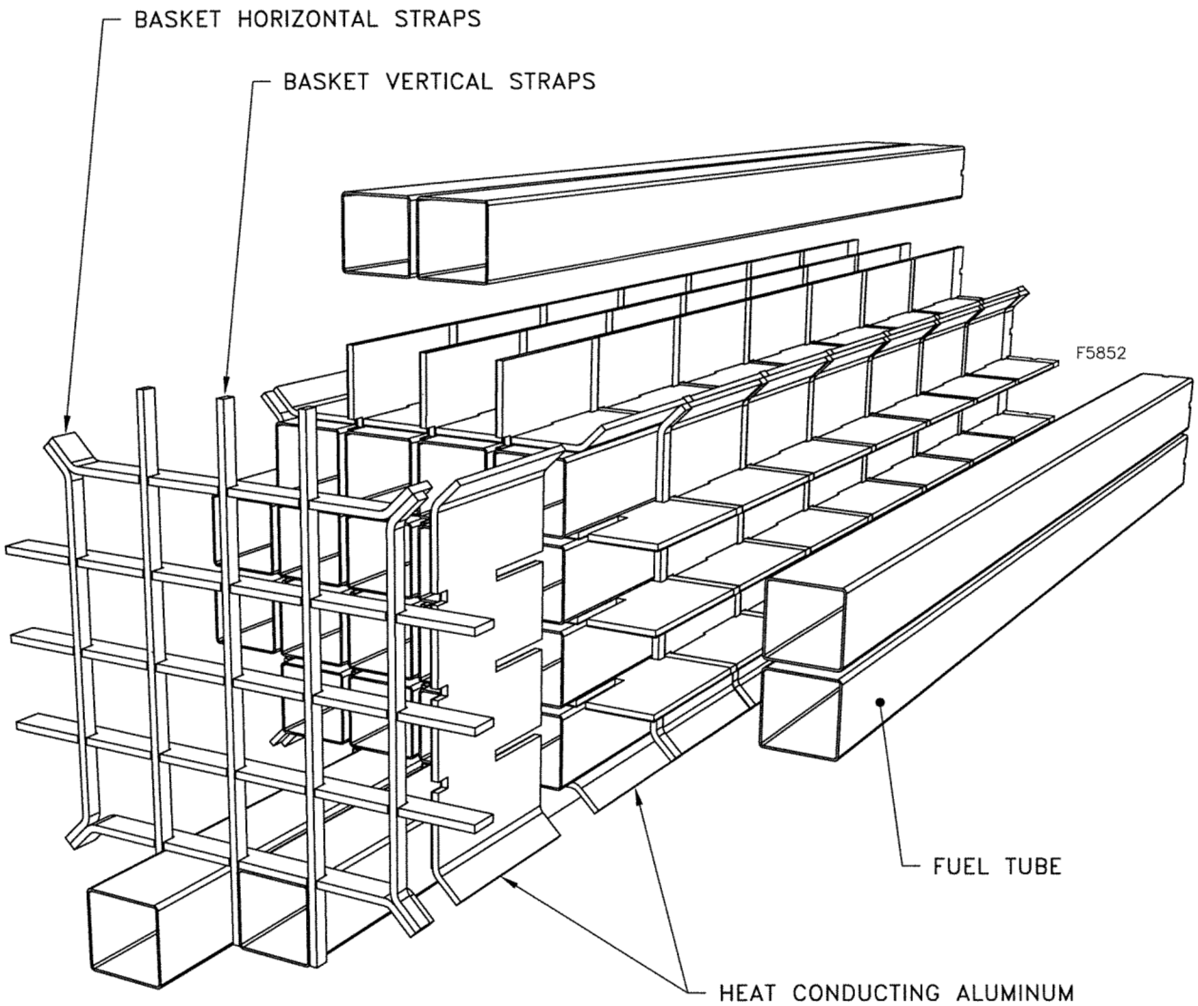



**Figure P.1-2**
**Disassembled View of the NUHOMS® 24PTH DSC *Types 1 and 2* Basket**

**Proprietary and Security Related Information for Drawing NUH24PTH-1001-SAR, Rev. 7A Withheld Pursuant to 10 CFR 2.390**

**Proprietary and Security Related Information for Drawing NUH24PTH-1002-SAR, Rev. 3A Withheld Pursuant to 10 CFR 2.390**

**Proprietary and Security Related Information for Drawing NUH24PTH-5013-SAR, Rev. 0A 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 NUH24PTH-5014-SAR, Rev. 0A Withheld Pursuant to 10 CFR 2.390**

8 7 6 5 4 3 2 1

H G F E D C B A

8 7 6 5 4 3 2 1

H G F E D C B A

**Proprietary and Security Related Information**
**for Drawing NUH24PTH-L-5011-SAR, Rev. 0A**
**Withheld Pursuant to 10 CFR 2.390**

H G F E D C B A

8 7 6 5 4 3 2 1

8 7 6 5 4 3 2 1

H G F E D C B A

**Proprietary and Security Related Information**
**for Drawing NUH24PTH-L-5012-SAR, Rev. 0A**
**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 NUH24PTH-S-5011-SAR, Rev. 0A**
**Withheld Pursuant to 10 CFR 2.390**

Proprietary and Security Related Information
for Drawing NUH24PTH-S-5012-SAR, Rev. 0A
Withheld Pursuant to 10 CFR 2.390

**Proprietary and Security Related Information**
**for Drawing NUH24PTH-S-LC-5011-SAR, Rev. 0A**
**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 NUH24PTH-S-LC-5012-SAR, Rev. 0A**
**Withheld Pursuant to 10 CFR 2.390**

8 7 6 5 4 3 2 1

H G F E D C B A

## P.2.1 Spent Fuel To Be Stored

As described in Appendix P.1, there are *six* design configurations for the NUHOMS®-24PTH DSC; S, L and S-LC. Each of the DSC configurations is designed to store intact (including reconstituted) and/or damaged and/or failed PWR fuel assemblies as specified in Table P.2-1 and Table P.2-3. The fuel to be stored is limited to a maximum assembly average initial enrichment of 5.0 wt. % U-235. The maximum allowable assembly average burnup is limited to 62 GWd/MTU. The nominal assembly width for intact and damaged fuel is 8.536 inches. The minimum required cool time for fuel to be stored with 380, 475, and 492 kgU/FA is explicitly specified as a function of burnup and enrichment in Tables M.2-5 through M.2-14f. For fuel with a kgU/FA loading between these values, the minimum required cool time for fuel to be stored as a function of burnup and enrichment is determined by using the interpolation methodology specified in the notes and examples following Table M.2-14f.

The 24PTH-S, 24PTH-L and 24PTH-S-LC DSCs are also designed to store control components (CCs) with thermal and radiological characteristics as listed in Table P.2-2. The CCs include burnable poison rod assemblies (BPRAs), thimble plug assemblies (TPAs), control rod assemblies (CRAs), rod cluster control assemblies (RCCAs), axial power shaping rod assemblies (APSRAs), orifice rod assemblies (ORAs), vibration suppression inserts (VSIs) , neutron source assemblies (NSAs), and neutron sources. Non-fuel hardware that are positioned within the fuel assembly after the fuel assembly is discharged from the core such as guide tube or instrument tube tie rods or anchors, guide tube inserts, BPRA spacer plates or devices that are positioned and operated within the fuel assembly during reactor operation such as those listed above are also considered as CCs.

Partial length shield assemblies (PLSAs) for the Westinghouse 15x15 class, where part of the active fuel is replaced with steel are also included as authorized.

The NUHOMS®-24PTH DSC is also authorized to store fuel assemblies containing blended low enriched uranium (BLEU) fuel material. Fuel pellets containing BLEU fuel material are no different than $UO_2$ fuel pellets except for the presence of a higher quantity of cobalt impurity. The consideration of cobalt impurity only affects the gamma source terms for fuel assemblies located in the DSC periphery. This does not affect any criticality, thermal or structural analysis inputs for evaluation of fuel assemblies with BLEU material. The qualification of fuel assemblies containing BLEU fuel pellets will require an additional cooling time of three years to ensure that the source terms calculated with $UO_2$ material are bounding.

time as the remaining fuel rods of the assembly. The reconstituted $UO_2$ rods are assumed to have the same irradiation history as the entire fuel assembly. The reconstituted rods can be at any location in the fuel assemblies. The maximum number of irradiated stainless steel rods in reconstituted assemblies per DSC is 40.

Fuel assemblies containing up to 10 stainless steel rods irradiated throughout the irradiation cycles are allowed for loading under the requirements of reconstituted fuels with irradiated stainless steel rods.

The NUHOMS®-24PTH DSCs can also accommodate up to a maximum of 12 damaged fuel assemblies placed in cells located at the outer edge of the DSC as shown in Figure P.2-6.

Damaged PWR fuel assemblies are assemblies containing missing or partial fuel rods, or fuel rods with known or suspected cladding defects greater than hairline cracks, or pinhole leaks. The extent of damage in the fuel assembly, including non-cladding damage, is to be limited such that a fuel assembly is able to be handled by normal means. The extent of damage in the fuel rods is to be limited such that a fuel pellet is not able to pass through the damaged cladding during handling and retrievability is assured following normal and off-normal conditions. The DSC basket cells which store damaged fuel assemblies are provided with top and bottom end caps to assure retrievability.

The NUHOMS®-24PTHF DSC, an alternative version of the NUHOMS®-24PTH DSC, is designed to accommodate up to a maximum of 8 failed fuel assemblies encapsulated in individual failed fuel cans and placed in cells located at the outer edge of the DSC as shown in Figure P.2-6. Failed fuel is defined as ruptured fuel rods, severed fuel rods, loose fuel pellets, or fuel assemblies that cannot be handled by normal means. Failed fuel assemblies may contain breached rods, grossly breached rods, and other defects such as missing or partial rods, missing grid spacers, or damaged spacers to the extent that the assembly cannot be handled by normal means.

Fuel debris and damaged fuel rods that have been removed from a damaged fuel assembly and placed in a rod storage basket are also considered as failed fuel. Loose fuel debris, not contained in a rod storage basket may also be placed in a failed fuel can for storage, provided the size of the debris is larger than the failed fuel can screen mesh opening and it is located at least 10″ above the top of the bottom shield plug of the DSC.

Fuel debris may be associated with any type of $UO_2$ fuel provided that the maximum uranium content and initial enrichment limits are met. The total weight of each failed fuel can plus all its contents shall be less than 1682 lb *for Type 1 and Type 2 baskets and 1715 lb for the Type 3 basket*.

A 24PTH DSC containing less than 24 fuel assemblies may contain either empty slots or dummy fuel assemblies in the empty slots. The dummy assemblies are unirradiated, stainless steel encased structures that approximate the weight and center of gravity of a fuel assembly.

The NUHOMS®-24PTH-S and 24PTH-L DSCs may store up to 24 PWR fuel assemblies arranged in any of the five alternate heat load zoning configurations shown in Figure P.2-1 through Figure P.2-4 and Figure P.2-9 with a maximum decay heat of 2.5 kW per assembly and a maximum heat load of 40.8 kW per canister.

The 24PTH-S-LC may store up to 24 B&W 15x15 fuel assemblies arranged in accordance with heat load zoning configuration No. 5 with a maximum decay heat of 1.5 kW per assembly and a maximum heat load of 24.0 kW per DSC, as shown in Figure P.2-5.

The 24PTH DSC basket is designed with *3* alternate options: Type 1 basket, which includes aluminum inserts in the R45 transition rails, Type 2 basket which does not include any aluminum inserts*, and Type 3 basket, which utilizes composite plate compartments.* Type 1 basket is the preferred option for canisters with high decay heat loads, since the aluminum inserts allow a more direct heat conduction path from the basket edge to the DSC shell. Type 2 basket offers the advantage of an adequate thermal performance but with a lower lifting weight requirement. *The Type 3 basket combines the high heat transfer performance and the advantage of the lower weight into a single design.*

The NUHOMS®-24PTH DSC basket is designed with three alternate poison materials: Borated Aluminum alloy, Boron Carbide/Aluminum Metal Matrix Composite (MMC) and Boral®. For criticality analysis, 90% of B-10 content present in the borated aluminum and MMC poison plates is credited, while only 75% is credited for Boral®.

For each poison material, the NUHOMS®-24PTH DSC basket is analyzed for *seven* alternate basket *poison* configurations, depending on the boron loadings analyzed (designated as "A" basket for low B-10 loading, "B" basket for moderate B-10 loading, "C" *or "D"* basket for high B-10 loading) and Basket-Type (Type 1*,* Type 2 *or Type 3*).

A summary of the alternate poison loadings considered and the corresponding credit taken in the criticality analysis for each poison material as a function of basket types is presented below:

| Poison Type | 24PTH Basket Type(1) | Poison Loading (B-10 mg/cm²) | % Credit Used in Criticality Analysis |
|---|---|---|---|
| Borated Aluminum Alloy/MMC | 1A or 2A | 7 | 90 |
| | 1B or 2B | 15 | |
| | 1C or 2C | 32 | |
| | *3D(2)* | *35* | |
| Boral® | 1A or 2A | 9 | 75 |
| | 1B or 2B | 19 | |
| | 1C or 2C | 40 | |

(1) Type 1A = Basket Type 1 with aluminum inserts in the R45 transition rails and Type A poison plate configuration; Type 2A = Basket Type 2 without aluminum inserts in the R45 transition rails and Type A poison plate configuration;

*(2) Borated Aluminum is not applicable for the Type 3 basket*

Table P.2-4 summarizes the maximum assembly average initial enrichment as a function of soluble boron concentration and basket neutron poison requirements for intact fuel assemblies. Table P.2-5 summarizes the maximum assembly average initial enrichment as a function of soluble boron concentration and basket neutron poison requirements for up to a maximum of 12 damaged fuel assemblies. Table P.2-5a summarizes the maximum assembly average initial enrichment as a function of soluble boron concentration and basket neutron poison requirements for up to a maximum of 8 damaged and/or failed fuel assemblies.

The method for determining the minimum required cooling times for the fuel assemblies with heavy metal loads between 380 and 492 kgU/FA is provided in Chapter 7, Section 7.2.3.2.

The NUHOMS®-24PTH DSC is inerted and backfilled with helium at the time of loading. The maximum fuel assembly weight with a CC is 1682 lbs *for Basket Types 1 and 2 and 1715 lbs for Basket Type 3.*

The maximum fuel cladding temperature limit of 400 °C (752 °F) is applicable to normal conditions of storage and all short term operations from spent fuel pool to ISFSI pad including vacuum drying and helium backfilling of the NUHOMS®-24PTH DSC per NUREG-1536 [2.1]. In addition, NUREG-1536 [2.1] does not permit thermal cycling of the fuel cladding with temperature differences greater than 65 °C (117 °F) during DSC drying, backfilling and transfer operations.

The maximum fuel cladding temperature limit of 570 °C (1058 °F) is applicable to accidents or off-normal thermal transients [2.1].

Calculations were performed to determine the fuel assembly type which was most limiting for each of the analyses including shielding, criticality, thermal and confinement. These evaluations are performed in Chapter P.5, P.6, P.4 and P.7, respectively. The fuel assembly classes considered are listed in Table P.2-3. It was determined that the B&W 15x15 may be used as a representative fuel assembly for dose rate calculations. For criticality safety, the B&W 15x15 assembly is the most reactive assembly type for a given enrichment. This assembly is used to determine the most reactive configuration in the DSC. Using this most reactive configuration, criticality analysis for all other fuel assembly classes is performed to determine the maximum enrichment allowed as a function of the soluble boron concentration and fixed poison plate loading. For thermal analysis, the WE 14x14 fuel assembly is limiting for the 24PTH-S and -L DSCs, and B&W 15x15 fuel assembly for the 24PTH-S-LC DSC since they result in the lowest fuel conductivity. The confinement analysis is based on B&W 15x15 fuel assembly, since it results in a smaller free volume inside the DSC cavity as compared to a 14x14 fuel assembly.

For calculating the maximum internal pressure in the NUHOMS®-24PTH DSC, it is assumed that 1% of the fuel rods are damaged for normal conditions, up to 10% of the fuel rods are damaged for off normal conditions, and 100% of the fuel rods will be damaged following a design basis accident event. A minimum of 100% of the fill gas and 30% of the fission gases within the ruptured fuel rods are assumed to be available for release into the DSC cavity, consistent with NUREG-1536 [2.1].

### P.2.2.5.1.1 NUHOMS®–24PTH DSC Shell Stress Limits

The stress limits for the NUHOMS®-24PTH DSC shell are taken from the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB, Article NB-3200 [2.2] for normal condition loads (Level A) and NB-3225, Appendix F for accident condition loads (Level D). The stress limits for Level B and Level C are taken from ASME, Section III, Subsection NB, Paragraph NB-3223 and 3224.

Local yielding is permitted at the point of contact where the Level D load is applied. If elastic stress limits cannot be met, the plastic system analysis approach and acceptance criteria of Appendix F of ASME Section III are used.

The allowable stress intensity value, $S_m$, as defined by the Code is based on the temperature calculated for each service load condition or a bounding temperature.

### P.2.2.5.1.2 NUHOMS®–24PTH DSC Basket Stress Limits - *Types 1 and 2*

The basket fuel compartment tube wall thickness is established to meet heat transfer, nuclear criticality, and structural requirements. The basket structure provides sufficient rigidity to maintain a subcritical configuration under the applied loads.

No credit is taken for neutron poison plates in any of the stress or stability analyses except for through the thickness compression (bearing) loads.

**Normal Conditions**

Normal Condition Stress Criteria for Steel Elements

As summarized in Table P.2-16, the normal condition stress criteria for the fuel compartment tubes and the transition rails, is based on Subsection NG of the ASME Code, Section III [2.2].

Normal Condition Stress Criteria for R90 Aluminum Transition Rails

The aluminum transition rail bodies (R90) perform their function (support of the fuel compartment tubes) by remaining in place. The loads on the rail bodies are primarily bearing from the fuel compartment tubes. "Failure" of the transition rail would require that the rail no longer provide support to the fuel compartment tubes. Since the aluminum rail bodies are constrained between the DSC shell and the fuel support compartment tubes, this cannot occur.

Therefore, for deadweight and handling condition loads, stress in the aluminum bodies will be compared to the allowable bearing stress, equal to $S_y$, from NG-3227.1(a). Values of $S_y$ are taken from Table P.3.3-4 for annealed 6061 aluminum material at temperature (as described in Section P.3.3, these yield stresses are lower bound values).

Normal Condition Stability Criteria

Stability criteria are addressed in two parts:

In addition, supplementary hand calculations were performed using the criteria of F-1334.3(b) for members under axial compression.

B. Under lateral loads, stability of the basket structure is demonstrated using detailed finite element models and the Collapse Load criteria from F-1341.3 [2.2]. These criteria establish the allowable load as 90% of the Limit Analysis Collapse Load where the Limit Analysis Collapse Load is the maximum load determined using elastic-perfectly plastic material properties with a yield stress equal to the lesser of $2.3S_m$ or $0.7S_u$.

In addition, supplementary hand calculations were performed using the criteria of F-1334.3(b) for members under axial compression.

*P.2.2.5.1.3* *NUHOMS® -24PTH DSC Basket Stress Limits - Basket Type 3*

*The ASME Boiler and Pressure Vessel (B&PV) code is not applicable to the 24PTH Type 3 basket since the primary structural components (i.e., the steel plates) are qualified as described in Section 2.4 of CoC Appendix A - Inspections, Tests, and Evaluations (ITE) [2.18]. However, the ASME code [2.16] provides the basis of the design criteria for the Type 3 basket for normal and off-normal conditions as described in this section. For accident conditions, strain-based criteria and consideration of permanent deformation are used instead.*

*The Type 3 basket is made up of interlocking, slotted plates to form an egg-crate type structure. The egg-crate structure forms a grid of 24 fuel compartments that house PWR spent fuel assemblies (SFAs). A typical stack-up of grid plates is composed of a structural steel plate, an aluminum plate for heat transfer and a neutron absorber plate (neutron poison) for criticality. This design utilizes the same concept as the EOS-37PTH DSC basket assembly that is designed and licensed under CoC 1042 [2-14].*

*The steel of the basket plates and the steel angles in the R45 transition rails are credited with the structural function of supporting the fuel assemblies in normal, off-normal, and accident conditions. The solid aluminum R90 rails are designed to resist the bearing loads due to the deadweight of the loaded basket while stored in the HSM.*

***Normal Conditions***

*Normal Condition Stress Criteria for Steel*

*The basis for the steel basket stress allowables is the ASME Code, Section III, Subsection NG [2-16]. Stress limits for Level A service loading conditions are summarized in Table P.3.8-1. Although the basket components are specified as "non-code", the ASME Code, Section III [2-16] serves as a design guide for determining the steel basket stress allowables based on the stress limits for normal (Level A) service loading conditions. The design stress intensity, $S_m$, is defined as the lower of $2/3S_y$ or $1/3\ S_u$ (Appendix 2 of ASME B&PV, Section II [2-17]).*

*<u>Normal Condition Stress Criteria for R90 Aluminum Transition Rails</u>*

*Similar to the Type 1 and 2 baskets, the aluminum transition rail bodies (R90) perform their function (support of the fuel compartment tubes) by remaining in place. As such, the loads on the rail bodies are primarily bearing from the fuel compartment tubes over 80 years while stored in the HSM. "Failure" of the transition rail would require that the rail no longer provide support to the fuel compartment tubes. Since the aluminum rail bodies are constrained between the DSC shell and the fuel support compartment tubes, this cannot occur. Consistent with CoC 1042 Section 3.9.2.1.6.3 [2-14] and [2-15], the allowable bearing stresses in the basket aluminum components, to limit creep strain to 0.01 in 550,000 hours, are as follows:*

- *0.254 ksi in the hottest aluminum plate, with a starting temperature of 680 °F.*
- *0.758 ksi in the hottest R90 rail, with a starting temperature of 470 °F.*
- *0.876 ksi in a less than hottest R90 rail, based on a starting temperature of 440 °F.*

*Although 550,000 hours is approximately 63 years, the creep strain time curve is very flat at 550,000 hours, such that the change in allowable bearing stress for 80 years is insignificant. Additional information regarding the creep evaluation is found in Section P.3.8. Annealed 6061 aluminum material properties are used for the basket evaluation, and are provided in Table P.3.3-12.*

***Accident Conditions***

*<u>Accident Condition Stress Criteria for Steel Elements - Basket Type 3</u>*

*Hypothetical impact accidents are evaluated as short duration Level D conditions. The structural steel plate displacements are evaluated against the acceptable permanent deformation that can be sustained by the basket structure while maintaining criticality control. Secondary and peak stresses are not required to be evaluated for Level D events, but should be evaluated to ensure that they are not a source of uncontrolled crack initiation.*

*The basket transition rails are classified as "non-code," and Section P.3.8 does not perform any stress analysis of the rail aluminum or steel plates for accident conditions. The membrane equivalent plastic strain in the steel grid plate is limited to 1%. Membrane + bending equivalent plastic strain is limited to 3% and peak equivalent plastic strain is limited to 10%. This ensures that displacement and permanent deformation of the steel grid is small and within failure limits for high-strength low-alloy steel such as American Iron and Steel Institute (AISI) 4130 material. The Level D Design Criteria are summarized in Table P.3.8-4.*

*Further discussion of the 24PTH Type 3 basket stress criteria is provided in Section P.3.8.6.5.*

P.2.2.5.2 <u>NUHOMS® HSM-H Structural Design Criteria</u>

A summary of the design loads for the HSM-H System is provided in Table P.2-18. The table also presents the applicable codes and standards for development of these loads. The design

criteria discussed below comply with the requirements of 10CFR72.122 [2.10], and ANSI 57.9 [2.9].

P.2.2.5.2.1 HSM-H Normal Loads

(A) Dead Loads (DW)

Dead load includes the weight of the HSM-H concrete structure and the steel structure (the 24PTH-DSC weight is considered as a live load rather than a dead load).

The dead load is varied by +5% from the estimated value to simulate the most adverse loading condition in accordance with ANSI-57.9 [2.9].

(B) Live Loads (LL)

Live loads include the roof design basis snow and ice load of 110 psf conservatively derived from ASCE 7-95 [2.8]. A total live load of 200 psf (which includes snow and ice load) is used to envelope all postulated live loading, including such items as ladders, handrails, conduits, etc. added for personnel protection. In addition, the normal handling loads (RO), and off-normal handling loads (RA), and the 24PTH-DSC weight are treated as live loads for the concrete component evaluation.

In accordance with ANSI-57.9 [2.9], the live load is varied between 0% and 100% of the estimated load to simulate the most adverse conditions for the structure.

(C) Normal Operating Thermal Loads (TN)

The normal thermal loads on HSM-H include the effects of design basis internal heat load (40.8 kW maximum heat load for the 24PTH system) generated by the canister plus the effects of normal ambient conditions (0ºF and 100ºF).

### P.2.5 Summary of NUHOMS®-24PTH DSC and HSM-H Design Criteria

#### P.2.5.1 24PTH DSC Design Criteria

The principal design criteria for the NUHOMS®-24PTH DSC are presented in Table P.2-18. The NUHOMS®-24PTH DSC is designed to store intact and/or damaged and/or failed PWR fuel assemblies with or without CCs with assembly average burnup, initial enrichment and cooling time as described in Table P.2-1 and Table P.2-3. The maximum total heat generation rate of the stored fuel is limited to 2.5 kW per fuel assembly (1.5 kW for 24PTH-S-LC DSC) and 40.8 kW per canister (24.0 kW for 24PTH-S-LC DSC) in order to keep the maximum fuel cladding temperature below the limit [2.5] necessary to ensure cladding integrity. The fuel cladding integrity is assured by the NUHOMS®-24PTH DSC and basket design which limits fuel cladding temperature and maintains a nonoxidizing environment in the DSC cavity as described in Appendix P.4.

The NUHOMS®-24PTH DSC (shell and closure) is designed and fabricated as a Class 1 component in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB [2.2], and the alternative provisions to the ASME Code as described in Table P.3.1-1.

The NUHOMS®-24PTH DSC is designed to maintain a subcritical configuration during loading, handling, storage and accident conditions. A combination of fixed neutron absorbers, soluble boron in the pool and favorable geometry are employed to maintain the upper subcritical limit of 0.9411. The fixed neutron absorbers are in the form of borated aluminum metallic plates or Boral®. The *Type 1 and Type 2 baskets are* designed and fabricated in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, Article NG-3200 [2.2] and the alternative provisions to the ASME Code as described in Table P.3.1-2. *The design criteria for the Type 3 basket is discussed in Section P.2.2.5.1.3.*

The NUHOMS®-24PTH DSC design, fabrication and testing are covered by TN America's Quality Assurance Program, which conforms to the criteria in Subpart G of 10 CFR Part 72.

The NUHOMS®-24PTH DSC is designed to withstand the effects of severe environmental conditions and natural phenomena such as earthquakes, tornadoes, lightning and floods. Appendix P.11 describes the NUHOMS®-24PTH DSC behavior under these accident conditions.

#### P.2.5.2 HSM-H Design Criteria

The principal design criteria for the NUHOMS® HSM-H module and steel support structure are presented in Table P.2-18. The load combination and design criteria for concrete and support structure components are the same as those described in Chapter 3, Section 3.2.5.1. These criteria, provided in Chapter 3, Tables 3.2-4, 3.2-5, 3.2-8 and 3.2-10 are also applicable to the HSM-H design.

## P.2.6 References


2.1 NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems at a General License Facility," Revision 1, July 2010.

2.2 American Society of Mechanical Engineers, ASME Boiler And Pressure Vessel Code, Section III, Division 1 - Subsections NB, NG and NF, 1998 edition including 2000 Addenda.

2.3 Young, W.C., "Roark's Formulas for Stress and Strain," 6th Edition, McGraw-Hill Book Company, New York, 1989.

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

2.5 Deleted.

2.6 "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76, U.S. Atomic Energy Commission, April 1974.

2.7 "Missiles Generated by Natural Phenomenon," Standard Review Plan, NUREG-0800, U.S. Nuclear Regulatory Commission.

2.8 American Society of Civil Engineers, ASCE 7-95, "Minimum Design Loads for Buildings and Other Structures" (formerly ANSI A58.1).

2.9 ANSI/ANS 57.9-1984, "Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type)," American Nuclear Society.

2.10 Title 10, Code of Federal Regulations, Part 72 (10CFR72), "Licensing Requirements for the Storage of Spent Fuel in the Independent Spent Fuel Storage Installation," U.S. Nuclear Regulatory Commission, August 31, 1988.

2.11 Regulatory Guide 1.60, "Design Response Spectra for Seismic Design of Nuclear Power Plants," U.S. Atomic Energy Commission, Revision 1, December 1973.

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

2.13 Bechtel Topical Report, "Design of Structures for Missile Impact," BC-TOP-9-A, Revision 2, September 1974.

*2.14 CoC 1042, Updated Final Safety Analysis Report (UFSAR) for the NUHOMS® EOS System, Revision 3, June 2020.*

*2.15 AREVA TN Technical Report, "Evaluation of Creep of NUHOMS® Basket Aluminum Components under Long Term Storage Conditions," E-25768, Rev. 0 (Structural Integrity Associates, Inc. File No. TNI-20Q-302, Rev. 0).*

2.16 *American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1 - Subsection NG, 2010 edition including 2011 Addenda.*

2.17 *American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section II, Materials Specifications, 2010 edition including 2011 Addenda.*

2.18 *CoC 1004 Technical Specifications for the Standardized NUHOMS® Horizontal Modular Storage System, Amendment 18.*

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-11 [1.TS].***

**Figure P.2-1**

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-12 [1.TS].***

**Figure P.2-2**

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-13 [1.TS].***

**Figure P.2-3**

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-14 [1.TS].***

**Figure P.2-4**

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-15 [1.TS].***

**Figure P.2-5**

***The detailed information associated with this figure can be found in Technical Specifications Figure 1-16 [1.TS].***

**Figure P.2-6**

**The detailed information associated with this figure can be found in Technical Specifications *Figure* 1-15a [1.TS].**

**Figure P.2-9**

# P.3 Structural Evaluation

## P.3.1 Structural Design

### P.3.1.1 Discussion

This section describes the structural evaluation of the NUHOMS®-24PTH system. The NUHOMS®-24PTH system consists of the NUHOMS® 24PTH DSC basket and shell assemblies, the HSM-H and HSM Model 102, and the OS197/OS197H/OS197FC Transfer Casks (TCs). The 24PTH DSC is a dual purpose canister that is designed to accommodate up to 24 intact PWR fuel assemblies (or up to 12 damaged assemblies, with the remaining intact) with total heat load of up to 40.8 kW. The HSM-H is an enhanced version of the NUHOMS® Standardized HSM and incorporates design features to enable storage of the higher heat load 24PTH DSC. The OS197FC TC is the OS197/OS197H TC with a modified top lid to improve the TC's thermal performance for the higher thermal loads during transfer.

The 24PTH DSC may also use the OS200 on-site transfer cask (TC) for transfer operations and the HSM-HS for storage operations. The HSM-HS is a "high seismic" HSM version for use in high seismic regions. The OS200 TC and HSM-HS components are described and evaluated in UFSAR Appendix U for transfer and storage of the 32PTH1 DSC. The 32PTH1 DSC bounds the loaded DSC weight and total heat load of the 24PTH; therefore, the Appendix U evaluations form the basis for acceptance of the 24PTH DSC in the OS200 TC and HSM-HS. Other transfer/storage component combinations are also acceptable, e.g., use of the OS197 TC with the HSM-HS storage module or the OS200 TC with the HSM (Model 102) or HSM-H, since the 24PTH DSC has been evaluated for transfer and storage in each of these components.

Certain modifications are made to the licensed OS200 TC and HSM-HS in order to enable their use with the smaller diameter 24PTH DSC. These modifications are summarized below:

1. When used with the 24PTH DSC, the OS200 TC is fitted with an internal aluminum sleeve that renders the radial gap between the 24PTH DSC outer diameter and the inside diameter of the OS200 TC equal to the gap when the 24PTH DSC is in the OS197 TC. The thermal evaluation of the 24PTH with the OS200 TC fitted with the internal sleeve is described in Section P.4.6.8. This evaluation shows that the thermal performance of the 24PTH DSC loaded in the OS200 TC fitted with the aluminum sleeve remains bounded by that of the 24PTH DSC in the OS197 TC. Therefore, the thermal stress results of the 24PTH in the OS197 TC remain applicable when the 24PTH DSC is used with the OS200 TC.

2. The OS200 TC sleeve provides radial support to the 24PTH DSC that is equivalent to that in the OS197 TC. Furthermore, the sleeve design is designed such that the cask support rails are maintained at the same locations as in the OS197 TC (at ± 18.5 from the bottom centerline of the TC), as shown in Section A-A, drawing NUH-08-8004-SAR in Section U.1.5 of Appendix U. These design features make the OS200 TC equivalent to the OS197 TC. Therefore, the existing stress analyses of the 24PTH DSC in the OS197 TC for normal, off-normal, and accident conditions documented in this appendix remain applicable when the 24PTH DSC is transferred in the OS200 TC.

3. The licensed HSM-HS design as described in UFSAR Appendix U is modified to allow use of the HSM-HS with the smaller diameter 24PTH DSC. These design modifications are consistent with those for smaller diameter DSCs shown for the HSM-H in Section P.1.5 and shown in the HSM-HS drawings in Appendix U, Section U.1.5. An assessment of the thermal performance of the 24PTH when stored in the HSM-HS is described in Section P.4.1 and concludes that the existing thermal evaluation of the 24PTH DSC remains applicable when the 24PTH DSC is stored in the HSM-HS. Therefore, the associated thermal stress results of the 24PTH DSC remain applicable when the 24PTH DSC is stored in the HSM-HS.

The generic term "transfer cask" or "TC", as used in this Chapter, refers to the OS197/OS197H/OS200 transfer cask, except when a specific transfer cask configuration is called out. Similarly, when the generic term HSM is used, it is meant to refer to any of the applicable HSMs (Models 102/HSM-H/HSM-HS) except when a specific HSM configuration is called out.

*Both the Alternates 1 and 2 of the Bottom Forging Type 5 for the 24PTH-S-LC DSC consist of components including the grapple ring support and outer bottom cover plate, for which the thicknesses are no smaller than those for the configuration of the 24PTH-S-LC DSC considered in the stress analyses presented in Sections P.3.6 and P.3.7. Therefore, the analysis results for the 24PTH DSC remain applicable.*

Where the new components have an effect on the structural evaluations presented in the FSAR, the changes are included in this section. Sections that do not have an effect on the evaluations presented in the FSAR include a statement that there is no change to the FSAR. In addition, a complete evaluation of the 24PTH DSC shell assembly and basket components and the HSM-H has been performed and is summarized in this section. This section also summarizes the OS197FC TC stress evaluation of the modified top cask lid, and the TC evaluations for the thermal profiles associated with the higher heat loads. The TC's thermal stress evaluations are applicable to the OS197/OS197H/OS197FC TCs for heat loads above 24 kW.

P.3.1.1.1 General Description of the 24PTH DSC

The 24PTH DSC shell assembly is shown on drawings NUH-24PTH-1001-SAR and NUH-24PTH-1002-SAR provided in Section P.1.5. Figure P.1.1-1 shows a schematic view of the 24PTH DSC.

There are three design types configurations for the 24PTH DSC, as shown in *Table P.1-1 and described in Chapter P.1. In addition, the introduction to Chapter P.1 describes six system configurations that provide a summary of the interfaces with other NUHOMS® System components.*

*24PTH DSC Shell Assembly*

The NUHOMS®-24PTH DSC shell assembly is the same as the NUHOMS®-24P DSC (or the 24P Long Cavity DSC) with the following exceptions:

- The nominal DSC shell thickness is reduced to 0.5 inch thick from 0.625 inch thick.
- The nominal thickness of the outer top cover plate is increased from 1.25 inches to 1.50 inches.
- The nominal thickness of the inner top cover plate is increased from 0.75 inches to 1.25 inches (for 24PTH-S and –L DSCs) or replaced by an integral inner top forging/lead shield plug design (for the 24PTH-S-LC DSC), similar to the 24PT4 DSC [3.17].
- For the 24PTH-S and –L DSCs, the nominal thickness of the inner bottom cover plate is increased from 0.75 inches to 1.75 inches and is designed for the internal pressure loads without taking credit for the structural support of the bottom shield plug and outer bottom cover plate. An optional configuration is added for the inner bottom cover plate that allows the use of a forging to provide the same structural function as the plate design. Also, a single forging 7.50-inch thick (equal to the sum of the individual bottom plates and bottom shield plug) is also allowed. For the 24PTH-S-LC DSC, a bottom forging and outer bottom cover plate are used to encapsulate the lead shield plug.

- The nominal thickness of the top shield plug is reduced from 8.25 inches to 6.25 inches for the 24PTH-S and 24PTH-L. For the 24PTH-S-LC DSC an integral inner top forging/lead shield plug is implemented.
- The nominal thickness of the bottom shield plug is reduced from 6.25 inches to 4.00 inches for the 24PTH-S and 24PTH-L. For the 24PTH-S-LC an integral inner bottom forging/lead shield plug is implemented.
- A test port has been added to the outer top cover plate to allow testing of the inner top cover plate welds and vent and siphon port cover plate welds to a leak tight criteria.

***24PTH DSC Basket Assembly***

*The 24PTH DSC basket is provided with three alternate options: with aluminum inserts in the R45 transition rails (Type 1), without aluminum inserts (Type 2), and with interlocking slotted plates (Type 3). In addition, depending on the boron content in the basket poison plates, each basket type is designated as type A, B, C, or D which results in seven different basket types (types 1A, 1B, 1C, 2A, 2B, 2C, and 3D).*

The NUHOMS®-24PTH *Types 1 and 2* basket assembly is shown on drawings NUH-24PTH-1003-SAR and -1004-SAR provided in Section P.1.5. The basket assembly consists of 24 stainless steel tubes that make up a fuel compartment structure designed to accommodate up to 24 PWR fuel assemblies. The basket assembly consists of the fuel compartment structure, made up of the steel tubes, and the transition rails. Sandwiched in between the tubes are aluminum alloy 1100 plates used as heat transfer material, and neutron absorbing plates for criticality control. The tubes are welded at 8 elevations along the axial length of the basket to stainless steel insert (strap) plates. The aluminum and neutron absorbing plates, which are arranged in an egg crate configuration, are separated along the basket length by the steel insert plates. No credit is taken for the structural capacity of the aluminum heat transfer plates or neutron absorbing materials in the structural evaluation except for through-thickness bearing (compression) loads.

The basket transition rails provide the transition between the "rectangular" fuel support compartment tubes and the cylindrical internal diameter of the DSC shell. There are two types of transition rails. The aluminum rails, located on the 0º, 90º, 180º and 270º axes, are referred to as the "R90" transition rails. The steel transition rails are located on the 45º, 135º, 225º and 315º axes, and are referred to as the "R45" transition rails.

The R90 transition rails are made from sections of 6061 aluminum alloy. The structural evaluation of these rails uses properties for annealed aluminum (no credit is taken for enhanced properties obtained by heat treatment).

The R45 steel transition rails are welded steel structures fabricated with 3/8" thick Type 304 stainless steel. The stiffener plates are 3/8" thick, which are welded at 15 locations along the axial length of each rail.

No credit is taken for the aluminum inserts in the structural evaluation of the steel transition rails.

*The 24PTH Type 3 basket assembly is shown on drawings NUH-24PTH-S-5012-SAR, NUH-24PTH-L-5012-SAR, and NUH-24PTH-S-LC-5012-SAR. The Type 3 basket is made up of interlocking, slotted plates to form an egg-crate type structure, resulting in no welds in the basket assembly. Extruded aluminum transition rails are bolted to the perimeter of the grid plate assembly. Each of the R90 transition rails is composed of two solid aluminum sections held with tie rods, and each of the R45 transition rails is a closed section reinforced with internal steel angle plates.*

*For the Types 1 and 2 basket, the* connections between the transition rails and fuel compartment tubes are not required to maintain structural capacity of the basket assembly. These connections allow free thermal expansion of the connected parts and are designed primarily to enhance thermal performance, and simplify fabrication.

The basket structure is open at each end such that longitudinal fuel assembly loads are applied directly to the DSC/cask body and not to the basket structure. The fuel assemblies are laterally supported by the fuel compartment tube structure, which is laterally supported by the basket transition rails and the DSC inner shell.

Inside the TC, the DSC rests on two 3" wide rails ("cask rails"), attached to the inside of the TC at +/-18.5° from the bottom centerline of the DSC. In the HSM-H and HSM Model 102, the DSC is supported by rails located at +/-30° from the bottom centerline of the DSC.

The nominal open dimension of each fuel compartment cell is 8.90 in. x 8.90 in. This cross section dimension is sufficient to allow insertion of the controlling fuel assembly with enough clearance. The overall basket length is less than the DSC cavity length to allow for thermal expansion and tolerances.

The 12 fuel compartment tubes around the perimeter of the basket may be loaded with damaged fuel. End caps are installed at the bottom and top of the basket fuel compartment tube cells to contain the damaged fuel. These end caps are shown in drawing NUH24PTH-1003-SAR *for the Types 1 and 2 basket and in drawing NUH24PTH-5013-SAR for the Type 3 basket* included in Section P.1.5.

P.3.1.1.2 General Description of the HSM-H

The HSM-H is a freestanding reinforced concrete structure designed to provide environmental protection and radiological shielding for the 24PTH-DSC. The HSM-H is designed to accommodate all three 24PTH DSC configurations (24PTH-S DSC, 24PTH-L DSC, and 24PTH-S-LC DSC). Each HSM-H provides a self contained modular structure for the storage of a 24PTH-DSC containing up to 24 PWR SFAs. The HSM-H provides heat rejection from the spent fuel decay heat by a combination of radiation, conduction and convection. Schematic sketches of the HSM-H showing the different components are provided in Figure P.1.1-2 and Figure P.1.1-3. Drawing NUH-03-7001-SAR, included in Section P.1.5, provides the nominal dimensions, materials of construction, and design parameters of the HSM-H.

The HSM-H is a reinforced concrete structure consisting of two separate units: a base, where the 24PTH-DSC is stored, and a roof that serves to provide environmental protection and radiation shielding. The roof is attached to the base by 4 vertical ties or by 4 angle brackets. Three-foot thick shield walls are installed behind each HSM-H (single row array only) and at the ends of each row to provide additional shielding and protection against missile impact.

The HSM-H modules may be prefabricated offsite, then transported to the ISFSI site and installed on a reinforced concrete basemat. The HSM-Hs are placed next to adjacent module(s) to form continuous single or double row (back-to-back) arrays. An array must have a minimum of two HSM-Hs in a row in order to meet stability requirements under the postulated design loads.

P.3.1.2.2 24PTH DSC Basket

The basket is designed to meet heat transfer, nuclear criticality, and structural requirements. The basket structure provides sufficient rigidity to maintain a subcritical configuration under the applied loads. The stainless steel fuel compartment tube sections in the NUHOMS®-24PTH *Types 1 and 2* basket are the primary structural components. *For the Type 3 basket, high strength low alloy (HSLA) steel compartments are used.* The aluminum heat transfer plates and neutron poison plates are the primary heat conductors, and provide the necessary criticality control. The stress analyses of the basket do not take credit for the neutron absorbing/heat transfer plate material. The transition rails provide support to the fuel compartment tube structure for mechanical loads and also transfer heat from the fuel compartment tubes to the DSC shell.

*For Types 1 and 2 basket, the* basket structural design criteria is provided in Section P.2.2. The basis for the allowable stresses for the stainless steel components in the basket assembly is Section III, Division 1, Subsection NG of the ASME Code [3.1]:

- Normal conditions are evaluated using criteria from NG-3200.
- Accident conditions are classified as Level D events and are evaluated using stress and stability criteria from Section III, Appendix F of the ASME Code [3.1].

*Structural design criteria for the Type 3 basket are provided in Section P.2.2.5.1.3.*

P.3.1.2.3 Alternatives to the ASME Code for the 24PTH DSC

The primary confinement boundary of the NUHOMS®-24PTH DSC consists of the DSC shell, the inner top cover plate, the inner bottom cover plate, (or the inner top and bottom forgings for the 24PTH-S-LC), the siphon and vent block, and the siphon/vent port cover plates. Even though the ASME B&PV code is not strictly applicable to the DSC, it is Transnuclear's (TN's) intent to follow Section III, Subsection NB of the Code as closely as possible for design and construction of the confinement vessel. The DSC may, however, be fabricated by other than N-stamp holders and materials may be supplied by other than ASME Certificate Holders. Thus the requirements of NCA are not imposed. TN's quality assurance requirements, which are based on 10CFR72 Subpart G and NQA-1 are imposed in lieu of the requirements of NCA-3800. The SAR is prepared in place of the ASME design and stress reports. Surveillances are performed by TN and utility personnel rather than by an Authorized Nuclear Inspector (ANI).

The basket is designed, fabricated and inspected in accordance with the ASME Code Subsection NG. The following alternative provisions to the ASME Code Section III requirements are taken:

The poison plates, and aluminum heat transfer plates are not considered for structural integrity. Therefore, these materials are not required to be Code materials. The quality assurance requirements of NQA-1 is imposed in lieu of NCA-3800. The basket is not Code stamped. Therefore, the requirements of NCA are not imposed. Fabrication and inspection surveillances are performed by TN and utility personnel rather than by an ANI.

A complete list of the alternatives to the ASME Code and corresponding justification for the NUHOMS®-24PTH DSC and basket is provided in Table P.3.1-1 and Table P.3.1-2. respectively.

## Table P.3.2-1
## Summary of the NUHOMS®-24PTH System Component Nominal Weights

(with HSM (Model 102), HSM-H and OS197 TC)

| Component Description | CALCULATED WEIGHT (kips) (1) | | | |
|---|---|---|---|---|
| | 24PTH-S | 24PTH-L | 24PTH-S-LC | Line Number |
| DSC Shell Assembly(2) | 13.1 | 13.3 | 12.2 | 1 |
| DSC Top Shield Plug Assembly(3) | 8.8 | 8.8 | 9.7 | 2 |
| DSC Internal Basket Assembly(4) | 30.1/26.7/*23.0* | 31.2/27.6/*23.8* | *NA*/27.2/*23.5* | 3 |
| **Total Empty Weight(4)** | **52.0/48.6/*44.9*** | **53.3/49.7/*45.9*** | *NA*/**49.1/*45.4*** | 4=1+2+3 |
| 24 PWR Spent Fuel Assemblies(5) | *≤40.4/≤40.4/≤41.2* | *≤40.4/≤40.4/≤41.2* | *≤40.4/≤40.4/≤41.2* | 5 |
| **Total Loaded DSC Weight (Dry) (4)** | **92.4/89.0/*86.1*** | **93.7/90.1/*87.1*** | *NA*/**89.5/*86.6*** | 6=4+5 |
| Water in Loaded DSC(6) | 4.2/*4.2/4.8* | 4.7/*4.7/5.3* | *NA*/5.6/*5.0* | 7 |
| **Total Loaded DSC Weight (Wet) (4)** | **96.6/93.2/*90.9*** | **98.4/94.8/*92.4*** | *NA*/**95.1/*91.6*** | 8=6+7 |
| TC Spacer | 1.1 | 0.8 | -- | 9 |
| TC Empty Weight(7) | 111.3/106.7 | 111.3/106.7 | *111.3*/106.7 | 10 |
| **Total Loaded TC Weight(4)(7)** | **204.8/196.8** | **205.8/197.6** | ***200.8*/196.2** | 11=6+9+10 |
| HSM-H Single Module Weight Max. (Empty)<br>HSM Model 102(8) | **306.1** | **306.1** | **306.1**<br>**263.0** | 12 |
| HSM-H Single Module Weight Max. (Loaded)<br>HSM Model 102(8) | **398.5** | **399.8** | **395.6**<br>**352.5** | 13=6+12 |

**Notes:**

1. All numbers are rounded up to the next hundred pounds
2. Excludes top cover plates and shield plug.
3. Includes top cover plates and shield plug.
4. *Weights provided are for the Type 1/Type 2/Type 3 baskets. For the 24PTH-S-LC, the Type 1 basket is not applicable.*
5. Based on B&W 15x15 fuel weight of 1,682 lbs *and 1,715 lbs* per assembly (with control components) *for Types 1 and 2 basket and Type 3 basket, respectively*.
6. Weights listed correspond to weight of water in DSC after draining 640 gallons (5,476 lbs) for hydrogen control. Total weight of water in the DSC is 9.7 kips, 10.2 kips, and 11.1 kips for 24PTH-S, 24PTH-L, and 24PTH-S-LC, *Types 1 and 2* respectively. *The water weight without aluminum inserts is conservatively considered for both Types 1 and 2 baskets. Total weight of water in the DSC for 24PTH-S, 24PTH-L, and 24PTH-S-LC Type 3 DSCs is 10.3 kips, 10.8 kips, and 10.5 kips, respectively*
7. *Includes the TC top cover plate. The TC weights provided in line 10 are with and without the weight of demineralized water in the neutron shield. The TC loaded weight (line 11) is provided using the heaviest DSC from line 6.*
8. The 24PTH-S-LC DSC can also be stored in the HSM Model 102. The weight for Model 102 is from Table 8.1-4.

## P.3.3 Mechanical Properties of Materials

### P.3.3.1 24PTH DSC Material Properties

The DSC shell and inner and outer top and bottom cover plates are fabricated from Type 304 stainless steel. The 24PTH-S-LC DSC shell assembly's top and bottom ends are fabricated from stainless steel forgings (material specification SA182 Type F304). Properties of the forging material are the same as the Type 304 plate material. The properties for the Type 304 material are from ASME Code Section II Part D [3.2] and are listed in Table P.3.3-1.

The 24PTH-S and 24PTH-L top and bottom shield plugs are fabricated from A36 carbon steel or Type 304 stainless steel. The properties for A36 carbon steel used in the analysis are from ASME Code Section II Part D [3.2], as listed in Table P.3.3-2. The 24PTH-S-LC top and bottom end steel forgings encase the lead shield plug material (ASTM B29). Properties for the ASTM B29 lead are in Table P.3.3-3.

*For the 24PTH Types 1 and 2 basket, the* fuel compartment tubes are fabricated with Type 304 stainless steel. The properties of this material are from ASME Code Section II, Part D [3.2] and are listed in Table P.3.3-1.

The steel transition rails (R45 rails) in the 24PTH *Types 1 and 2* basket are fabricated with Type 304 stainless steel. The properties of this material are from ASME Code Section II, Part D [3.2] and are listed in Table P.3.3-1.

*For the 24PTH Types 1 and 2 basket, the* aluminum transition rails (R90 rails) use sections of Type 6061 aluminum. Analysis properties are taken from [3.3] for annealed aluminum. Use of properties for annealed material ensures that no credit is taken for enhanced properties obtained by heat treatment. The selection of properties for annealed material is based on the possibility that the maximum temperature in the rails may exceed the temperatures for which strength properties are provided (for aluminum) in the ASME Code (see Table P.3.3-4). This is acceptable for the following reasons:

The R90 transition rails are not pressure boundary parts. Loading on the rails is primarily bearing and the transition rails are "captured" between the fuel compartment tube structure and the DSC shell. Deformation of the transition rails (to conform to the inside diameter of the DSC shell) will distribute the applied loads and will not adversely impact the basket structure.

For applications where the aluminum properties result from heat treatment, it is necessary to limit the maximum temperature to values below which the effects of the heat treatment are maintained. Heat treatment provides significant differences in strength properties at low temperatures. However, as temperature increases, the effect(s) of heat treatment on strength properties decreases. The strength properties used in the design of the 24PTH are based on annealed aluminum. Thus, changes in strength which may occur under exposure to temperatures exceeding 400°F have no adverse impact on the properties used in the design.

For the stress analyses of the 24PTH DSC, material properties for the Type 304 steel materials are taken from Table P.3.3-1. For elastic-plastic analyses, the plastic slope is taken as 0.05E (5% of the elastic modulus at temperature). Figure P.3.3-1 shows the stress-strain relationship used for the elastic-plastic analysis. Properties for the aluminum rails are taken directly from Table P.3.3-5 [3.3]. For elastic-plastic analyses, the plastic slope of the aluminum is taken as 0.01E. This approximates elastic-perfectly plastic properties while providing a small stiffness to enhance *numerical* stability.

Table P.3.3-6 provides additional material properties.

*For the Type 3 basket, the primary structural material for the fuel compartments is a high-strength low-alloy (HSLA) steel. Basket component stress intensity allowables used for the evaluation of normal and off-normal conditions (ASME Code Service Level A and B) are developed based on the mechanical properties ($S_u$ and $S_y$) listed in Table P.3.3-10. A strain-based criterion is used for evaluation of the basket for accident conditions (Service Level D). Thus, the basket is regarded as a non-ASME Code component. If ASTM 829 Gr 4130 is used, ORANO test report [3.42], which is Reference 3.9.2-5 of CoC 1042 [3.46] and provides material qualification and testing requirements for ASTM 829 Gr 4130, determines the optimum tempering for the desired toughness and the corresponding minimum yield and tensile strength. The A829 Gr 4130 steel plates are heat-treated and tempered per* **[**

**]** *Specification and acceptance testing of the HSLA steel are included in Section P.9.1.8.*

*The aluminum plates in the basket perform only a heat conducting function with no credit taken for their strength in supporting the fuel in the various loading conditions. The aluminum 6061 peripheral transition rails are entrapped between the fuel compartment structure and the DSC shell. For normal and off-normal loading conditions the primary stresses are limited to $S_y$. For accident conditions, qualification of the fuel compartment demonstrates that the rails perform their structural support safety function. The transition rails are specified as ASTM B221 or B209 Alloy 6061. The important-to-safety (ITS) Cat C rail fasteners are specified as ASTM A564 TYPE 630 H1100 material. The mechanical properties for the aluminum 6061 used for the basket transition rails are taken in the annealed (T0) condition to consider the effect of creep due to long term storage at the service temperature near 400 °F. Therefore, the material may be supplied in any temper condition. Creep behavior of these rails is discussed in Section P.3.8.6.6.*

*The fixed neutron absorber plates are composed of boron carbide/aluminum metal matrix composite. These materials perform no structural function in supporting the fuel in the various loading conditions. They are subject to TN Americas specification and acceptance testing described in Section P.9.1.7*

*The properties of the materials used in the 24PTH Type 3 basket are listed in Table P.3.3-10 through Table P.3.3-13.*

### P.3.3.2 HSM-H Material Properties

The temperature dependent material properties for concrete and reinforcing steel are taken from [3.26] and are provided in Table P.3.3-7 and Table P.3.3-8 respectively.

The material properties of the ASTM A992 steel used for fabrication of the rails of the support structure are listed in Table P.3.3-9. The material properties used for the Type 304 stainless steel used for the heat shield support plate and the A36 steel used for the rail assembly extension plates are provided in Table 8.1-3. The heat shield fins, the aluminum backing sheet, and the louvered heat shield are made of commercial grade aluminum.

### P.3.3.3 Materials Durability

The materials used in the fabrication of the NUHOMS®-24PTH system are shown in Table P.3.3-1 through Table P.3.3-9. Essentially all of the materials meet the appropriate requirements of the ASME Code, ACI Code, and appropriate ASTM Standards. The durability of the DSC shell assembly and basket assembly stainless steel components and the HSM-H steel components is well beyond the design life of the applicable components. The aluminum material used in the basket is only relied upon for its thermal conductivity and bearing strength properties. The poison material selected for criticality control of the NUHOMS®-24PTH system has been tested and is currently in use for similar applications. Additionally, the NUHOMS®-24PTH basket assembly resides in an inert helium gas environment for the majority of the design life. The specifications controlling the mix of concrete, specified minimum concrete strength requirements, and fabrication control ensure durability of the materials for this application. Therefore, the materials used in the NUHOMS®-24PTH system will maintain the required properties for the design life of the system.

## *Table P.3.3-10*
## *Materials Properties, High Strength Low Alloy Steel*

| Temp (°F) | $E^{(1)}$ ($10^3$ ksi) | $S_y$ (1)(3) (ksi) | $S_u$ (1)(4) (ksi) | Thermal Expansion $10^{-6}$ in/(in-°F) (1)(5) | Thermal Conductivity Btu/(hr-ft-°F) (1)(5) | Specific Heat Btu/(lb-°F) (1) | Density lbs/$in^3$ |
|---|---|---|---|---|---|---|---|
| -20 | 29.3 | 100.2 | 105.2 | | | | 0.283(1) |
| 70 | 29.0 | 96.4 | 101.2 | | | | |
| 100 | 28.9 | 95.4 | 100.2 | 6.50 | 23.6 | | |
| 200 | 28.4 | 91.6 | 96.2 | 6.70 | 23.5 | 0.110 | |
| 300 | 28.0 | 87.7 | 92.1 | 6.90 | 23.4 | | |
| 400 | 27.6 | 83.9 | 88.1 | 7.10 | 23.1 | 0.120 | |
| 500 | 27.0 | 80.0 | 84.0 | 7.30 | 22.7 | | |
| 600 | 26.2 | 76.1 | 79.9 | 7.40 | 22.2 | 0.130 | |
| 700 | 25.2 | 71.3 | 74.9 | 7.60 | 21.6 | | |
| 800 | 24.1 | 66.0 | 69.3 | 7.80 | 21.0 | 0.145 | |

*Notes:*
*(1) Listed values for yield stress calculated from rate of reduction provided in Figure 2.3.1.1.1, Figure 2.3.1.1.4 for modulus of elasticity, and Figure 2.3.1.0 for thermal properties from Reference [3.43].*
*(2) Listed values based on Reference [3.43].*
*(3) Yield stress values calculated based on 80 ksi @ 500 °F.*
*(4) Ultimate strength conservatively determined based on 1.05 Sy. However, ultimate strength values 20% greater than those listed above may be used provided that they are supported by test data.*
*(5) Thermal expansion and thermal conductivity values conservatively represents the lower numbers for high strength low alloy steels (such as ASTM A829 Gr. 4130 or ASME SA-517 Gr A, B, E or P).*

## *Table P.3.3-11*
## *Material Properties – SA-516 Gr 70 and ASTM A516 Gr 70*

| Temp (°F) | $S_m$ (ksi) | $S_y$ (ksi) | $S_u$ (ksi) | E ($10^3$ ksi) | $\alpha_{INST}$ ($10^{-6}$ °$F^{-1}$) | $\alpha_{AVG}$ ($10^{-6}$ °$F^{-1}$) | ρ (lb/$in^3$) | K (Btu/hr-ft-°F) | $C_p$ (Btu/lb-°F) |
|---|---|---|---|---|---|---|---|---|---|
| -100 | -- | -- | -- | 30.3 | -- | -- | -- | -- | -- |
| -20 – 100 | 23.3 | 38.0 | 70.0 | -- | -- | -- | | | |
| 70 | -- | -- | -- | 29.4 | 6.4 | 6.4 | | 34.9 | 0.103 |
| 100 | -- | -- | -- | -- | 6.6 | 6.5 | | 34.7 | 0.106 |
| 150 | 23.3 | 35.7 | -- | -- | 6.8 | 6.6 | | 34.2 | 0.110 |
| 200 | 23.2 | 34.8 | 70.0 | 28.8 | 7.0 | 6.7 | | 33.7 | 0.114 |
| 250 | -- | 34.2 | -- | -- | 7.2 | 6.8 | | 33.0 | 0.117 |
| 300 | 22.4 | 33.6 | 70.0 | 28.3 | 7.3 | 6.9 | | 32.3 | 0.119 |
| 350 | -- | -- | -- | -- | 7.5 | 7.0 | | 31.6 | 0.122 |
| 400 | 21.6 | 32.5 | 70.0 | 27.9 | 7.7 | 7.1 | 0.280 | 30.9 | 0.124 |
| 450 | -- | -- | -- | -- | 7.8 | 7.2 | | 30.1 | 0.126 |
| 500 | 20.6 | 31.0 | 70.0 | 27.3 | 8.0 | 7.3 | | 29.4 | 0.128 |
| 550 | -- | -- | -- | -- | 8.2 | 7.3 | | 28.7 | 0.131 |
| 600 | 19.4 | 29.1 | 70.0 | 26.5 | 8.3 | 7.4 | | 28.0 | 0.134 |
| 650 | 18.8 | 28.2 | 70.0 | -- | 8.5 | 7.5 | | 27.3 | 0.136 |
| 700 | 18.1 | 27.2 | 70.0 | 25.5 | 8.7 | 7.6 | | 26.6 | 0.140 |
| 750 | -- | 26.3 | 69.1 | -- | 8.8 | 7.7 | | 26.0 | 0.143 |
| 800 | -- | 25.5 | 64.3 | 24.2 | 9.0 | 7.8 | | 25.3 | 0.147 |
| ASME | Table 2A p. 274 line 26 | Table Y-1 p. 546-547 Line 40 | Table U pg 465 | Table TM-1 C≤0.30% p. 738 | Table TE-1 p. 708 Group 1 | | Table PRD | Calculated from Table TCD p. 726, Group A | |

Source: ASME Section II, Part D – Properties, 2011a Edition [3.39]

## Table P.3.3-12
## Material Properties – Aluminum ASTM B221 or B209 Alloy 6061-O

| Temp (°F) | E ($10^3$ ksi) | Elongation in 4D, % | $S_u$ (ksi) | $S_y$ (ksi) | $\alpha_{AVG}$ ($10^{-6}$ °$F^{-1}$) | ρ (lb/in³) | K (Btu/hr-ft-°F) | $C_p$ (Btu/lb-°F) |
|---|---|---|---|---|---|---|---|---|
| -100 | | | | | | | | |
| -20 | | | | | | 0.098 | | |
| 70 | | | | | 12.1 | | 96.1 | 0.213 |
| 75 | 9.9 | 30 | 18.0 | 8.0 | | | | |
| 100 | | | | | 12.4 | | 96.9 | 0.215 |
| 150 | | | | | 12.7 | | 98.0 | 0.218 |
| 200 | | | | | 13.0 | | 99.0 | 0.221 |
| 212 | 9.5 | 30 | 18.0 | 8.5 | | | | |
| 250 | | | | | 13.1 | | 99.8 | 0.223 |
| 300 | 9.1 | 35 | 15.0 | 9.5 | 13.3 | | 100.6 | 0.226 |
| 350 | 8.9 | 45 | 12.0 | 8.5 | 13.4 | | 101.3 | 0.228 |
| 400 | 8.6 | 60 | 10.0 | 7.5 | 13.6 | | 101.9 | 0.230 |
| 450 | 8.3 | 75 | 8.5 | 6.0 | 13.8 | | | |
| 500 | 7.9 | 80 | 7.0 | 5.5 | 13.9 | | | |
| 550 | | | | | 14.1 | | | |
| 600 | 6.8 | 80 | 5.0 | 4.2 | 14.2 | | | |
| ASME | Kaufman, p. 163(1) | Kaufman, p. 163(1) | Kaufman, p. 163(1) | Kaufman, p. 163(1) | Table TE-2 p. 714 Aluminum Alloys | Table PRD p. 744 | Calculated based on Table TCD p. 735, group A96061 | |

*Source: ASME Section II, Part D – Properties, 2011a Edition [3.39]*

*Notes:*
*(1) Annealed values used for analysis are typical tensile properties from [3.44] p. 163.*
*(2) Mechanical properties are used for design of the basket peripheral transition rails. The thermal design analysis uses values for density, thermal conductivity, and heat capacity that are lower than those in this table.*
*(3) Thermal conductivity and heat capacity used in the design analyses are lower than those shown in the table.*

**Table P.3.3-13**
**Material Properties – SA-564 Gr. 630 H1100**

Nominal Composition: 17Cr-4Ni-4Cu

| Temp (°F) | $S_m$ (ksi) | S | $S_y$ (ksi) | $S_u$ (ksi) | E ($10^3$ ksi) | $\alpha_{INST}$ ($10^{-6}$ °F$^{-1}$) | $\alpha_{AVG}$ ($10^{-6}$ °F$^{-1}$) | ρ (lb/in$^3$) | K (Btu/hr-ft-°F) | $C_d$ (Btu/lb-°F) |
|---|---|---|---|---|---|---|---|---|---|---|
| -20 | 46.7 | 40.0 | | | | | | 484 | | |
| 70 | 46.7 | 40.0 | 115 | 140 | 28.5 | 5.3 | 5.3 | | 10 | 0.188 |
| 100 | 46.7 | 40.0 | 115 | 140 | -- | 5.4 | 5.4 | | 10.1 | 0.189 |
| 150 | -- | | 109.2 | -- | -- | 5.6 | 5.5 | | 10.3 | 0.189 |
| 200 | 46.7 | 40.0 | 106.3 | 140 | 27.8 | 5.7 | 5.5 | | 10.6 | 0.189 |
| 250 | -- | | 103.9 | -- | -- | 5.8 | 5.6 | | 10.9 | 0.19 |
| 300 | 46.7 | 40.0 | 101.8 | 140 | 27.2 | 6 | 5.7 | | 11.2 | 0.19 |
| 350 | -- | | -- | -- | -- | 6.1 | 5.7 | | 11.5 | 0.19 |
| 400 | 45.4 | 38.9 | 98.3 | 136.1 | 26.7 | 6.2 | 5.8 | | 11.7 | 0.19 |
| 450 | -- | | -- | -- | -- | 6.3 | 5.8 | | 12 | 0.19 |
| 500 | 44.5 | 38.1 | 95.2 | 133.4 | 26.1 | 6.4 | 5.9 | | 12.3 | 0.19 |
| 550 | -- | | -- | -- | -- | 6.4 | 5.9 | | 12.5 | 0.19 |
| 600 | 43.8 | 37.5 | 92.7 | 131.4 | 25.5 | 6.5 | 6.0 | | 12.8 | 0.189 |
| 650 | 43.4 | 37.2 | 91.5 | 130.1 | -- | 6.6 | 6.0 | | 13 | 0.188 |
| ASME | Table 2A p. 290 line 14 | Table 1A p. 48 Line 25 | Table Y-1 p. 582-583 Line 8 | Table U p. 479 Line 19 | Table TM-1 S17400 | Table TE-1 p. 710 Group F 17 Cr Steels | | Table PRD | Table TCD p. 727, Group I | |

Source: ASME Section II, Part D - Properties, 2011a Edition [3.39]

## P.3.4 General Standards for Casks

### P.3.4.1 Chemical and Galvanic Reactions

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

The 24PTH DSC is exposed to the following environments:

- During loading and unloading, the DSC is placed inside of the TC. The annulus between the cask and DSC is filled with demineralized water and an inflatable seal is used to cover the annulus between the DSC and cask. The exterior of the DSC will not be exposed to pool water.
- The space between the top of the DSC and inside of the TC is sealed to prevent contamination. For PWR plants the pool water is borated. This affects the interior surfaces of the DSC, the shield plug, and the basket. The TC and DSC are kept in the spent fuel pool for a short period of time, typically about 6 hours to load or unload fuel, and 2 hours to lift the loaded TC/DSC out of the spent fuel pool.
- During storage, the interior of the DSC is exposed to an inert helium environment. The helium environment does not support the occurrence of chemical or galvanic reactions because both moisture and oxygen must be present for a reaction to occur. The DSC is thoroughly dried before storage by a vacuum drying process. It is then backfilled with helium, thus stopping corrosion. Since the DSC is vacuum dried, galvanic corrosion is also precluded as no water is present at the point of contact between dissimilar metals.
- During storage, the exterior of the DSC is protected by the concrete NUHOMS® HSM Model 102 or HSM-H/HSM-HS. The HSM Model 102 and the HSM-H/HSM-HS is vented, so the exterior of the DSC is exposed to the atmosphere. The DSC shell and cover plates are fabricated from austenitic stainless steel and are resistant to corrosion.

The NUHOMS®-24PTH DSC materials are shown in the Parts List on Drawings NUH-24PTH-1001-SAR through NUH-24PTH-1004-SAR provided in Section P.1.5. The DSC shell material is SA-240 Type 304 Stainless Steel. The top and bottom shield plug material is A36 carbon steel. The top shield plug is coated with a corrosion resistant electroless nickel coating. Alternatively, the top shield plug may be fabricated from Type 304 stainless steel (without coating). The bottom shield plug is sealed within the shell and inner and outer bottom cover plates and, thus, it does not come in contact with the external environment. For the 24PTH-S-LC DSC, the shell assembly top and bottom ends include stainless steel-enclosed and sealed lead in the shield plugs. The lead is not exposed to the external environment and is thus not subject to any chemical reactions.

The *Types 1 and 2* basket fuel compartment structure is composed of tube assemblies made from Type 304 stainless steel. Sandwiched between the tube assemblies are plates of Type 1100 aluminum and neutron absorbing materials composed of either enriched borated aluminum alloy, natural boron, or Boral® plates. These plates are not fastened to the fuel compartment tube structure but are captured along the axial length of the basket by stainless steel insert plates (straps) that are welded to the fuel compartment tubes.

*For the Types 1 and 2 basket, there* are two types of transition rails that provide the transition between the fuel compartment structure and the DSC shell. The aluminum transition rails (R90 rails) are made of Type 6061 aluminum. The stainless steel rails (R45 rails) consist of welded Type 304 stainless steel plates with optional Type 1100 aluminum inserts between the stiffener plates. The transition rails are attached to the grid structure using corrosion resistant fasteners. Similarly, the optional Type 1100 aluminum inserts installed in between the stiffener plates in the R45 transition rails are attached using corrosion resistant fasteners.

*For the Type 3 basket, a typical stack-up of fuel compartment grid plates is composed of a high-strength low-alloy (HSLA) steel plate, a Type 1100 aluminum plate and a neutron absorber plate. The aluminum 6061 peripheral transition rails are entrapped between the fuel compartment structure and the DSC shell.*

Potential sources of chemical or galvanic reactions are the interaction between the aluminum, aluminum-based neutron poison and stainless steel within the basket and the pool water. Additionally, an interaction exists with the stainless steel top and bottom plates and the top shield plug.

**Behavior of Aluminum in Borated Water**

Aluminum is used for many applications in spent fuel pools. In order to understand the corrosion resistance of aluminum within the normal operating conditions of spent fuel storage pools, a discussion of each of the types of corrosion is addressed separately. None of these corrosion mechanisms is expected to occur in the short time period that the cask is submerged in the spent fuel pool.

***General Corrosion***

General corrosion is a uniform attack of the metal over the entire surfaces exposed to the corrosive media. The severity of general corrosion of aluminum depends upon the chemical nature and temperature of the electrolyte and can range from superficial etching and staining to dissolution of the metal. Figure P.3.4-1 shows a potential-pH diagram for aluminum in high purity water at 77°F and 140°F. The potential for aluminum coupled with stainless steel and the limits of pH for PWR pools are shown in the diagram to be well within the passivation domain at both temperatures. The passivated surface of aluminum (hydrated oxide of aluminum) affords protection against corrosion in the domain shown because the coating is insoluble, non-porous and adherent to the surface of the aluminum. The protective surface formed on the aluminum is known to be stable up to 275°F and in a pH range of 4.5 to 8.5.

The water aluminum reactions are self-limiting because the surface of the aluminum becomes passive by the formation of a protective and impervious coating making further reaction impossible until the coating is removed by mechanical or chemical means.

The ability of aluminum to resist corrosion from boron ions is evident from the wide usage of aluminum in the handling of borax and in the manufacture of boric acid. Aluminum storage racks with Boral plates (aluminum 1100 exterior layer) in contact with 800 ppm borated water showed only small amounts of pitting after 17 years in the pool at the Yankee Rowe Power Plant. These racks maintained their structural integrity.

***Stress Corrosion***

Stress corrosion is failure of the metal by cracking under the combined action of corrosion and stresses approaching the yield stress of the metal. During spent fuel pool operations, the 24PTH-DSC is upright and there is negligible load on the basket assembly. The stresses on the basket are small, well below the yield stress of the basket materials.

**Behavior of Austenitic Stainless Steel in Borated Water**

The fuel compartment structure is made from Type 304 stainless steel tubes and the transition rails that support the fuel compartments are made from aluminum Type 6061 (R90 rails) and welded Type 304 stainless steel plates (R45 rails). Stainless steel does not exhibit general corrosion when immersed in borated water. Galvanic attack can occur between the aluminum in contact with the stainless steel in the water. However, the attack is mitigated by the passivity of the aluminum and the stainless steel in the short time the pool water is in the DSC. Also the low conductivity of the pool water tends to minimize galvanic reactions.

Stress corrosion cracking in the Type 304 stainless steel welds of the basket is also not expected to occur, since the baskets are not highly stressed during normal operations. There may be some residual fabrication stresses as a result of welding of the stainless steel plates together.

Of the corrosive agents that could initiate stress corrosion cracking in the stainless steel basket welds, only the combination of chloride ions with dissolved oxygen occurs in spent fuel pool water. Although stress corrosion cracking can take place at very low chloride concentrations and at low temperatures such as those in spent fuel pools (less than 10 ppb and 160°F, respectively), the effect of low chloride concentration and low temperature greatly increases the induction time. That is, the time period during which the corrodent is breaking down the passive oxide film on the stainless steel surface is increased. Below 60°C (140°F), stress corrosion cracking of austenitic stainless steel does not occur at all. At 100°C (212 °F), chloride concentration on the order of 15% is required to initiate stress corrosion cracking [3.5]. At 288 °C (550 °F), with tensile stress at 100% of yield in PWR water that contains 100 ppm $O_2$, time to crack is about 40 days in sensitized 304 stainless steel [3.6]. Thus, the combination of low chlorides, low temperature and short time of exposure to the corrosive environment eliminates the possibility of stress corrosion cracking in the basket and DSC welds.

The chloride content of all expendable materials which come in contact with the basket materials are restricted and water used for cleaning the baskets is restricted to 1.0 ppm chloride.

*The HSLA steel plates of the Type 3 basket are* **[**

**]** *or alternative surface treatment will provide short-term corrosion protection, sufficient for the manufacturing process and short-term immersion in the pool. It can be expected that a small amount of rust will form, but this will be insufficient to affect the performance of design functions or to cause turbidity in pool water during loading operations.*

**Behavior of Aluminum Based Neutron Poison in Borated Water**

To investigate the use of borated aluminum in a spent fuel pool, tests were performed by Eagle Picher to evaluate its dimensional stability, corrosion resistance and neutron capture ability. These studies showed that borated aluminum performed well in a spent fuel pool environment.

The 1100 series aluminum component is a ductile metal having a high resistance to corrosion. Its corrosion resistance is provided by the buildup of a protective oxide film on the metal surface when exposed to a water or moisture environment. As stated above, for aluminum, once a stable

weight with a NUHOMS® 24PTH DSC loaded in the OS200 TC is approximately 229,500 lbs. Therefore, the OS200 cask is acceptable when loaded with any NUHOMS®-24PTH DSC.

P.3.4.4 Heat and Cold

P.3.4.4.1 Summary of Pressures and Temperatures

Temperatures and pressures for the 24PTH DSC and basket are calculated in Section P.4. Section P.4.4 provides the thermal evaluation of the HSM-H/HSM Model 102/HSM-HS. Section P.4.5 provides the thermal evaluation of the transfer cask. Section P.4.6 provides the thermal evaluation of the DSC. Section P.4.6.8 describes the thermal analysis of the OS200 TC with the 24PTH DSC.

Section P.4.6 also provides/addresses the maximum pressures during normal, off-normal and accident conditions which are used in the evaluations presented later in this Appendix.

The pressures and temperatures of the 24PTH DSC in the OS200 TC and HSM-HS have been evaluated and found to be bounded by those in the OS197/OS197H TCs and HSM-H as described in Section P.4.

P.3.4.4.2 Differential Thermal Expansion

Clearances are provided between the various components of the 24PTH DSC to accommodate differential thermal expansion and to minimize thermal stress. In the radial direction clearance is provided between the basket outer diameter and DSC cavity inside diameter, and between the poison/aluminum plates and the interfacing basket components. In the axial direction clearances are provided between the DSC cavity and all the basket parts *or the grid plates for the Type 3 basket*. Additionally, the connections between the transition rails and the fuel support structure are designed to permit relative axial growth.

- In the axial direction, required clearances are determined using hand calculations.
- In the "radial" direction, clearance between the neutron absorbing/aluminum heat transfer plate materials and the transition rails is evaluated using hand calculations.
- In the "radial" direction, clearance between the *Types 1 and 2* basket assembly was included in the LS-DYNA thermal stress analyses described in Section P.3.4.4.3.1. The normal and off- normal condition stress analyses are described in P.3.6 and the accident condition analyses are described in P.3.7. *The analyses for the Type 3 basket are described in P.3.8.* Thus, stresses due to any thermal interference are included in the stress results.

*P.3.4.4.2.1 Types 1 and 2 DSC Basket*

The thermal analyses of the basket for the handling/transfer and storage conditions are described in Section P.4.6. As described there, thermal analyses are performed to determine the temperature distributions in the 24PTH DSC for the following cases:

- Vacuum Drying Operations

| Relative Axial Thermal Growth (Vacuum Drying) | Component Growth (in) | Cavity Growth (in) | Required Clearance(1) (in) |
|---|---|---|---|
| Fuel Support Tube Structure to Cavity | 0.873/0.849 | 0.228/0.225 | 0.65/0.62 |
| R45 Steel Transition Rails to Cavity | 0.873/0.849 | 0.228/0.225 | 0.65/0.62 |
| R90 6061 Transition Rails to Cavity | 1.229/1.200 | 0.228/0.225 | 1.00/0.98 |

Notes: 1. The actual clearances provided in the design are 1.0 in. for the tube structure and R45 rails (steel components) and 2.0 in. for the R90 rails (aluminum components). Therefore, cavity clearance is adequate for thermal expansion.

The thermal expansion of the aluminum/poison plate segments, which are captured in between the steel straps (2.375 in. wide), along the axial length of the basket is calculated below:

**24PTH Axial Thermal Expansion, Vacuum Drying**

| Component | $T_{max}$ (°F) | $\alpha_{avg}$ (°F$^{-1}$) | L(1) (in) | ΔL (in) |
|---|---|---|---|---|
| Tube (24PTH-S/-L) | 580 | 9.8E-06 | 20.875. | 0.104 |
| Tube (24PTH-S-LC) | 573 | 9.8E-06 | 21.395 | 0.105 |
| Aluminum/ Poison Plates (24PTH-S/-L) | 572 | 1.41E-05 | 20.8 | 0.147 |
| Aluminum/ Poison Plates (24PTH-S-LC) | 567 | 1.41E-05 | 21.3 | 0.149 |

Notes: 1 For the tube L is the clear distance between steel straps. For the aluminum/poison plates, L is the height of the plate.

$$
\begin{aligned}
\Delta L_{Tube} &= \alpha_{steel} L_{segment} \Delta T \\
&= \left(9.80\ x\ 10^{-6} {}^\circ F^{-1}\right)\left(20.875\ in\right)\left(580^\circ F - 70^\circ F\right) \\
&= 0.104\ in
\end{aligned}
$$

The differential thermal expansion or required clearance is 0.147–0.104 = 0.04 inches, which is less than the 0.1 in. gap provided in the design.

*P.3.4.4.2.2* *Type 3 DSC Basket*

*Minimum Gaps within the Interlocking Slots*

*The NUH24PTH Type 3 DSC basket assembly is made up of interlocking slotted plates to form an egg-crate type structure. To avoid any interference between the perpendicular basket assembly plates, the location of slots within the aluminum/MMC plates should not extend past the location of the slots within the steel plates. The thermal expansion of the basket assembly plates is calculated as:*

$$L_{Hot,i} = L_{Cold,i} + [L_{Cold,i} \times \alpha_i(T_{avg,B} - T_{ref})]$$

*where*
$L_{Hot,i}$ = *Hot length of the steel plates* ($L_{Hot,St}$) *and the aluminum plates* ($L_{Hot,Al}$)
$L_{Cold,i}$ = *Cold length of the steel plates* ($L_{Cold,St}$) *and the aluminum plates* ($L_{Cold,Al}$)
$\alpha_i$ = *Thermal expansion coefficient of the steel* ($\alpha_{St}$) *and aluminum plates* ($\alpha_{Al}$) *at* $T_{avg,B}$
$T_{avg,B}$ = *Average temperature of the basket assembly plates based at hottest cross section*
$T_{ref}$ = *Reference ambient temperature*

*The effective net gap left for each slots within the steel plates and the aluminum/MMC plates is calculated as:*

$$\Delta_{Net\text{-}gap} = Minimum(L_{Hot\text{-}Steel\_max}, L_{Hot\text{-}Al\_max}) - Maximum(L_{Hot\text{-}Steel\_min}, L_{Hot\text{-}Al\_min})$$

*The effective net gaps left in slots within the composite plates is more than the total thicknesses of the composite plate at respective slots in hot condition. Therefore, there is no interference between intersecting plates.*

*Axial Gaps between the Basket Assembly Plates*

*To accommodate the axial thermal growth between the various basket assembly plates, the aluminum/MMC plates are designed to be smaller than the paired steel plates. Each aluminum/MMC plate and the steel plate have a nominal cold gap of* [ ] *and the hot gap between the steel and aluminum/MMC plates due to the axial thermal expansion of the basket assembly plates is* [ ] *There is sufficient clearance for the thermal growth of aluminum/MMC plates.*

*Radial Gap between the Basket Assembly and the DSC Shell*

*The minimum radial gap between the basket assembly and the DSC shell is* [ ] *Therefore, there is no interference between the basket assembly and the DSC shell.*

*Axial Gaps between Fuel Assemblies and the DSC Cavity*

*For the fuel assemblies loaded in the 24PTH Type 3 DSC, the bounding average fuel assembly temperature during normal/off-normal conditions of transfer and storage is lower than the average fuel assembly temperature considered in computation of thermal expansion and clearance between fuel assemblies and 24PTH Type 1 DSC. Therefore, no further analysis is required.*

*Axial Gap between the Basket Assembly and the DSC Cavity*

*The following steps present the methodology to determine a bounding cold gap between the basket assembly and the DSC cavity that will encompass any variations due to the different fuel assemblies.*

1. *The maximum hot lengths of the basket assemblies are calculated using the cold dimension.*

   $L_{BSK,S,Hot} = L_{BSK,S}[1+\alpha_{BSK}(T_{BSK} - 70)]=$ **[ ]**

   *where,*
   $\alpha_{BSK}$ = *Coefficient of thermal expansion of basket assembly (AISI 4130)*
   $T_{BSK}$ = *Average temperature of basket assembly*
   $L_{BSK,S}$ = *Cold length of the short basket assembly*
   $L_{BSK,S,Hot}$ = *Nominal hot length of the short basket assembly*

2. *Assuming a zero gap under hot conditions, the maximum hot length of the DSC cavity is assumed to be equal to the hot length of the basket assembly.*

   $L_{BSK,S,Hot} = L_{DSC,S,Hot}$

   *where*
   $L_{DSC,S,Hot}$ = *Nominal hot length of the DSC cavity*

3. *Using the hot length of the DSC cavity, the cold lengths of the DSC cavity are determined as:*

   $L_{DSC,S} = L_{BSK,S,Hot}/[1+\alpha_{DSC}(T_{DSC} -70)]$

   *where*
   $\alpha_{DSC}$ = *Coefficient of thermal expansion of DSC Shell*
   $T_{DSC}$ = *Average temperature of DSC shell*
   $L_{DSC,S}$ = *Cold length of the short DSC*

4. *The net gap at cold conditions between the DSC cavity and the basket assembly is determined.*

   $\Delta_{DSC\_S-BSK\_S} = L_{DSC,S} - L_{BSK,S}$

5. *As long as the cold gap calculated in Step 4 is maintained, there will be no interference under hot conditions. Similarly, for other configurations of the DSC, there will be no interference under hot conditions.*

*The bounding net cold gap is* **[ ]** *and, to bound any uncertainties, a minimum axial cold gap of* **[ ]** *is specified between the DSC cavity and the basket assembly.*

*Axial Gap between the Transition Rails and the DSC Cavity*

*To determine the bounding cold gap to avoid interference between the transition rails and the DSC cavity, the steps outlined for the axial gap between the basket assembly and the DSC cavity are repeated for the transition rails.*

*The bounding net cold gap is* **[ ]** *and, to bound any uncertainties, a minimum axial cold gap of* **[ ]** *is recommended between the DSC cavity and the transition rails.*

*Axial Gap between the OS197FC TC Cavity and the DSC Shell*

*Thermal expansion of the DSC shell loaded with the 24PTH Type 3 basket is less than the expansion in the bounding load case for the Type 1 DSC because the thermal evaluations of the Type 3 DSC and basket are bounded by the Type 1 for the normal conditions of transfer and storage. Therefore, no further analysis is required for the axial gap between the OS197FC TC cavity and HSM-H cavity.*

*Axial Gap between the HSM-H Support Structure and the HSM-H cavity*

*Thermal expansion of the HSM-H support structure in the case of a DSC shell loaded with the 24PTH Type 3 basket is less than the expansion in the bounding load case for the Type 1 DSC because the thermal evaluation of the Type 3 DSC is bounded by the Type 1 DSC for the normal condition of storage. Therefore, no further analysis is required for the axial gap between the HSM-H support structure and the HSM-H cavity.*

#### P.3.4.4.3 Thermal Stress Calculations

The thermal stress calculations for the 24PTH DSC basket assembly is presented in this section. *This section applies to the Types 1 and 2 basket only. The analysis of the Type 3 basket is presented in Section P.3.8.* A summary of the thermal stress evaluations for HSM-H, and OS197/OS197H/OS197FC TCs are also presented in this section. The thermal stress evaluations for the 24PTH DSC shell assemblies, the HSM-H, and the TCs are provided in Section P.3.6 (for normal and off-normal conditions) and in Section P.3.7 for accident conditions. The thermal stresses for the Standardized TC and HSM Model 102 are not changed from those reported in Chapter 8 because they are based on a maximum heat load of 24 kW which is the same as the heat load for the 24PTH-S-LC DSC.

Thermal stresses are considered separately and in combination with other loads. Only the separate thermal stresses are presented here. Thermal stresses in combination with other loads are addressed in the appropriate sections.

P.3.4.4.3.3 OS197/OS197H/OS197FC Thermal Stress Calculations

The OS197/OS197H/OS197FC is used for transfer of a 24PTH DSC for heat loads of up to 31.2 kW with basket type 1. For DSCs with basket type 1 with heat load above 31.2 kW or DSCs with basket type 2, use of the OS197FC TC is required. The only difference between the OS197/OS197H TC and the OS197FC TC is the TC top lid vents (which allow for air circulation) and the optional wedge-shaped plates added to the TC bottom provided in the OS197FC TC. The thermal analysis of the TC is based on the bounding temperature profiles for 31.2 kW (steady state with and without air circulation) and 40.8 kW (with air circulation) *which is bounding for the Type 3 basket as well.* Therefore, the thermal stress analyses are applicable to the OS197/OS197H and OS197FC TCs.

The OS197FC thermal stress calculations are described in Section P.3.6.1.5.

The controlling stresses from these analyses are tabulated in Table P.3.6-2 and Table P.3.6-3 for the 24PTH-S/-L DSC and the 24PTH-S-LC DSC, respectively.

(E) Evaluation of the Results

The maximum calculated DSC shell stresses induced by normal operating load conditions are shown in Table P.3.6-2 for the 24PTH-S/-L DSCs and Table P.3.6-3 for 24PTH-S-LC DSC. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table P.2-14. The resulting stresses for the controlling load combinations are reported in Section P.3.7.11 along with the ASME Code allowable stresses.

P.3.6.1.3 NUHOMS®-24PTH Basket Structural Analysis

*This section applies to the Types 1 and 2 basket only. The analysis of the Type 3 basket is presented in Section P.3.8.*

Stresses in the basket assembly are determined using a combination of hand calculations and three dimensional LS DYNA finite element models. The following loads are addressed:

- Dead Weight
- Thermal Stresses
- Handling/Transfer Loads
- Accident Drops
- Seismic Loads

Thermal loads for the basket are addressed in Section P.3.4.4. The drop loads are Level D loads and are addressed in Section P.3.7. The seismic loads are Level C loads, which are enveloped by the on-site handling loads as described in Section P.3.6.1.3.2.

P.3.6.1.3.1 LS-DYNA Finite Element Model Analysis

(A) LS DYNA Finite Element Model Description

A finite element model of the basket assembly is developed using the LS-DYNA computer program [3.18]. LS-DYNA is used for the analysis of the 24PTH basket because of its robust contact algorithms which are able to model contact between the different components of the basket assembly.

The LS DYNA model of the 24PTH basket assembly is shown in Figure P.3.6-6. The model uses fully integrated shell elements (with five integration points through the thickness) to represent the fuel compartment tubes, the steel insert plates (straps) that are welded to the tubes, and the R45 transition rails. Fully integrated solid elements are used for the aluminum R90 transition rails. The model is a 24-inch long section of the basket assembly. This span corresponds to the 24" periodicity of the basket assembly steel insert plates (straps) and strap-to-fuel compartment tube welds, and to twice (12") the periodicity of the stiffener plates in the R45 transition rails. The steel insert (straps) plates, steel insert plates-to-tube welds, and a full-thickness R45 transition rail stiffener plate are modeled at Z=0.0". The model is extended half way to the next strap plate/weld location to Z=+12" and Z=-12". Half-thickness R45 stiffeners are included at the ends of the model (Z=$\pm$12"). The model includes a segment of the DSC shell,

For an operating NUHOMS® System, off-normal events could occur during fuel loading, TC handling, trailer towing, canister transfer and other operational events. Two off-normal events are defined which bound the range of off-normal conditions. The limiting off-normal events are defined as a jammed DSC during loading or unloading from the HSM Model 102/HSM-H and the extreme ambient temperatures of -40°F (winter) and +117°F (summer). These events envelope the range of expected off-normal structural loads and temperatures acting on the DSC, TC, and HSM Model 102/HSM-H. These off-normal events are described in Section 8.1.2.

*The analysis of the Type 3 basket is presented in Section P.3.8.*

P.3.6.4 Failed Fuel Cans

Up to 8 failed fuel cans may be loaded in the 24PTH basket with failed fuel with the remainder intact, PWR fuel assemblies with or without Control Components (CCs). The basket structure consists of a welded assembly of stainless steel tubes with the space between adjacent tubes filled with aluminum and neutron poison plates and surrounded by support rails.

The failed fuel assemblies are to be placed in individual Failed Fuel Cans (FFCs) in cells located at the outer edge of the 24PTH basket as described in Chapter P.2. Each FFC is constructed of sheet metal and is provided with a welded bottom closure and a removable top closure which allows lifting of the FFC with the enclosed failed fuel. The FFC is provided with screens at the bottom and top to contain fuel debris and allow fill/drainage of water from the FFC during loading operations. The FFC is protected by the fuel compartment tubes and its only function is to confine the failed fuel and allow its retrievability from the basket fuel compartment under normal and off-normal conditions.

The maximum fuel assembly load applied to each associated basket compartment location bounds the load due to the FFC. Therefore, the 24PTH basket analyses with intact fuel are applicable when the basket is loaded with failed fuel.

The FFC is evaluated for a load of 1.5g which bounds the loads associated with lifting, handling and other normal and off-normal loads. Thermal loads for the FFC are not considered based on the following: (1) NF does not require evaluation of internal thermal stresses, (2) during lifting and handling, when primary stresses in the FFC are largest, there are no significant thermal gradients, (3) the more significant thermal gradients occur when the FFC is in the horizontal position when the transfer stresses occur, which are much lower than the lifting and handling stresses, and (4) similar thermal gradients and stresses occur in the basket which are already qualified. The controlling stresses due to the 1.5g loading are compared to normal condition allowable stresses based on NF criteria *([3.1] for the Types 1 and 2 basket FFC and [3.39] for the Type 3 basket FFC)*. The maximum allowable stresses based on a conservative temperature of 750°F, are shown in the following table *for the Types 1 and 2 basket FFC*:

**FFC Allowable Stresses**

| Stress Category | Maximum Allowable Stress (ksi) |
|---|---|
| Tensile / Combined | Min ($S_m$; $S_y$) = 15.8 |
| Bending | 1.5 × $S_m$ = 23.7 |

Conservative hand calculations based on [3.10] demonstrate that maximum handling stresses meet the allowable stress criteria. The controlling stresses and comparison to allowable stresses are summarized below *for the Types 1 and 2 basket FFC*:

**FFC Summary of Stresses**

| Location | Type of Stress | Calculated Stress (ksi) | Allowable Stress (ksi) |
|---|---|---|---|
| FFC Wall | Tensile | 3.0 | 15.8 |
| Bottom Lid | Bending | 13.5 | 23.7 |

*The FFC for the 24PTH Type 3 basket is similar to the FFC for the EOS-37PTH basket evaluated in Section 3.9.2.1A of [3.46]. The controlling stresses and comparison to allowable stresses are summarized below for the Type 3 basket FFC:*

***FFC Summary of Stresses***

| ***Location*** | ***Type of Stress*** | ***Calculated Stress (ksi)*** | ***Allowable Stress (ksi)*** |
|---|---|---|---|
| *FFC Wall* | *Tensile* | *2.9* | *15.5* |
| *Bottom Lid* | *Bending* | *10.4* | *23.2* |

Based on the summary above, the FFC meets the normal allowable stress criteria for a conservative lift and handling load of 1.5g. Therefore, the structural integrity and retrievability of the FFC is assured.

**Table P.3.6-4**
**NUHOMS® -24PTH *Types 1 and 2* Basket Model Components, Element Types and Materials**

| Structural Component | LS DYNA Element Type | Material |
|---|---|---|
| Fuel Compartment Tube Structure | Fully Integrated Shell | Type 304 Stainless Steel |
| DSC Shell | Fully Integrated Shell | Type 304 Stainless Steel |
| R45 Transition Rails | Fully Integrated Shell | Type 304 Stainless Steel |
| R90 Transition Rails | Fully Integrated Solid | Type 6061 Aluminum |
| TC Shell & TC Rails | Fully Integrated Shell | N/A (Rigid Bodies) |
| Steel Insert Plates (Straps)-to-Tube Welds | Beam | Type 304 Stainless Steel |

**Table P.3.6-5**
**Material Properties Used in Normal Condition 24PTH *Types 1 and 2* Basket Analyses**

| Component | Material(2) (3) | Evaluation Temperature(1) |
|---|---|---|
| Fuel Compartment Tube Structure | 1/4" Thick, Type 304 Stainless Steel | 800°F (All conditions) |
| Steel Insert Plates (Straps) | Type 304 Stainless Steel | 800°F (All conditions) |
| Welded R45 Steel Transition Rails | 3/8" Thick Type 304 Stainless Steel | 800°F (All conditions) |
| R90 Aluminum Transition Rails | 6061 Aluminum Alloy | 600°F |

**Notes:**

1. For the steel components, stress checks were performed at the enveloping temperatures listed.
2. ASME Code properties for Type 304 Stainless Steels from Table P.3.3-1.
3. Properties for 6061 Aluminum from Table P.3.3-5.

## Table P.3.6-6
## Normal Condition Stress Summary for 24PTH *Types 1 and 2* Basket Components –Vertical DW/Handling Loads

| Component | Stress (Axial Compression) | | | Notes |
|---|---|---|---|---|
| | Calculated Stress (ksi) | Allowable Stress (ksi) | Ratio | |
| Fuel Compartment Tubes | 0.087 | 7.70 | 0.01 | DW, Type 304, 800ºF |
| Fuel Compartment Tubes | 0.17 | 7.70 | 0.02 | Handling, Type 304, 800ºF |
| R45 Transition Rails | 0.14 | 7.70 | 0.02 | DW, Type 304, 800ºF |
| R45 Transition Rails | 0.28 | 7.70 | 0.04 | Handling, Type 304, 800ºF |
| R90 Transition Rails | 0.017 | 4.2 | < 0.01 | DW, 800ºF, Type 6061, 600ºF |
| R90 Transition Rails | 0.034 | 4.2 | 0.01 | Handling, Type 6061, 600ºF |

## Table P.3.6-7
## Normal Condition Stress Summary for 24PTH *Types 1 and 2* Basket Components
## Horizontal DW/Handling

**Stainless Steel Components**

| Component | Stress Category | Maximum SI | | | Allowable SI (ksi) | Stress Ratios | | |
|---|---|---|---|---|---|---|---|---|
| | | OS197 DW (ksi) | HSM DW (ksi) | Handling (ksi) | | OS197 DW | HSM DW | Handling |
| Fuel Tubes | $P_m$ | 1.87 | 1.54 | 3.74 | 15.2 | 0.12 | 0.10 | 0.25 |
| | $P_m + P_b$ | 2.84 | 2.55 | 5.69 | 22.8 | 0.12 | 0.11 | 0.25 |
| | $P_m + P_b + Q$ | 9.65 | 8.68 | 13.5 | 45.6 | 0.21 | 0.19 | 0.30 |
| R45 Main Plates | $P_m$ | 1.53 | 6.08 | 3.06 | 15.2 | 0.10 | 0.40 | 0.20 |
| | $P_m + P_b$ | 6.11 | 6.42 | 12.21 | 22.8 | 0.27 | 0.28 | 0.54 |
| | $P_m + P_b + Q$ | 14.83 | 15.14 | 20.93 | 45.6 | 0.33 | 0.33 | 0.46 |
| R45 Stiffeners | $P_m$ | 1.03 | 6.65 | 2.06 | 15.2 | 0.07 | 0.44 | 0.14 |
| | $P_m + P_b$ | 2.22 | 6.68 | 4.45 | 22.8 | 0.10 | 0.29 | 0.20 |
| | $P_m + P_b + Q$ | 5.22 | 9.62 | 7.44 | 45.6 | 0.11 | 0.21 | 0.16 |
| Basket Straps | $P_m$ | 0.85 | 0.34 | 1.71 | 15.2 | 0.06 | 0.02 | 0.11 |
| | $P_m + P_b$ | 2.81 | 1.75 | 5.62 | 22.8 | 0.12 | 0.08 | 0.25 |
| | $P_m + P_b + Q$ | 8.17 | 7.11 | 11.0 | 45.6 | 0.18 | 0.16 | 0.24 |

Note: Level A allowables for SA-240 Type 304 at 800°F

**Aluminum (R90 Transition Rails)**

| Component | Stress Category | Maximum SI | | | Yield $S_y$, 6061 | Stress Ratios | | |
|---|---|---|---|---|---|---|---|---|
| | | OS197 DW (ksi) | HSM DW (ksi) | Handling (psi) | | OS197 DW | HSM DW | Handling |
| R90 Rails | Max. Stress | 17 | 134 | 268 | 4,200 | 0.004 | 0.03 | 0.06 |

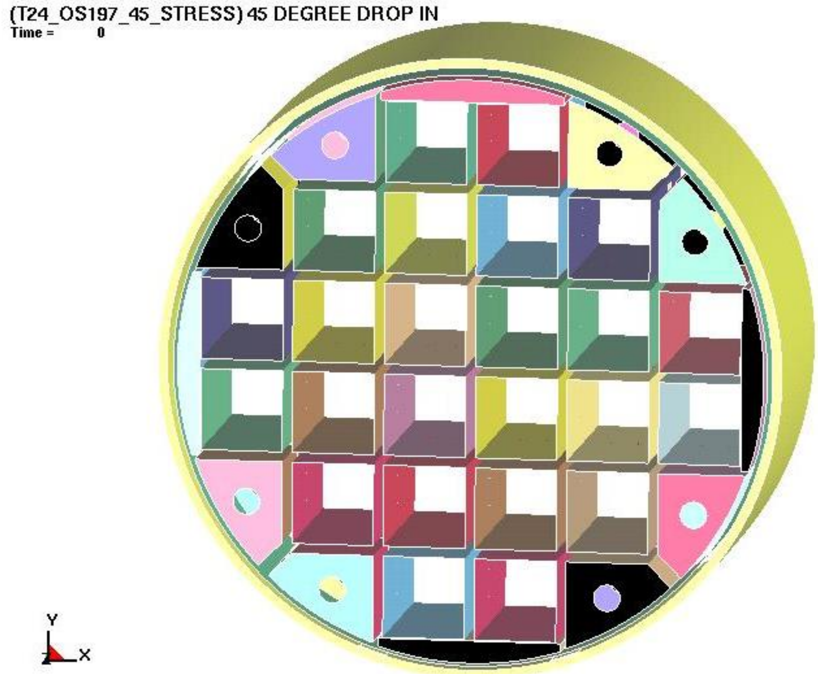
**Notes:** 1. Conservatively, the yield stress corresponding to annealed 6061 aluminum at 600ºF is used.

2. Handling loads are 2 x DW loads.

**Table P.3.6-8**
**Normal Condition Fuel Compartment Tubes-to-Steel Insert Plates (Straps) Weld Loads for 24PTH *Types 1 and 2* Basket**

| Load Condition | Enveloping Load (Kips) |
|---|---|
| OS197 Deadweight | 1.2 |
| HSM-H Deadweight | 0.8 |
| Thermal Loads | 1.7 |

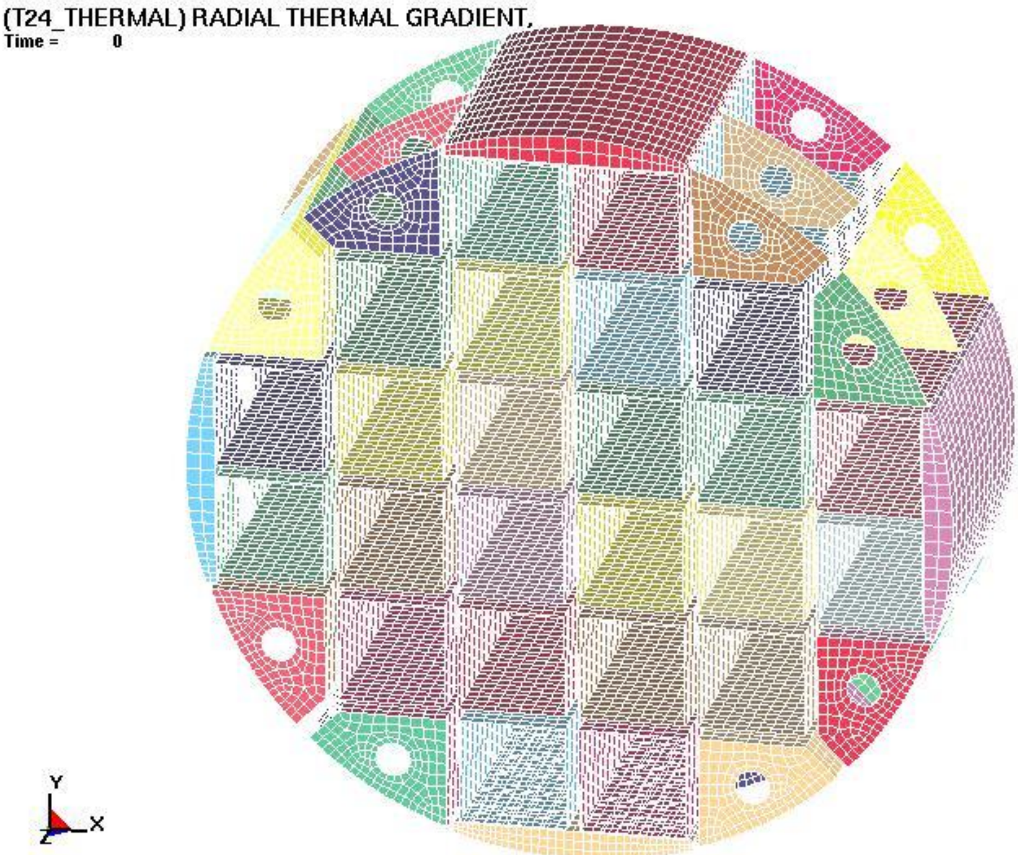
**Note:** 1. Handling loads are 2 x DW loads.




**DYNA STRESS ANALYSIS MODEL - ALL PARTS**

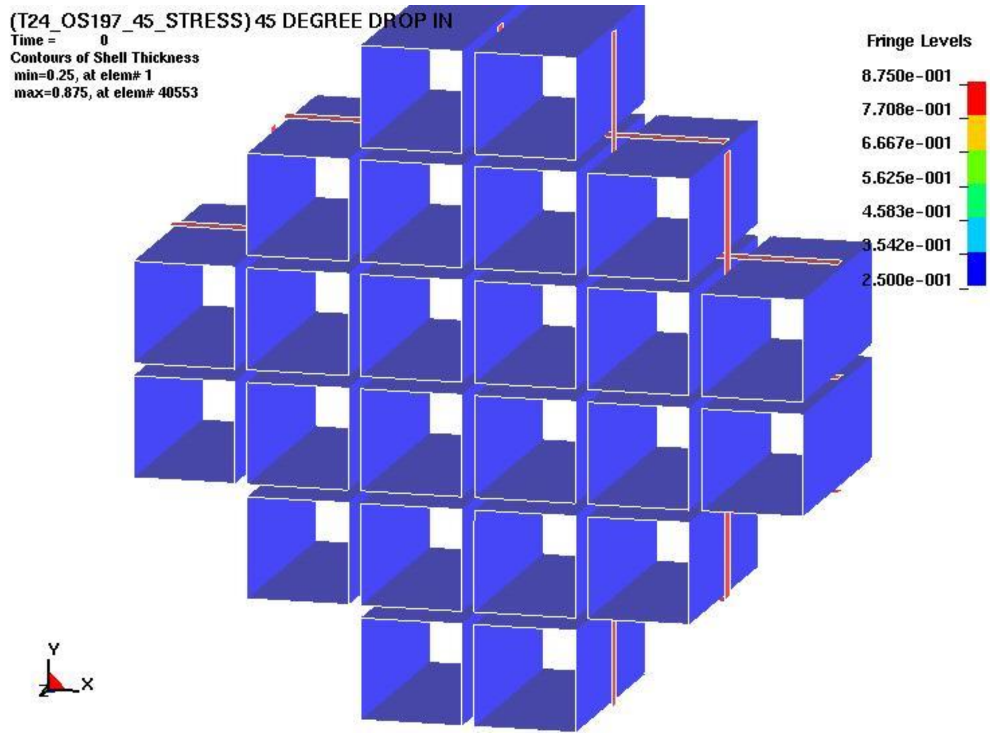

**DYNA STRESS ANALYSIS MODEL - BASKET ASSEMBLY**

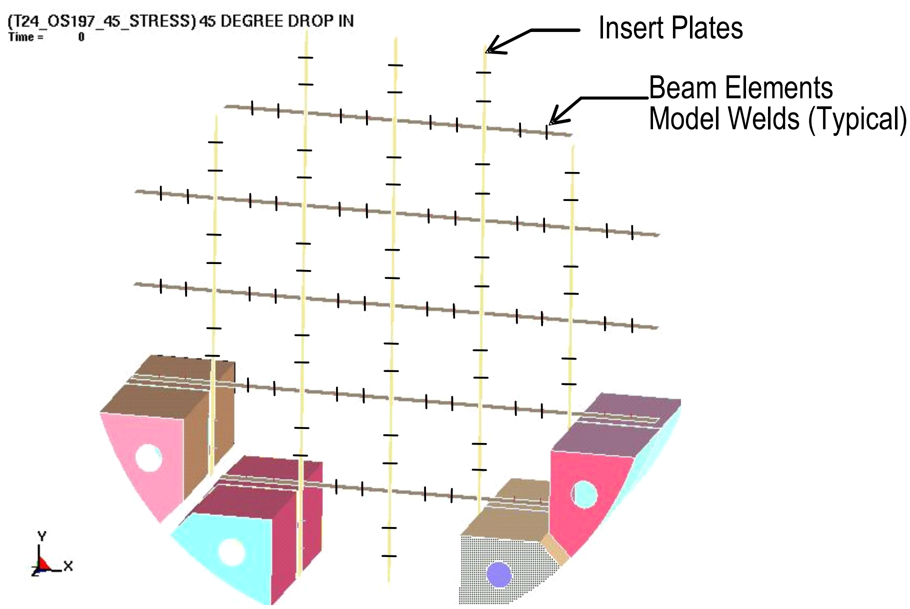
**Figure P.3.6-6**
**24PTH *Types 1 and 2* Basket LS-DYNA Stress Analysis Model**




**DYNA STRESS ANALYSIS MODEL - BASKET ASSEMBLY MESH**

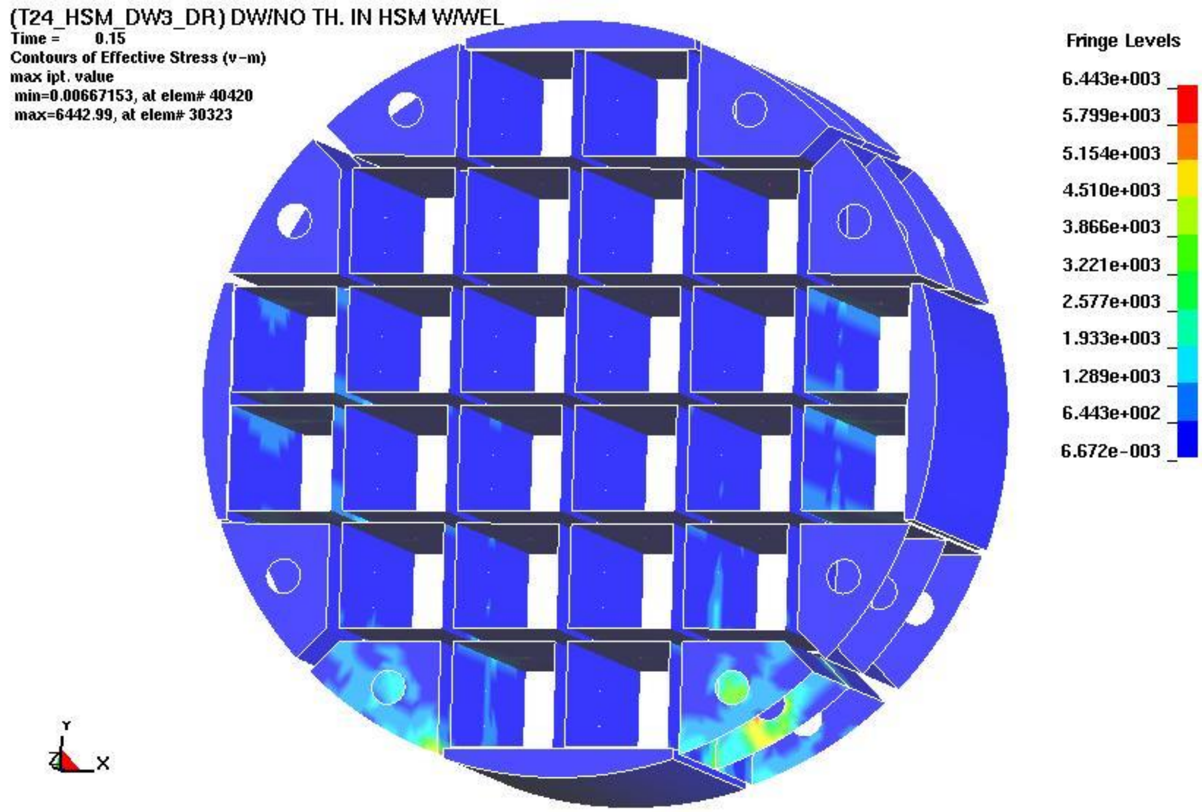
**Figure P.3.6-7**
**24PTH *Types 1 and 2* Basket LS-DYNA Finite Element Stress Analysis Model**



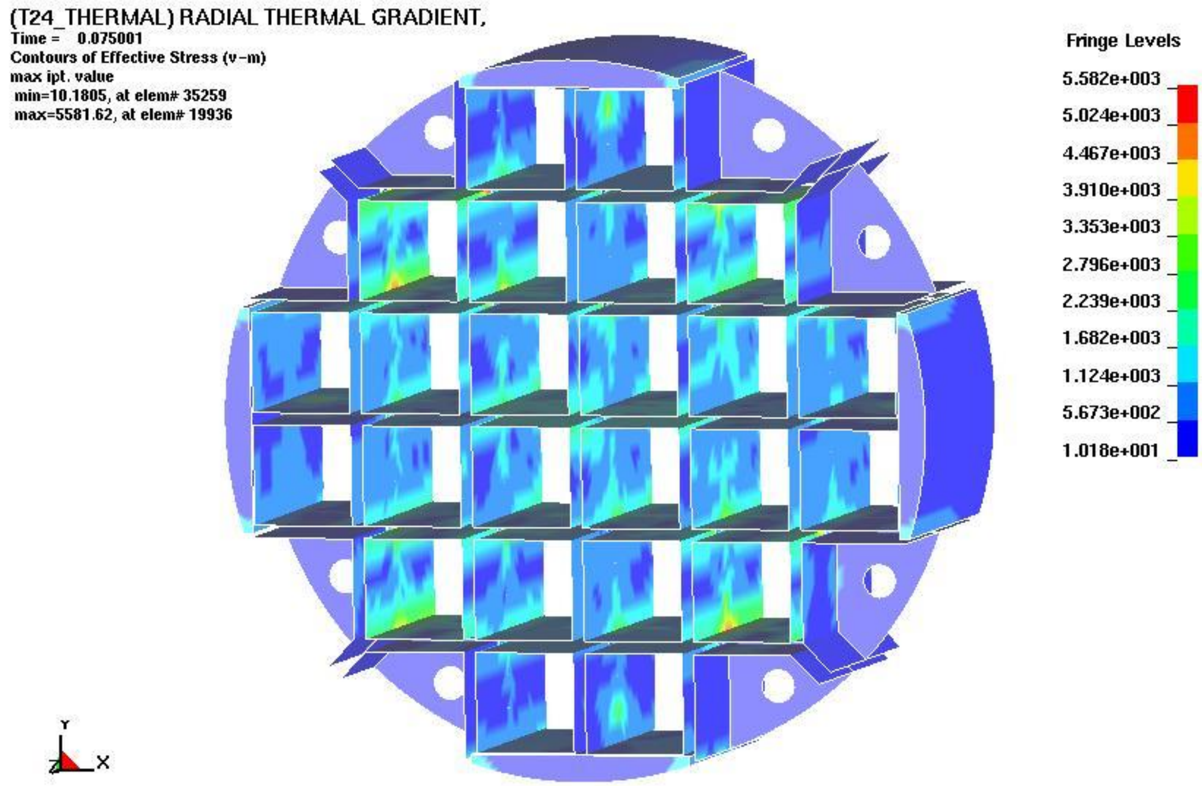

**–Tubes not shown for clarity.–**

**Figure P.3.6-8**
**24PTH *Types 1 and 2* Basket Model Showing Fuel Compartment Tubes, Steel Insert Plates (Straps), and Beam Elements Modeling Connection Welds**




Note: These stresses are effective von Mises stresses

**Figure P.3.6-9**
**24PTH *Types 1 and 2* Basket LS-DYNA Model Analyses Results – Deadweight Stresses**




Note: These stresses are effective von Mises stresses

**Figure P.3.6-10**
**24PTH *Types 1 and 2* Basket LS DYNA Model Analysis Results – Thermal Stresses**

sliding of the HSM-H is 0.6 x 354 or 212.5 kips. The drag force acting on a HSM-H (considering a minimum of two modules in an array) is 0.5 x 8.07 kips/ft x 20.67 = 83.4 kips total acting on the side wall of a single HSM-H, due to a flood velocity of 15 fps. The resulting factor of safety against sliding of a free standing HSM-H due to the design basis flood water velocity is 2.55.

Therefore, a minimum of two (2) HSM-Hs adjacent to each other are required to prevent sliding.

P.3.7.3.2 DSC Flooding Analyses

The DSC is evaluated for the design basis 50-foot hydrostatic head of water producing external pressure on the DSC shell and outer cover plates. To determine design margin which exists for this condition, the allowable external pressure on the DSC shell is calculated for Service Level C stress using the methodology presented in NB-3133.3 of the ASME Code [3.1]. The resulting allowable pressure of 45.0 psi is about 2 times the maximum external pressure of 21.7 psi due to the postulated 50- foot flood height. This demonstrates stability of the DSC under the worst-case external pressure due to flooding.

The DSC shell stresses for the postulated flood condition are determined using the ANSYS analytical model shown in Figure P.3.6-1 and Figure P.3.6-2 (24PTH-S/-L DSCs) and Figure P.3.6-4 (24PTH-S-LC DSC). The 21.7 psig external pressure is applied to the model as a uniform pressure on the outer surfaces of the top cover plate, DSC shell and bottom cover plate. The maximum DSC shell primary membrane plus bending stress intensity for the 21.7 psi external pressure is 3.00 ksi for the 24PTH-S/-L and 5.78 ksi for the 24PTH-S-LC. Both these stresses are considerably less than the Service Level C allowable primary membrane plus bending stresses of 32.6 ksi and 31.5 ksi, respectively. The maximum primary membrane plus bending stress in the flat heads of the DSC occurs in the inner bottom cover plate for the 24PTH-S/-L and in the bottom forging for the 24PTH-S-LC. The maximum primary membrane plus bending stresses are 1.54 ksi for the 24PTH-S/-L and 4.44 ksi for the 24PTH-S-LC. Both these stresses are also considerably less than the Service Level C allowable for primary membrane plus bending. These stresses are combined using the load combinations shown in Table P.2-14.

P.3.7.4 Accidental TC Drop

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

TC drop evaluations include the following:

- DSC Shell Assembly (P.3.7.4.2),
- Basket Assembly (P.3.7.4.3 *for Types 1 and 2 and P.3.8 for Type 3*),
- On-Site TC (P.3.7.4.4), and
- Loss of the TC Neutron Shield (P.3.7.4.5).

P.3.7.4.3 <u>24PTH Basket Assembly Drop Evaluation</u>

*This section applies to the Types 1 and 2 basket only. The analyses of the Type 3 basket is presented in Section P.3.8.*

As discussed in previous chapters, the structural components of the basket assembly include the fuel compartment tube structure and the transition rails.

The DSC resides in the TC for all drop conditions. Horizontally, the DSC is supported in the TC by two TC rails that are integral to the TC wall. The effect of these TC rails are included in the horizontal drop evaluations.

Vertical drops are non-mechanistic for the 24PTH horizontal storage system, therefore, as noted in Section P.3.7.4.1, no end drops are postulated. However, to provide an enveloping load for the postulated 25g corner drop, a 60g end drop is evaluated. For this drop, the end of the DSC/basket assembly is supported by the ends of the TC.

The stress evaluation of the 24PTH DSC basket assembly is presented in three parts:

1. Basket assembly horizontal drop stress analysis, which includes evaluation of the fuel compartment tube structure and transition rails using the LS-DYNA model described in Section P.3.6.1.3.
2. Basket assembly horizontal drop stability evaluations which use the LS-DYNA model described in Section P.3.7.4.3.3 and the criteria of the ASME B&PV Code, Appendix F-1341.3. As noted, the LS-DYNA models include the fuel compartment tube structure and the transition rails.
3. Basket assembly vertical drop analysis which includes a stress evaluation of the fuel compartment tube structure and transition rails using hand calculations as described in Section P.3.6.1.3 for vertical deadweight. The stress criteria used for the vertical drop analysis also provides assurance of structural stability.

Within the basket structure, captured between the fuel compartment tubes, are Type 1100 aluminum plates and neutron absorbing plates which perform heat transfer and criticality functions. The hand-calculated bounding accident condition axial stress in the plates is 0.14 ksi, due to the 60g end drop, which is below the yield stress value of 1.3 ksi (Type 1100 aluminum at 800°F). This ensures that the plates remain in position to perform their heat transfer and criticality functions. For the 75g side drop loading, the aluminum plates are supported in the transverse direction along their length by the fuel compartment tube structure. Thus, displacements of the aluminum plates are limited.

P.3.7.4.3.1 <u>24PTH Basket Assembly Horizontal Drop Analysis</u>

P.3.7.4.3.1.1 <u>Basket and Basket Rail Stress Analysis</u>

The LS-DYNA model described in Section P.3.6.1.3 is used to perform stress analyses of the 24PTH basket assembly for horizontal drop accident loads. The LS-DYNA model includes the fuel compartment tube structure, transition rails, DSC shell, and the effects of the TC rails. Contact elements between the parts of the structure are active for all the stress analyses.

**Table P.3.7-3**
**List of Drop Condition LS-DYNA Stress Analyses of the 24PTH *Types 1 and 2* Basket Assembly**

| Case | Load | Support Conditions |
|---|---|---|
| 1 | 75g Side Drop at 0° | TC (Support Rails at ± 18.5°) |
| 2 | 75g Side Drop at 30° from bottom center | TC (Support Rails at ± 18.5°) |
| 3 | 75g Side Drop at 45° from bottom center | TC (Support Rails at ± 18.5°) |

## Table P.3.7-4
## Summary of Material Properties for Drop Accident Analyses of the 24PTH *Types 1 and 2* Basket Assembly (1) (2)

| Component | Material | Drop Condition Analysis Material Properties | | Stress Evaluation Temperature |
|---|---|---|---|---|
| | | Stress Analysis | Stability Analysis | |
| Fuel Compartment Tube | 1/4" Thick, Type 304 Stainless Steel | Bilinear Elastic-Plastic<br>$S_y$ = Code $S_y$ (Table P.3.3-1)<br>$E_{tan}$ =.05$E_{Code}$ (Table P.3.3-1) | Bilinear Elastic-Perfectly Plastic (F-1341.3):<br>$S_y$ = min(2.3$S_m$,0.7$S_u$)<br>$E_{tan}$ = 0 | 800°F |
| R45 Steel Transition Rails | 3/8" Thick Type 304 Stainless Steel | Bilinear Elastic-Plastic<br>$S_y$ = Code $S_y$ (Table P.3.3-1)<br>$E_{tan}$ =.05$E_{Code}$ (Table P.3.3-1) | Bilinear Elastic-Perfectly Plastic (F-1341.3):<br>$S_y$ = min(2.3$S_m$,0.7$S_u$)<br>$E_{tan}$ = 0 | 800°F |
| R90 Aluminum Transition Rails | 6061 Aluminum Alloy | Bilinear Elastic-Plastic<br>$S_y$ = (Table P.3.3-5)<br>$E_{tan}$ =.01E (Table 3.3-5) | Bilinear Elastic-Plastic<br>$S_y$ = (Table P.3.3-5)<br>$E_{tan}$ =.01E (Table P.3.3-5) | Note 3 |

**Notes:**
1. Prior to application of drop loads, the structure was initialized to the temperature profile shown in Figure P.3.4-2.
2. For the steel components, stress checks were performed at the enveloping temperatures listed.
3. For accident condition loading, the transition rails support the fuel compartment tubes such that stresses and displacements in the fuel compartment tubes are acceptable. Since the transition rails are entrapped between the fuel compartment tubes and the DSC shell, no additional checks (of the aluminum) are required for accident/drop loading. Qualification of the fuel tube structure demonstrates that the rails perform their intended function.

**Table P.3.7-5**
**24PTH *Types 1 and 2* Basket, Enveloping Stress Results - 75g Side Drops**

| Component | Stress Category | Maximum Drop SI | Allowable SI | Stress Ratio |
|---|---|---|---|---|
| Fuel Compartment Tubes | $P_m$ | 37.9 | 44.0 | 0.86 |
| | $P_m + P_b$ | 48.2 | 56.5 | 0.85 |
| | $P_m + P_b + Q$ | N/A | N/A | N/A |
| R45 Transition Rail Main Plates | $P_m$ | 39.1 | 44.0 | 0.89 |
| | $P_m + P_b$ | 53.9 | 56.5 | 0.95 |
| | $P_m + P_b + Q$ | N/A | N/A | N/A |
| R45 Transition Rail Stiffeners | $P_m$ | 31.1 | 44.0 | 0.71 |
| | $P_m + P_b$ | 39.5 | 56.5 | 0.70 |
| | $P_m + P_b + Q$ | N/A | N/A | N/A |
| Steel Insert Plates (Straps) | $P_m$ | 20.9 | 44.0 | 0.47 |
| | $P_m + P_b$ | 31.8 | 56.5 | 0.56 |
| | $P_m + P_b + Q$ | N/A | N/A | N/A |

Note: Level D allowables for SA-240 Type 304 at 800°

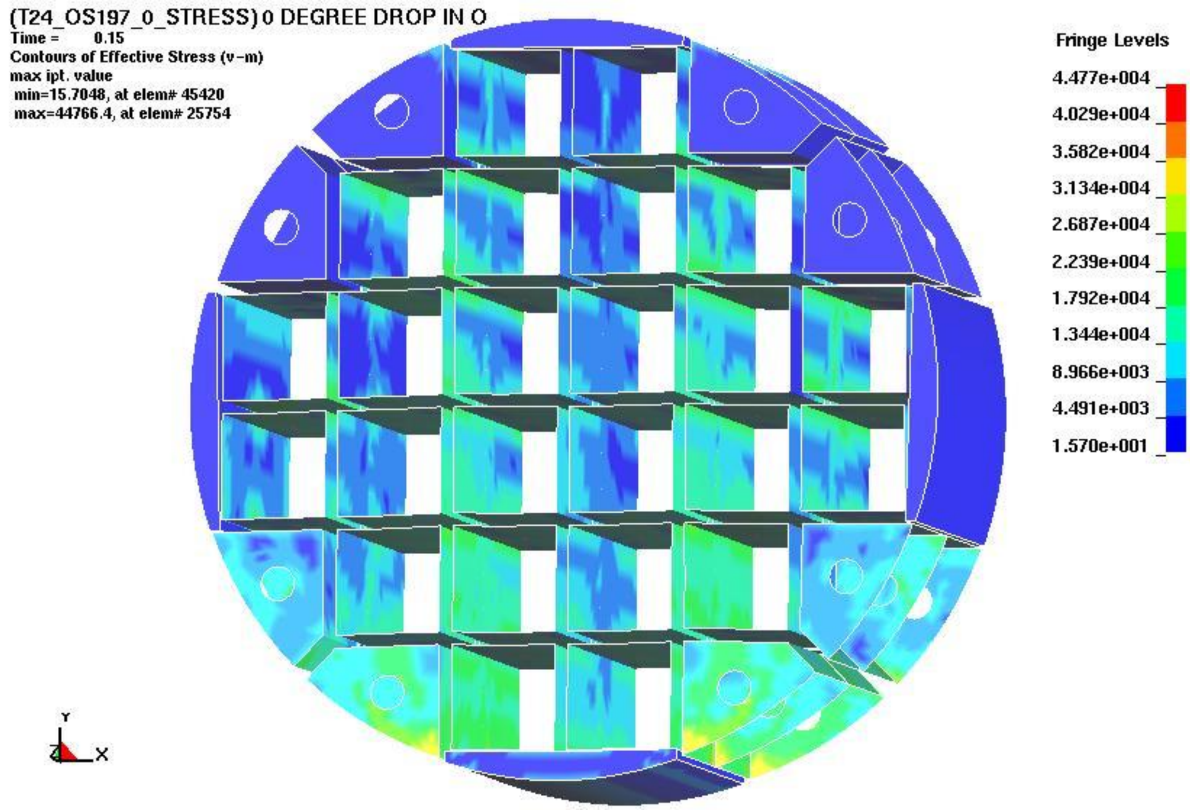
**Table P.3.7-6**
**24PTH *Types 1 and 2* Basket, Enveloping Stress Results - 60g End Drop**

| Component | Stress (Axial Compression) | | | Notes |
|---|---|---|---|---|
| | Calculated Stress (ksi) | Allowable Stress (ksi) | Ratio | |
| Fuel Compartment Tube | 5.25 | 14.8 | 0.35 | $F_a$, Level D Type 304, 800°F |
| R45 Steel Transition Rails | 8.47 | 14.8 | 0.57 | $F_a$, Level D Type 304, 800°F |
| R90 Aluminum Transition Rails | 1.03 | 4.20 | .25 | $S_Y$, 6061 Al., 600°F |

**Table P.3.7-7**
**Drop Condition ANSYS Stability Analyses for the 24PTH *Types 1 and 2* Basket Assembly**

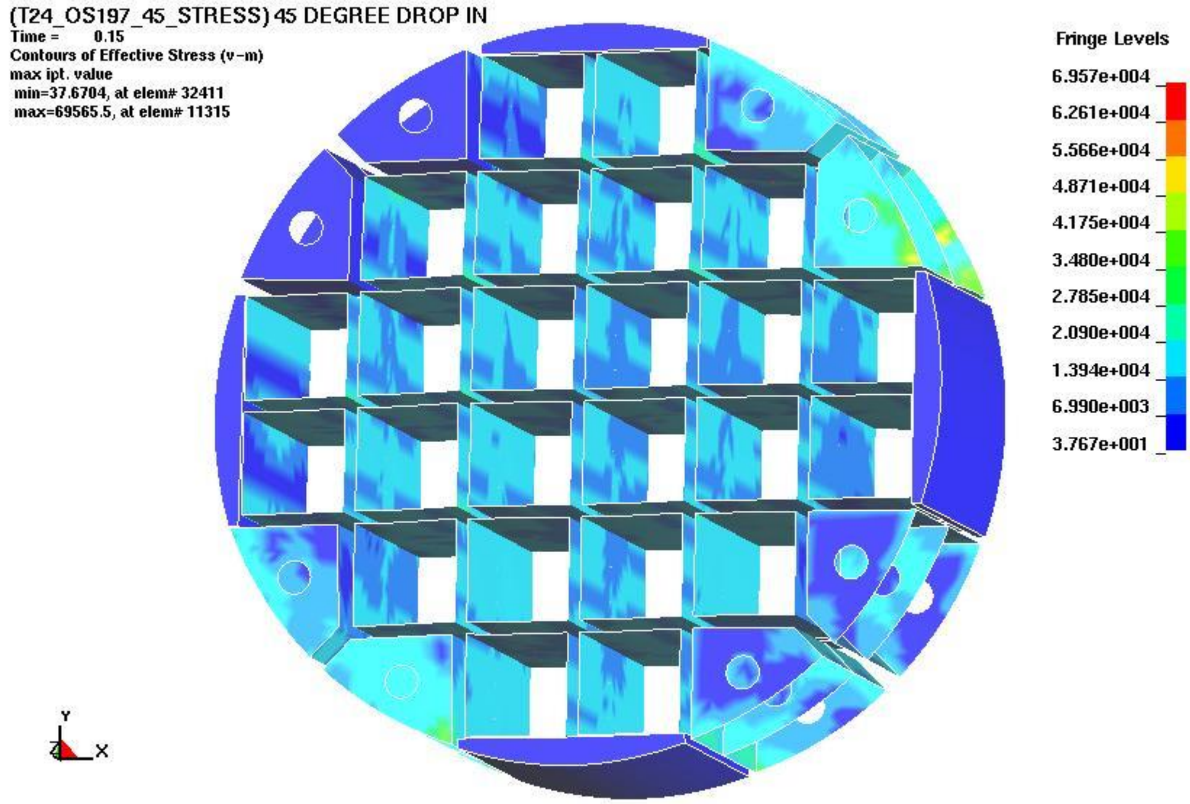
| Case | Load/Drop Orientation | Maximum Stable Load (LS-DYNA Stability Analyses) | ASME F-1341.3 Allowable Load | Support Conditions |
|---|---|---|---|---|
| 1 | Side drop at 0° | 160 g | 144 g | TC<br>(Support Rails at ± 18.5°) |
| 2 | Side drop at 45° from bottom center | 150 g | 135 g | TC<br>(Support Rails at ± 18.5°) |
| 3 | Side drop at 180° from bottom center | 160 g | 144 g | N/A (cask rails not impacted) |

**Note:** As described in F-1341.3, the allowable load is 90% of the Limit Analysis Collapse Load.




Note: These stresses are effective von Mises stresses.

**Figure P.3.7-2**
**0° Side Drop Stresses, 24PTH *Types 1 and 2* Basket**
**(TC Support Rails at ±18.5°)**




Note: These stresses are effective von Mises stresses.

**Figure P.3.7-3**
**45° Side Drop Stresses, 24PTH *Types 1 and 2* Basket**
**(TC Support Rails at ±18.5°)**

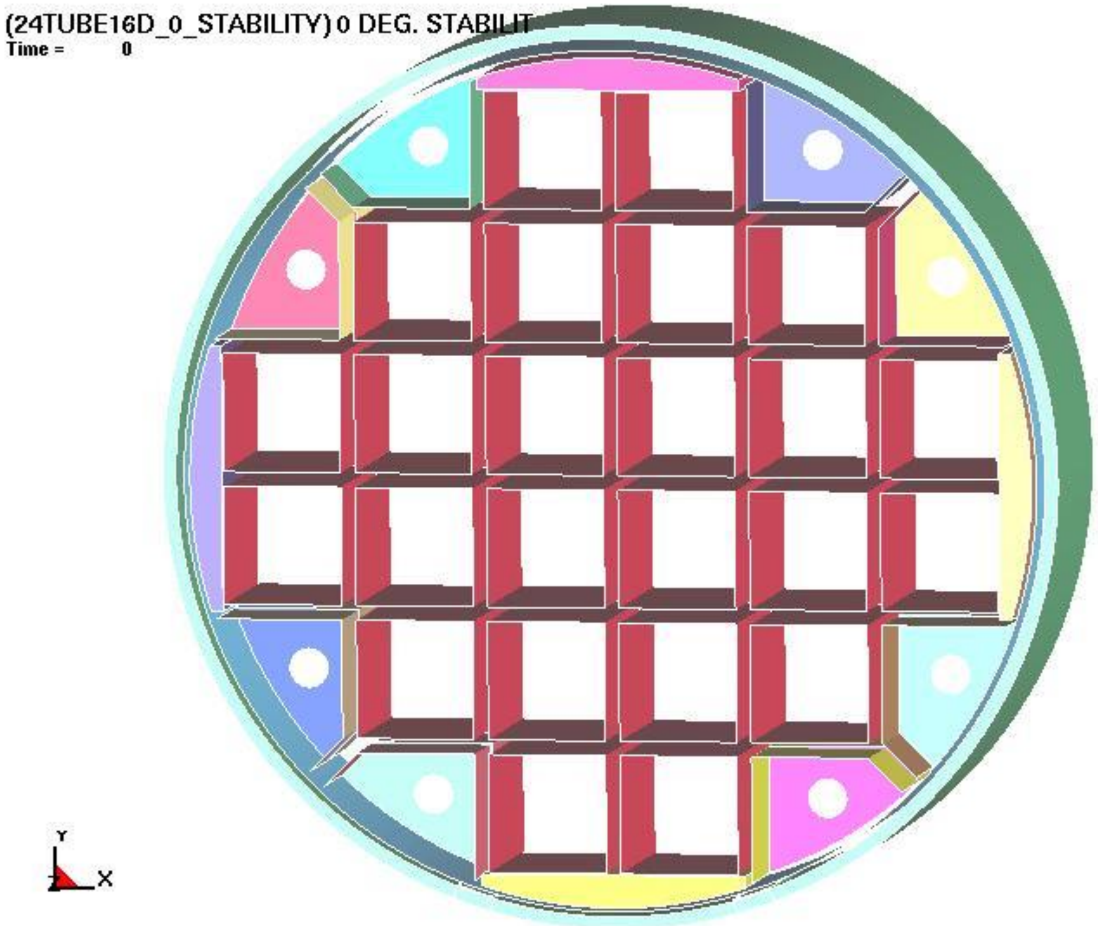



**Figure P.3.7-4**
**24PTH *Types 1 and 2* Basket LS-DYNA Stability Analysis Model (TC Support Rails at ±18.5°)**

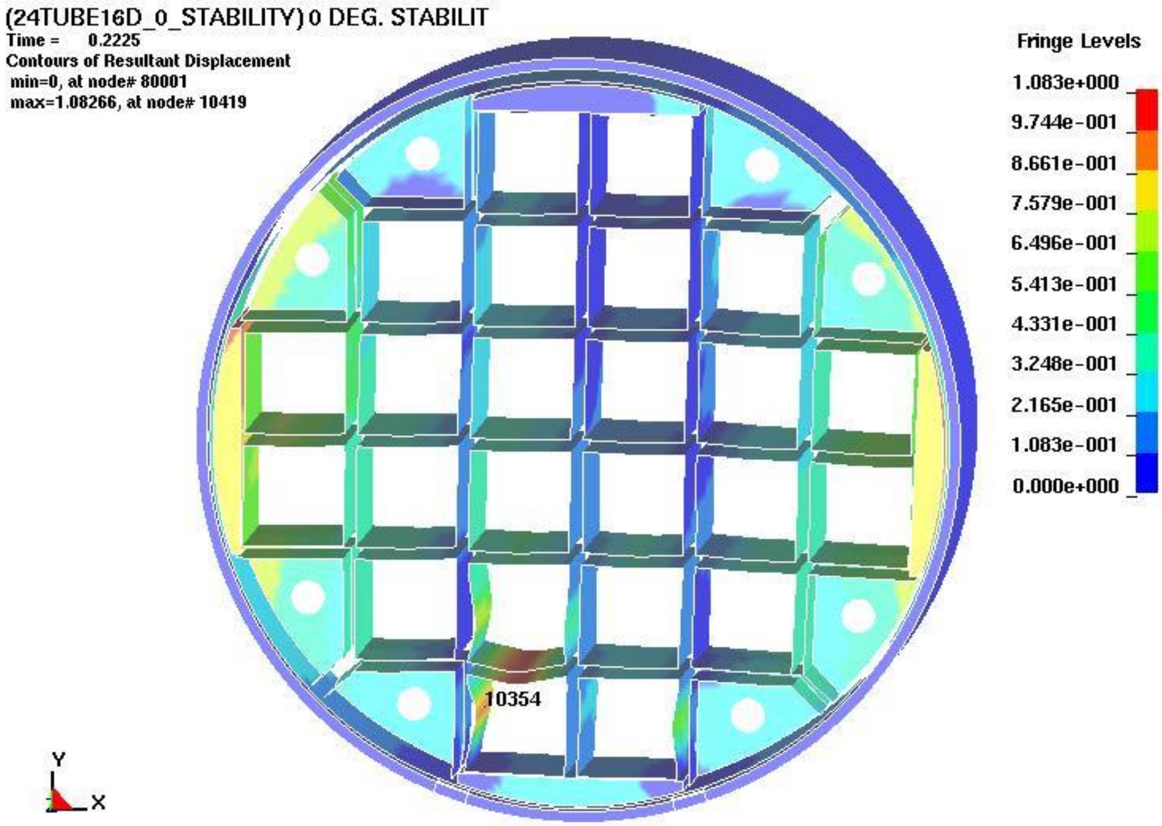



**Figure P.3.7-5**
**0° Drop Stability Analysis *for 24PTH Types 1 and 2 Basket* - Displaced Shape at 172g**

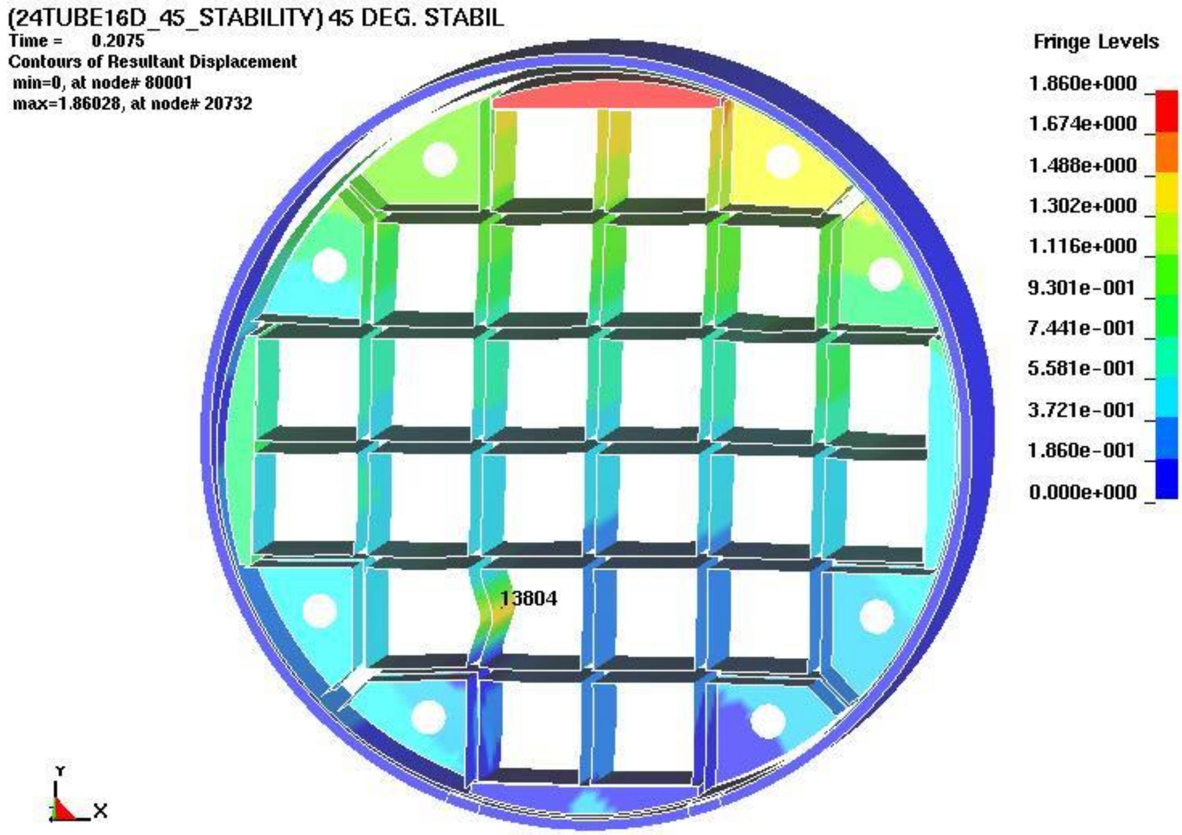



**Figure P.3.7-7**
**45° Drop Stability Analysis *for 24PTH Types 1 and 2 Basket* - Resultant Displacements at 158g**

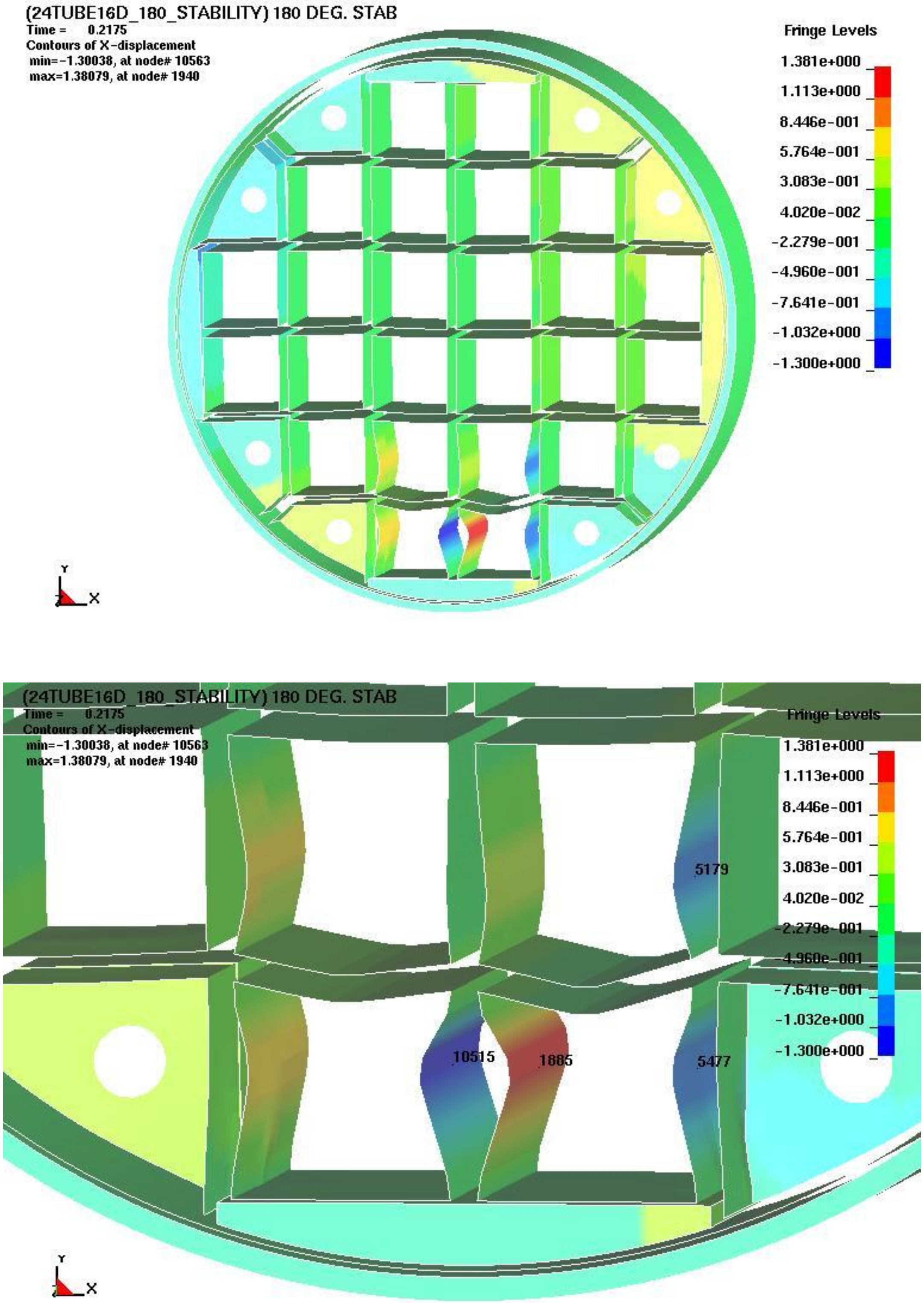



**Figure P.3.7-9**
**180° Drop Stability Analysis *for 24PTH Types 1 and 2 Basket* – Displaced Shape at 167g**

## P.3.8 24PTH Type 3 Basket Structural Analysis

*This section evaluates the structural integrity of the NUHOMS® 24PTH Type 3 basket for normal, off-normal, and side and end drop accident loads. The 24PTH Type 3 basket is based on the EOS-37PTH basket design [3.46], and the analysis methodologies and design criteria presented in this section are based on those for the EOS-37PTH basket described in Section 3.9.2 of the EOS SAR [3.46].*

### P.3.8.1 General Description

*The NUHOMS® 24PTH Type 3 DSC consists of the 24PTH DSC shell assembly that provides confinement and shielding, and the 24PTH Type 3 basket assembly that locates and supports the SFAs. Structural evaluations of the DSC shell for the 24PTH Type 3 basket are described in Sections P.3.6 and P.3.7 for normal/off-normal loads and accident loads, respectively. The 24PTH Type 3 basket is made up of interlocking, slotted plates to form an egg-crate type structure, which forms a grid of 24 fuel compartments that house SFAs. A typical stack-up of grid plates is composed of a structural steel plate, an aluminum plate for heat transfer and a neutron absorber plate (neutron poison) for criticality.*

*Extruded aluminum transition rails are bolted to the perimeter of the grid plate assembly to provide the transition to a cylindrical exterior surface that matches the DSC shell's inside surface. Each of the transition rails at the 0°, 90°, 180°, and 270° locations (R90 transition rails) is composed of two solid aluminum sections, held with tie rods to extended grid plates.*
**[**

**]** *Each of the rails at the other locations (R45 transition rails) is a closed section that is reinforced with internal steel angle plates. There are no welds in the basket assembly.*

*The minimum open dimension of each fuel compartment cell is sized to allow storage of the applicable fuel, which provides clearance around the FAs. The same three alternate configurations described in Section P.1, namely, 24PTH-S, 24PTH-L, and 24PTH-S-LC, are available for the 24PTH Type 3 basket. The basket length is less than the DSC cavity length to allow for thermal expansion and tolerances.*

*The TC and HSM models in which the 24PTH Type 3 DSC can be loaded are provided in Section P.1. In Section P.3.8, generic terms "TC" and "HSM" are used to refer to those TC and HSM models unless specified otherwise. The basket is keyed to the DSC at 0° and 180° and, therefore, its orientation with respect to the DSC always remains fixed. Under normal transfer conditions, the DSC rests on the inner two 3-inch wide, 0.12-inch thick rails attached to the inside of the TC at 161.5° and 198.5° (or +/- 18.5° off 180°). Under normal storage conditions, the DSC rests on the HSM rails.*

### P.3.8.2 Key Dimensions and Materials

*The key basket dimensions and materials are provided in Drawings NUH-24PTH-S-5012-SAR, NUH-24PTH-L-5012-SAR, and NUH-24PTH-S-LC-5012-SAR (Section P.1.5).*

#### *P.3.8.3 Material Properties*

*The mechanical properties of structural materials used for the basket assembly as a function of temperature are shown in Section P.3.3.*

#### *P.3.8.4 Temperature Data*

*Temperature data from the thermal analyses in Section P.4.12 at the axial location of hottest temperatures are considered for the thermal stress analysis and component evaluations. A bounding temperature gradient is used in the thermal stress analysis.*

#### *P.3.8.5 Fuel Data*

*Section P.2.1 provides design characteristics for the types of PWR FAs to be considered. Fuel loads are applied as uniform pressures for side loads including the deadweight, handling, and on-site accident side drop load.*

#### *P.3.8.6 Methodology*

*ANSYS 17.1 [3.38] is used for the evaluation of side loads and thermal loads. Hand calculations are performed to calculate the stresses due to the axial handling load and on-site axial end drop loads. Axial loads are combined with the corresponding side loads, as applicable. Load conditions for the vertical orientation of the DSC/TC are not controlling. However, the temperature gradient applied in the thermal analysis bounds the gradients applicable to both the horizontal and vertical orientations (see Section P.3.8.6.4).*

##### *P.3.8.6.1 Finite Element Model for Side Loads*

[ ]

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*P.3.8.6.2* *Finite Element Model for Thermal Loads*

*P.3.8.6.3* *Material Properties in Analyses*

*The components of the basket and DSC in the ANSYS model are based on lower bound material properties. For normal/off-normal conditions, the material properties used for stress analyses (except thermal stress analyses) are based on bounding average temperature values at the hottest section for off-normal transfer in the TC. Elastic analyses are used for all normal and off-normal conditions. For the accident side drop analyses, the material properties are based on average temperature values. For elastic-plastic strain and buckling analyses, bilinear material stress-strain curves are used with a 1% tangent modulus for all materials except the bolts and tie rods.*

*P.3.8.6.4* *Loads*

*For side loading, the fuel weight load is modeled using a pressure load equivalent to the applicable acceleration times the FA weight divided by the basket fuel compartment area associated with the active fuel region length and the fuel compartment width between slots (8.9 inches). A fuel load of 11.5 lbf/in acting on the fuel compartment width between slots is applied to bound the load distribution in the active fuel region for all PWR fuel types identified in Section P.2.1. Figure P.3.8-3 shows the application of fuel weight pressure loads to the model.*

*For 0° and 180° side load orientations, the equivalent FA pressure acts only on the horizontal plates. For 90° and 270° side load orientations, the equivalent FA pressure acts only on the vertical plates. For other orientations, the equivalent FA pressure acts on the horizontal and vertical plates, proportioned based on the cosine and sine of the orientation angle.*

*The following bounding normal side load conditions (DSC and basket in horizontal position) are evaluated for the normal and off-normal conditions to consider the handling loads described in Section P.3.6.1.3.2:*

- *DW + 1g Vertical*
- *DW + 0.5g Vert. + 0.5g Transverse*
- *DW + 1.0g Transverse*

[ ]

*For the accident side drop analyses, a drop load of 75g is evaluated to bound the acceleration during a side drop accident as in Section P.3.7.4.1. A 75g end drop is also considered to conservatively envelop the effects of a corner drop. The following accident side drop load conditions (DSC and basket in horizontal position) are evaluated:*

- *0° Side Drop away from TC Rails*
- *180° Side Drop on TC Rails*
- *210° Side Drop on one TC Rail*
- *225° Side Drop away from TC Rails*
- *270° Side Drop away from TC Rails*

*P.3.8.6.5 <u>Criteria</u>*

*The basis for the steel basket stress allowables is the ASME Code, Section III, Division 1, Subsection NG [3.39]. Stress limits for Level A through D service loading conditions are summarized in Table P.3.8-1. Allowable stresses for the threaded fasteners, used to connect the transition rails to the basket grid structure, are from Section NG-3230 of [3.39]. The criteria are summarized in Table P.3.8-2. The hypothetical impact accidents are evaluated as short duration Level D conditions.*

*The component allowable stress values for normal/off-normal conditions are summarized in Table P.3.8-3. The temperatures considered bound the average temperatures at the hottest section for the grid plates and transition rails, respectively, summarized in Section P.4.12.2 for off-normal transfer conditions in a horizontal TC.*

*For the accident side drop analyses, the strain criteria for the basket grid plates are shown in Table P.3.8-4. The strain criteria in the table ensure that displacement and permanent deformation of the steel grid is small and within failure limits for high-strength low-alloy steel such as American Iron and Steel Institute (AISI) 4130 material.* [

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P.3.8.6.6 *Creep Evaluation for Long Term Storage*

*The aluminum R90 rails are designed to resist the bearing loads due to the deadweight of the loaded basket for 80 years while stored in the HSM. For long-term creep effects, where loading on the aluminum transition rail redistributes over time, an average bearing stress is an appropriate value to consider. Conservatively, it is assumed that the entire weight of the basket is resisted by the two pieces of a single aluminum R90 rail. The 1g deadweight load from the entire weight of a 6-inch long portion of the basket is approximately 2,555 lb. The area of the corresponding 6 inch long portion of the R90 rail that resists the load is approximately 120 $in^2$. However, credit for the outer portion of the width of the rail is excluded by conservatively considering only half of the rail width. The corresponding bearing stress is:*

*Basket 1g vertical bearing stress = 0.046 ksi. (on aluminum R90 transition rail)*

*The individual compartment load at each SFA location on the supporting aluminum plate gives a much lower bearing stress:*

*SFA 1g vertical bearing stress = 0.0013 ksi. (on aluminum plate)*

*The allowable bearing stresses are based on Reference [3.40]; they represent the stress in Aluminum 1100 to produce a strain of 0.01 in 550,000 hours (approximately 63 years). However, the creep strain curve is flat enough that the values at 80 years are approximately the same. The allowable bearing stress for Aluminum 1100 represents a conservative lower bound. The initial temperature values (time = 0) and the corresponding allowable bearing stresses in the basket aluminum components, to limit creep strain to 0.01, are as follows:*

- *0.254 ksi in the hottest aluminum plate, with a starting temperature of 680 °F*
- *0.758 ksi in the hottest R90 rail, with a starting temperature of 470 °F*
- *0.876 ksi in a less than hottest R90 rail, based on a starting temperature of 440 °F*

*From Section P.4.12.1 for normal conditions (applicable to long-term storage conditions) at the hottest cross-section of the basket, the average R90 transition rail temperature is 470 °F, which is the same as the above temperature of 470 °F for the hottest R90 rail. Similarly, the hottest basket plate temperature is not more than 572 °F, which is less than the above temperature of 680 °F for the hottest aluminum plate. Based on this comparison of temperatures, and since the heat dissipation rate for the 24PTH Type 3 basket is better than that for the basket temperature data (temperature versus time) used in Reference [3.40], the allowable creep stresses given above are applicable to the aluminum components of the 24PTH Type 3 basket.*

P.3.8.7 *Results*

P.3.8.7.1 *Results for On-Site DW+Handling and Thermal Stress Analysis*

*Combined results for basket component stress results for normal condition deadweight + handling loads and thermal stress analysis are shown in Table P.3.8-5. The tabulated results show that all stresses meet the corresponding code limits.*

*P.3.8.7.2 Aluminum Components – Long Term Storage Deadweight Bearing Stress*

*The aluminum R90 rails are designed to resist the bearing loads due to the deadweight of the loaded basket for 80 years while stored in the HSM. A review of the R90 transition rail stresses shows that for the 1g deadweight loading, the R90 rail carries most of the loading. The aluminum R45 rails take some of the bearing load but are not controlling. For long-term creep effects, where loading on the aluminum transition rail redistributes over time, an average bearing stress is a more appropriate value to consider. The stresses calculated in Section P.3.8.6.6 are compared to allowable stress values that are reduced to limit the effect due to creep:*

| Component | Bearing Stress | Allowable Creep Stress | Stress Ratio |
|---|---|---|---|
| Aluminum Rail | 0.046 ksi | 0.758 ksi | 0.0594 |
| Aluminum Plate | 0.0013 ksi | 0.254 ksi | 0.0051 |

*Since the aluminum bearing stresses are significantly lower than allowable creep stresses, creep under long term storage conditions is not an issue.*

*P.3.8.7.3 Results for Analysis of 75g Accident Side Loading*

*75g accident side drop loads are analyzed using the ANSYS model described in Section P.3.8.6.1. Equivalent static elastic-plastic analyses are performed for computing the equivalent plastic strains.*

*Basket grid plate equivalent plastic strain results for accident 75g side drop loads are shown in Table P.3.8-6. Results based on the updated model for the bounding orientation of 210° are shown in Table P.3.8-7. An ANSYS strain contour plot corresponding to the bounding equivalent plastic strain values is shown in Figures P.3.8-6 and P.3.8-7 for with bolts and tie rods and without bolts and tie rods, respectively. The tabulated results show that all strains meet the corresponding allowable strain limits.*

*Side drop accelerations beyond 75g are considered and the last converged load step is considered the buckling load, which is compared with 75g, the required g-load for accident conditions. The buckling analysis results are shown in Table P.3.8-8 and results based on the updated model for the bounding orientation of 210° are shown in Table P.3.8-9. The minimum factor of safety is 1.25.*

*The only significant stress in the basket aluminum rails is a bearing type stress where the transition rail is compressed between the basket grid plates and the inside surface of the DSC. Since bearing stresses are not required to be evaluated for accident conditions, no further evaluation of the basket transition rails is required.*

*P.3.8.7.4 75g Accident End Drop Loading Calculations*

*Compressive stress associated with the 75g end drop condition is calculated using conservative loads and geometry. For the 75g end drop load condition, the steel grid plates are assumed to carry their own weight plus the weight of all of the aluminum components. The fuel assembly loads are applied directly to the cover plates/shield plugs of the DSC shell assembly and not to the basket assembly. The basket weight considered below bounds the weight summarized in Section P.3.2. The axial stress calculated below represents the general membrane stress in the steel grid plates. The local bearing and peak stresses at the intersections of the slots are not required to be evaluated for accident conditions. There is no significant out-of-plane bending in the grid plates for the 75g end drop condition.*

$$\sigma_{axial\_75g} = 75(W_{basket})/A_s$$

*where*
$W_{basket}$ = 32.0 kips (conservative)
$A_s = 135.2\ in^2$

*Therefore,*

$$\sigma_{axial\_75g} = 17.75\ ksi$$

*This stress value is well below the yield stress, such that the 75g end drop load condition strains do not control and no further evaluation is required.*

*P.3.8.7.5 Adjacent Fuel Compartment Relative Displacements*

*The maximum relative perpendicular displacement from one fuel compartment plate to another is determined from the ANSYS results for the accident side drops. These differences are addressed in the criticality evaluations to ensure that the fuel assembly array pitch does not significantly change due to the accident side drop. Maximum relative displacements for those adjacent compartments that have moved closer together are tabulated in Table P.3.8-10. Maximum relative displacements based on the updated model for the bounding orientation of 210° are shown in Table P.3.8-11. The summary table includes results for analyses with bolts and tie rods modeled and for analyses without bolts and tie rods modeled.*

### P.3.8.8 Evaluation of Potential Crack Propagation and Growth

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### P.3.8.9 Conclusions

*Finite element analyses and hand calculations for the 24PTH Type 3 basket assembly are performed for normal and off-normal conditions. Controlling stress intensities are reported in Table P.3.8-5. A comparison of stress intensities to the corresponding allowable values indicate that all load conditions and combinations show acceptable stress levels.*

*Finite element analyses and hand calculations for the 24PTH Type 3 basket assembly are performed for accident side and end drop conditions. Controlling equivalent plastic strains are reported in Table P.3.8-7. A comparison of strains to the corresponding allowable values indicates that all load conditions show acceptable results. Uncontrolled crack propagation in the grid plates is not an issue for the selected gird plate material.*

***Table P.3.8-1***
***24PTH Type 3 Basket Assembly Stress Criteria for Subsection NG Components***

| *Service Level* | *Stress Category(2)* | *Notes* |
|---|---|---|
| *Level A (NG-3222)* | $P_m \le 1.0S_m$<br>$P_m + P_b \le 1.5S_m$<br>$P_m + P_b + Q \le 3.0S_m$ *(Note 1)* | *Note 3* |
| *Level D Elastic Analysis (NG-3225, App. F)* | $P_m \le \min(\max(1.2S_y, 1.5S_m), 0.7S_u)$<br>$P_m + P_b \le \min(\max(1.8S_y, 2.2S_m), S_u)$ | |
| *Level D Plastic Analysis (Austenitic) (NG-3225, App. F)* | $P_m \le \max(0.7S_u, S_y + 1/3(S_u - S_y))$<br>$P_m + P_b \le 0.9S_u$ | *Note 4* |
| *Level D Plastic Analysis (Ferritic) (NG-3225, App. F)* | $P_m \le 0.7S_u$<br>$P_m + P_b \le 0.9S_u$ | *Note 5* |

*Notes:*

*(1) This limit may be exceeded provided the requirements of NG-3228.3 are satisfied, see NG-3222.2 and NG-3228.3.*

*(2) As appropriate, the special stress limits of NG-3227 should be applied.*

*(3) In accordance with NG-3222 and Note 9 of Figure NG-3221-1, the Limit Analysis provisions of NG-3228 may be used.*

*(4) Level D criteria for austenitic materials are also applicable to high-nickel alloy and copper nickel alloy materials.*

*(5) Alternatively, the criteria in the table may be exceeded for the steel basket plates if equivalent plastic strains are within 1% for membrane, 3% for membrane plus bending and 10% for peak equivalent plastic strains.*

*Table P.3.8-2*
*Threaded Fastener Stress Design Criteria (Normal/Off-Normal)*

| ***Stress Category*** | ***Allowable Stresses*** |
|---|---|
| *Primary + Secondary Membrane* $P_m + Q_m^{(2)}$ | $min(0.9S_y, 2/3S_u)$ |
| *Primary + Secondary Shear* $P_m + Q_m^{(3)(6)}$ | $0.6S_y$ |
| *Primary + Secondary Bearing* $P_m + Q_m^{(4)}$ | $2.7S_y$ |
| *Primary Membrane* $P_m^{(2)}$ | $S_m$ |
| *Primary Shear* $P_m^{(3)}$ | $0.6S_m$ |
| *Primary + Secondary Membrane + Bending* $P_m + Q_m + P_b + Q_b^{(5)(6)}$ | $min(1.2S_y, 8/9S_u)$ |

*Notes:*

*(1) Classification and stress limits are as defined in ASME Code, Section III, Subsection NG [3.39].*
*(2) Averaged stress intensity on tensile stress area at threaded section.*
*(3) Averaged stress across shear area of threaded section.*
*(4) Averaged bearing stress under the fastener head.*
*(5) Stress intensity, excluding effects of stress concentrations.*
*(6) Not applicable to this evaluation; no significant thermal shear due to oversized/slotted holes, and no significant bending.*

***Table P.3.8-3***
***Component Allowable Stresses (Normal / Off-Normal)***

| Component | Material | Temperature (°F) | Stress Category | Allowable Stress (ksi) |
|---|---|---|---|---|
| Steel Grid Plates | AISI 4130 | 700 | $P_m$ | 24.96 |
| | | | $P_m + P_b$ | 37.43 |
| | | | $P_m + P_b + Q$ | 74.87 |
| Rail Angle Plates | SA-516 Grade 70 | 550 | $P_m$ | 20.00 |
| | | | $P_m + P_b$ | 30.00 |
| | | | $P_m + P_b + Q$ | 60.00 |
| Transition Rails | Aluminum 6061 | 550 | $P_m + P_b$ | 4.85 |
| | | | $P_m + P_b + Q$ | 9.70 |
| Bolts(1) | SA-564 Gr. 630 H1100 | 550 | Tension, $P_m$ | 44.15 |
| | | | Tension, $P_m + Q_m$ | 84.56 |
| Tie Rods(1) | SA-564 Gr. 630 H1100 | 550 | Tension, $P_m$ | 44.15 |
| | | | Tension, $P_m + Q_m$ | 84.56 |

*Notes:*
*(1) For basket side loading, only tension loads are transferred through the bolts and tie rods due to oversized/slotted bolts holes that allow for thermal expansion.*

***Table P.3.8-4***
***Basket Grid Plate Accident Drop Strain Design Criteria***

| ***Strain Category*** | ***Allowable Strains[(1)]*** |
|---|---|
| *Primary Membrane* $\varepsilon_m$ | *1.0%* |
| *Primary Membrane + Bending* $\varepsilon_m + \varepsilon_b$ | *3.0%* |
| *Primary + Peak* $\varepsilon_m + \varepsilon_b + \varepsilon_F$ | *10.0%[(2)]* |
| *Compression or Buckling* | *Note [(3)]* |

*Notes:*
*(1) Equivalent plastic strain limits.*
*(2) Membrane + bending equivalent plastic strains determined from the analyses conservatively include peak equivalent plastic strain, such that the limit on primary + peak does not need to be evaluated.*
*(3) Determine the buckling load for each postulated drop orientation to demonstrate that the basket does not buckle within maximum drop load of 75g. Report the safety margin.*

**Table P.3.8-5**
**24PTH Type 3 Basket Stress Summary – Enveloped DW + Handling + Thermal**

| Load Combination | Component | Stress Category | Maximum Stress (ksi) | Allowable Stress (ksi) | Stress Ratio |
|---|---|---|---|---|---|
| Enveloping Results for Normal Conditions in the TC | Grid Plates | $P_m$ | 12.64 | 24.96 | 0.51 |
| | | $P_m + P_b$ | 28.16 | 37.43 | 0.75 |
| | | $P_m + P_b + Q$ | 38.55 | 74.87 | 0.51 |
| | Angle Plates | $P_m$ | 4.10 | 20.00 | 0.20 |
| | | $P_m + P_b$ | 5.52 | 30.00 | 0.18 |
| | | $P_m + P_b + Q$ | 15.72 | 60.00 | 0.26 |
| | Transition Rails | $P_m + P_b$ | 2.09 | 4.85 | 0.43 |
| | | $P_m + P_b + Q$ | 7.97 | 9.70 | 0.82 |
| | Bolts(1) | $P_m$ | 15.03 | 44.15 | 0.34 |
| | | $P_m + Q_m$ | 58.83 | 84.56 | 0.70 |
| | Tie Rods(1) | $P_m$ | 22.16 | 44.15 | 0.50 |
| | | $P_m + Q_m$ | 22.16 | 84.56 | 0.26 |

*Notes:*
*(1) Bolt and tie rod stresses listed are increased for the reduced area at the threads.*
*(2) Grid plate stresses include hand calculated stresses for 0.5g axial, if controlled by DW + 0.5g Vertical + 0.5g Transverse + 0.5g Axial handling load combination.*

*Table P.3.8-6*
*24PTH Type 3 Basket Grid Plate Strain – Side Drops with Bolts and Tie Rods*

| Side Drop Load Case | Fastener Status | Strain(1) Category | Maximum Strain (in/in) | Allowable Strain (in/in) |
|---|---|---|---|---|
| 75g, 0° Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00175 | 0.03 |
| 75g, 180°Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00433 | 0.03 |
| 75g, 210° Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00777 | 0.03 |
| 75g, 225° Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00487 | 0.03 |
| 75g, 270° Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00243 | 0.03 |

*Notes:*
*(1) Equivalent plastic strain*

*Table P.3.8-7*
*24PTH Type 3 Basket Bounding Grid Plate Strain from the Updated Model – Side Drops with and without Bolts and Tie Rods*

| Side Drop Load Case | Fastener Status | Strain(1) Category | Maximum Strain (in/in) | Allowable Strain (in/in) |
|---|---|---|---|---|
| 75g, 210° Side Drop | with Bolts and Tie Rods | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00664 | 0.03 |
| | without Bolts and Tie Rods(2) | $\varepsilon_m$ | 0.00000 | 0.01 |
| | | $\varepsilon_m + \varepsilon_b$ | 0.00673 | 0.03 |

*Notes:*
*(1) Equivalent plastic strain*
*(2) Bolts and tie rods are removed from the model for this analysis, assuming that they fail.*

*Table P.3.8-8*
*24PTH Type 3 Basket Buckling Analysis Results Summary*

| Load condition | Last Converged Load (g)(1) | Actual Maximum Load(g) | Factor of Safety |
|---|---|---|---|
| 75g 0° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |
| 75g 180° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |
| 75g 210° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |
| 75g 225° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |
| 75g 270° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |

*Notes:*
*(1) A maximum load of 94g is applied. Therefore, the buckling load and factor of safety may be greater.*

*Table P.3.8-9*
*24PTH Type 3 Basket Bounding Buckling Analysis Results from the Updated Model*

| Load condition | Last Converged Load (g)(1) | Actual Maximum Load(g) | Factor of Safety |
|---|---|---|---|
| 75g 210° drop with bolts and tie rods | 94.0 | 75.0 | 1.25 |
| 75g 210° drop without bolts and tie rods | 94.0 | 75.0 | 1.25 |

*Notes:*
*(1) A maximum load of 94g is applied. Therefore, the buckling load and factor of safety may be greater.*

*Table P.3.8-10*
*24PTH Type 3 Basket Maximum Adjacent Fuel Compartment Relative Displacements*

| **Load Condition** | **Drop Orientation** | **Maximum Absolute Relative Displacement (in)** | |
|---|---|---|---|
| | | **With bolts and tie rods** | |
| | | $\Delta_{ux}$ | $\Delta_{uz}$ |
| *75g Accident Side Drop* | *0°* | *0.035810* | *0.096722* |
| | *180°* | *0.043568* | *0.095689* |
| | *210°* | *0.069562* | *0.11426* |
| | *225°* | *0.093409* | *0.095402* |
| | *270°* | *0.091852* | *0.034103* |

*Table P.3.8-11*
*24PTH Type 3 Basket Bounding Maximum Adjacent Fuel Compartment Relative Displacements from the Updated Model*

| **Load Condition** | **Drop Orientation** | **Maximum Absolute Relative Displacement (in)** | | | |
|---|---|---|---|---|---|
| | | **With bolts and tie rods** | | **Without bolts and tie rods(1)** | |
| | | $\Delta_{ux}$ | $\Delta_{uz}$ | $\Delta_{ux}$ | $\Delta_{uz}$ |
| *75g Accident Side Drop* | *210°* | *0.066351* | *0.11468* | *0.067193* | *0.11634* |

*Notes:*
*(1) Bolts and tie rods are removed from the model for this analysis, assuming that they fail.*

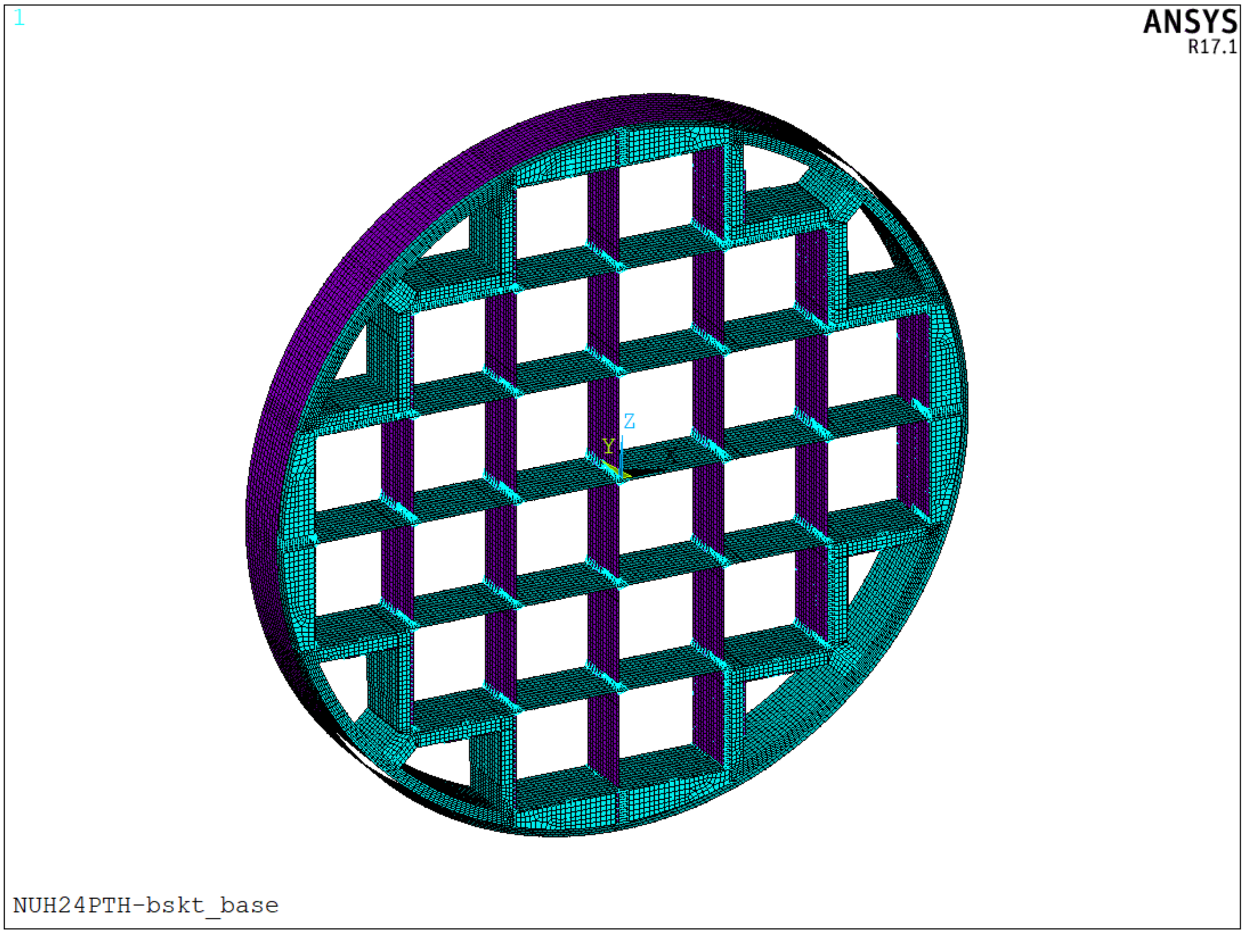


***Figure P.3.8-1***
***24PTH Type 3 Basket Assembly ANSYS Model – Isometric View***

Proprietary Information on Pages P.3.8-19 through P.3.8-24
Withheld Pursuant to 10 CFR 2.390

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Section P.4.10 discusses the thermal analysis of the 24PTH Type 1 DSC with HLZC #6 as shown in Appendix P.2, Figure P.2-9. As shown in Section P.4.10, the thermal analysis of HLZC #6 is bounded by the thermal analysis of HLZC #1 presented in Section P.4.6.

*Section P.4.12 discusses the thermal analysis of the 24PTH Type 3 DSC during storage and transfer conditions.*

The thermal analysis is carried out for the three NUHOMS®-24PTH DSC configurations (24PTH-S, 24PTH-L, and 24PTH-S-LC DSC types in combination with *three* basket types *(Types 1, 2 or 3)* of the NUHOMS®-24PTH system described in Section P.2.1). A summary of the three system configurations analyzed in this chapter are summarized below:

| System Configuration | DSC Type | *Basket Type* | Fuel Type | Total Heat Load per DSC, kW | Transfer Cask*(2)* | Storage Module*(2)* |
|---|---|---|---|---|---|---|
| 1 | 24PTH-S or 24PTH-L | *Type 1 or 3* | All Fuels | 40.8 | OS197FC/ OS200FC | HSM-H/ HSM-HS |
| | | | | 31.2 | OS197/ OS197H/OS200 | HSM-H/ HSM-HS |
| 2 | 24PTH-S or 24PTH-L | *Type 2 or 3* | All Fuels | 31.2 | OS197FC/ OS200FC | HSM-H/ HSM-HS |
| 3 | 24PTH-S-LC(1) | *Type 2 or 3* | B&W 15x15 | 24 | Standardized TC/ OS197/OS197H | HSM-H/HSM-HS or HSM Model 102 or 202 |

(1) The maximum heat load allowed in the 24PTH-S-LC DSC is 24 kW. The HSM Model 102 is designed for a maximum heat load of 24 kW from a NUHOMS® 24P DSC as described in Section 8.1.3. Therefore no additional analysis of HSM Model 102 is required with 24PTH-S-LC DSC. Thermal evaluation of 24PTH-S-LC DSC in OS197 TC is presented in Section P.4.11.

*(2) Transfer operations in OS200FC/OS200 and Storage operations in HSM-HS are not applicable for Type 3 basket.*

The thermal evaluations presented herein include steady state and transient analyses of the thermal response of the NUHOMS®-24PTH system components to a defined set of thermal loading conditions. These loading conditions envelop the thermal conditions expected during all normal, off-normal, and postulated accident loading, transfer and dry storage operations for the design basis thermal conditions as defined in Section P.2. The applicable allowable temperatures are presented and comparisons are made with calculated temperatures as the basis for acceptance.

The analyses conservatively apply a uniform maximum peaking factor of 1.11 [4.1] along the active fuel length to bound the effect of the decay heat flux varying axially along the active fuel length.

A description of the detailed analyses performed for the storage of NUHOMS®-24PTH DSC under normal, off-normal, and accident conditions is provided in Sections P.4.4 and for transfer is provided in Section P.4.5. Section P.4.6 describes the 24PTH DSC basket and fuel cladding analysis for storage and transfer conditions. Section P.4.6.8 describes thermal analysis of the OS200 TC with the 24PTH DSC and Section P.4.6.9 describes evaluation of the 24PTH DSC with damaged/failed fuel assemblies (FAs). The DSC cavity internal pressures are also calculated in Section P.4.6 for all conditions of storage and transfer. Section P.4.7 describes the evaluation performed for loading/unloading conditions. The thermal evaluation concludes that each of the three NUHOMS®-24PTH systems configurations listed above meets all the design criteria.

The effective thermal conductivity of the fuel assemblies used in the 24PTH DSC thermal analysis is based on the conservative assumption of radiation and conduction heat transfer only, where any convection heat transfer is neglected. In addition, the lowest effective thermal conductivity among the fuel assemblies to be stored using 24PTH-S DSC, -L DSC, and -S-LC DSC is selected as the basis for the thermal analysis. Section P.4.8 presents the calculations that determined the fuel assembly effective thermal conductivity in a helium or vacuum environment. The thermal analysis model conservatively neglects convection heat transfer in the basket regions.

The DSC basket and fuel cladding temperature calculation methodology has been benchmarked [4.20] against experimental data [4.21] obtained for the TN-24 cask.

### P.4.2 Summary of Thermal Properties of Materials

The analyses performed herein use interpolated values where appropriate for intermediate temperatures. The interpolation assumes a linear relationship between the reported values. The use of linear interpolation between temperature values in the tables for determining intermediate value of property is justified by the near-linear behavior as a function of temperature for the range of interest.

The emissivity of stainless steel is 0.587 [4.5]. For additional conservatism an emissivity of 0.46 for stainless steel is used for the basket steel plates in the analysis. The emissivity assumed for oxidized Zircaloy cladding surfaces, including Babcock & Wilcox (B&W) M5 cladding material, is 0.8 [4.11]. The emissivity assumed for anodized and non-anodized aluminum portion of side heat shields are 0.8 and 0.1, respectively [4.26] [4.30] [4.47].

*The emissivities of the different materials used in the analyses for the 24PTH Type 3 DSC in Section P.4.12 are provided in the following table.*

| ***Material*** | ***Emissivity (ε)*** | ***References*** |
|---|---|---|
| *Zircaloy based Fuel Cladding* | *0.8* | *[4.11]* |
| *Stainless steel* | *0.46 (1)* | *Appendix U, Section U.4.2* |
| | *0.587 (2)* | *[4.5]* |
| | *0.6 (3)* | *Appendix U, Section U.4.2* |
| *Carbon steel* | *0.55* | *Appendix U, Section U.4.2* |
| *Concrete* | *0.9* | *[4.30]* |

*Notes:*
1. *For machined or flat stainless steel surfaces*
2. *For rolled surfaces of the DSC cylindrical shell*
3. *For the inner surface of the structural shell of the OS197 TC to account for the expected surface oxidation that will occur during the lead pour process.*

[ ]

The tables below provide the thermal properties of materials used in the analysis of the NUHOMS®-24PTH DSC.

*Additional thermal properties of materials used in the 24PTH Type 3 DSC basket are discussed in Section P.4.12.1.2.*

The effective thermal properties are the lowest calculated values among the various PWR fuel assembly types that may be stored in 24PTH DSC. Since 24PTH-S-LC DSC is designed for storage of B&W 15x15 fuel, an additional subset of bounding effective thermal properties are reported.

## 1. PWR Fuel with Helium Backfill

| Temperature, °F | k, Btu/min-in-°F | ρ, $lb_m/in^3$ | T, °F | $C_p$,Btu/$lb_m$-°F |
|---|---|---|---|---|
| **Bounding Fuel in Helium, Transverse** (Used in 24PTH-S and 24PTH-L DSC Analysis) **[See Section P.4.8 ]** | | | | |
| 178 | 2.798E-04 | 0.1114 | 80 | 0.05924 |
| 267 | 3.257E-04 | | 260 | 0.06538 |
| 357 | 3.829E-04 | | 692 | 0.07255 |
| 448 | 4.547E-04 | | 1502 | 0.07779 |
| 541 | 5.389E-04 | | | |
| 635 | 6.326E-04 | | | |
| 730 | 7.398E-04 | | | |
| 826 | 8.558E-04 | | | |

| | | | | |
|---|---|---|---|---|
| **Bounding B&W 15x15 Fuel in Helium, Transverse** (Used in 24PTH-S-LC DSC Analysis) **[See Section P.4.8]** | | | | |
| 162 | 3.560E-04 | 0.1265 | 80 | 0.05931 |
| 254 | 4.064E-04 | | 260 | 0.06544 |
| 346 | 4.780E-04 | | 692 | 0.07261 |
| 439 | 5.639E-04 | | 1502 | 0.07790 |
| 533 | 6.620E-04 | | | |
| 629 | 7.733E-04 | | | |
| 725 | 8.957E-04 | | | |
| 822 | 1.031E-03 | | | |

## P.4.3 Specifications for Components

The 24PTH DSC design allows for the use of various poison materials. The tables below show the required minimum thermal conductivity for poison materials in the 24PTH DSCs. Boral® has the lowest thermal conductivity compared to the other poison materials. The thermal analysis is carried out with the lowest thermal conductivity values for the poison material to bound the various poison materials used. The neutron poison plates must have the following minimum thermal conductivity.

**Boral**

| Temperature (°F) | K (Btu/min-in-°F) |
|---|---|
| 100 | 0.0761 |
| 500 | 0.0699 |
| 774 | 0.0699(*) |

**Enriched Borated Aluminum**

| Temperature (°F) | K (Btu/min-in-°F) |
|---|---|
| 68 | 0.136 |
| 212 | 0.141 |
| 392 | 0.149 |
| 774 | 0.149* |

**Natural Borated Aluminum****

| Temperature (°F) | K (Btu/min-in-°F) |
|---|---|
| 68 | 0.120 |
| 212 | 0.144 |
| 482 | 0.148 |
| 571 | 0.148 |
| 774 | 0.148* |

Notes:

* Assumed values.

** A full thickness (0.875 inch) piece of natural borated aluminum shall have a minimum thermal conductivity of 0.136 Btu/min-in-F. Conductivity values provided are based on a 0.125 inch piece of natural borated aluminum.

*The 24PTH Type 3 DSC neutron absorber plate must have a minimum conductivity of 130 W/m-K. The thermal models described in Section P.4.12 refer to the neutron absorber plate as poison plate, in general, or, specifically, as MMC plate.*

### *P.4.11* Thermal Evaluation of 24PTH-S-LC DSC in OS197 TC

Thermal performance of the 24PTH-S-LC DSC during transfer operations in Standardized TC is based on a two-step approach. In Step 1, the DSC shell temperatures are evaluated as noted in Section P.4.5.1. In Step 2, the DSC temperatures evaluated in Step 1 are utilized as boundary conditions to determine the maximum fuel cladding and basket component temperatures as noted in Section P.4.6.5.2. The temperatures resulting from Step 1 are listed in Table P.4-39.

A similar evaluation to that described in Step 1 was performed to evaluate the thermal performance of a 32PT DSC during transfer operation in the OS197 TC as noted in Appendix M, Section M.4.4.1.6.1. This evaluation considers a two-dimensional (2D) cross section of the 32PT DSC in OS197 TC. Since a 2D cross-section model is employed the results of this evaluation are applicable to any configuration wherein the diameter of the DSC shell, the material of the shell and the heat load are the same. Since the outer diameter, material, and the maximum heat load (i.e. 24 kW) of the 24PTH-S-LC DSC and the 32PT DSC are identical, the DSC shell temperatures presented in Section M.4.4.1.6.1 can be applied to the 24PTH-S-LC DSC. The following table presents a comparison of the DSC shell temperatures determined for the 24PTH-S-LC DSC in the Standardized TC to the temperatures determined for 32PT DSC in the OS197 TC:

**Comparison of DSC Shell Maximum Temperatures**

| Operating Condition | Standardized TC @ 24 kW | OS197 @ 24 kW |
|---|---|---|
| Normal, 100 °F Ambient | 448 [Table P.4-39] | 445 [Table M.4-3] |
| Off-Normal, 117 °F Ambient | 470 [Table P.4-39] | 433 [Table M.4-9] |
| Accident, 117 °F Ambient | 487 [Table P.4-39] | 600 [Table M.4-14] |

A comparison of the DSC shell maximum temperatures shows that for normal and off-normal conditions, the maximum temperatures determined in the Standardized TC bound that of the OS197 TC. Therefore, no further evaluation is required for normal and off-normal conditions.

For accident conditions, the DSC shell maximum temperature of the OS197 TC is 600 °F and is significantly higher than 487 °F determined in the Standardized TC. This is because, the liquid neutron shield, which improves the thermal performance of the OS197 TC compared to Standardized TC during normal and off-normal conditions, is considered lost during the accident evaluation.

However, this temperature of 600 °F is bounded by the blocked vent accident condition of the 24PTH-S-LC DSC in HSM Model 102, which was analyzed based on a shell temperature of 613 °F as shown in Table P.4-28. As shown in Table P.4-25 and P.4-28 for HLZC # 5, the maximum fuel cladding temperature for blocked vent accident conditions when analyzed based on a bounding 613 °F shell temperature is 821 °F with significant margin to the temperature limit of 1058 °F. Therefore, even under accident conditions in the OS197 TC, the 24PTH-S-LC DSC will maintain the fuel cladding temperature significantly below the temperature limit of 1058 °F.

To estimate the impact on the internal pressure of 24PTH-S-LC DSC during accident conditions due to this temperature increase, the average helium temperature determined for blocked vent accident condition, i.e., 618 °F (See Section P.4.6.7.5) is also assumed for the transfer accident case. The maximum internal pressure for 24PTH-S-LC during a postulated transfer accident is then calculated as:

## *P.4.12 Thermal Evaluation of NUHOMS 24PTH Type 3 DSC*

*This section evaluates the thermal performance of the 24PTH Type 3 DSC based on HLZC #1 through #6 during storage and transfer conditions with intact, damaged and failed FAs.*

*A new basket assembly designated as Type 3 is proposed for the 24PTH-S, 24PTH-L and the 24PTH-S-LC DSCs based on the EOS-37PTH DSC design. The EOS style basket design includes various features to improve the thermal performance such as* [

]

*The Type 3 basket replaces the Type 1 (with aluminum inserts) or Type 2 baskets (without aluminum inserts) within the 24PTH-S or the 24PTH-L DSCs and the Type 2 basket within the 24PTH-S-LC DSC. The 24PTH system configurations applicable to the analyses presented in this section for Type 3 DSC are shown in the table from Section P.4.1. The evaluations for Type 1 and Type 2 baskets during storage and transfer conditions are presented in Sections P.4.4 through P.4.6 for HLZCs #1 through #5. Section P.4.10 presents the thermal evaluation of 24PTH Type 1 DSC with HLZC #6.*

*This section presents the thermal evaluation for Type 3 basket for all HLZCs. The objective of these evaluations is to demonstrate that the thermal performance of the Type 3 Basket exceeds the thermal performance of the Type 1 Basket (with aluminum inserts). Since the Type 1 Basket (with aluminum inserts) is better than Type 2 (without aluminum inserts), this will also ensure that the Type 3 basket is better than the Type 2 basket without additional evaluations. In addition, the 24PTH-S-LC DSC is limited to 24 kW. Therefore, the sensitivity analyses are based on the 40.8 kW considered for 24PTH-S or 24PTH-L DSCs during storage operations, and 40.8 kW during transfer operations with time limits and 31.2 kW heat load without time limits. The Type 3 basket is only permitted for use with the OS197 cask variants and cannot be used with the OS200 cask unlike the Type 1 or 2 baskets and no discussion is presented for this configuration. The Type 3 basket design has the same length as the Type 1 and Type 2 baskets.*

### P.4.12.1 Storage Analysis of 24PTH Type 3 DSC in HSM-H

*For the storage evaluation, a computational fluid dynamics model of the 24PTH Type 3 DSC in HSM-H is utilized to determine the bounding temperatures. This model is based on the approach presented in Section U.4.11.1 of the UFSAR for the 32PTH1 DSC in HSM-H and also the approach presented in Section 4.4.2 of the NUHOMS® EOS UFSAR [4.53]. It includes the 24PTH Type 3 DSC basket, HSM-H and the external air domain surrounding the HSM-H.*

#### *P.4.12.1.1 Bounding Storage Condition*

*A review of the maximum fuel cladding temperatures in Table P.4-14 and Section P.4.10 demonstrates that the load case with HLZC #1 results in bounding maximum fuel cladding temperature among HLZCs #1 and #4 through #6. As mentioned in Section P.4.6, HLZC #1 bounds HLZCs #2 and #3. Therefore, HLZC #1 is bounding among HLZCs #1 through #6.*

*Based on a review of the maximum fuel cladding temperatures in Table P.4-14 for normal conditions, Table P.4-20 for off-normal conditions, and Table P.4-25 for accident conditions, along with Section P.4.10, the normal hot storage with 100 °F ambient temperature is the bounding normal storage load case.* [

] *Table P.4-44 lists the limiting design load cases to evaluate the thermal performance of the 24PTH Type 3 DSC during storage conditions in HSM-H.*

*P.4.12.1.2 Material Properties*

*Material properties for the 24PTH Type 3 DSC and HSM-H components are listed in Table P.4-45. Figure P.4-56 shows the schematic view of basket assembly grid along with location of the center basket plates, off-center basket plates and steel outer plates. Figure P.4-56 also shows that, center and off-center basket plates are* [

]

*The bounding effective thermal properties of PWR FAs loaded in 24PTH Type 3 DSC are discussed in Section P.4.12.1.2.2.*

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*P.4.12.1.2.2 Bounding Effective thermal properties of PWR FAs Loaded in 24PTH DSC*

*The calculation of the effective thermal properties for the homogenized FAs within the 24PTH Type 3 DSC follows the same methodology as that discussed in Section P.4.8. Based on the discussion in Section P.4.8, the thermal properties for the bounding WE14x14 are updated to account for the increased compartment size and the high emissivity steel plates within the 24PTH DSC Type 3 basket assembly. The bounding transverse and axial thermal conductivities as well as specific heat and density are listed in Table P.4-50.*

*P.4.12.1.3 Computer-Aided Design and Meshing*

*In addition to modeling the convection within the HSM-H cavity, the model also includes the thermal conduction within the basket and the HSM-H; radiation heat transfer among the DSC shell, heat shields, and HSM-H; and heat dissipation from the HSM-H and the vent outlet via convection and radiation to the ambient.*

*Section P.4.12.1.3.1 presents the computer-aided design (CAD) model for the 24PTH Type 3 DSC basket in ANSYS ICEM CFD [4.55]. Section P.4.12.1.3.2 presents the CAD model for the HSM-H with the 24PTH Type 3 DSC shell and end plates in ANSYS ICEM CFD [4.55]. The meshes are imported into ANSYS FLUENT [4.54] to develop a CFD model for thermal evaluation.*

*P.4.12.1.3.1 CAD of 24PTH Type 3 DSC Basket Assembly*

*Based on the dimensions in Table P.1-1, the following table summarizes the basket, cavity and DSC lengths for the 24PTH DSC system.*

Proprietary Information on Pages P.4-70e through P.4-70i
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*P.4.12.1.3.2 CAD of HSM-H with 24PTH Type 3 DSC Shell*

*The CAD model of the HSM-H with the 24PTH DSC shell and end plates is generated in ANSYS ICEM CFD [4.55].* [

]

*Some simplifications and assumptions are discussed as follows:*

[

]

*To ensure the high quality of the mesh, the guidelines on grids and grid design from NUREG-2152 [4.57] are considered in choosing the mesh parameters and techniques.*

- *Maintain the expansion ratio between two consecutive cells below 1.3 in the regions where high gradients of temperature and velocity are expected or material changes. In solid regions, the expansion ratio is allowed to be 2 or higher.*
- *Avoid highly skewed elements with angles less than 45 degrees or larger than 135 degrees, especially in critical regions. In this mesh, around 99% of the elements have an angle between 45 and 135 degrees, and around 79% of the total elements have an angle between 81 and 99 degrees.*
- *Keep the aspect ratio of most elements less than 20 except for those in the near wall regions. In this mesh, 85% elements maintain the aspect ratio below 20, and 54% elements have the aspect ratio smaller than 5.*
- *Use finer and high-quality mesh in critical regions with high temperature and velocity gradients or with significant changes in geometry, such as regions near the DSC outer surfaces.*

- *Ensure sufficient resolution in the near-wall regions adjacent to the wall to capture the large variations in the flow.* [

] *The dimensionless wall distance* $y^+$ *is defined as:*

$$y^+ = \frac{\rho y U_\tau}{\mu}$$

*Where*
$\rho$ *is the fluid density*
$\mu$ *is the fluid viscosity*
*y is the element size*
$U_\tau = \sqrt{\tau_w / \rho}$ *is the friction velocity*
$\tau_w$ *is the wall shear stress.*

[ ]

*P.4.12.1.4 CFD Modeling*

*The CFD modeling follows the same setup as the EOS-37PTH DSC in the EOS-HSM with the wind effect as described in Section 4.4.2.3 and Section 4.9.4.2.3 in NUHOMS® EOS SAR [4.53].*

[ ]

*The following sections present a detailed overview of the methodology used in the CFD model of the HSM-H with 24PTH Type 3 DSC.*

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*P.4.12.1.5 Results*

*P.4.12.1.5.1 Maximum Component Temperatures*

*Table P.4-54 compares the maximum fuel cladding and DSC component temperatures for the 24PTH Type 3 DSC in the HSM-H with HLZC #1 to the design basis values presented in Table P.4-14 and Table P.4-15 for normal hot storage condition with 100 °F ambient. The design basis values presented for the 24PTH Type 3 DSC are based on the bounding temperatures determined for HLZC #1 with a maximum heat load of 40.8 kW for the normal hot storage condition with 100 °F ambient.*

*As shown in Table P.4-54, the maximum temperatures of the components for the 24PTH Type 3 DSC and the HSM-H with HLZC #1 under the normal storage condition are bounded by design basis values listed in Table P.4-14 and Table P.4-15. Therefore, the design basis values in Table P.4-20 and Table P.4-21 for off-normal storage condition and Table P.4-25 and Table P.4-26 for accident blocked vent condition also remain bounding for the 24PTH Type 3 DSC.*

*Figure P.4-68 shows the temperature profiles for the fuel cladding and key components of the 24PTH Type 3 DSC shell and HSM-H. Figure P.4-69 shows the velocity contours on the symmetry middle plane of the HSM-H loaded with the 24PTH Type 3 DSC. The streamlines for the airflow inside the HSM-H loaded with the 24PTH Type 3 DSC under normal hot storage condition is shown in Figure P.4-70.*

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*P.4.12.1.5.4 Maximum Internal Pressures*

*As shown in Section P.4.12.1.5.1, the maximum temperatures of all components for the 24PTH Type 3 DSC are bounded by design basis values for the bounding normal condition with HLZC #1. Therefore, the average helium temperatures determined for the 24PTH Type 3 DSC are also bounded by the design basis values discussed in Section P.4.6.5.4 for determining the maximum internal pressures. The maximum internal pressures in Table P.4-19, Table P.4-24, and Table P.4-29 remain bounding for the 24PTH Type 3 DSC under normal, off-normal, and accident storage conditions, respectively.*

*Since both the temperatures and internal pressure for the 24PTH Type 3 DSC are lower compared to the design basis evaluation with 24PTH Type 1 DSC, the Type 3 basket offers enhanced thermal performance. Also, since the Type 1 (with aluminum insert) basket already exceeds the thermal performance for Type 2 (without aluminum insert) basket, no additional evaluation is required to replace the Type 2 basket with the Type 3 basket during storage operations.*

*P.4.12.2 Transfer Analysis of 24PTH Type 3 DSC in OS197*

*P.4.12.2.1 Bounding Transfer Condition*

*As discussed in Section P.4.1, there are six HLZCs allowed for 24PTH DSCs. HLZC #1 with 40.8 kW results in higher fuel cladding and basket temperatures compared to HLZCs #2 or #3. HLZC #1 also bounds HLZC #6 with 35.2 kW as discussed in Section P.4.10. In addition, based on a review of the maximum fuel cladding temperatures in Table P.4-14 for normal conditions, Table P.4-20 for off-normal conditions and Table P.4-25 for accident conditions along with Section P.4.10, the maximum fuel cladding temperatures with HLZC #1 and HLZC #4 bound those for HLZC #5. Therefore, HLZC #1 with time limits and HLZC #4 under steady-state normal conditions represent the bounding load cases for 24PTH Type 1 basket (with inserts). These bounding scenarios are re-evaluated for the 24PTH Type 3 DSC to demonstrate that the thermal performance exceeds the thermal performance of Type 1 or Type 2 basket assemblies.*

*The bounding transfer operations for the 24PTH Type 3 DSC in OS197FC TC are the horizontal transfer with HLZC #1 with time limits and HLZC #4 under steady-state conditions. Table P.4-61 lists the limiting design load cases to evaluate the thermal performance of the 24PTH Type 3 DSC during transfer conditions.*

*P.4.12.2.2 Material Properties*

*Various components of the 24PTH Type 3 DSC basket assembly and their materials are discussed in Section P.4.12.1.2 and listed in Table P.4-45.*

*The material properties for the design basis evaluation of the OS197FC using SINDA/FLUINT thermal model from Section P.4.5.2 are utilized in this evaluation.*

*P.4.12.2.3* *Computer-Aided Design and Meshing*

*The half symmetric CAD model of the OS197FC TC is based on the model for the OS197FC-B TC with the 61BTH Type 2 DSC shell from Section B.4.5.6.2.1 of Appendix B.4 of EOS SAR [4.53]. Since the same transfer cask is used for transferring the 24PTH DSC, and also because both the 24PTH and 61BTH DSCs have the same outer diameter, the same model is modified using ANSYS ICEM CFD [4.55] to accommodate the 24PTH DSC shell and the top, bottom end plates using the dimensions from Drawing NUH24PTH-1002-SAR in Section P.1.5. In addition, since the 24PTH-S DSC is smaller, a spacer disc is introduced at the bottom of the cask between the DSC and the inner surface of the TC. No convection is considered within the empty regions of the spacer disc. Figure P.4-71 presents the 3D model of the TC model.*

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#### *P.4.12.2.5 Results*

##### *P.4.12.2.5.1 Temperature Calculations*

*The maximum temperatures of fuel cladding and key components of the OS197FC TC for the various load cases described in Table P.4-61 are reported in Table P.4-64. Table P.4-64 shows that the maximum fuel cladding temperature after 11.5 hours of transfer operation without forced air circulation is considerably lower than the 752 °F temperature limit described in Section P.4.1.*

*Also, for scenario when transfer operation cannot be completed within defined time limit, and air circulation is turned on to cool down the 24PTH DSC, maximum fuel cladding temperature is 707 °F and is also considerably lower than 752 °F temperature limit.*

*Table P.4-64 shows that in various conditions of transfer operation, for load cases with 40.2 kW the maximum temperature of ASTM B29 lead used in gamma shield is considerably lower than the 620 °F limit defined in [4.47]. Similarly, the highest neutron shield average temperature, which occurs in LC #T-3, is lower than the limit of 287 °F defined in Table P.4-9. Bulk average temperatures for NS-3 solid neutron shielding material in LC #T-1 and LC #T-4 are lower than the temperature limit of 250 °F defined for long term operation in Table P.4-9.*

*Figure P.4-72 shows the temperature history of the fuel cladding during the transient transfer operations for LCs T-1, T-2 and T-3. As seen from Figure P.4-72, during LC T-2 the air circulation slows down the heat up rate of the TC loaded with the DSC. Temperatures reported in Table P.4-64 show that the temperatures of all key components remain below allowable limits at the end of forced cooling. Based on LC T-2 analysis, the air circulation must be operated for at least 8 hours to cool down the TC/DSC system once initiated.*

*Based on LC T-3, a maximum of 4 hours is allowed to complete the transfer of the 24PTH Type 3 DSC to the storage module or to re-establish the air circulation. Table P.4-64 shows that the temperatures for all LCs remain below the maximum allowable temperature limits discussed in Section P.4.1.*

*Figure P.4-73 through Figure P.4-76 show the temperature contours for LCs T-1 through T-4.*

*Table P.4-64 also shows that maximum fuel cladding temperature in steady state transfer operation with HLZC #4 (31.2 kW) is considerably lower than the 752 °F temperature limit. It also shows that the maximum temperature of ASTM B29 lead used in gamma shield is considerably lower than the 620 °F limit. Similarly, the highest neutron shield average temperature is lower than the limit of 287 °F.*

*As shown in Table P.4-66, the maximum fuel cladding temperatures determined for LC # T-1 with 40.8 kW and LC #T-4 with 31.2 kW for 24PTH Type 3 DSC are lower compared to those determined for 24PTH DSC Type 1 DSC.*

*For LC #T-1, the DSC shell temperature for the evaluation performed with the 24PTH Type 3 DSC is higher compared to the previous evaluation performed for the 24PTH Type 1 basket, while for LC #T-4, it remains below that for 24PTH Type 1 DSC shell with a similar margin as seen for the basket plates. This is primarily due to the difference in the thermal mass of the system, which only impacts the transient evaluations. Based on Table P.1-1, the dry weight of the 24PTH Type 3 basket is 86.1 kips compared to 92.4 kips for the 24PTH Type 1 basket. This reduction in the weight increases the heat up rate of the system resulting in higher temperature for the DSC Shell during transient operations. However, as seen from Table P.4-64, the maximum temperatures for all components remain within the design limits.*

*Based on the above discussion, the Type 3 basket can be used to replace the Type 1 basket. Also, since the Type 1 (with aluminum insert) basket already exceeds the thermal performance for Type 2 (without aluminum insert) basket, no additional evaluation is required to replace the Type 2 basket with the Type 3 basket during transfer operations.*

*P.4.12.2.5.2 GCI Calculation*

*P.4.12.2.5.3 Discussion of Applicable Time Limits*

*Based on the results for LC #T-4 summarized in Table P.4-64, steady state operations are permitted for OS197FC TC loaded with 24PTH Type 3 DSC with heat load of ≤ 31.2 kW for HLZC 4.*

*For the 24PTH Type 3 DSC with HLZC #1 in OS197FC TC, based on the results of LC #T-1 for horizontal transfer operation without air circulation, the maximum fuel cladding temperature increases with time and may exceed the maximum allowable temperature limit of 752 °F. Therefore, steady-state transfer operations without air circulation are not permitted for HLZC #1 and a time limit is required to complete horizontal transfer operations. Similarly, steady state transfer operations are also not permitted for HLZC# 2, 3, and 6. The maximum time limits determined for HLZC # 1 remain applicable for HLZC # 2, 3, and 6 based on the discussion presented in Section P.4.12.1.1.*

As shown in Figure P.4-72, at the end of the 11.5 hours transient transfer operation, the maximum fuel cladding temperature has sufficient margin to the fuel cladding temperature limit of 752 °F. However, a time limit of 9.5 hours is chosen to provide an additional margin to the temperature limit for both the vertical transfer operations within the fuel building and horizontal transfer operations that occur outside the building consistent with the time limits for 24PTH Type 1 DSC. During the vertical transfer operations performed within the building, the OS197 TC is not exposed to the sun (i.e., no solar load), whereas, for horizontal transfer operation performed outside the building it is exposed to the solar load, which makes the horizontal transfer operations the bounding case compared to vertical operations. The maximum fuel cladding temperature at 9.5 hours after the start of operations is [ ] for LC #T-1. Further, this reduction in the time limit will ensure that sufficient time is provided to initiate the recovery actions. If the maximum heat load of a DSC is less than 40.8 kW, a new time limit can be determined and recalculated based on the maximum heat load for that DSC using the methodology/models presented in Sections P.4.12.2.2 through P.4.12.2.4 to provide more realistic time limit for transfer operations.

If transfer operations cannot be completed within the time limit of 9.5 hours and the TC/DSC is in a horizontal orientation, one of the recovery actions is to initiate air circulation within 2 hours.

If air circulation is initiated as a recovery option, it must be operated for a minimum duration of 8 hours to allow sufficient time for the TC/DSC components to cool down before it is turned off. After 8 hours has elapsed with the blower in operation, it can be turned off to complete the DSC transfer. The maximum fuel cladding temperature 4 hours after the air circulation is turned off has sufficient margin to the temperature limit of 752 °F. As shown in Figure P.4-72, these time limits are conservatively calculated based on the initial temperatures at the end of the 11.5 hours transient transfer operation before the blowers in operation.

Even for this worst-case condition, the maximum fuel cladding temperature remains below the allowable limit of 752 °F. In addition to the fuel cladding temperature, a review of the maximum temperatures presented in Table P.4-64 shows large margins for other TC components.

The minimum duration of 8 hours to run the blower and the time limit of 4 hours after the blower is turned off for completion of the transfer operations are determined based on the 24PTH Type 3 DSC in the OS197FC TC with the maximum allowable heat load of 40.8 kW.

### P.4.12.3 Impact of Top and Bottom Forging modifications on 24PTH-S-LC DSCs

The 24PTH-S-LC DSC includes lead shield plugs encased within the inner top forging and the bottom forging for the Type 1 and Type 2 baskets. For these baskets, the lead was poured into the forging. For the Type 3 basket, a lead disc is considered in lieu of pouring the lead into the forgings. To accommodate the lead discs, additional gaps are introduced into the design in both the axial and radial directions as shown in Drawing NUH24PTH-1001-SAR for the top forging and Drawing NUH24PTH-1002-SAR for the bottom forging. In addition, the thickness of the steel plates was increased within the bottom forging while reducing the thickness of the lead.

*Heat dissipation from the top and bottom ends of the DSC is primarily along the axial direction, with very limited heat transfer in the radial direction due to the small thickness of the end plates. To determine the impact of these modifications on the thermal performance, a heat balance was performed on LC # S-1 in Table 4-44. Based on this heat balance, about 95% of the heat dissipated from the basket assembly is rejected through the DSC shell with only 2% rejected through the top end of the DSC and 3% towards the bottom. This shows that the top and bottom ends of the DSC only have a marginal impact on the thermal performance. In addition, since the Type 3 basket assembly has better thermal performance compared to Type 2 basket and also because the heat load is limited to 24 kW for the 24PTH-S-LC DSCs, these changes will not have an adverse impact on the thermal performance.*

## *P.4.13* References


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**Table P.4-44**
**Design Load Cases for 24PTH Type 3 DSC during Storage Conditions**

| Load Case # | Description | HLZC # | Ambient Temperature | Solar Insolation | Note |
|---|---|---|---|---|---|
| S-1 | Normal storage condition, steady-state | 1 (40.8 kW) | 106 °F | No | (1) |
| S-1f | Normal storage condition, steady-state, fine mesh | 1 (40.8 kW) | 106 °F | No | (1), (2) |

Notes:

[ ]

Proprietary Information on Pages P.4-116b through P.4-116i
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**_Table P.4-52_**
**_Applied Peaking Factors for PWR Fuel Assemblies in 24PTH Type 3 DSC_**

| % of Core Height [4.58] | Length | Peaking Factor [4.58] |
|---|---|---|
| 0.00 | 0.00 | 0 |
| 2.78 | 4.00 | 0.652 |
| 8.33 | 12.00 | 0.967 |
| 13.89 | 20.00 | 1.074 |
| 19.44 | 27.99 | 1.103 |
| 25.00 | 36.00 | 1.108 |
| 30.56 | 44.01 | 1.106 |
| 36.11 | 52.00 | 1.102 |
| 41.69 | 60.03 | 1.097 |
| 47.22 | 68.00 | 1.094 |
| 52.78 | 76.00 | 1.094 |
| 58.33 | 84.00 | 1.095 |
| 63.89 | 92.00 | 1.096 |
| 69.44 | 99.99 | 1.095 |
| 75.00 | 108.00 | 1.086 |
| 80.56 | 116.01 | 1.059 |
| 86.11 | 124.00 | 0.971 |
| 91.67 | 132.00 | 0.738 |
| 97.22 | 140.00 | 0.462 |
| 100.00 | 144.00 | 0 |

**Table P.4-53**
**Peaking Factors for Fuel Assemblies in the 24PTH Type 3 DSC Model with Coarse Mesh**

| Region # | CFD Model Z-Coord.(1) (in) | | % of Active Fuel Length(2) | | Average Height from Bottom (in) | Peaking Factor | Area Under Curve (in) |
|---|---|---|---|---|---|---|---|
| | From | To | From | To | | | |
| 1 | 0 | 2.140 | 0 | 0.0149 | 1.070 | 0.174 | 0.3731 |
| 2 | 2.140 | 8.129 | 0.0149 | 0.0564 | 5.134 | 0.661 | 3.9570 |
| 3 | 8.129 | 16.193 | 0.0564 | 0.1125 | 12.161 | 0.945 | 7.6213 |
| 4 | 16.193 | 23.753 | 0.1125 | 0.1649 | 19.973 | 1.065 | 8.0478 |
| 5 | 23.753 | 31.269 | 0.1649 | 0.2171 | 27.511 | 1.099 | 8.2611 |
| 6 | 31.269 | 40.193 | 0.2171 | 0.2791 | 35.731 | 1.107 | 9.8786 |
| 7 | 40.193 | 48.122 | 0.2791 | 0.3342 | 44.158 | 1.106 | 8.7676 |
| 8 | 48.122 | 56.129 | 0.3342 | 0.3898 | 52.125 | 1.102 | 8.8213 |
| 9 | 56.129 | 64.243 | 0.3898 | 0.4461 | 60.186 | 1.097 | 8.9028 |
| 10 | 64.243 | 71.753 | 0.4461 | 0.4983 | 67.998 | 1.094 | 8.2184 |
| 11 | 71.753 | 80.129 | 0.4983 | 0.5564 | 75.941 | 1.094 | 9.1643 |
| 12 | 80.129 | 88.193 | 0.5564 | 0.6125 | 84.161 | 1.095 | 8.8306 |
| 13 | 88.193 | 95.753 | 0.6125 | 0.6649 | 91.973 | 1.096 | 8.2838 |
| 14 | 95.753 | 104.129 | 0.6649 | 0.7231 | 99.941 | 1.094 | 9.1631 |
| 15 | 104.129 | 112.158 | 0.7231 | 0.7789 | 108.143 | 1.083 | 8.6988 |
| 16 | 112.158 | 119.753 | 0.7789 | 0.8316 | 115.955 | 1.052 | 7.9909 |
| 17 | 119.753 | 128.129 | 0.8316 | 0.8898 | 123.941 | 0.953 | 7.9840 |
| 18 | 128.129 | 136.193 | 0.8898 | 0.9458 | 132.161 | 0.728 | 5.8674 |
| 19 | 136.193 | 142.495 | 0.9458 | 0.9895 | 139.344 | 0.444 | 2.8012 |
| 20 | 142.495 | 144.000 | 0.9895 | 1.0000 | 143.248 | 0.087 | 0.1307 |
| | | | | | Sum | | 141.76 |
| | | | | | Normalized | | 0.984 |
| | | | | | Corr. Factor | | 1.016 |

*Notes:*

(1) *Assuming Z=0 is the bottom of the fuel, Z=144" is the top of the fuel*

(2) *The percentage is calculated as the Z-coordinate divided by the active fuel length of 144"*

**Table P.4-54**
**Maximum Component Temperatures for 24PTH Type 3 DSC in HSM-H for Normal Storage with 106 °F Ambient Temperature**

| Components | Design Basis, Tables P.4-14 and P.4-15 | LC S-1 (1) (with HLZC #1) | $\Delta T$ ($T_{HLZC\ \#1} - T_{Design\ Basis}$) |
|---|---|---|---|
| **Fuel Cladding** | 734 | 705 (2) | -29 |
| **Basket Plate** | 668 | 623 (2) | -27 |
| **DSC Shell** | 461 | 410 (2) | -51 |

*Note:*

*(1) See Table P.4-44 for the description of the load cases.*

*(2) According to the discussion in Section P.4.12.1.5.3, a bounding value of 3 °F should be added to the maximum component temperatures to accommodate the effects from the calculated hot gap between the DSC and basket.*

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**Table P.4-58**
**Maximum Temperatures of Key Components in HSM-H loaded with 24PTH Type 3 DSC for Bounding Storage Condition**

| Maximum Temperature (°F) | | | |
|---|---|---|---|
| Diametric Gap between DSC and basket | 0.331" | 0.3" (LC #S-1[(1)]) | ΔT |
| Fuel Cladding | 707.81 | 705.46 | 2.35 |
| Concrete | 246.84 | 247.76 | -0.92 |
| Basket Plate | 625.41 | 622.61 | 2.80 |
| Transition Rails | 509.56 | 506.59 | 2.97 |
| DSC Shell | 408.74 | 410.45 | -1.71 |
| Side Heat Shield | 245.43 | 246.50 | -1.07 |
| Top Heat Shield | 247.88 | 248.51 | -0.63 |
| Support Structure | 336.28 | 338.82 | -2.54 |

*Notes:*

*(1) See Table P.4-44 for the description of the load cases.*

**Table P.4-59**
**Average Temperatures of Key Components in HSM-H Loaded with 24PTH Type 3 DSC for Bounding Storage Condition**

[ ]

**Table P.4-60**
**Not Used**

### *Table P.4-61*
### *Design Load Cases for 24PTH Type 3 DSC during Transfer Conditions*

| Load Case # | Description | HLZC # | Ambient Temperature | Solar Insolation | Note |
|---|---|---|---|---|---|
| T-1A | Normal, hot, indoor horizontal transfer condition, no air circulation, initial condition | 1 (40.8 kW) | 120 °F | No | (2) |
| T-1 | Normal, hot, outdoor horizontal transfer condition, no air circulation, @ 11.5 hours | 1 (40.8 kW) | 100 °F | Yes | (1), (3) |
| T-2 | Normal, hot, outdoor horizontal transfer condition, air circulation, @ 8 hours after the end of LC #T-1 | 1 (40.8 kW) | 100 °F | Yes | (1), (4) |
| T-3 | Normal, hot, outdoor horizontal transfer condition, no air circulation, @ 4 hours after the end of LC #T-2 | 1 (40.8 kW) | 100 °F | Yes | (1), (5) |
| T-4 | Normal, hot, outdoor horizontal transfer condition, no air circulation, steady-state | 4 (31.2 kW) | 100 °F | Yes | (1) |
| T-4f | Normal, hot, outdoor horizontal transfer condition, no air circulation, steady-state, fine mesh | 4 (31.2 kW) | 100 °F | Yes | (1), (6) |

*Notes:*

*(1) Insolation in accordance with 10 CFR Part 71.71(c)(1)*

*(2) Assumes initial steady-state conditions with 223 °F water in the cask-DSC annulus and indoor ambient temperature of 120 °F. TC is in vertical orientation inside the fuel building during loading of DSC, but horizontal orientation is assumed as this case is performed to compute the initial condition for horizontal outdoor transfer operation (LC #T-1A).*

*(3) Initial conditions taken from LC #T-1A for LC #T-1 Normal hot transient. At time = 0, the water is drained, the forced air circulation is off, and the system begins to heat up.*

*(4) Initial conditions are taken from the end of 11.5 hours in LC #T-1 transient.*

*(5) Initial conditions are taken from the end of 8 hours in LC #T-2 transient.*

*(6) This is the fine mesh model for grid convergence index (GCI) study.*

### *Table P.4-62*
### *Not used*

### *Table P.4-63*
### *Not used*

**Table P.4-64**
**Maximum Temperatures of Key Components of the OS197FC TC Loaded with 24PTH Type 3 DSC**

| | LC # T-1A | LC # T-1 @11.5 hours | LC #T-2 @ 8 hours | LC #T-3 @ 4 hours | LC #T-4 | Max. Allowable Temp. (°F) |
|---|---|---|---|---|---|---|
| | Maximum Component Temperatures (°F) | | | | | |
| Fuel Cladding | 615 | 690 | 707 | 711 | 708 | 752 |
| Basket Plates | 513 | 609 | 622 | 632 | 644 | |
| Max. DSC Shell | 288 | 458 | 441 | 467 | 501 | 800 |
| Inner Liner | 227 | 313 | 340 | 347 | 366 | 800 |
| Gamma Shield | 225 | 306 | 333 | 340 | 359 | 620 |
| Structural Shell | 207 | 254 | 281 | 289 | 310 | |
| Neutron Shield, Max /Avg | 203/193 | 249/210 | 276/214 | 284/218 | 304/254 | - / 290 |
| Closure Lid | 182 | 180 | 256 | 218 | 213 | |
| Top Forging | 203 | 207 | 256 | 237 | 250 | |
| Bottom Forging | 215 | 187 | 165 | 171 | 215 | |
| Neutron Shield Outer Skin | 195 | 235 | 260 | 267 | 286 | |
| Bulk Average NS-3, Bottom | 195 | 169 | 122 | 134 | 190 | 250 (Table U.4-8) |
| Transition Rail | 399 | 523 | 514 | 530 | 566 | |

*Note:*

*(1) See Table P.4-61 for the description of the load case.*

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**Table P.4-66**
**Comparison of Maximum Temperatures between 24PTH Type 3 DSC and 24PTH Type 1 DSC during Transfer Operations**

| Load Case(1) | LC # T-1 | Design Basis, Tables P.4-14 and P.4-15 (DSC in TC, 100°F Ambient) | LC # T-4 | Design Basis, Tables P.4-14 and P.4-16 (DSC in TC, 100°F Ambient) |
|---|---|---|---|---|
| Heat Load | HLZC #1 (40.8 kW) | | HLZC #4 (31.2 kW) | |
| Time limit (Hours) | 11.5 | 11.5 | Steady | Steady |
| | Maximum Component Temperatures (°F) | | | |
| **Fuel Cladding** | 690 | 711 | 708 | 733 |
| **Basket Plates** | 609 | 643 | 644 | 680 |
| **Max. DSC Shell** | 458 | 445 | 501 | 548 |

Proprietary Information on Pages P.4-171 through P.4-180
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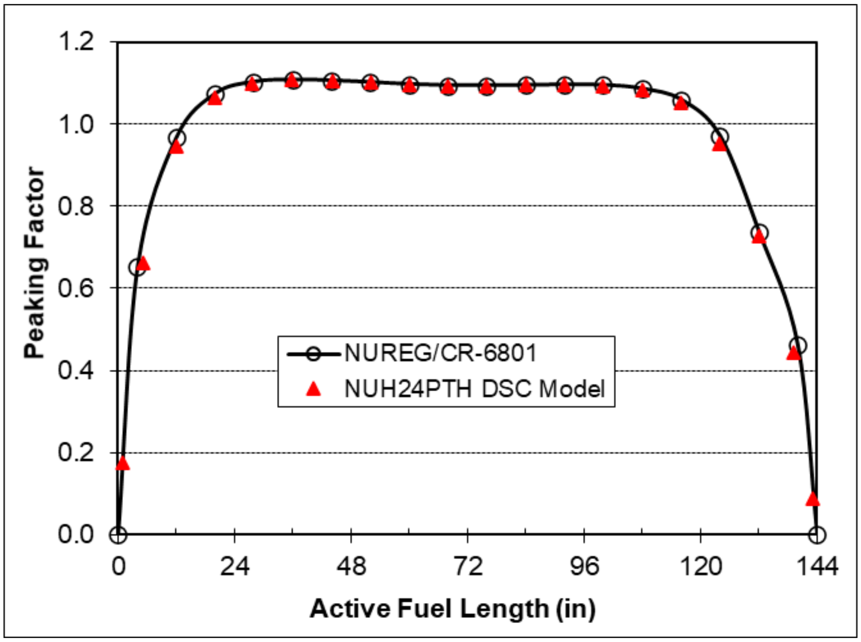


***Figure P.4-66***
***Peaking Factor Curve for PWR Fuel Assemblies in 24PTH Type 3 DSC***

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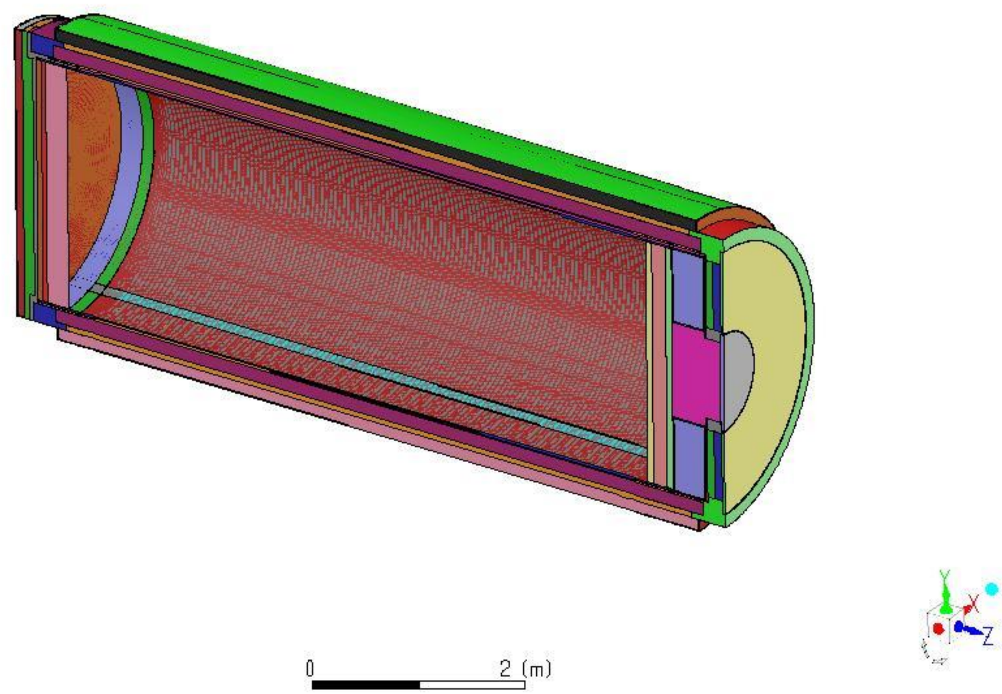


***Figure P.4-71***
***Isometric View of CAD Model of OS197 with 24PTH Type 3 DSC***

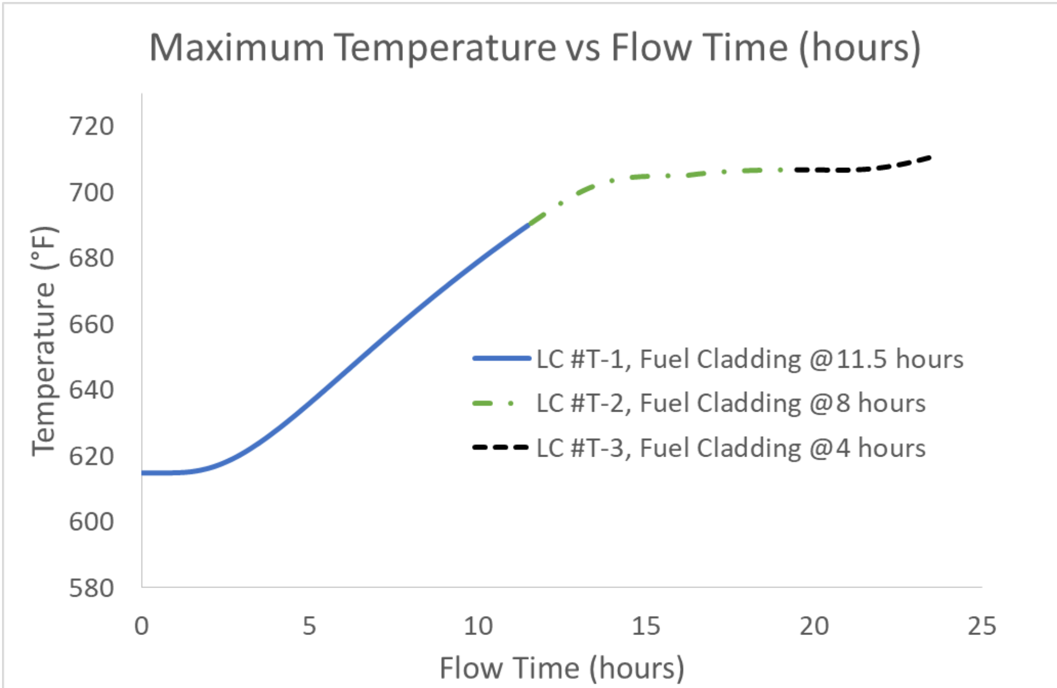


***Figure* P.4-*72***
***Time History of Fuel Cladding for Transient LCs T-1, T-2 and T-3 during Transfer Operations***

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## P.5 Shielding Evaluation

The radiation shielding evaluation for the Standardized NUHOMS® System (during loading, transfer and storage) for the other NUHOMS® canisters is discussed in other sections and appendices of the FSAR. The following radiation shielding evaluation specifically addresses the shielding evaluation of the NUHOMS® 24PTH system with design-basis PWR fuel and control components (CCs) loaded in a NUHOMS®-24PTH DSC.

The shielding analysis is carried out for the three DSC configurations (24PTH-L, 24PTH-S, and 24PTH-S-LC) of the NUHOMS®-24PTH system described in Section P.1.

*There are also three different basket types, as defined in Section P.1:*

- *Type 1 basket has square compartment tubes and aluminum inserts in the rails*
- *Type 2 basket has square compartment tubes and does not have aluminum inserts in the rails*
- *Type 3 basket is an alternate interlocking design with aluminum rails*

*Each basket type is available with the 24PTH-S and -L DSCs, while only basket Types 2 and 3 are available for the 24PTH-S-LC DSC. When referring to specific DSC/basket combinations, basket type is listed after the DSC configuration, e.g., "24PTH-L Type 1 DSC" refers to the 24PTH-L DSC with the Type 1 basket. When referring to the basket explicitly, "DSC" is replaced with "basket," e.g., "24PTH-L Type 1 basket."*

The 24PTH-L and 24PTH-S DSCs are transferred either in the OS197/OS197H Transfer Cask (TC) or the OS197FC TC depending upon the heat load and stored in the HSM-H. The 24PTH-S-LC DSC is transferred in the Standardized TC *or OS197/OS197H TC* and stored in either the HSM-H or HSM-Model 102*/202*. The possible loading combinations are listed below:

(1) 24PTH-L DSC → OS197FC TC (bounds OS197/OS197H TCs)
(2) 24PTH-L DSC → HSM-H
(3) 24PTH-S DSC → OS197FC TC (bounded by #1)
(4) 24PTH-S DSC → HSM-H (bounded by #2)
(5) 24PTH-S-LC DSC → Standardized TC
(6) 24PTH-S-LC DSC → HSM-H *or HSM Model 202* (bounded by #7)
(7) 24PTH-S-LC DSC → HSM-Model 102
*(8) 24PTH-S-LC DSC → OS197/OS197H TC*

The design of HSM-H is similar to HSM Model 102 except the HSM-H has improved shielding performance due to the following design features:

- Elimination of 6" uniform gap between adjacent modules,
- Innovative shielded inlet and outlet ventilation openings,
- Increased concrete thickness in roof, front and backwalls and shield walls, and
- Increased shielding in the HSM door.

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These design features results in the occupational and site dose rates ALARA.

The NUHOMS® 24PTH DSC can also be stored within an upgraded HSM model, designated as HSM-HS as described in Appendix U. From a shielding standpoint, the HSM-HS module is identical to the HSM-H module. Therefore, all calculations performed with the HSM-H are applicable to the HSM-HS.

The NUHOMS® *24PTH-L/S Type 1 or 2 DSC may also be* transferred in a modified version of the OS200 TC as described in Appendix U. The OS200 TC is fitted with an aluminum sleeve to accommodate the smaller diameter 24PTH DSC.

The basket layout for the three DSC configurations is identical except for the length of the DSC components and the shield plug design. The 24PTH-S DSC and 24PTH-L DSC differ in DSC and cavity length, while the 24PTH-S-LC DSC and 24PTH-S DSC differ in cavity length due to a different shield plug design. The 24PTH-L/S has carbon steel shield plugs, while the 24PTH-S-LC has thinner lead shield plugs to increase cavity length to allow for greater fuel lengths in a shorter canister.

Each DSC configuration is designed to store up to 24 intact (and up to 12 damaged, with remaining intact) PWR fuel assemblies. The 24PTH-L and 24PTH-S-LC DSCs are also designed to store up to 24 intact standard PWR fuel assemblies with or without CC; such as burnable poison rod assemblies (BPRAs), Control Rod Assemblies (CRAs), Thimble Plug Assemblies (TPAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs) and neutron sources. For shielding purposes, the 24PTH-L and the 24PTH-S DSC are identical. Therefore, the shielding evaluation presented herein is not performed for the 24PTH-S DSC.

The 24PTH DSCs are also authorized to store Westinghouse 15x15 class Partial Length Shield Assemblies (PLSAs). The PLSAs are similar to regular fuel assemblies except that a portion (axial section) of the active fuel is replaced by stainless steel rods. In essence, a PLSA rod would therefore consist of a fuel section and a steel section. Fuel qualification of these PLSAs, therefore, requires that the combined source term from the irradiated active fuel and steel regions be bounded by the design basis source terms.

The NUHOMS® 24PTH DSC is also designed to store up to 8 failed fuel assemblies in the peripheral locations of the basket. Each failed fuel assembly is housed inside a failed fuel canister prior to loading in these designated positions within the basket.

For the 24PTH-L DSC, Heat Load Zoning Configuration 2 (Figure P.2-2) is the configuration that produces the highest dose rates on the surfaces of the HSM-H and OS197FC TC as compared to configurations 1, 3, 4, and 6 because the highest source fuel assemblies are on the outer periphery of the basket region where self-shielding due to adjacent assemblies is limited. This configuration 2 consists of 20 2.0 kW fuel assemblies located in the outer regions of the DSC. For the 24PTH-S-LC, which has only one heat load zoning configuration (Configuration 5, Figure P.2-5). To bound the shielding analysis for heat load zoning configuration 5, fuel assemblies with a decay heat of 1.5 kW at all 24 location is used. This results in a shielding analysis corresponding to a total of 36 kW decay heat per DSC which is very conservative because the total decay heat in 24PTH-S-LC DSC is limited to 24kW. These bounding gamma and neutron source terms are then used in the radiation shielding models to conservatively calculate dose rates on and around the NUHOMS®-24PTH system.

The bounding burnup, minimum initial enrichment and cooling time combinations for the fuel assemblies used in the shielding analyses of the 24PTH-L DSC in the HSM-H and the OS197FC TC are as follows:

- Dose rates with 24PTH-L DSC in HSM-H: 41 GWd/MTU, 3.3 wt. % U-235, 3.0-year cooled fuel
- Dose rates with 24PTH-L DSC in OS197FC TC: 62 GWd/MTU, 3.4 wt. % U-235, 5.6-year cooled fuel

The bounding burnup, minimum initial enrichment and cooling time combinations for the fuel assemblies used in the shielding analysis of the 24PTH-S-LC DSC are as follows:

- Dose rates with 24PTH-S-LC DSC in Standardized TC: 32 GWd/MTU, 2.6 wt. % U-235, 3.0-year cooled fuel *(the same source term is assumed to be bounding for OS197/OS197H analysis)*
- Dose rates with 24PTH-S-LC DSC in HSM-Model 102: 32 GWd/MTU, 2.6 wt. % U-235, 3.0-year cooled fuel (same as for Standardized TC)

Note that for the 24PTH-L DSC, the source terms are different for calculating dose rate when in HSM-H and OS197FC TC. However, for the 24PTH-S-LC DSC, the source terms are the same for calculating the dose rates when in HSM-Model 102 and Standardized TC. The method of selecting the bounding source terms is explained in detail in Section P.5.2.

The design basis CC source term that envelops all CCs allowed in the 24PTH DSCs is taken from Appendix J for BPRAs with burnups up to 36 GWd/MTU. While Appendix J was developed to specifically address the additional source from a BPRA, this source term is selected as the bounding source term for all CCs. The TPAs and ORAs do not extend into the active fuel region of a fuel assembly. Therefore, they are limited to the source term equivalent to the top

## P.5.1 Discussion and Results

All 24PTH-L DSC MCNP calculations are performed for heat-load zoning configuration 2 which includes 20 design-basis PWR fuel assemblies (with CC) using 2.0 kW fuel. All 24PTH-S-LC DSC MCNP calculations are performed for 24 design-basis PWR fuel assemblies (with CC) using 1.5 kW fuel.

Table P.5-1 summarizes the maximum and average dose rates for the NUHOMS®-24PTH-L DSC loaded into the NUHOMS® HSM-H.

Table P.5-2 summarizes the maximum and average dose rates for the NUHOMS®-24PTH-S-LC DSC loaded into the NUHOMS® HSM-Model 102. Note that the HSM-H is more heavily shielded than the HSM-Model 102 (thicker roof, shield walls, front and back wall including HSM door); therefore, HSM-Model 102 is conservatively modeled to bound HSM-H.

Table P.5-3 provides a summary of the dose rates on and around the OS197FC TC for transfer of the 24PTH-L *Type 2* DSC under normal, off-normal and accident conditions. *Table P.5-3a provides similar dose rate results for the 24PTH-L Type 3 DSC.*

Table P.5-4 provides a summary of the dose rates on and around the OS197FC TC for decontamination and welding operations for the 24PTH-L *Type 2* DSC. *Table P.5-4a provides similar dose rate results for the 24PTH-L Type 3 DSC.*

Table P.5-5 provides a summary of the dose rates on and around the Standardized TC for transfer of the 24PTH-S-LC *Type 2* DSC under normal, off-normal and accident conditions. *Table P.5-5a provides similar dose rate results for the 24PTH-S-LC Type 3 DSC.*

The dose rates reported in Tables P.5-1 through *P.5-5a* are scaled by footnotes to account for dose rate increases due to the unified FQTs and corresponding source terms. The unified FQTs are documented in Section M.5.2.6, and the corresponding source terms are documented in Section P.5.2.6. The scaling factors are developed in Section P.5.4.11.

A discussion of the method used to determine the design-basis fuel source terms is included in Section P.5.2. The design basis CC source term which is from Appendix J is shown in Table P.5-12. The shielding material densities are given in Section P.5.3. The method used to determine the dose rates due to design-basis fuel assemblies with CC in the various NUHOMS® 24PT DSC design configurations is provided in Section P.5.4. The shielding evaluation is performed with the MCNP4C2 [5.2] or MCNP5 [5.19] code with the ENDF/B-VI cross section library. Sample input files used for calculating neutron and gamma source terms and dose rates are included in Section P.5.5.

The NUHOMS®-24PTH DSC is also authorized to store fuel assemblies containing Blended Low Enriched Uranium (BLEU) fuel material. [

]

The design basis CC source terms are developed based upon an examination of the following three BPRA types (1) B&W 15 X 15 (2 cycles, 5 year cooled), (2) WE 17 X 17 Pyrex Burnable Absorber (2 cycles, 10 year cooled), and (3) WE 17 X 17 WABA Burnable Absorber (2 cycles, 10 year cooled). All BPRA types are irradiated to a burnup of 36 GWd/MTU using ORIGEN2. The final design basis CC source term is a hybrid of the worst-case results for the top, plenum, and core regions for these three BPRA types. The core region is taken from the WE 17 X 17 Pyrex BPRA, while the top and plenum regions are taken from the B&W 15 X 15 BPRA.

High burnup BPRAs may have a burnup up to 45 GWd/MTU. As the design basis CC source term assumes only 36 GWd/MTU, additional cooling time is required for high-burnup CCs so that the CC source remains bounded by the design basis. Calculations show that high-burnup B&W 15 X 15 BPRAs are acceptable for storage after 8 years of decay time. Both WE 17 X 17 Pyrex Burnable Absorber and WE 17 X 17 WABA Burnable Absorber high-burnup BPRAs are acceptable for storage after 13 years of decay time.

CCs that exceed the design basis CC source terms per assembly as addressed in Table P.5-12 may be loaded if they will not result in exceeding the dose rates in Tables P.5-1 through P.5-5*a*, so long as the per DSC Technical Specification limit of Table 1-1n is met and the decay heat of the CC plus the fuel assembly does not exceed the limits of the applicable heat zone loading (HZL) configuration.

P.5.2.1.3 Uncertainty in Gamma Source Terms

Almost 100% of the gamma spectrum from light elements is in the range of *1.0* to 1.33 MeV 72.48
which corresponds exactly to two the most prominent lines of $^{60}$Co. As for fission products, the
main contributors after six years with a fraction greater *than* 5% in the range of 0.01 to 0.90 72.48
MeV are: $^{90}$Sr, $^{90}$Y, $^{106}$Rh, $^{137}$Cs, $^{144}$Pr, $^{154}$Eu, and $^{155}$Eu. Contributions from $^{90}$Y, $^{106}$Rh, $^{137}$Cs,
$^{144}$Pr, and $^{154}$Eu are dominant in the range of 0.90 to 1.50 MeV. $^{106}$Rh, $^{147}$Sm, and $^{142}$Ce are the
strongest emitters at energies greater *than* 2.0 MeV. The accuracy of gamma spectrum is 72.48
dependent upon the energy. Photon rates computed for fission products tend to be more accurate
then those for actinides because the calculation of their inventory has less uncertainty [5.1].

Shortly after discharge the emission at higher energies is dominated by actinides. This is true for energies >4 MeV at all cooling times and energy above 3.5 MeV for cooling times after 10 years [5.1]. The major part of this emission comes from $^{244}$Cm. Thus the uncertainty for energy groups of order 3.0 MeV and greater is bounded with the precision with which the inventory of $^{244}$Cm is calculated. Per SCALE 4.4 [5.1], reported experimental $^{244}$Cm densities are accurate within ± 20%. The gamma emission intensity from Cm, which is proportional to the quantity of Cm in the actinide inventory, is bounded by this value. Uncertainty in the source strength in the gamma energy range 0.5 to 2.5 MeV is in the vicinity of 10 to 15 % [5.1].

P.5.2.2 Neutron Source Term for MCNP

One SAS2H/ORIGEN-S run is required for each burnup/initial enrichment/cooling time combination to determine the total neutron source term for the active fuel regions. At discharge the neutron source is almost equally produced from $^{242}$Cm and $^{244}$Cm. The other strong contributor is $^{252}$Cf, which is approximately 1/10 of the Cm intensity, but its share vanishes after 6 years of cooling time because the half-life of $^{252}$Cf is 2.65 years. The half-lives of $^{242}$Cm and

## P.5.4 Shielding Evaluation

Dose rate contributions from the bottom, in core, plenum and top regions, as appropriate, from 20 or 24 0.490 MTU fuel assemblies with control components (CCs) are calculated with the MCNP4C2 Code [5.2] *or MCNP5 code [5.21]* at various locations on and around the NUHOMS® -24PTH DSCs, HSM, and TC.

The following shielding evaluation discussion specifically addresses the NUHOMS®-24PTH-L in an HSM-H or OS197FC TC, and the 24PTH-S-LC DSC in an HSM-Model 102*,* Standardized TC *, or OS197/OS197H TC* using the 0.490 MTU design-basis source terms determined in Section P.5.2.

Dose rate contributions from the bottom, in-core, plenum and top regions, as appropriate, from 24 0.380 MTU fuel assemblies with CCs are also calculated with the MCNP5 Code [5.21] at various locations on and around the NUHOMS® 24PTH DSCs within the HSM and TC.

The shielding evaluation that determines the effect of loading 0.380 MTU per assembly on the dose rates is described in Section P.5.4.11.

### P.5.4.1 Computer Program

MCNP4C2 [5.2] is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. The code treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and some special fourth-degree surfaces. Pointwise (continuous energy) cross-section data are used. For neutrons, all reactions given in a particular cross-section evaluation are accounted for in the cross section set. For photons, the code takes account of incoherent and coherent scattering, the possibility of fluorescent emission after photoelectric absorption, absorption in pair production with local emission of annihilation radiation, and bremsstrahlung. Important standard features that make MCNP4C2 very versatile and easy to use include a powerful general source; an extensive collection of cross-section data; and an extensive collection of variance reduction techniques that can be employed to track particles through very complex deep penetration problems.

An updated version of the MCNP code, MCNP5 [5.21] with the continuous energy ENDFB-VI cross section library is used to determine the dose rates for the shielding analysis described in Section P.5.4.11 *and for Type 3 basket analysis*. MCNP5 has been used to perform the shielding analysis of the 24PTH System (Appendix P5), the 32PT System (Appendix M5), the 32PTH1 System (Appendix U.5), and the 37PTH System (Appendix Z.5).

### P.5.4.2 Spatial Source Distribution

The source components are:

- The neutron sources due to the active fuel region,
- The gamma source due to the active fuel region,

#### P.5.4.6.4 OS197FC TC and Standardized TC Dose Rate Analysis Assumptions

- The 24PTH-L *Type 2 and 3 DSCs are* modeled within the OS197FC TC. The 24PTH-S DSC is not modeled because it is bounded by the 24PTH-L DSC. The 24PTH-S-LC *Type 2 and 3 DSCs are* modeled within the Standardized TC. *The Type 2 basket bounds the Type 1 basket because the Type 2 basket does not have aluminum inserts in the transition rails. In this chapter, all Type 2 basket results also bound the Type 1 basket. The Type 2 and 3 baskets are explicitly modeled because the basket designs are different.*
- Only the OS197FC is modeled for the welding operation. Three inches of supplemental neutron shielding and one inch of steel are assumed to be placed on top of the 24PTH-L DSC cover plates during welding.
- During the accident case, the cask neutron shield (either water or NS-3) and the neutron shield jacket (outer steel skin) is assumed to be lost.
- The borated neutron absorber sheets in the 24PTH-L DSC and 24PTH-S-LC DSC are modeled as aluminum.
- Axial source distribution assumed as shown in Table P.5-13.
- Fuel is homogenized within the fuel compartments, although the 24PTH-L DSC and 24PTH-S-LC DSC baskets are modeled explicitly.
- In the OS197FC TC model, the gap in the cask lid is assumed to extend around the entire circumference of the lid.

### P.5.4.7 Normal Condition Models

Three classes of *MCNP* models are developed: (1) 24PTH-L *Type 2* DSC in HSM-H, (2) 24PTH-L *Type 2 or 3* DSC in OS197FC TC, and (3) 24PTH-S-LC *Type 2 or 3* DSC in Standardized TC. A fourth scenario, 24PTH-S-LC DSC in HSM-Model 102, is analyzed by scaling the results from a similar analysis in Appendix N.5. *A fifth scenario, the 24PTH-S-LC DSC inside the OS197/OS197H TC, is shown to be bounded by previously considered scenarios.* These models are described in subsequent sections.

#### P.5.4.7.1 24PTH-L DSC in HSM-H

Two three-dimensional MCNP4C2 models are developed for the 24PTH-L *Type 2* DSC within a HSM-H, one model for neutrons and the other for gammas. These models are presented in Figure P.5-3 through Figure P.5-7. The HSM-H length is designated as the x axis, the width as the y axis, and the height as the z axis. The HSM-H door is designated as the south side and the –x direction, with the east wall as the –y direction. The roof is the +z direction. The east wall is designated as a reflective boundary and an end shield wall (3 ft thick) is attached to the west wall.

The bottom (bottom of bottom fitting) of the fuel assembly is assigned to an x plane at -213.84 cm. The center of the HSM-H is at y=0 and z=0. The 24PTH-L DSC lid is located 5" from the HSM-H rear wall (x=254.84 cm) which places the bottom of the DSC at x=-232.69 cm, about 9.5 in from the door interior. The 24PTH-L DSC support rails are not included in the model. The heat shields are modeled as flat plates without fins or louvers, and horizontal vent "liner" plates (2 cm thick) are modeled in the top side vents.
Dose rates are calculated on thin cells surrounding the HSM-H and are segmented into 30 cm increments to capture the peak dose rates. Dose rates are also calculated at the inlet and outlet vents. Dose rates for this scenario are provided in Table P.5-1. Dose rates for the front, roof, and side shield wall surface at DSC centerline of the HSM-H are also plotted as a function of distance in Figure P.5-16 through Figure P.5-18 respectively.

A sample MCNP4C2 model input file of HSM-H with 24PTH-L *Type 2* DSC is included in Section P.5.5.2.

*Explicit models of the 24PTH-L Type 3 DSC inside the HSM-H are not developed because the explicit MCNP analysis of the 24PTH-L Type 3 DSC inside the OS197 TC (see Section P.5.4.7.3) indicates that side dose rates decrease due to the aluminum transition rails in the Type 3 basket. Because dose rates at inlet and outlet vents are primarily due to radiation that exits the side of the DSC, vent dose rates will decrease for the Type 3 basket compared to the Type 2 basket. However, based on the OS197FC TC analysis, the dose rates at the bottom of the cask (i.e., at the bottom of the DSC) increase for the Type 3 basket.*

*Because the bottom of the DSC is positioned near the HSM-H door, a door centerline dose rate for the Type 3 basket is added to Table P.5-1 and is obtained by scaling the door centerline dose rate computed with the Type 2 basket. Because the door centerline dose rate is gamma-dominated, the scaling factor is developed as the ratio of the maximum bottom gamma dose rates from Table P.5-3 and Table P.5-3a, or 2440/1660 = 1.47. The scaled door centerline dose rate is then (1.3 mrem/hr)(1.47) = 1.9 mrem/hr.*

#### P.5.4.7.2 24PTH-S-LC DSC in HSM-Model 102

MCNP4C2 was not used for the shielding analysis of the HSM-Model 102. Rather, dose rates on the surface of the HSM-Model 102 were estimated by appropriately scaling the HSM-Model 102 results from Appendix N.5 to properly account for the differences in source and DSC designs.

First, the scaling factors due to the higher source are determined. These scaling factors are generated by comparing the sources from Appendix N.5 to the design basis sources for the HSM-Model 102 from Table P.5-11. The design basis gamma source from Appendix N.5 is for a decay heat of 1.3 kW/assembly, 46.1 GWd/MTU burnup, 3.2 wt.% U-235, and 5.5 years cooled, as shown in Appendix N.5, Table N.5-10. The design basis neutron source is 9.65E+08 n/s, from Table N.5-13 of Appendix N.5.

The neutron source scaling factor would simply be the ratio of the total source strengths, or 0.22, because both neutron sources follow the Cm-244 spectrum. As can be seen, the neutron source from Appendix N.5 is stronger than the 24PTH neutron source by this factor. For the gammas, it is necessary to compare the sources on a group by group basis because the spectra are different.

Using the HSM-H response function from Table P.5-18, it may be demonstrated that the gamma dose rate on the HSM surface is dominated by gammas in groups 29, 31, and 32 (i.e, 1-1.33 MeV, 1.33-1.66 MeV, and 2-2.5 MeV), so further analysis is limited to these three groups. The gamma scaling factor is then generated by weighting the dose rate fraction of each of these three energy groups for the Appendix N.5 gamma source by the ratio of gammas in each energy group and summing the results. Using this methodology, the gamma source scaling factor is approximately 1.6.

Note that the gamma source scaling factor of 1.6 is valid only when the source is dominated by the fuel, such as the HSM-Model 102 roof, side, front vent, and roof vent. At the front and back of the HSM-Model 102, where dose rates are assumed to have roughly equal contributions from the nozzles and fuel, the scaling factor must be reexamined. The dose rate from the nozzles is primarily from Co-60, which is in energy groups 31 and 32. The gamma ratio for these energy groups is approximately 1.04, so that the gamma energy scaling factors at the front and back are approximately 0.5*1.04+0.5*1.6*24/20~1.6. The factor 24/20 is introduced at the ends because the 24PTH-S-LC DSC contains 24 assemblies, while Appendix N.5 utilized only 20 design basis assemblies. The scaling factor at the HSM-Model 102 side do not need this 24/20 factor because the center four assemblies are self-shielded.

*Explicit MCNP analysis of the 24PTH-S-LC Type 3 DSC inside the Standardized TC (see Section P.5.4.7.4) indicates that side dose rates decrease due to the aluminum transition rails in the Type 3 basket. Because dose rates at inlet and outlet vents are primarily due to radiation that exits the side of the DSC, vent dose rates will decrease for the Type 3 basket compared to the Type 2 basket. However, based on the Standardized TC analysis, the dose rates at the bottom of the cask (i.e., at the bottom of the DSC) increase for the Type 3 design.*

*Because the bottom of the DSC is positioned near the HSM Model 102 door, a door centerline dose rate for the Type 3 basket is added to Table P.5-2 and is obtained by scaling the door centerline dose rate computed with the Type 2 basket. Because the door centerline dose rate is gamma-dominated, the scaling factor is developed as the ratio of the maximum bottom gamma dose rates from Table P.5-5 and Table P.5-5a, or 6360/4420 = 1.44. The scaled door centerline dose rate is then (62.2 mrem/hr)(1.44) = 90 mrem/hr.*

P.5.4.7.3 24PTH-L DSC in OS197FC TC

Two three-dimensional MCNP4C2 models are employed for shielding analyses of the 24PTH-L *Type 2* DSC within an OS197FC TC, one model for neutrons and the other for gammas. These models are presented in Figure P.5-8 through Figure P.5-11. The z-axis in the MCNP models coincides with the axis of rotation of the cask and the 24PTH-L DSC. Select features within the cask and on its surface are neglected because they produce only localized effects and have minimal impact on operational dose rates. Examples of neglected features include the 24 neutron shield panel support angles, the 4 trunnions, relief valves, clevises, and eyebolts. With the exception of the 24 neutron shield support angles and the trunnions, the balance of these items are local features that increase the shielding in a small area without replacing any of the shielding material which is included in the model. The additional shielding material that these features provide is not smeared into the bulk shielding, nor is any credit taken for it in the occupational exposure calculation. The 24 neutron shield support angles provide support for the neutron shield skin, which contains the water for the neutron shield. The steel that forms these angles is not smeared with the water in the neutron shield; rather it is modeled as water. This is conservative for gamma radiation because water is less than one seventh the density of steel. The density of the neutron shield water used in the cask MCNP models is 0.96 g/cm$^3$. The resultant reduction in the hydrogen density as compared to full density water results in the water attenuating the neutron dose rate at about the same rate as that for full density steel. Therefore, replacing the steel with the lower density water results in little to no effect on the neutron dose rate outside the cask.

The trunnions penetrate the neutron shield, which locally changes the shielding configuration of the neutron shield. The trunnions are thick steel structures filled with NS-3 neutron shielding material. These structures protrude well past the neutron shield and are made of materials which provide more gamma shielding and comparable neutron shielding as compared to the 0.96 g/cm$^3$ water that these replace. In addition, with the exception of the neutron shield support angles, none of these features is located near the axial center of the cask where the surface dose rate is the largest due to the axial peaking of the fuel.

Design features relevant to the shielding analysis of the OS197FC TC and 24PTH-L DSC are modeled in MCNP4C2. The overall length of the OS197FC TC is 202.97”. The outer diameter of the OS197FC TC is 85.50” (neutron shield included). The outer diameter excluding the neutron shield is 79.12”. The bottom of the OS197FC TC is designed to mate with a 24PTH-L DSC. The overall length of the 24PTH-L DSC is 192.55” (excluding the grapple) and its outer diameter is 67.19”. The bottom end of the 24PTH-L DSC is in contact with the structural shell assembly of the transfer cask.

The OS197FC TC has a ventilated top lid to facilitate air circulation using fan as described in Section P.4.7. In MCNP4C2, the ventilation cutouts in the top cover assembly are modeled as complete annular gaps. The supporting steel around the bolts is not included for modeling convenience and conservatism in the results. Likewise, the neutron shielding in the top lid is also reduced to the inner radial dimension to conservatively account for the bolt cutouts. Use of cone adapters and cask spacers during air circulation will offset shielding lost by the removal of ram access cover.

Dose rates for *the 24PTH-L Type 2 DSC in the OS197FC TC* are provided in Table P.5-3. Dose rates at the sides, top, and bottom of this cask are presented graphically in Figure P.5-19 through Figure P.5-21.

A sample MCNP4C2 model input file for OS197FC TC with 24PTH-L *Type 2* DSC is included in Section P.5.5.3.

*Because the 24PTH-L Type 3 basket design is significantly different than the 24PTH-L Type 2 basket design, an explicit MCNP5 model is developed for the 24PTH-L Type 3 basket based upon the drawings provided in Section P.1. The OS197FC TC cask model, dose rate tallies, and source terms are identical to the 24PTH-L Type 2 DSC MCNP model. Separate MCNP models are developed for gamma, neutron, and secondary gamma radiation to facilitate the use of weight windows generated by ADVANTG [5.22]. A cross-sectional view of the Type 3 basket is provided in Figure P.5-25. Dose rates for the 24PTH-L Type 3 DSC in the OS197FC TC are provided in Table P.5-3a.*

*Comparing the dose rates in Table P.5-3 and Table P.5-3a, side dose rates decrease for the Type 3 basket compared to the Type 2 basket due to the different transition rail design. However, because the basket members are generally lighter in the Type 3 basket, the end dose rates increase for the Type 3 basket compared to the Type 2 basket.*

P.5.4.7.4 <u>24PTH-S-LC in Standardized TC</u>

Two three-dimensional MCNP4C2 models are employed for shielding analyses of the 24PTH-S-LC *Type 2* DSC within a Standardized TC, one model for neutrons and the other for gammas. These models are presented in Figure P.5-12 through Figure P.5-15. The z-axis in the MCNP models coincides with the axis of rotation of the cask and the 24PTH-DSC. Select features within the cask and on its surface are neglected because they produce only localized effects and have minimal impact on operational dose rates. Examples of neglected features include the 24 neutron shield panel support angles, the 4 trunnions, relief valves, clevises, and eyebolts as justified in Section P.5.4.7.3. Design features relevant to the shielding analysis of the cask and DSC are modeled in MCNP.

The overall length of the standardized transfer cask is 192.97”. The outer diameter of the cask is 85.50” (neutron shield included). The outer diameter excluding the neutron shield is 79.12”. The bottom of the transfer cask is designed to mate with a DSC. The overall length of the 24PTH-S-LC is 186.55”, and its outer diameter is 67.19”. The bottom end of the 24PTH-DSC is in contact with the structural shell assembly of the transfer cask.

Dose rates *the 24PTH-S-LC Type 2 DSC in the Standardized TC* are provided in Table P.5-5. Dose rates at the sides, top, and bottom of this cask are presented graphically in Figure P.5-22 through Figure P.5-24.

*Because the 24PTH-S-LC Type 3 basket design is significantly different than the 24PTH-S-LC Type 2 basket design, an explicit MCNP5 model is developed for the 24PTH-S-LC Type 3 basket based upon the drawings provided in Section P.1.*

*The 24PTH-S-LC DSC has lead in the top and bottom shield plugs. There are two primary fabrication options for the lead shield plugs. Option A is a poured-lead design and is featured in the original Type 2 basket MCNP models. Option B is a machined-lead design and is featured in the Type 3 basket MCNP models. For option B, 1/8 inch radial gaps are modeled between all lead shield plugs and steel interfaces, and the lead density is reduced from 11.34 g/cm$^3$ to 11.0 g/cm$^3$. The shield plug lead thickness is also reduced for option B compared to option A, as indicated in the drawings provided in Section P.1. Therefore, option B results in higher cask end dose rates than option A.*

*The Standardized TC model, dose rate tallies, and source terms are identical to the Type 2 basket MCNP model. Separate MCNP models are developed for gamma, neutron, and secondary gamma radiation to facilitate the use of weight windows generated by ADVANTG [5.22]. A cross-sectional view of the Type 3 basket is provided in Figure P.5-25. Dose rates for the 24PTH-S-LC Type 3 DSC in the Standardized TC are provided in Table P.5-5a.*

*Comparing the dose rates in Table P.5-5 and Table P.5-5a, side dose rates decrease for the Type 3 basket compared to the Type 2 basket due to the different transition rail design. However, because the basket members are generally lighter in the Type 3 basket, the end dose rates increase for the Type 3 basket compared to the Type 2 basket. In addition, end dose rates also increase due to modeling the machined-lead shield plug option.*

#### *P.5.4.7.5 24PTH-S-LC DSC in the OS197/OS197H TC*

*The 24PTH-S-LC DSC may also be transferred in the OS197/OS197H TC. No explicit MCNP models are developed for this configuration because it is bounded by previously analyzed configurations.*

*Recall the 24PTH-L DSC/OS197 TC analysis is performed for source terms consistent with heat load zone configuration (HLZC) 2. These source terms are much stronger than the HLZC 5 source terms developed for the 24PTH-S-LC DSC. The basket cross-section is also the same for the 24PTH-L and 24PTH-S-LC DSCs. Therefore, the 24PTH-L DSC/OS197 TC side dose rates presented in Tables P.5-3 and P.5-3a bound the side dose rates for the 24PTH-S-LC DSC within the OS197 TC.*

*The OS197 TC and Standardized TC have the same shielding dimensions and materials on the bottom and top (i.e., lid), although the OS197 TC is longer than the Standardized TC. Therefore, when the 24PTH-S-LC DSC is transferred in the OS197 TC, the Standardized TC bottom and top dose rates from Tables P.5-5 and P.5-5a remain bounding.*

P.5.4.8 Accident Models

No accident models were developed for the HSM-H because no accident scenario in Chapter P.11 has been identified that would alter the dose rates provided in Table P.5-1. For the HSM-Model 102 in an array, in an accident condition HSM-Model 102 is assumed to slide next to an adjacent HSM and therefore double the gap on one side as described in Chapter P.11. It is further conservatively assumed the dose rates from the array double as a result of this accident. The HSM-Model 102 accident analysis and results are provided in Chapter P.11.

For both the OS197FC TC and Standardized TC, accident cases are performed assuming the neutron shield and steel neutron shield jacket (outer skin) of each have been torn off. Accident dose rates at 1m, 100m, and 500m from the side of the cask are presented in Table P.5-3 and Table P.5-5 for the OS197FC TC and Standardized TC, respectively. *Because accident dose rates are dominated by radiation exiting the side of the cask, accident dose rates computed for the Type 2 basket bound the Type 3 basket, as side dose rates decrease for the Type 3 basket.*

P.5.4.9 OS197FC TC Models During Fuel Loading Operations

*MCNP* models are developed for the cask decontamination and welding operations during fuel loading using the 24PTH-L *Type 2 and 3 DSCs*. As the *side and top* dose rates from this cask with 24PTH-L DSC bounds the 24PTH-S-LC DSC due to the higher source term used in 24PTH-L DSC, calculations are not performed for the loading operations with Standardized TC with 24PTH-S-LC DSC.

***Cask Decontamination*****.** The 24PTH-L DSC and the OS197FC TC are assumed to be completely filled with water, including the region between 24PTH-DSC and cask, which is referred to as the "cask/24PTH-DSC annulus." The 24PTH-DSC inner cover plate is assumed to be in place and the temporary shielding has not yet been installed. Results for this case are provided in Table P.5-4 *and Table P.5-4a for the Type 2 and 3 baskets, respectively.*

***Welding and 24PTH-L DSC Draining*****.** Before the start of welding operation, approximately 60% of the water in the DSC cavity is removed due to hydrogen generation. A dry DSC cavity is assumed in all welding models to be conservative. Temporary shielding consisting of three inches of NS3 and one inch of steel is assumed to cover the 24PTH-L DSC top shield plug. In addition, the DSC outer top cover plate is not present. The cask/24PTH-DSC annulus is assumed to remain completely filled with water. Results for this case are provided in Table P.5-4 *and Table P.5-4a for the Type 2 and 3 baskets, respectively.*

#### P.5.4.10 Impact on Dose Rates due to Reduced Density Concrete and Gaps between HSMs

A bounding analysis is performed by employing a minimum concrete density of 140 pounds per cubic foot (pcf) in the HSM-H MCNP model combined with a maximum gap of 1.5 inches between adjacent HSM-H modules and shield walls to determine the effect on maximum and average dose rates due to a fully loaded 32PTH1 DSC. These calculations are documented in Appendix U.5, Section U.5.4.10. The ratios shown in Appendix U.5, Table U.5-18 and Table U.5-19 can be used as scaling factors to increase the maximum and surface-average dose rates of the 24PTH in the HSM-H to account for low density concrete and 1.5-inch gaps during HSM fabrication and installation. Note that the HSM-H concrete contains high density rebar which is not credited in the MCNP models. Further, the modules are installed adjacent to each other such that there will not be a "uniform" gap of 1.5 inches. Ignoring the effect due to increased vent dose rates, the increase in the average dose rates caused by both the maximum postulated uniform gaps and the minimum postulated concrete density is expected to be less than 20% at the front and roof surfaces of the HSM-H module. Dose reduction hardware may be installed to further reduce these dose rates.

#### P.5.4.11 Shielding Analysis with a Loading of 0.380 MTU per Fuel Assembly

As discussed in Section P.5.4, additional shielding analysis is performed with a reduced Uranium loading of 0.380 MTU per fuel assembly. The objective of this analysis is to determine the impact that reduced uranium loading has on system dose rates. The results of this analysis are employed to scale the dose rate results for the 24PTH System (all DSCs). For this purpose, the MCNP4C2 models used for the 0.490 MTU analyses are rerun using MCNP5 with updated source terms as described in P.5.2.6, and with updated material specifications to reflect the reduction in MTU. MCNP5 calculations are performed for the 24PTH-L *Type 2* DSC inside the HSM-H in the normal storage configuration, and dose rate scaling factors are derived using the same methodology as that described in Appendix U, Section U.5.4.12. MCNP5 calculations are also performed for the 24PTH-L *Type 2* DSC inside the OS197 TC in the decontamination and welding configurations, and in the normal and accident transfer configurations, and dose rate and occupational exposure scaling factors are derived using the same methodology as that described in Appendix U, Section U.5.4.12. These results are also applicable to the 24PTH-S and 24PTH-S-LC DSCs. Based on the updated results, six scaling factors are determined and are summarized as follows:

- The dose rates for the HSM-H front and roof are to be scaled by 1.13.
- The dose rates for the HSM-H side and rear are to be scaled by 1.30.
- The site dose for the HSM is to be scaled by 1.13.
- The dose rates for the TC for normal, welding and decontamination are to be scaled as follows:
  - No scaling is required for the side,
  - by 1.18 for the top,
  - by 1.19 for the bottom.
- The dose rates for the TC for accidents are to be scaled by 1.13.
- The occupational exposure for the TC loading and storage operations is to be scaled by 1.10.

These scaling factors are included as footnotes in the dose rate results summarized in Table P.5-1 through Table P.5-5*a*, Table P.5-21, Table P.5-22, Table P.5-24, and Table P.5-26.

These scaling factors are also used to scale the occupational exposure and generic site dose (2X10 back-to-back and front-to-front arrays) results calculated for the 24PTH System in Appendix P.10, and to scale the dose rate consequences of accidents for the 24PTH System in Appendix P.11.

For the 24PTH-S or -L DSC, HLZC 2 is bounding, with 2.0 kW/FA in the peripheral region. Comparing HLZC 1 through 4 and HLZC 6, the highest heat load is 2.5 kW/FA and occurs in the inner region of HLZC 6. Based on the methodology provided in Section B 10 TS 2, the 2.5 kW/FA FQT is included in the Technical Specifications [1.TS] and is applicable to all fuel to be loaded in the 24PTH-S or -L DSC. The 2.0 kW/FA FQT is also provided in the Technical Specifications and is applicable only to the peripheral region of HLZC 2 and 3. The complete set of FQTs is provided in Appendix M.2.

The 24PTH-S-LC DSC uses only HLZC 5. For this DSC, the 1.5 kW/FA FQT is included in the Technical Specifications [1.TS] and is applicable to all fuel to be loaded in the 24PTH-S-LC DSC.

5.13 Japan Atomic Energy Research Institute, "Technical Development on Burn-up Credit for Spent LWR Fuels," JAERI-Tech 2000-071, September 21, 2000.

5.14 U.S. Nuclear Regulatory Commission, "Nuclide Importance to Criticality Safety, Decay Heating, and Source Terms Related to Transport and Interim Storage of High Burnup LWR Fuel," NUREG/CR-6700, Published January 2001, ORNL/TM-2000/284.

5.15 "Characteristics of Potential Repository Waste," DOE/RW-0184-R21, Volume 1, Oak Ridge National Laboratory, Tennessee, July 1992.

5.16 U.S. Nuclear Regulatory Commission, "Analysis of Experimental Data for High Burnup PWR Spent Fuel Isotopic Validation-Calvert Cliffs, Takahama, and Three Mile Island Reactors," NUREG/CR-6968, Published February 2010, ORNL_TM-2008-71.

5.17 U.S. Nuclear Regulatory Commission, "Uncertainties in Predicted Isotopic Compositions for High Burnup PWR Spent Nuclear Fuel," NUREG/CR-7012, Published January 2011, ORNL-TM-2010-41.

5.18 U.S. Nuclear Regulatory Commission, "Analysis of Experimental Data for High-Burnup PWR Spent Fuel Isotopic Validation -- Vandellós II Reactor," NUREG/CR-7013, Published January 2011, ORNL-TM-2009-321.

5.19 LA-UR-03-1987, MCNP - A General Monte Carlo N-Particle Transport Code, Version 5, Los Alamos National Laboratory, April 2003.

5.20 ORNL/TM-2005/39, Version 6, SCALE: A Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation, Oak Ridge National Laboratory, January 2009.

5.21 "Monte Carlo N-Particle Transport Code System," CCC-730, Oak Ridge National Laboratory, RSICC Computer Code Collection, August 2001.

*5.22 Oak Ridge National Laboratory, "ADVANTG – An Automated Variance Reduction Parameter Generator," ORNL/TM-2013/416, Rev. 1, August 2015.*

## Table P.5-1
## Summary of NUHOMS®-24PTH-L DSC in HSM-H, Maximum and Average Dose Rates, Configuration 2 (2) *(6)*

| Dose Rate Location | Maximum Gamma (mrem/hr) | Gamma MCNP 1σ Error | Maximum Neutron (mrem/hr) | Neutron MCNP 1σ Error | Maximum Total(1, 5) (mrem/hr) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| HSM Roof (centerline) (3) | 20.1 | 0.038 | 0.5 | 0.018 | 20.6 | 0.037 |
| HSM Roof Birdscreen(3) | 205.8 | 0.019 | 4.1 | 0.012 | 209.9 | 0.018 |
| HSM End (Side) Shield Wall Surface(4) | 3.4 | 0.081 | 0.1 | 0.016 | 3.5 | 0.079 |
| HSM Door Exterior Surface (centerline) (3)*(7)* | 1.3 | 0.143 | 0.1 | 0.524 | 1.3 | 0.139 |
| HSM Front Birdscreen(3) | 1232.0 | 0.068 | 5.5 | 0.076 | 1237.0 | 0.068 |

| Dose Rate Location | Average (mrem/hr) | Gamma MCNP 1σ Error | Average Neutron (mrem/hr) | Neutron MCNP 1σ Error | Average Total (mrem/hr)(5) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| HSM Roof(3) | 20.3 | 0.011 | 0.5 | 0.006 | 20.8 | 0.011 |
| HSM End (Side) Shield Wall Surface(4) | 1.0 | 0.016 | 0.1 | 0.033 | 1.1 | 0.015 |
| HSM Front (3) | 32.2 | 0.047 | 0.1 | 0.066 | 32.3 | 0.047 |
| HSM Back Shield Wall(4) | 0.6 | 0.074 | 0.1 | 0.025 | 0.6 | 0.074 |

**Notes:**

(1) Gamma and Neutron dose rate peaks do not always occur at same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.
(2) Dose rates calculated using Configuration 2 in 24PTH-L DSC bounds configurations 1, 3, 4, and 6. Dose rates can be higher by 6% to account for the use of grout during HSM fabrication and installation.
(3) These dose rates increase by 13% when loading 0.380 MTU FAs.
(4) These dose rates increase by 30% when loading 0.380 MTU FAs.
(5) Use the ratios shown in Appendix U.5, Table U.5-18 and Table U.5-19 to increase the maximum and surface-average dose rates, respectively to account for reduced density concrete and gaps of up to 1.5″ as described in Appendix U.5, Section U.5.4.10.
*(6) Dose rates are applicable to the Type 1, 2, and 3 baskets.*
*(7) The door centerline dose rate provided in the table is for the Type 2 basket. Total dose rate increases to 1.9 mrem/hr for the Type 3 basket (2.2 mrem/hr including note (3)).*

## Table P.5-2
## Summary of NUHOMS®-24PTH-S-LC DSC in HSM-Model 102, Maximum and Average Dose Rates, Configuration 5[(1)][(4)]

| Dose Rate Location | Maximum Gamma (mrem/hr) | Maximum Neutron (mrem/hr) | Maximum Total (mrem/hr) |
|---|---|---|---|
| HSM Roof (centerline)[(2)] | 59.3 | 0.2 | 59.5 |
| HSM Roof Birdscreen[(2)] | 976.5 | 3.2 | 979.7 |
| HSM End (Side) Shield Wall Surface[(3)] | 266.9 | 0.3 | 267.2 |
| HSM Door Exterior Surface [(2)(5)] (centerline) | 60.6 | 1.6 | 62.2 |
| HSM Front Birdscreen[(2)] | 489.6 | 2.5 | 492.1 |
| HSM Back Shield Wall[(3)] | 2.5 | 0.02 | 2.5 |

| Dose Rate Location | Average Gamma (mrem/hr) | Average Neutron (mrem/hr) | Average Total (mrem/hr) |
|---|---|---|---|
| HSM Roof[(2)] | 47.3 | 0.2 | 47.5 |
| HSM End (Side) Shield Wall Surface[(3)] | 31.7 | 0.1 | 31.8 |
| HSM Front[(2)] | 45.6 | 0.9 | 46.5 |
| HSM Back Shield Wall[(3)] | 0.8 | 0.01 | 0.8 |

**Notes:**
(1) Dose rates can be higher by 6% to account for the use of grout during HSM fabrication and installation.
(2) These dose rates increase by 13% when loading 0.380 MTU FAs.
(3) These dose rates increase by 30% when loading 0.380 MTU FAs.
*(4) Dose rates are applicable to the Type 2 and 3 baskets.*
*(5) The door centerline dose rate provided in the table is for the Type 2 basket. Total dose rate increases to 90 mrem/hr for the Type 3 basket (101 mrem/hr including note (2)).*

## Table P.5-3
## Summary of NUHOMS®-24PTH-L *Type 2* DSC, OS197FC TC Maximum Dose Rates During Transfer Operations, Configuration 2

| Dose Rate Location | Maximum Gamma (mrem/hr) | Gamma MCNP 1σ Error | Maximum Neutron (mrem/hr) | Neutron MCNP 1σ Error | Maximum Total(1) (mrem/hr) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| Cask Side Surface (Radial)(3) | 7.45E+02 | 0.0180 | 7.56E+02 | 0.0120 | 1.50E+03 | 0.0108 |
| Cask Top Axial Surface(4) | 2.37E+02 | 0.0566 | 4.48E+01 | 0.0499 | 2.61E+02 | 0.0523 |
| Cask Bottom Axial Surface(5) | 1.66E+03(2) | 0.0353 | 2.57E+03(2) | 0.0246 | 4.23E+03(2) | 0.0204 |
| 1 ft from Cask Side (Radial)(3) | 4.76E+02 | 0.0179 | 4.82E+02 | 0.0107 | 9.58E+02 | 0.0104 |
| 1 ft from Cask Top Axial Surface(4) | 7.86E+01 | 0.0741 | 3.11E+01 | 0.0455 | 9.58E+01 | 0.0636 |
| 1 ft from Cask Bottom Axial Surface(5) | 9.80E+02 | 0.0355 | 9.44E+02 | 0.0340 | 1.92E+03 | 0.0246 |
| 3 ft from Cask Side (Radial)(3) | 2.85E+02 | 0.0163 | 2.78E+02 | 0.0096 | 5.63E+02 | 0.0095 |
| 3 ft from Cask Top Axial Surface(4) | 3.95E+01 | 0.1189 | 1.47E+01 | 0.0550 | 5.05E+01 | 0.0972 |
| 3 ft from Cask Bottom Axial Surface(5) | 3.44E+02 | 0.0341 | 2.79E+02 | 0.0600 | 6.23E+02 | 0.0328 |
| Cask 1 m (Radial) Accident Condition(6) | 3.10E+02 | *0.0677* | 3.19E+03 | 0.0124 | 3.51E+03 | 0.0128 |
| Cask 100 m (Radial) Accident Condition(6) | 1.50E-01 | *0.0297* | 5.10E-01 | 0.0134 | 6.61E-01 | 0.0124 |
| Cask 500 m (Radial) Accident Condition(6) | 4.95E-04 | *0.0250* | 4.10E-04 | 0.0305 | 9.05E-04 | 0.0194 |

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**Notes:**

(1) Gamma and Neutron dose rate peaks do not always occur at same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.
(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 340 mrem/hr gamma, 419 mrem/hr neutron for a total average dose rate of 758 mrem/hr.
(3) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.
(4) The Top dose rates increase by 18% when loading 0.380 MTU FAs.
(5) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.
(6) The Accident dose rates increase by 13% when loading 0.380 MTU FAs.

## *Table P.5-3a*
## *Summary of NUHOMS®-24PTH-L Type 3 DSC, OS197 FC Maximum Dose Rates During Transfer Operations, Configuration 2*

| *Dose Rate Location* | *Maximum Gamma (mrem/hr)* | *Gamma MCNP 1σ Error* | *Maximum Neutron (mrem/hr)* | *Neutron MCNP 1σ Error* | *Maximum Total(1) (mrem/hr)* | *Total MCNP 1σ Error* |
|---|---|---|---|---|---|---|
| *Cask Side Surface (Radial)(3)* | *6.14E+02* | *0.0010* | *6.40E+02* | *0.0018* | *1.25E+03* | *0.0010* |
| *Cask Top Axial Surface(4)* | *2.48E+02* | *0.0378* | *6.07E+01* | *0.0060* | *2.73E+02* | *0.0344* |
| *Cask Bottom Axial Surface(5)* | *2.44E+03(2)* | *0.0063* | *3.11E+03(2)* | *0.0028* | *5.55E+03(2)* | *0.0032* |
| *1 ft from Cask Side (Radial)(3)* | *3.87E+02* | *0.0009* | *4.09E+02* | *0.0017* | *7.95E+02* | *0.0010* |
| *1 ft from Cask Top Axial Surface(4)* | *7.73E+01* | *0.0480* | *3.99E+01* | *0.0051* | *9.43E+01* | *0.0394* |
| *1 ft from Cask Bottom Axial Surface(5)* | *1.38E+03* | *0.0072* | *1.12E+03* | *0.0031* | *2.49E+03* | *0.0042* |
| *3 ft from Cask Side (Radial)(3)* | *2.28E+02* | *0.0009* | *2.38E+02* | *0.0015* | *4.66E+02* | *0.0009* |
| *3 ft from Cask Top Axial Surface(4)* | *3.67E+01* | *0.0583* | *1.92E+01* | *0.0099* | *4.84E+01* | *0.0444* |
| *3 ft from Cask Bottom Axial Surface(5)* | *4.80E+02* | *0.0100* | *3.09E+02* | *0.0042* | *7.88E+02* | *0.0063* |
| *Accident* | *Accident dose rates in Table P.5-3 remain applicable* | | | | | |

***Notes:***

*(1) Gamma and Neutron dose rate peaks do not always occur at the same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.*
*(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 424 mrem/hr gamma, 484 mrem/hr neutron, for a total average dose rate of 908 mrem/hr.*
*(3) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.*
*(4) The Top dose rates increase by 18% when loading 0.380 MTU FAs.*
*(5) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.*

## Table P.5-4
## Summary of NUHOMS®-24PTH-L *Type 2* DSC, OS197FC TC Maximum Dose Rates During Decontamination and Welding Operations, Configuration 2

| Dose Rate Location | Maximum Gamma (mrem/hr) | Gamma MCNP 1σ Error | Maximum Neutron (mrem/hr) | Neutron MCNP 1σ Error | Maximum Total(1) (mrem/hr) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| Decontamination | | | | | | |
| Cask Side Surface (Radial)(4) | 4.34E+02 | 0.0210 | 8.23E+02 | 0.0069 | 1.26E+03 | 0.0085 |
| Top Axial Surface(5) | 7.83E+02 | 0.0272 | 3.14E-01 | 0.2858 | 7.83E+02 | 0.0272 |
| Cask Bottom Axial Surface(6) | 1.15E+03(2) | 0.0478 | 5.83E+01(2) | 0.0126 | 1.21E+03(2) | 0.0455 |
| 1 ft from Cask Side (Radial)(4) | 2.82E+02 | 0.0206 | 5.32E+02 | 0.0060 | 8.14E+02 | 0.0082 |
| 1 ft from Top Axial Surface(5) | 5.93E+02 | 0.0262 | 1.05E+01 | 0.0304 | 5.93E+02 | 0.0262 |
| 1 ft from Cask Bottom Axial Surface(6) | 7.07E+02 | 0.0486 | 2.73E+01 | 0.0215 | 7.29E+02 | 0.0471 |
| 3 ft from Cask Side (Radial)(4) | 1.68E+02 | 0.0187 | 3.14E+02 | 0.0054 | 4.83E+02 | 0.0074 |
| 3 ft from Top Axial Surface(5) | 4.02E+02 | 0.0305 | 9.40E+00 | 0.0099 | 4.03E+02 | 0.0305 |
| 3 ft from Cask Bottom Axial Surface(6) | 2.54E+02 | 0.0494 | 1.86E+01 | 0.0085 | 2.62E+02 | 0.0480 |
| Welding | | | | | | |
| Cask Side Surface (Radial)(4) | 6.22E+02 | 0.0224 | 5.46E+02 | 0.0123 | 1.17E+03 | 0.0132 |
| Top Axial Surface(5) | 8.56E+02 | 0.0264 | 3.37E+01 | 0.0658 | 8.84E+02 | 0.0256 |
| Cask Bottom Axial Surface(6) | 1.64E+03(3) | 0.0397 | 2.69E+03(3) | 0.0297 | 4.34E+03(3) | 0.0238 |
| 1 ft from Cask Side (Radial)(4) | 4.06E+02 | 0.0217 | 3.51E+02 | 0.0108 | 7.58E+02 | 0.0127 |
| 1 ft from Top Axial Surface(5) | 6.48E+02 | 0.0371 | 2.42E+01 | 0.0814 | 6.69E+02 | 0.0360 |
| 1 ft from Cask Bottom Axial Surface(6) | 9.78E+02 | 0.0401 | 9.23E+02 | 0.0395 | 1.90E+03 | 0.0282 |
| 3 ft from Cask Side (Radial)(4) | 2.47E+02 | 0.0191 | 2.05E+02 | 0.0097 | 4.52E+02 | 0.0113 |
| 3 ft from Top Axial Surface(5) | 4.44E+02 | 0.3175 | 1.33E+01 | 0.0815 | 4.51E+02 | 0.3124 |
| 3 ft from Cask Bottom Axial Surface(6) | 3.41E+02 | 0.0386 | 2.51E+02 | 0.0663 | 5.92E+02 | 0.0358 |

**Notes:**

(1) Gamma and Neutron dose rate peaks do not always occur at same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.

(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 238 mrem/hr gamma, 13 mrem/hr neutron for a total average dose rate of 251 mrem/hr.

(3) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 331 mrem/hr gamma, 417 mrem/hr neutron for a total average dose rate of 748 mrem/hr. Note that this bottom axial dose rate has no impact on the occupational exposure because no operations are performed near bottom axial location.

(4) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.

(5) The Top dose rates increase by 18% when loading 0.380 MTU FAs.

(6) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.

## *Table P.5-4a*
## *Summary of NUHOMS®-24PTH-L Type 3 DSC, OS197 FC Maximum Dose Rates During Decontamination and Welding Operations, Configuration 2*

| Dose Rate Location | Maximum Gamma (mrem/hr) | Gamma MCNP 1σ Error | Maximum Neutron (mrem/hr) | Neutron MCNP 1σ Error | Maximum Total(1) (mrem/hr) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| Decontamination | | | | | | |
| Cask Side Surface (Radial)(4) | 3.34E+02 | 0.0014 | 6.43E+02 | 0.0007 | 9.77E+02 | 0.0007 |
| Cask Top Axial Surface(5) | 9.90E+02 | 0.0033 | 1.80E+01 | 0.0012 | 9.91E+02 | 0.0033 |
| Cask Bottom Axial Surface(6) | 1.55E+03(2) | 0.0085 | 6.17E+01(2) | 0.0022 | 1.61E+03(2) | 0.0082 |
| 1 ft from Cask Side (Radial)(4) | 2.17E+02 | 0.0013 | 4.15E+02 | 0.0006 | 6.33E+02 | 0.0006 |
| 1 ft from Cask Top Axial Surface(5) | 7.79E+02 | 0.0038 | 7.95E+00 | 0.0063 | 7.79E+02 | 0.0038 |
| 1 ft from Cask Bottom Axial Surface(6) | 9.02E+02 | 0.0093 | 2.38E+01 | 0.0026 | 9.25E+02 | 0.0091 |
| 3 ft from Cask Side (Radial)(4) | 1.30E+02 | 0.0013 | 2.44E+02 | 0.0006 | 3.74E+02 | 0.0006 |
| 3 ft from Cask Top Axial Surface(5) | 4.89E+02 | 0.0041 | 7.19E+00 | 0.0018 | 4.90E+02 | 0.0041 |
| 3 ft from Cask Bottom Axial Surface(6) | 3.13E+02 | 0.0125 | 1.46E+01 | 0.0014 | 3.21E+02 | 0.0122 |
| Welding | | | | | | |
| Cask Side Surface (Radial)(4) | 4.99E+02 | 0.0010 | 4.66E+02 | 0.0023 | 9.65E+02 | 0.0012 |
| Cask Top Axial Surface(5) | 1.06E+03 | 0.0028 | 4.15E+01 | 0.0036 | 1.10E+03 | 0.0027 |
| Cask Bottom Axial Surface(6) | 2.43E+03(3) | 0.0063 | 3.04E+03(3) | 0.0027 | 5.47E+03(3) | 0.0032 |
| 1 ft from Cask Side (Radial)(4) | 3.24E+02 | 0.0010 | 2.98E+02 | 0.0021 | 6.22E+02 | 0.0011 |
| 1 ft from Cask Top Axial Surface(5) | 8.23E+02 | 0.0033 | 2.80E+01 | 0.0037 | 8.51E+02 | 0.0032 |
| 1 ft from Cask Bottom Axial Surface(6) | 1.37E+03 | 0.0072 | 1.09E+03 | 0.0029 | 2.46E+03 | 0.0042 |
| 3 ft from Cask Side (Radial)(4) | 1.95E+02 | 0.0010 | 1.74E+02 | 0.0019 | 3.69E+02 | 0.0010 |
| 3 ft from Cask Top Axial Surface(5) | 5.17E+02 | 0.0036 | 1.40E+01 | 0.0043 | 5.31E+02 | 0.0035 |
| 3 ft from Cask Bottom Axial Surface(6) | 4.73E+02 | 0.0100 | 2.99E+02 | 0.0038 | 7.73E+02 | 0.0063 |

***Notes:***

*(1) Gamma and Neutron dose rate peaks do not always occur at the same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.*
*(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 281 mrem/hr gamma, 13.4 mrem/hr neutron, for a total average dose rate of 295 mrem/hr.*
*(3) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 416 mrem/hr gamma, 465 mrem/hr neutron, for a total average dose rate of 882 mrem/hr.*
*(4) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.*
*(5) The Top dose rates increase by 18% when loading 0.380 MTU FAs.*
*(6) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.*

## Table P.5-5
## Summary of NUHOMS®-24PTH-S-LC *Type 2* DSC, Standardized TC Maximum Dose Rates During Transfer Operations, Configuration 5

| Dose Rate Location | Maximum Gamma (mrem/hr) | Gamma MCNP 1σ Error | Maximum Neutron (mrem/hr) | Neutron MCNP 1σ Error | Maximum Total(1) (mrem/hr) | Total MCNP 1σ Error |
|---|---|---|---|---|---|---|
| Cask Side Surface (Radial)(3) | 4.19E+02 | 0.0600 | 1.81E+02 | 0.0178 | 5.77E+02 | 0.0273 |
| Cask Top Axial Surface(4) | 3.01E+01 | 0.0894 | 8.03E+00 | 0.0778 | 3.25E+01 | 0.0829 |
| Cask Bottom Axial Surface(5) | 4.42E+03(2) | 0.1154 | 3.30E+02(2) | 0.0276 | 4.75E+03(2) | 0.1074 |
| 1 ft from Cask Side (Radial)(3) | 2.95E+02 | 0.0536 | 1.14E+02 | 0.0176 | 3.78E+02 | 0.0242 |
| 1 ft from Cask Top Axial Surface(4) | 2.06E+01 | 0.0251 | 5.44E+00 | 0.0576 | 2.43E+01 | 0.0224 |
| 1 ft from Cask Bottom Axial Surface(5) | 2.31E+03 | 0.1261 | 1.17E+02 | 0.0308 | 2.43E+03 | 0.1200 |
| 3 ft from Cask Side (Radial)(3) | 1.89E+02 | 0.0449 | 9.20E+01 | 0.0158 | 2.31E+02 | 0.0368 |
| 3 ft from Cask Top Axial Surface(4) | 1.06E+01 | 0.0201 | 2.73E+00 | 0.0567 | 1.31E+01 | 0.0165 |
| 3 ft from Cask Bottom Axial Surface(5) | 8.82E+02 | 0.1398 | 3.33E+01 | 0.0403 | 9.15E+02 | 0.1347 |
| Cask 1 m (Radial) Accident Condition(6) | 3.44E+02 | *0.0505* | 4.18E+02 | 0.0219 | 7.62E+02 | 0.0258 |
| Cask 100 m (Radial) Accident Condition(6) | 1.67E-01 | *0.0422* | 6.76E-02 | 0.0232 | 2.35E-01 | 0.0308 |
| Cask 500 m (Radial) Accident Condition(6) | 6.20E-04 | *0.0302* | 5.34E-05 | 0.0341 | 6.74E-04 | 0.0279 |

72.48

**Notes:**

(1) Gamma and Neutron dose rate peaks do not always occur at same location therefore the total dose rate is not always the sum of the gamma plus neutron dose rate.
(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 730 mrem/hr gamma, 61 mrem/hr neutron for a total average dose rate of 791 mrem/hr.
(3) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.
(4) The Top dose rates increase by 18% when loading 0.380 MTU FAs.
(5) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.
(6) The Accident dose rates increase by 13% when loading 0.380 MTU FAs.

## *Table P.5-5a*
## *Summary of NUHOMS®-24PTH-S-LC Type 3 DSC, Standardized TC Maximum Dose Rates During Transfer Operations, Configuration 5*

| ***Dose Rate Location*** | ***Maximum Gamma (mrem/hr)*** | ***Gamma MCNP 1σ Error*** | ***Maximum Neutron (mrem/hr)*** | ***Neutron MCNP 1σ Error*** | ***Maximum Total[(1)] (mrem/hr)*** | ***Total MCNP 1σ Error*** |
|---|---|---|---|---|---|---|
| *Cask Side Surface (Radial)[(3)]* | *3.12E+02* | *0.0026* | *9.74E+01* | *0.0027* | *4.10E+02* | *0.0021* |
| *Cask Top Axial Surface[(4)]* | *2.92E+01* | *0.0280* | *8.35E+00* | *0.0081* | *3.23E+01* | *0.0254* |
| *Cask Bottom Axial Surface[(5)]* | *6.36E+03[(2)]* | *0.0104* | *3.40E+02[(2)]* | *0.0061* | *6.70E+03[(2)]* | *0.0099* |
| *1 ft from Cask Side (Radial)[(3)]* | *2.19E+02* | *0.0024* | *6.08E+01* | *0.0024* | *2.80E+02* | *0.0020* |
| *1 ft from Cask Top Axial Surface[(4)]* | *2.09E+01* | *0.0048* | *5.82E+00* | *0.0078* | *2.43E+01* | *0.0043* |
| *1 ft from Cask Bottom Axial Surface[(5)]* | *3.05E+03* | *0.0110* | *1.21E+02* | *0.0062* | *3.17E+03* | *0.0106* |
| *3 ft from Cask Side (Radial)[(3)]* | *1.39E+02* | *0.0021* | *3.48E+01* | *0.0022* | *1.73E+02* | *0.0018* |
| *3 ft from Cask Top Axial Surface[(4)]* | *9.92E+00* | *0.0026* | *2.89E+00* | *0.0111* | *1.21E+01* | *0.0022* |
| *3 ft from Cask Bottom Axial Surface[(5)]* | *1.08E+03* | *0.0131* | *3.46E+01* | *0.0073* | *1.12E+03* | *0.0127* |
| *Accident* | *Accident dose rates in Table P.5-5 remain applicable* | | | | | |

***Notes:***

*(1) Gamma and Neutron dose rate peaks do not always occur at the same location; therefore, the total dose rate is not always the sum of the gamma plus neutron dose rate.*

*(2) The peak bottom surface dose rate is directly below the grapple ring cut out in the bottom of the cask. The bottom average dose rates, including the grapple area, are 1020 mrem/hr gamma, 63.0 mrem/hr neutron, for a total average dose rate of 1090 mrem/hr.*

*(3) The Side dose rates do not need to be scaled when loading 0.380 MTU FAs.*

*(4) The Top dose rates increase by 18% when loading 0.380 MTU FAs.*

*(5) The Bottom dose rates increase by 19% when loading 0.380 MTU FAs.*

## Table P.5-21
## Surface Average Dose Rates on HSM-Model 102 with 24PTH-S-LC *Type 2* DSC

| Surfaces | Dose Components | Dose Rate from Table N.5-4 of Appendix N (mrem/hr) | Scaling factors | Dose Rate (mrem/hr) |
|---|---|---|---|---|
| **Back**(3) | Gamma | 1.3 | 0.6 | 0.8 |
| | Neutron | 0.1 | 0.1 | 0.01 |
| **Front (excluding bird screen)** (1)(2) | Gamma | 4.9 | 6.8 | 33.5 |
| | Neutron | 2.0 | 0.4 | 0.9 |
| **Roof (excluding bird screen)** (1) (2) | Gamma | 25.4 | 1.1 | 27.1 |
| | Neutron | 0.5 | 0.2 | 0.1 |
| **Side**(3) | Gamma | 29.6 | 1.1 | 31.7 |
| | Neutron | 0.5 | 0.2 | 0.1 |
| **Front Bird Screen**(2) | Gamma | 261.3 | 1.1 | 279.6 |
| | Neutron | 6.2 | 0.2 | 1.1 |
| **Roof Bird Screen**(2) | Gamma | 408.9 | 1.1 | 437.5 |
| | Neutron | 9.0 | 0.2 | 1.5 |

Notes:
(1) If the front average dose rate includes the contribution from the front birdscreen, the dose rates are 45.6 mrem/hr for gammas and 0.9 mrem/hr for neutron radiation. Likewise, if the roof average dose rate includes the contribution from the roof birdscreen, the dose rate is 47.3 mrem/hr for gammas and 0.2 mrem/hr for neutron radiation.
(2) These dose rates increase by 13% when loading 0.380 MTU FAs.
(3) These dose rates increase by 30% when loading 0.380 MTU FAs.

**Table P.5-22**
**Maximum Dose Rates on HSM-Model 102 with 24PTH-S-LC *Type 2* DSC**

72.48

| Surfaces | Dose Components | Dose Rate from Table N.5-4 of Appendix N (mrem/hr) | Scaling factors | Dose Rate (mrem/hr) |
|---|---|---|---|---|
| Back(3) | Gamma | 4 | 0.6 | 2.5 |
| | Neutron | 0.1 | 0.1 | 0.02 |
| Front(2) | Gamma | 9 | 6.8 | 60.6 |
| | Neutron | 4 | 0.4 | 1.6 |
| Roof(2) | Gamma | 55 | 1.1 | 59.3 |
| | Neutron | 1.0 | 0.2 | 0.2 |
| Side(3) | Gamma | 250 | 1.1 | 266.9 |
| | Neutron | 2.0 | 0.2 | 0.3 |
| Front Bird Screen(2) | Gamma | 458 | 1.1 | 489.6 |
| | Neutron | 14(1) | 0.2 | 2.5 |
| Roof Bird Screen(2) | Gamma | 913 | 1.1 | 976.5 |
| | Neutron | 18 | 0.2 | 3.2 |

Notes:
(1) Not calculated in appendix N.5. Estimated here as approximately twice the average dose rate.
(2) These dose rates increase by 13% when loading 0.380 MTU FAs.
(3) These dose rates increase by 30% when loading 0.380 MTU FAs.

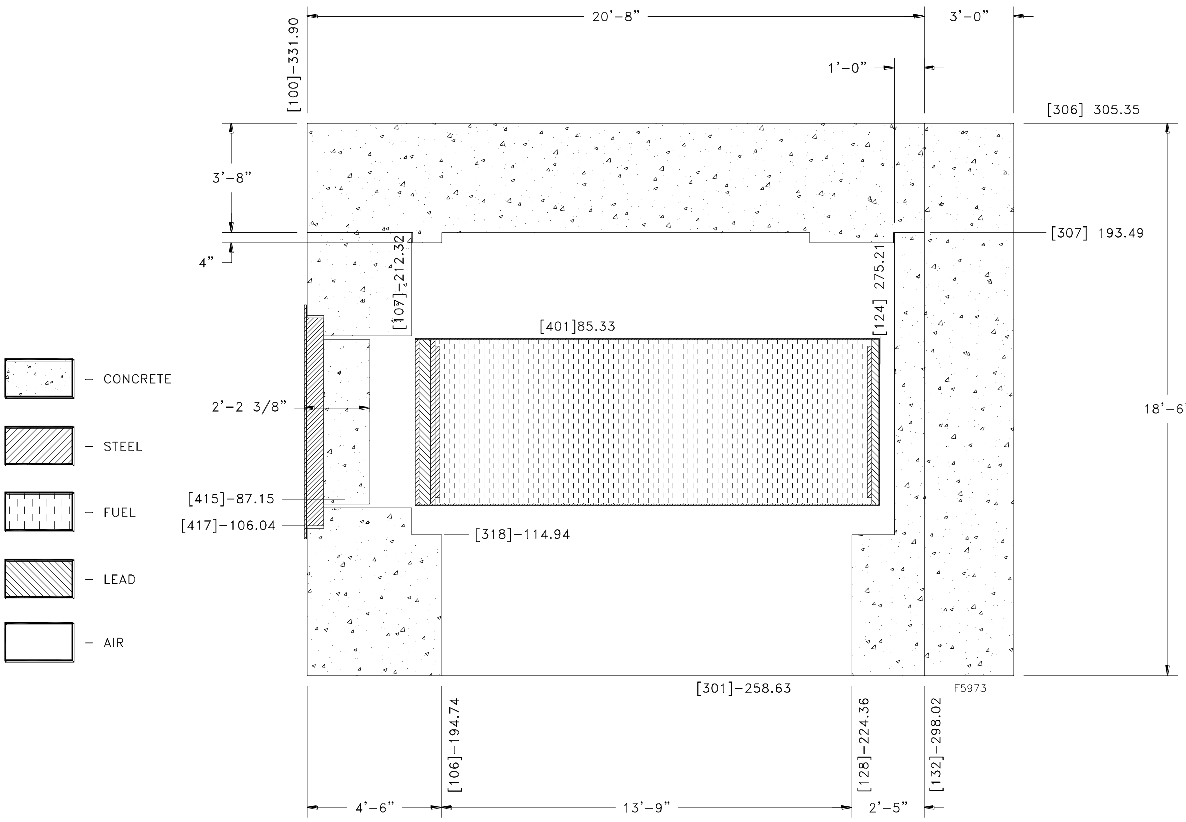



**Figure P.5-3**
**24PTH-L *Type 2* DSC Within HSM-H, Side View at Centerline of DSC**

[xxx] = surface numbers, all dimensions without units are in cm

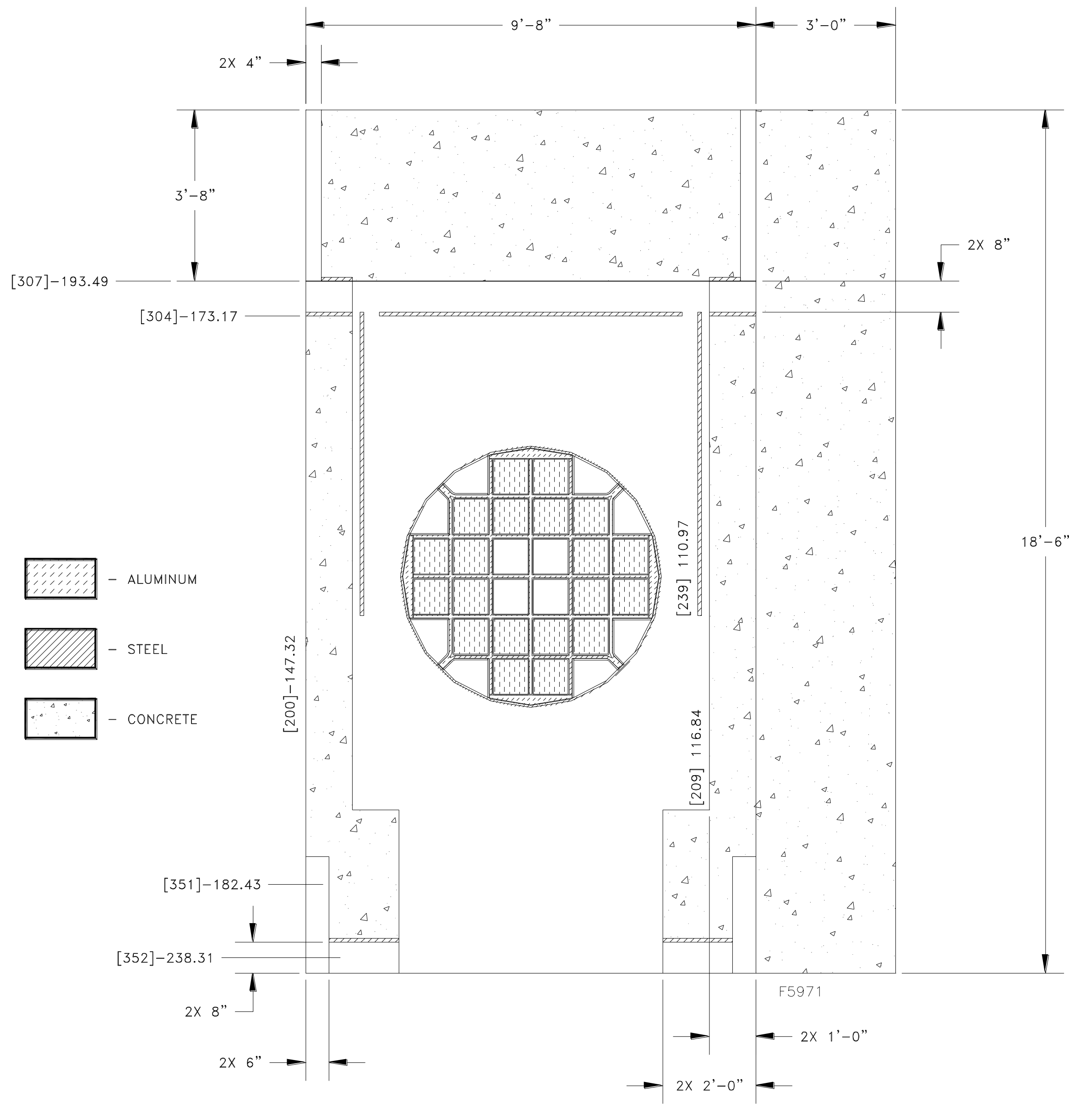



**Figure P.5-4**
**24PTH-L *Type 2* DSC Within HSM-H, Head-on View at X=0**

[xxx] = surface numbers, all dimensions without units are in cm

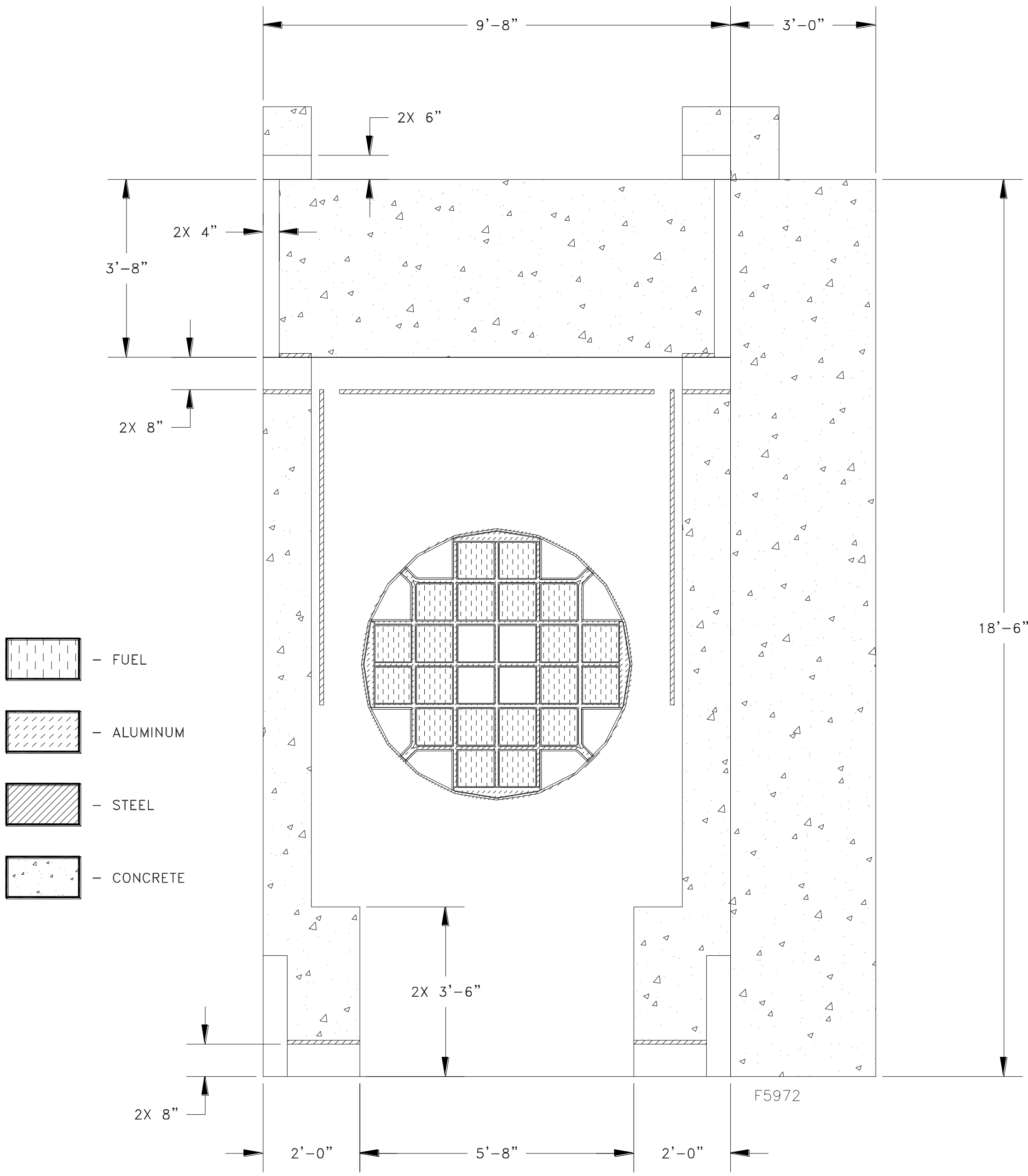



**Figure P.5-5**
**24PTH-L *Type 2* DSC Within HSM-H, Head-on View Showing Top Vents**

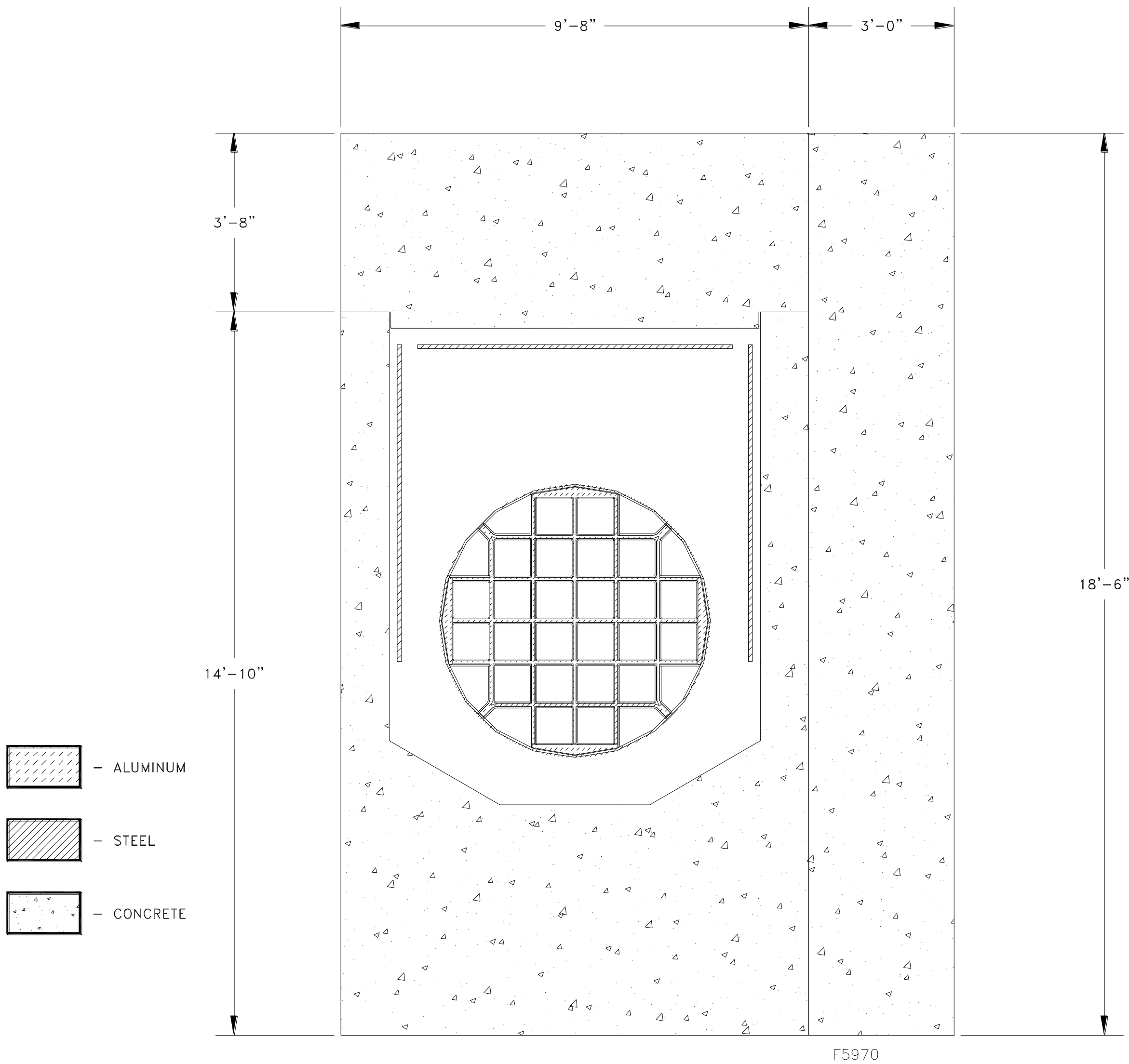



**Figure P.5-6**
**24PTH-L *Type 2* DSC Within HSM-H, Head-on View at Lid End of DSC (X=225 cm)**

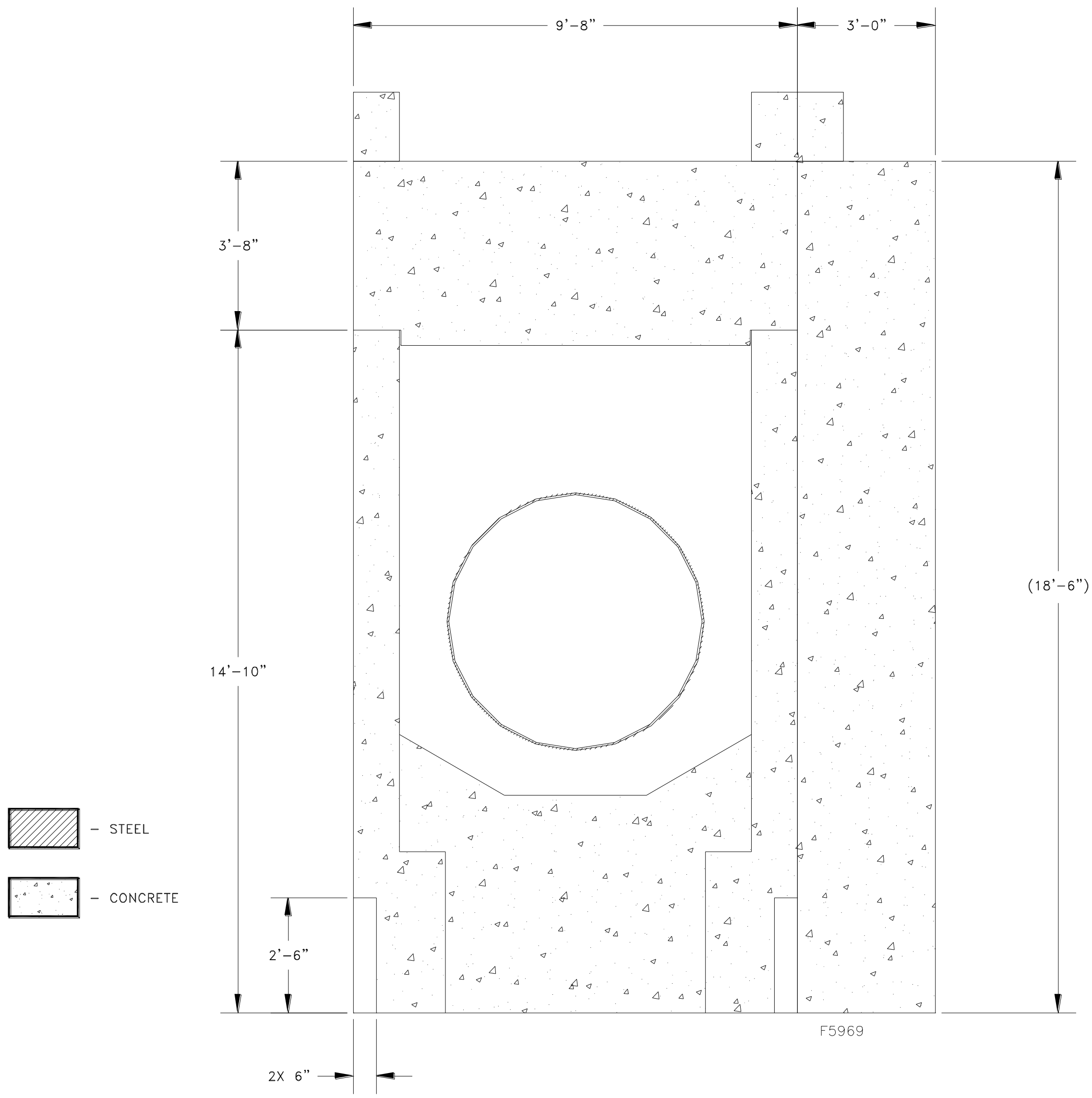
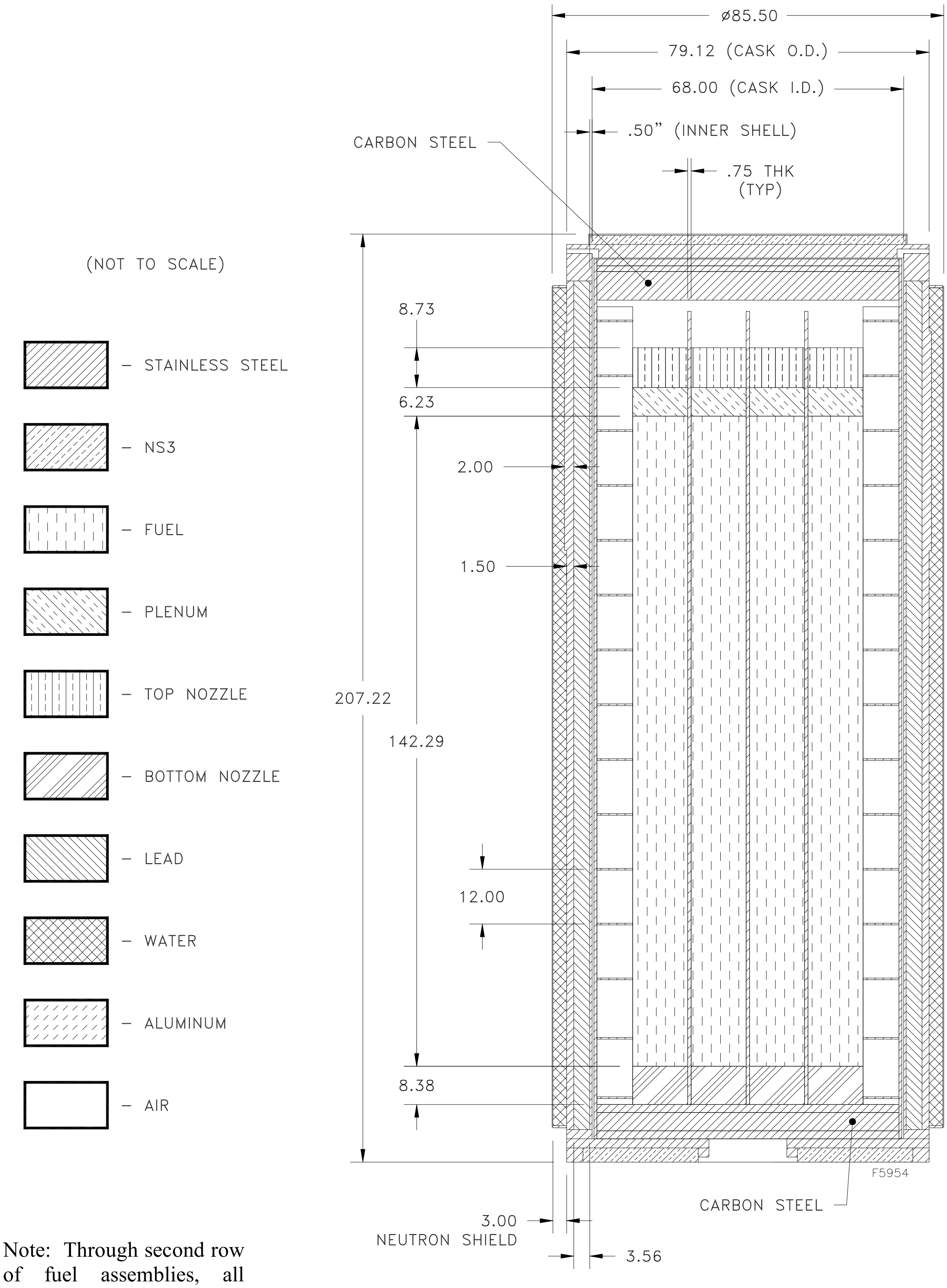
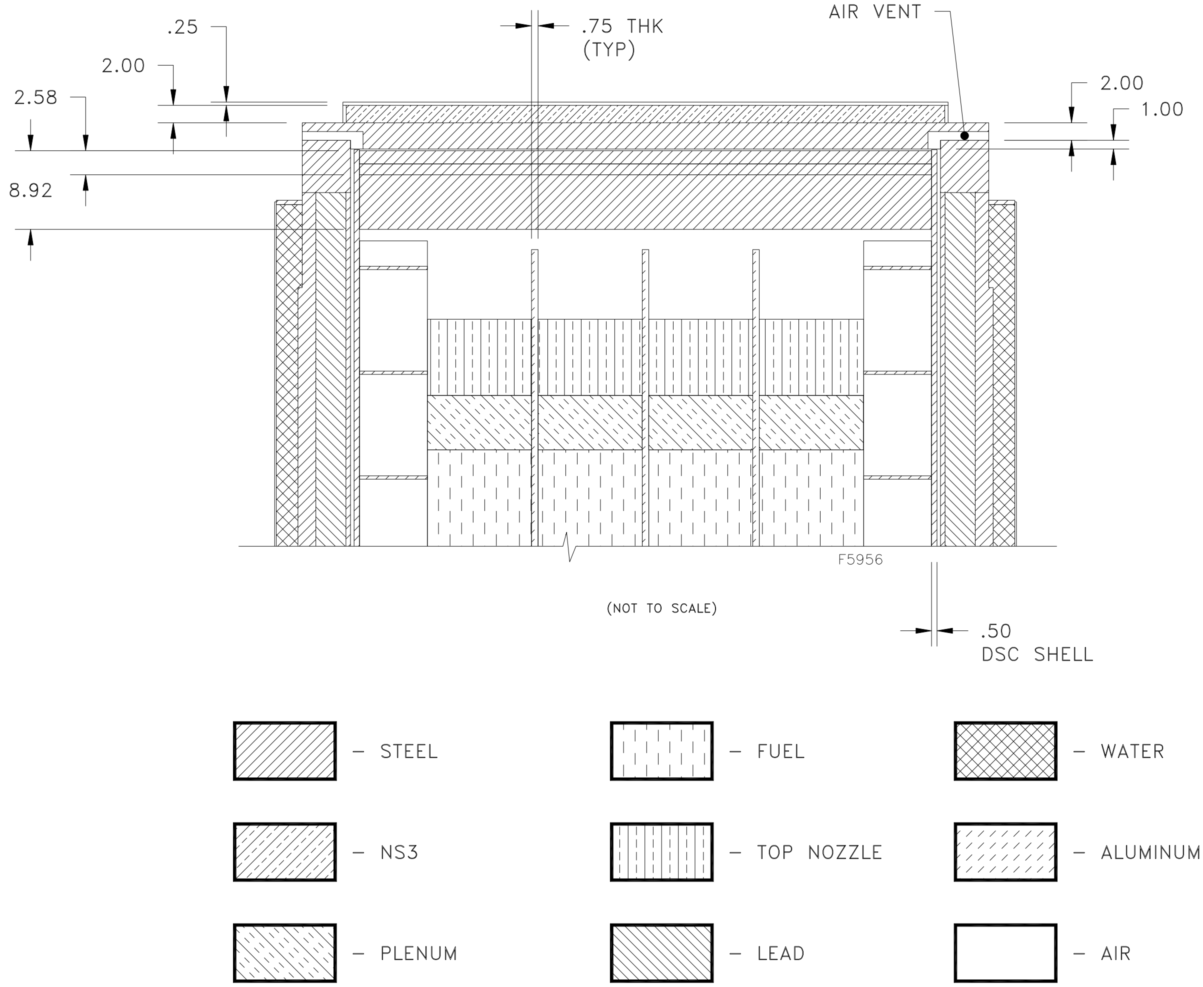



**Figure P.5-7**
**24PTH-L *Type 2* DSC Within HSM-H, Head-on View at Bottom End of DSC (X=-225 cm)**



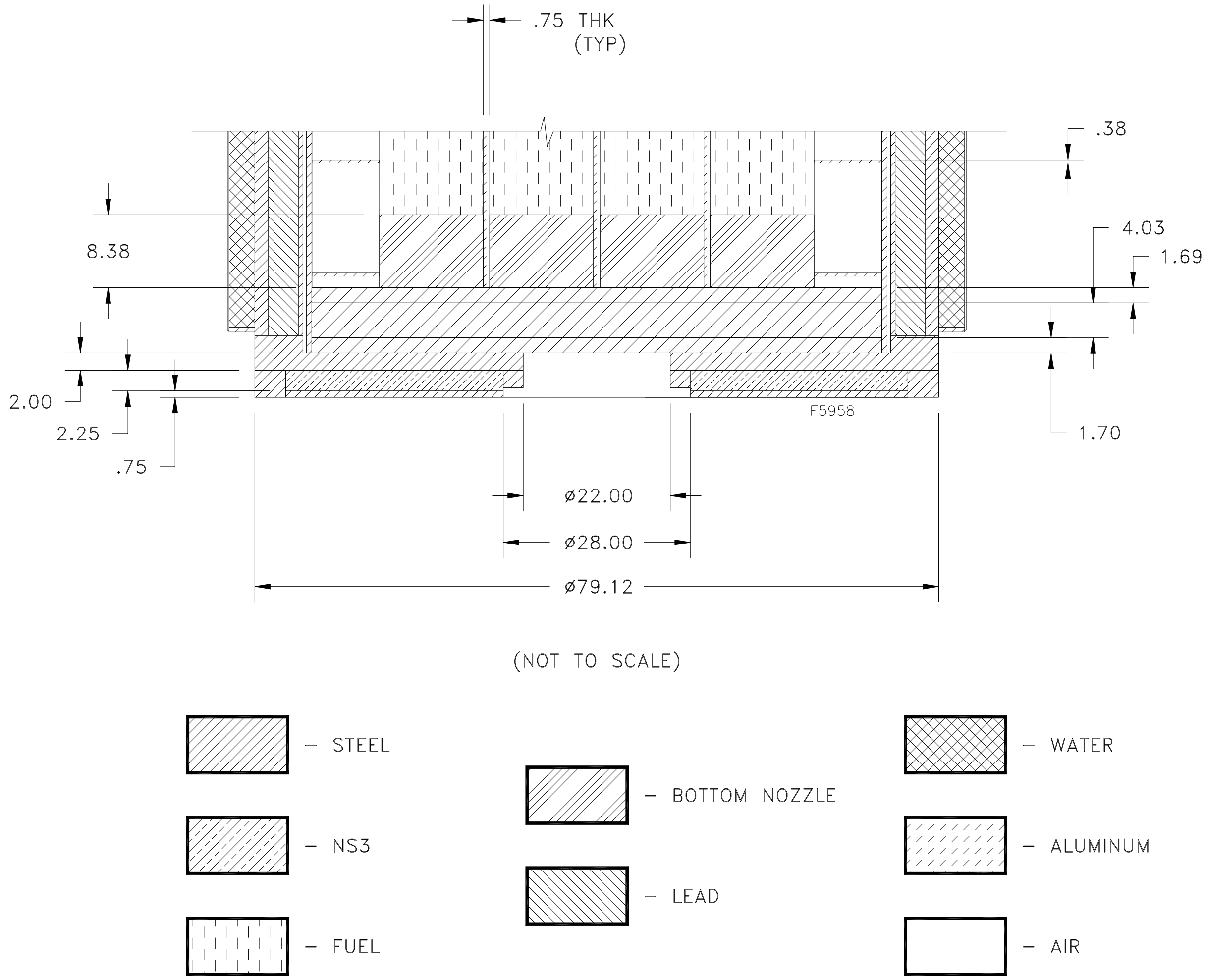

Note: Through second row of fuel assemblies, all dimensions are in inches

**Figure P.5-8**
**24PTH-L *Type 2* DSC Within OS197FC TC, Axial View of Transfer Model**




Note: All dimensions are in inches.

**Figure P.5-9**
**24PTH-L *Type 2* DSC Within OS197FC TC, Top View of Transfer Model Showing Cask Lid with Gap, Top Nozzle, and Plenum**




Note: All dimensions are in inches.

**Figure P.5-10**
**24PTH-L *Type 2* DSC Within OS197FC TC, Bottom View of Transfer Model Showing Cask Bottom and Bottom Nozzle**

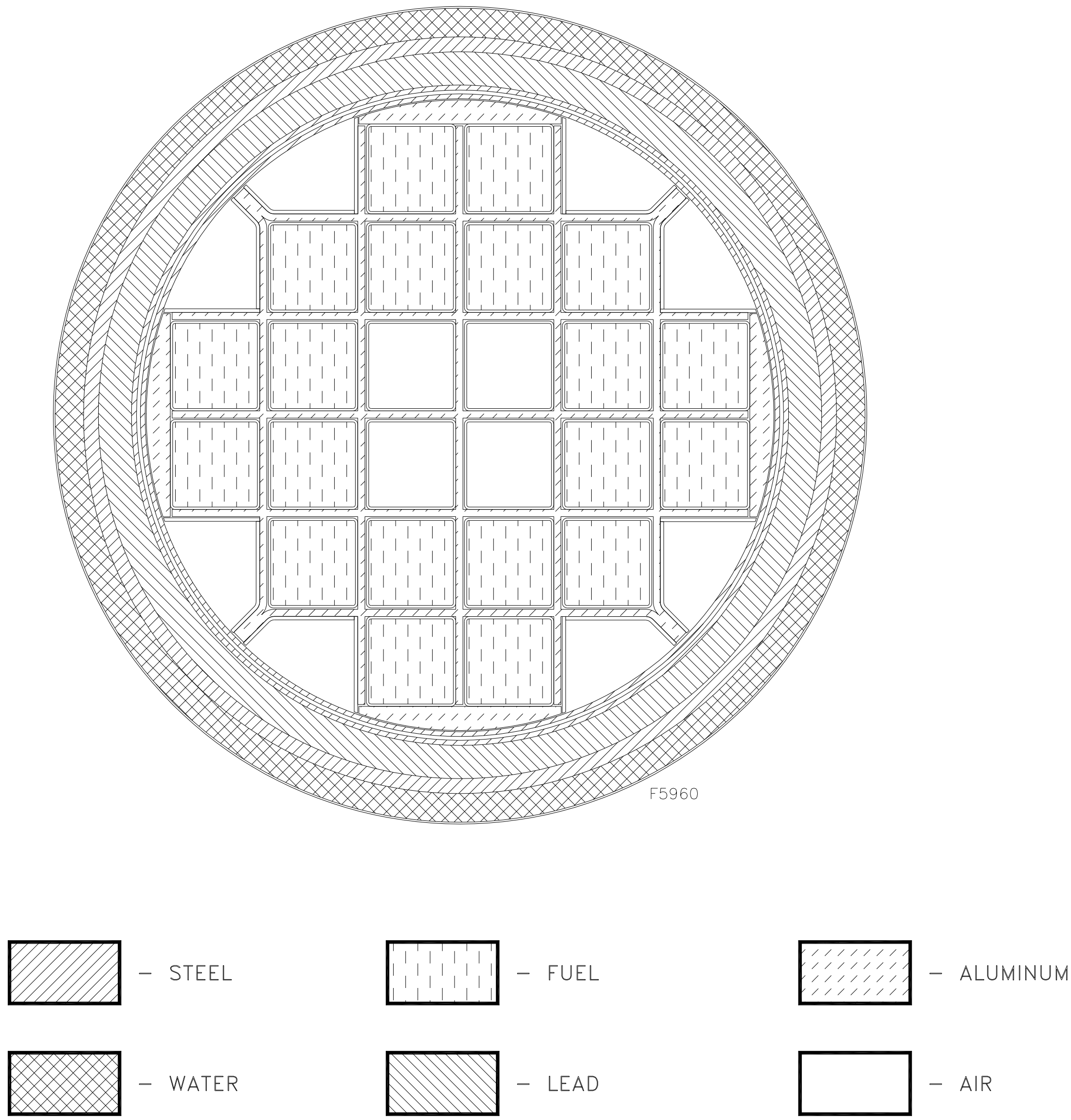
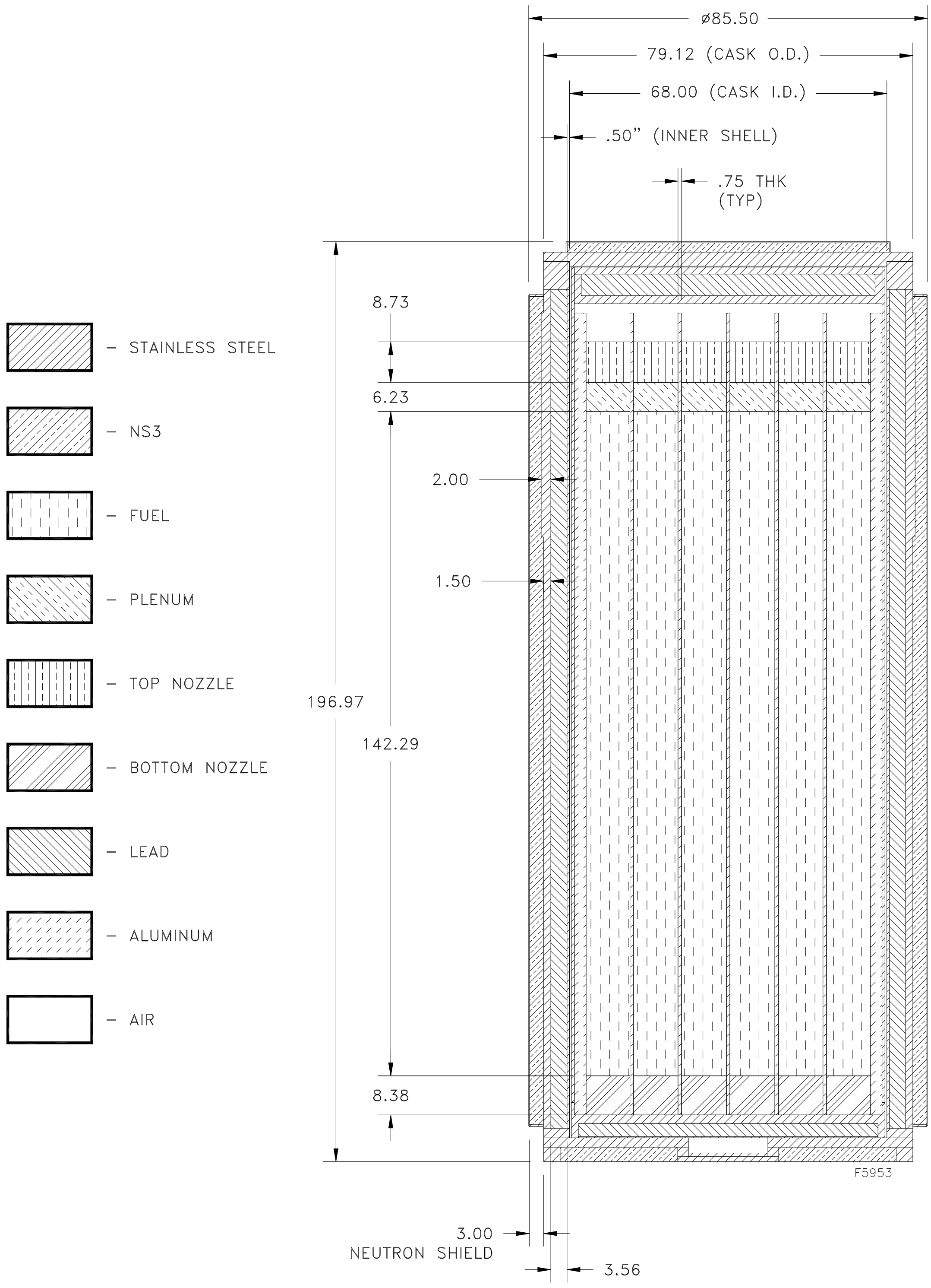
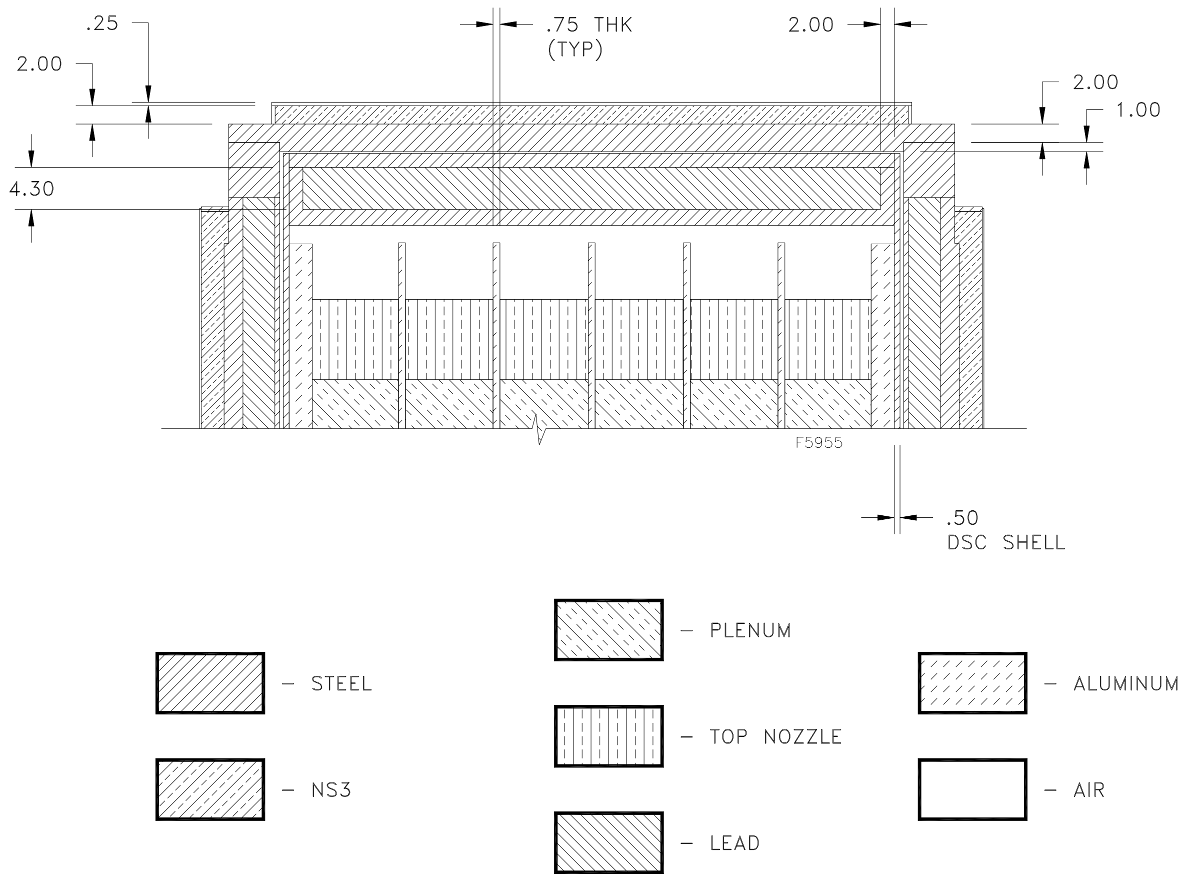



**Figure P.5-11**
**24PTH-L *Type 2* DSC Within OS197FC TC, Radial Cut View of Transfer Models Showing Fuel Locations**



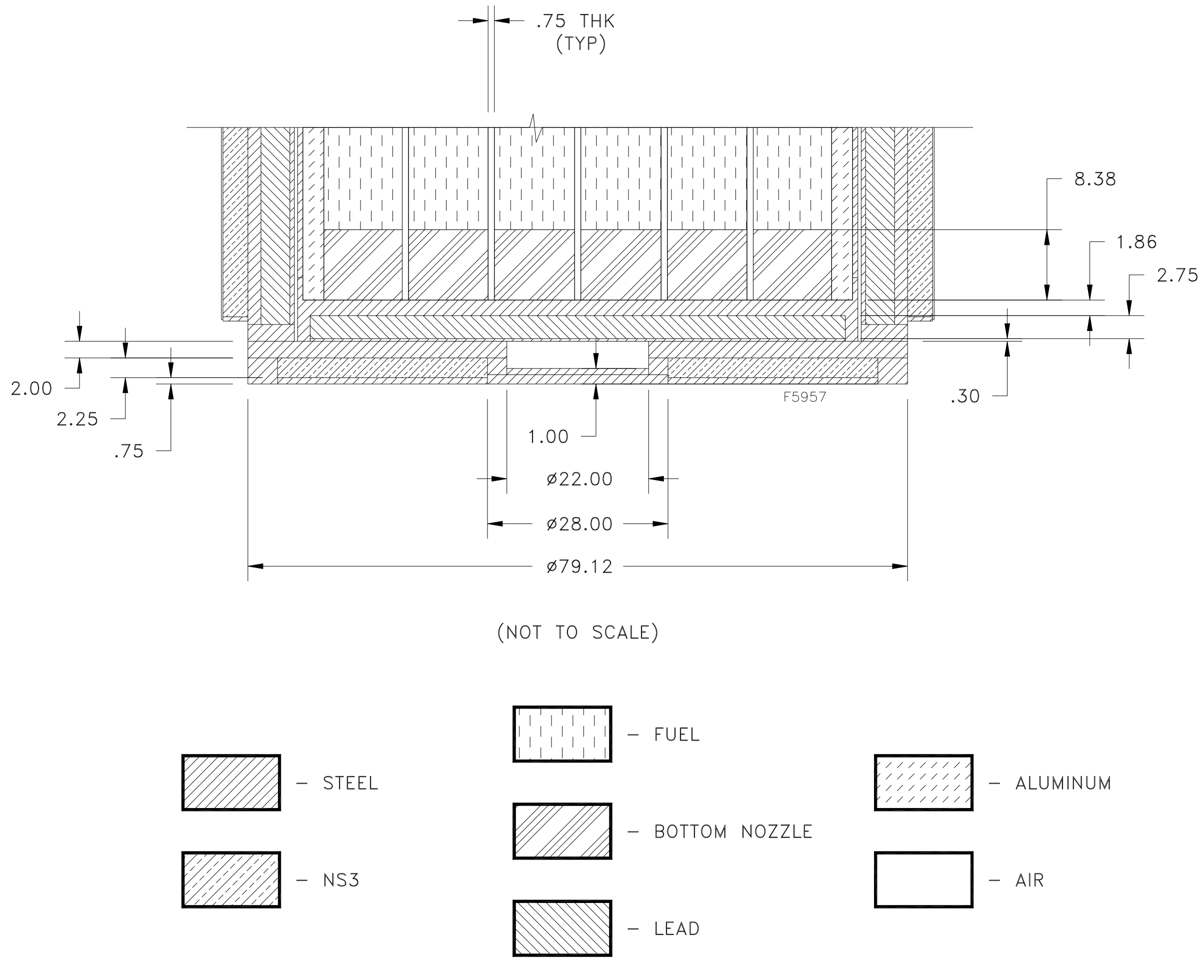

Note: All dimensions are in inches.

**Figure P.5-12**
**24PTH-S-LC *Type 2* DSC Within Standardized TC, Axial View of Transfer Model**




Note: All dimensions are in inches.

**Figure P.5-13**
**24PTH-S-LC *Type 2* DSC Within Standardized TC, Top View of Transfer Model Showing Cask Lid with Gap, Top Nozzle, and Plenum**




Note: All dimensions are in inches.

**Figure P.5-14**
**24PTH-S-LC *Type 2* DSC Within Standardized TC, Bottom View of Transfer Model Showing Cask Bottom and Bottom Nozzle**

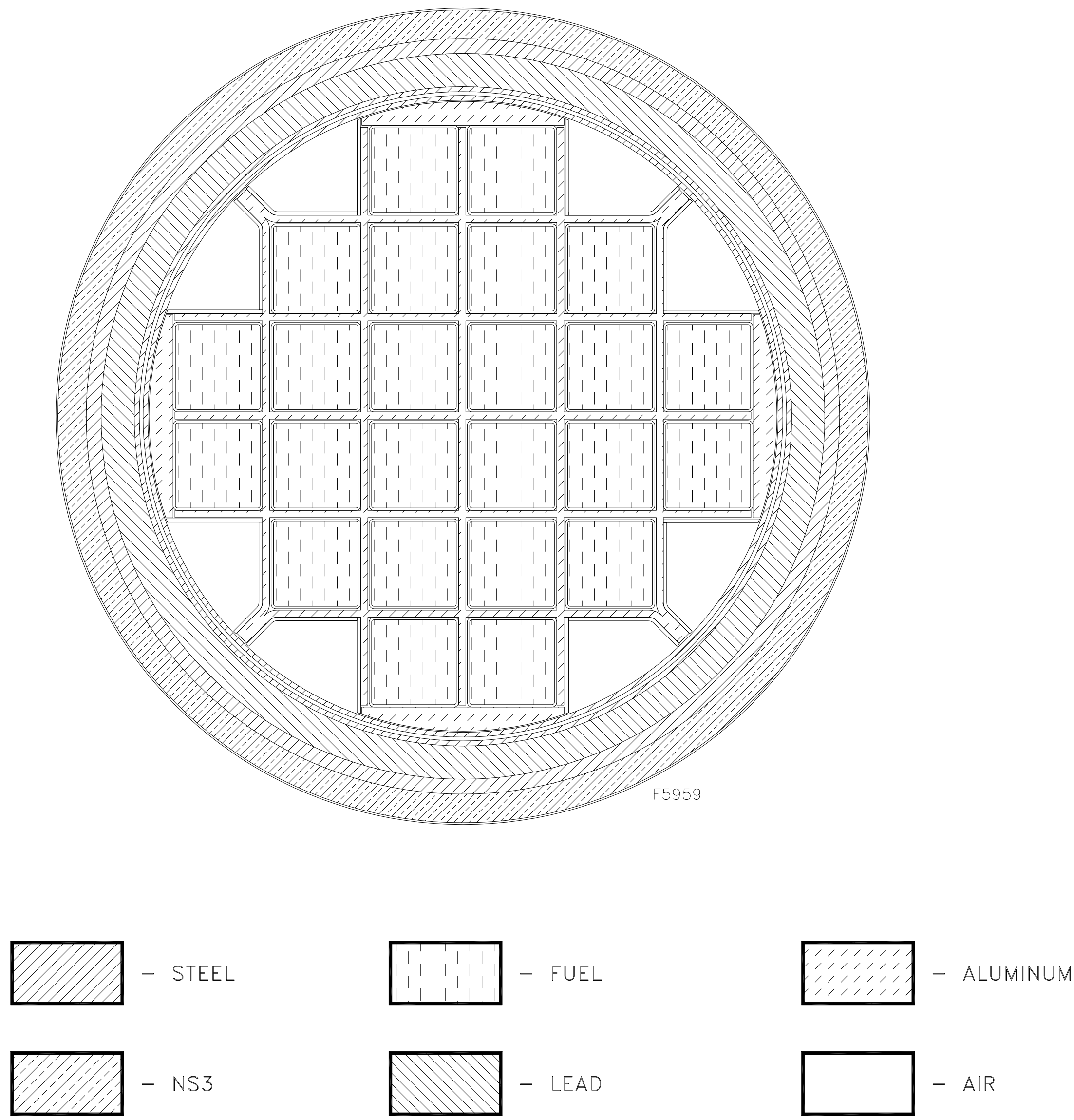



**Figure P.5-15**
**24PTH-S-LC *Type 2* DSC Within Standardized TC, Radial Cut Views of Transfer Model Showing Fuel Locations**

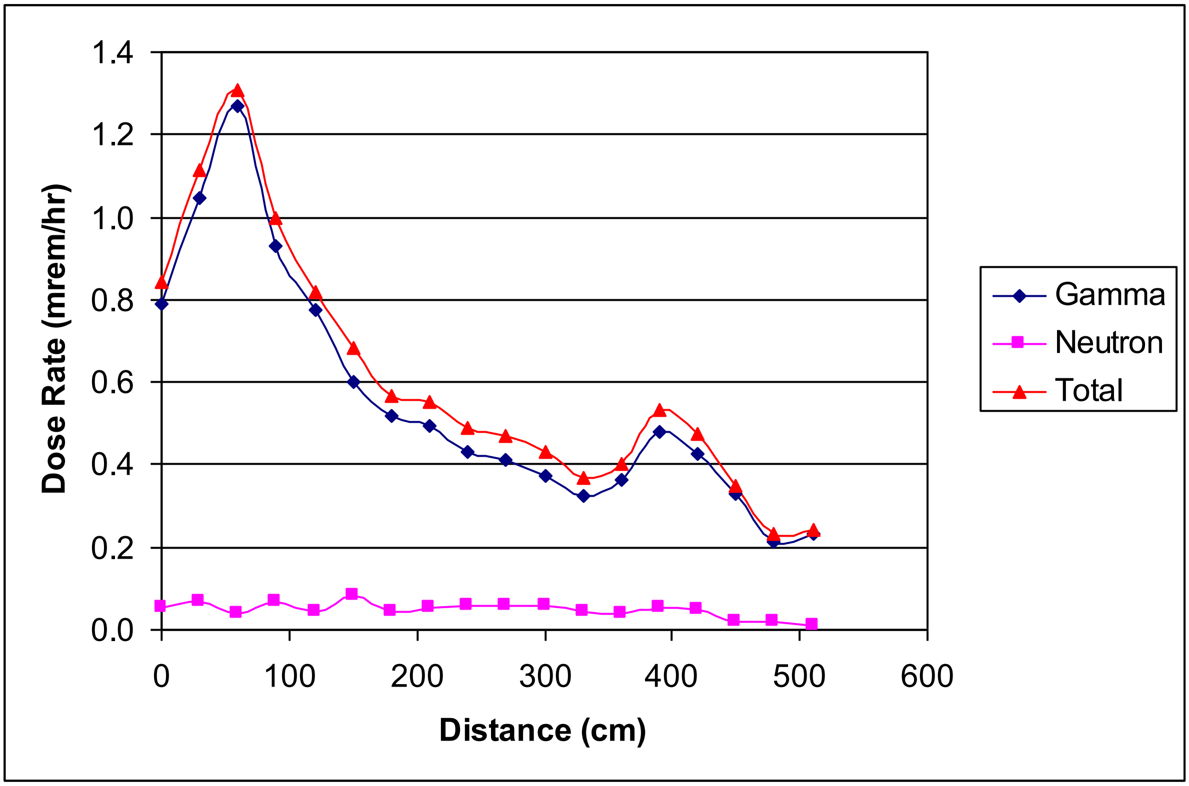



**Figure P.5-16**
**HSM-H with 24PTH-L *Type 2* DSC, Front Door Centerline Dose Rate**

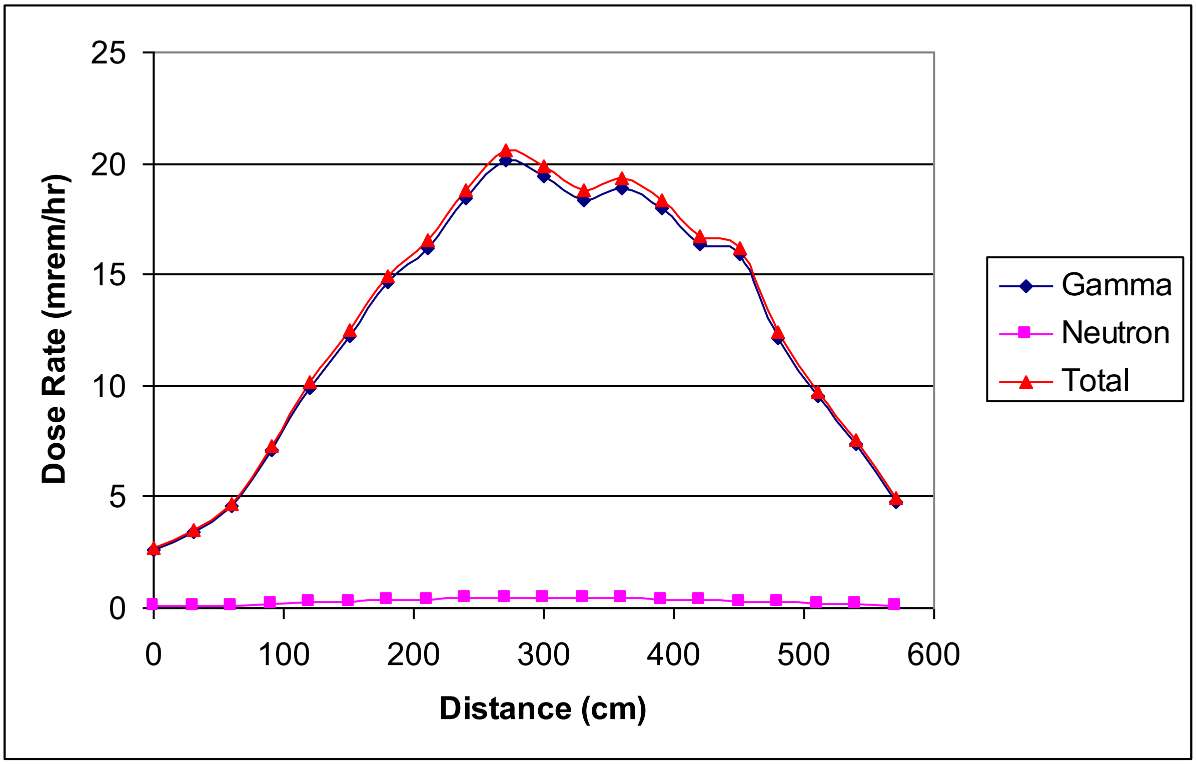



**Figure P.5-17**
**HSM-H with 24PTH-L *Type 2* DSC, Roof Centerline Dose Rate**

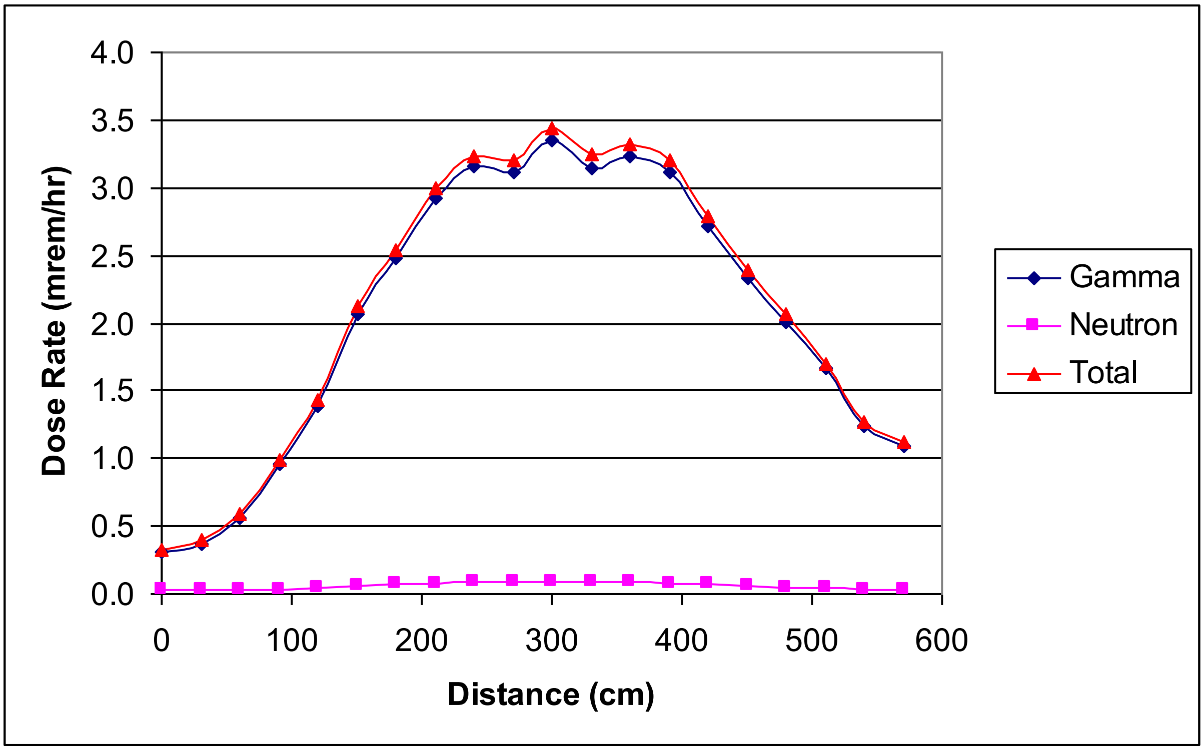



**Figure P.5-18**
**HSM-H with 24PTH-L *Type 2* DSC, Side Shield Wall Surface at DSC Centerline Dose Rate**

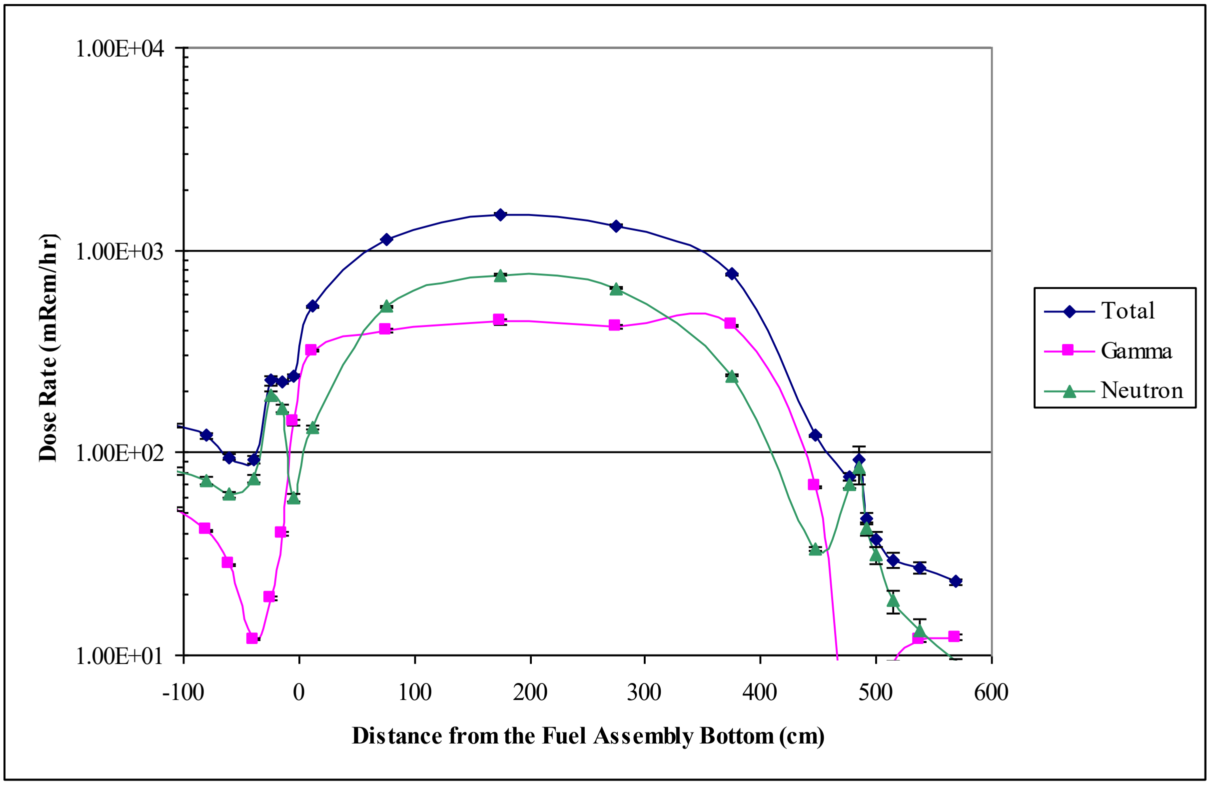



**Figure P.5-19**
**OS197FC TC with 24PTH-L *Type 2* DSC, Side Surface Dose Rate**

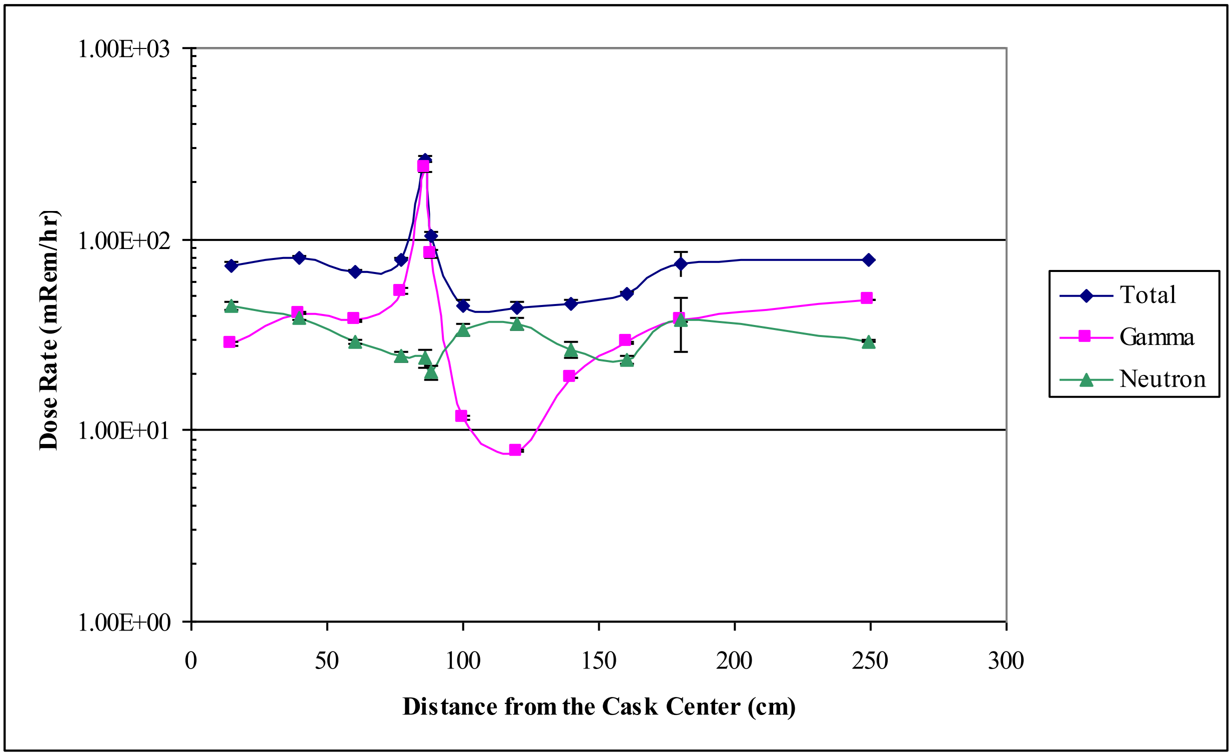



**Figure P.5-20**
**OS197FC TC with 24PTH-L *Type 2* DSC, Top Surface Dose Rate**

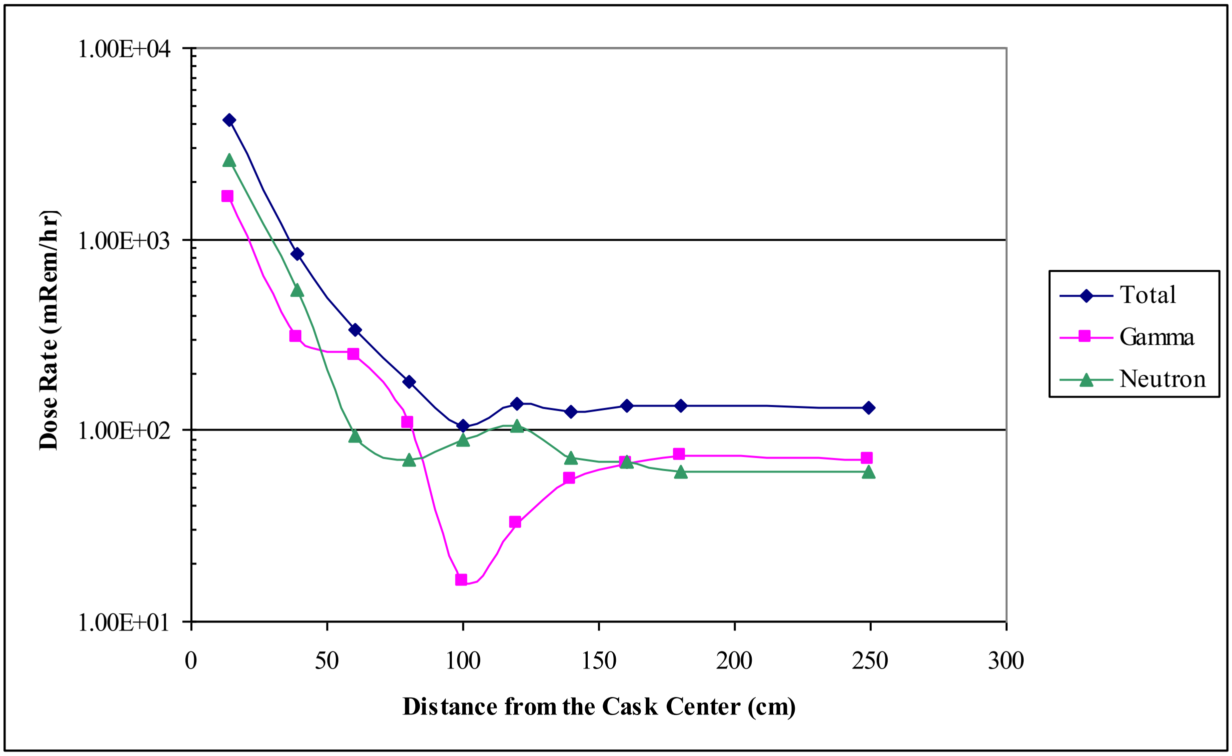



**Figure P.5-21**
**OS197FC TC with 24PTH-L *Type 2* DSC, Bottom Surface Dose Rate**

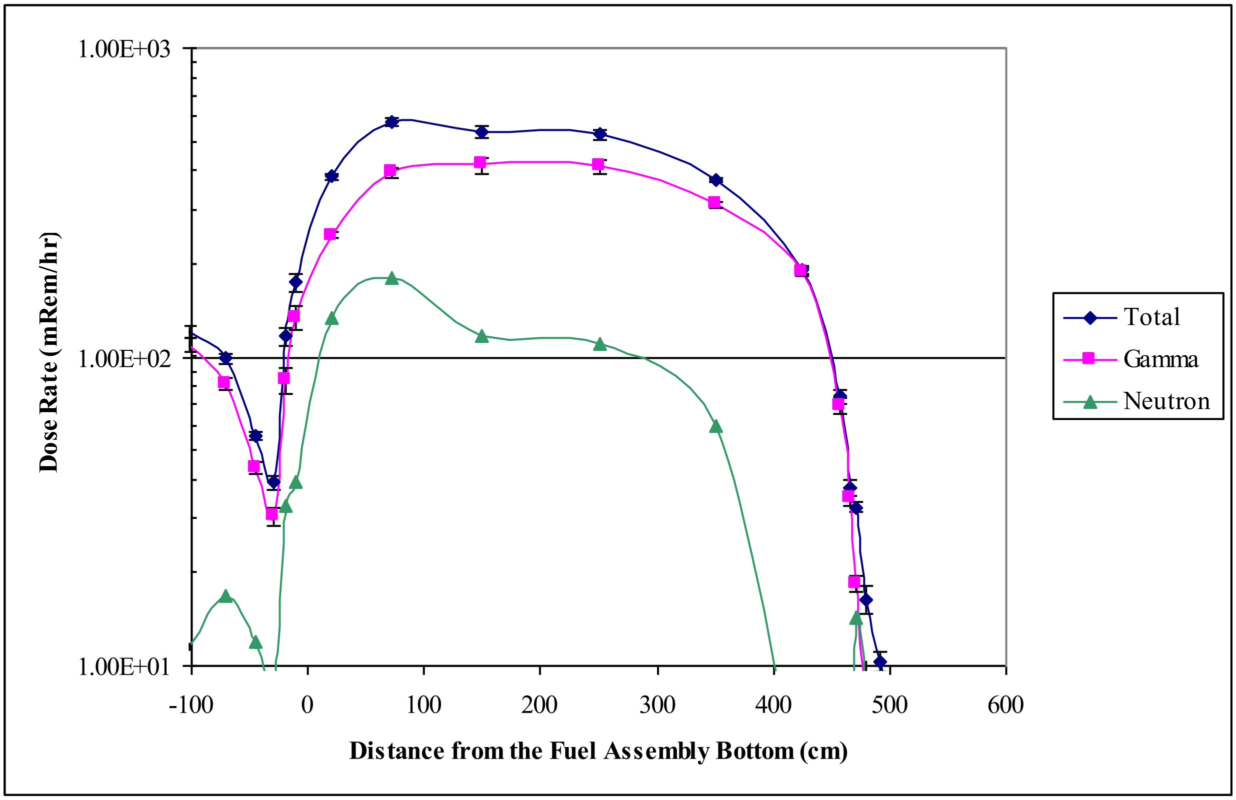



**Figure P.5-22**
**Standardized Transfer Cask with 24PTH-S-LC *Type 2* DSC, Side Surface Dose Rate**

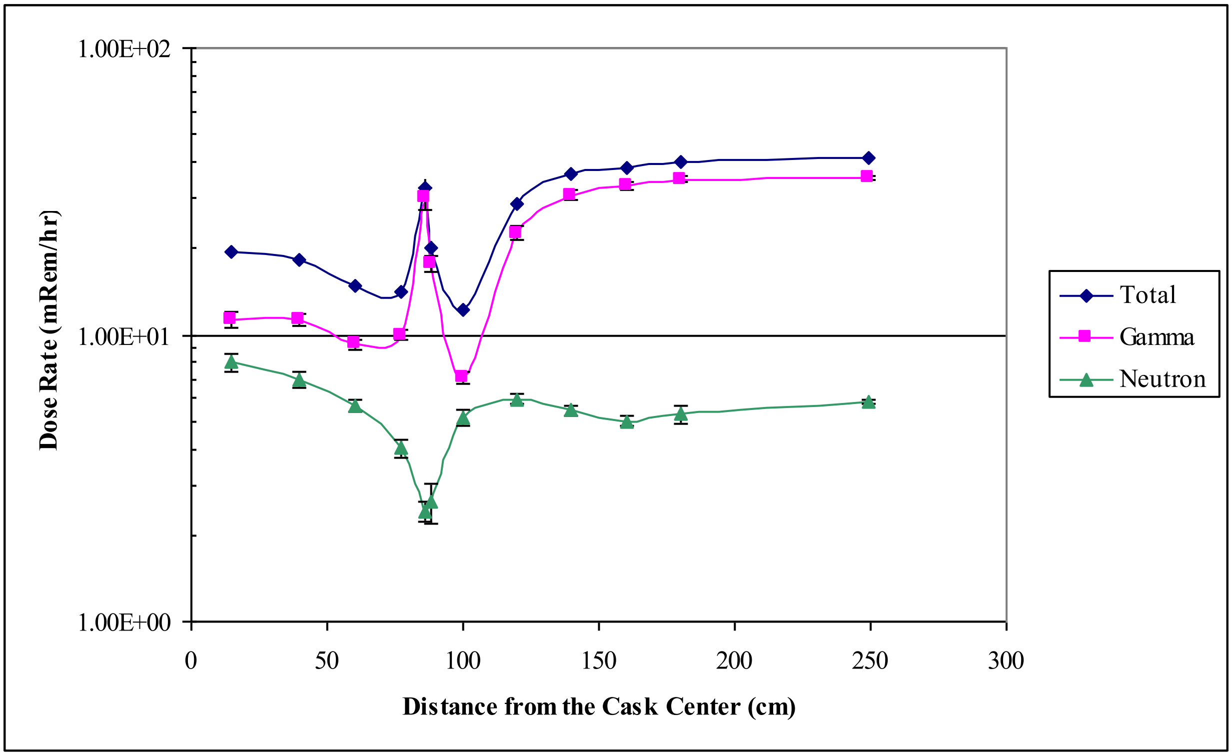



**Figure P.5-23**
**Standardized Cask with 24PTH-S-LC *Type 2* DSC, Top Surface Dose Rate**

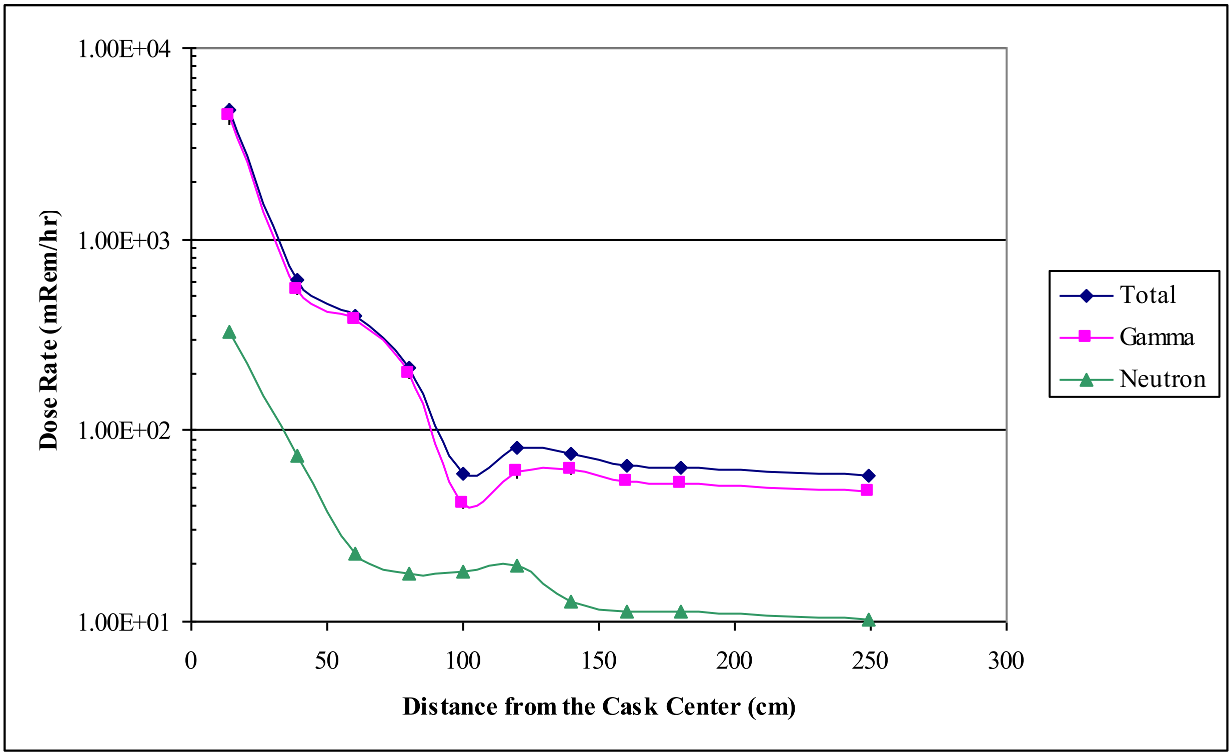
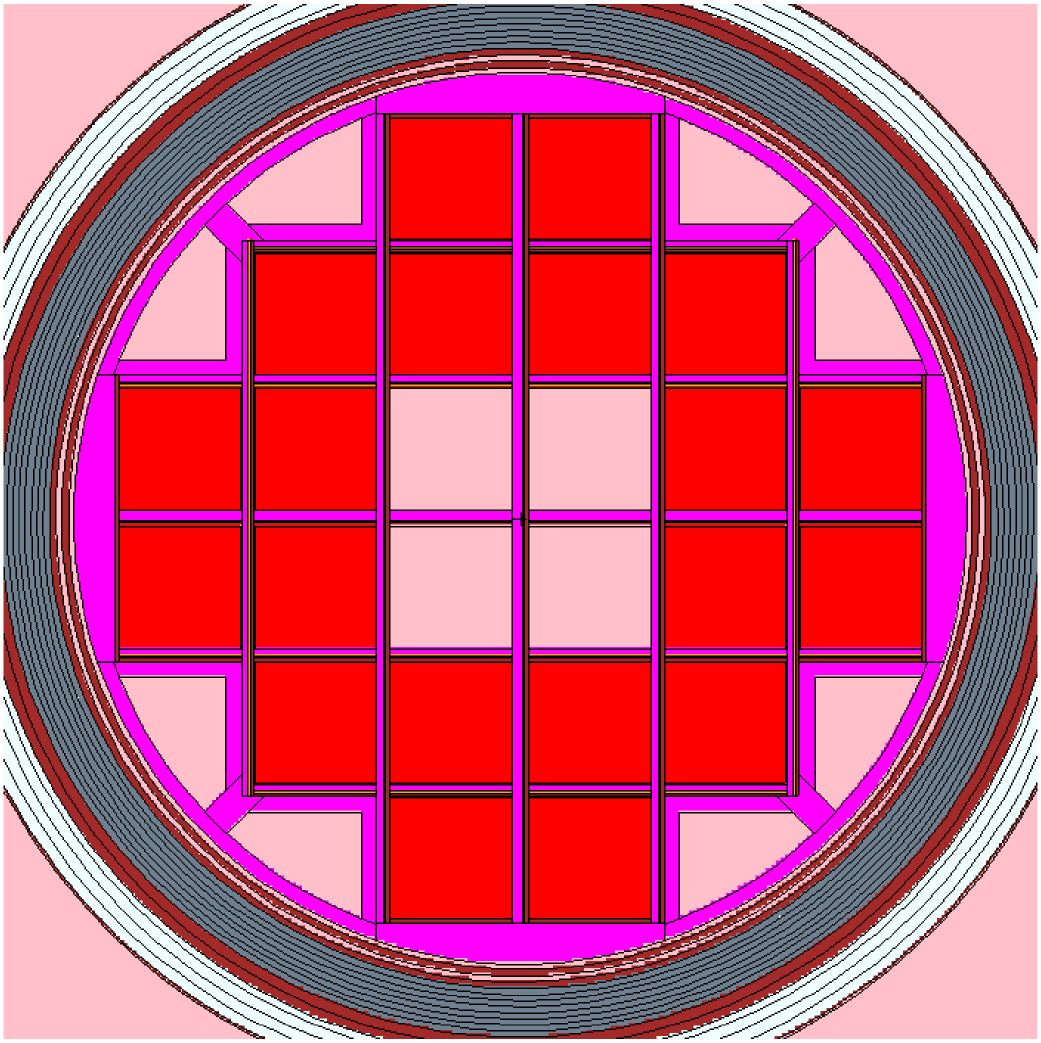



**Figure P.5-24**
**Standardized Cask with 24PTH-S-LC *Type 2* DSC, Bottom Surface Dose Rate**



*Note: The 24PTH-L Type 3 DSC is depicted in this figure with 20 fuel assemblies. The 24PTH-S-LC Type 3 DSC cross-sectional view is the same but with 24 fuel assemblies.*

***Figure P.5-25***
***24PTH-L Type 3 DSC Cross-Section***

## P.6 Criticality Evaluation

The design criteria for the NUHOMS®-24PTH DSC requires that the fuel loaded in the DSC remain subcritical under normal, and accident conditions as defined in 10CFR Part 72.

The NUHOMS®-24PTH system's criticality safety is ensured by fixed neutron absorbers in the basket, soluble boron in the pool and favorable basket geometry. Burnup credit is not taken in this criticality evaluation. The DSC basket uses a Borated-Aluminum alloy, Aluminum/$B_4C$ metal matrix composite or Boral® as its fixed neutron poison material. These materials are ideal for long-term use in the radiation and thermal environments of a DSC. Section P.9 provides the justification for the use of 90% credit for borated aluminum. Similarly, Metal Matrix Composites have been qualified for use as a neutron absorber with 90% credit as justified in Section P.9. Therefore, the collective term B-Al refers to all those fixed poison materials where 90% credit is justified. A credit of 75% is taken for the presence of neutron poison for Boral® plates.

*There are three different basket types:*

- *The Type 1 basket features aluminum inserts in the R45 transition rails.*
- *The Type 2 basket does not include aluminum inserts in the R45 transition rails.*
- *The Type 3 basket features an alternate design compared to the Type 1 or 2 baskets.*

*The available poison loadings for each basket type are provided in Table P.6-1. Poison loadings A, B, and C are available only for the Type 1 and 2 baskets, while poison loading D is available only for the Type 3 basket.*

In addition to utilizing three different fixed poison loadings, the soluble boron concentration in the pool credited in the analysis is also varied from 2100 ppm to 3000 ppm.

## P.6.1 Discussion and Results

*The criticality analysis presented in the main body of this chapter is based on the Type 1 and 2 basket designs. It is demonstrated in a sensitivity study that all enrichment limits developed for the Type 1C/2C baskets may be conservatively applied to the Type 3D basket. This sensitivity study is provided in Section P.6.6.4.*

Figure P.6-1 shows the cross section of the NUHOMS®-24PTH DSC. The NUHOMS®-24PTH DSC stainless steel basket consists of an "egg-crate" plate design. The fuel assemblies are housed in 24 stainless steel fuel compartment tubes with up to 12 damaged fuel assemblies occupying peripheral locations, as shown in Figure P.2-6. In addition, the 24PTH DSC is also designed to store up to 8 failed fuel assemblies in the peripheral locations of the basket (designated as "A" locations in Figure P.2-6). Each failed fuel assembly is housed inside a failed fuel canister prior to loading in these designated positions within the basket. The basket structure, including the fuel compartment tubes, is held together with stainless steel insert plates and the poison and aluminum plates that form the "egg-crate" structure. The basket compartment structure is connected to perimeter rail assemblies, portions of it comprising of aluminum interface. The fuel compartment tube structure is connected to perimeter transition rail assemblies as shown on the drawings in Section P.1.5. The poison/aluminum plates are located between the fuel compartment tubes, as shown in Figure P.6-1.

The analysis presented herein is performed for a NUHOMS®-24PTH DSC in the NUHOMS®-OS197, OS197H, or OS197FC and Standardized Transfer casks (TCs) during normal, off-normal and accident loading conditions. The 24PTH DSC is also transferred in a modified version of the OS200 TC as described in Appendix U. The OS200 TC is fitted with an aluminum sleeve to accommodate the smaller diameter 24PTH DSC. This analysis also bounds all conditions of storage in the HSM (either HSM-H, HSM-HS or HSM Model 102). The NUHOMS® TCs are identical for criticality purposes. The OS197FC design is identical to OS197 or OS197H TC with a modified lid design to allow for air circulation for enhanced heat removal. The NUHOMS® Transfer casks consist of an inner stainless steel shell, lead gamma shield, a stainless steel structural shell and a hydrogenous (liquid or solid) neutron shield. This analysis is applicable to any licensed cask of similar construction. The NUHOMS®-24PTH DSC/Cask configuration is shown to be subcritical under normal, off-normal and accident conditions of loading, transfer and storage.

The criticality analysis determines the most reactive configuration for the basket and fuel assembly position. Then criticality calculations evaluate a variety of fuel assembly types, initial enrichments and poison loadings (fixed and soluble poison). Table P.6-2 lists the fuel assemblies considered as authorized contents of the NUHOMS®-24PTH System. Finally, the maximum allowed initial enrichment for each fuel assembly type as a function of basket type (fixed poison loading and aluminum inserts) and soluble boron concentration is determined and is listed in Table P.6-3. Table P.6-10 shows the results of the analysis performed to determine the bounding configuration for Type 1 or Type 2 baskets (with or without aluminum inserts in R45 transition rails). The calculations determine $k_{eff}$ with the CSAS25 control module of SCALE-4.4 [6.1] for each assembly type and initial enrichment, including all uncertainties to assure criticality safety under all credible conditions.

The Control Components (CCs) are also authorized for storage in the 24PTH DSCs. The authorized CCs are Burnable Poison Rod Assemblies (BPRAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies (TPAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. The

## P.6.6 Appendix

### P.6.6.1 References


6.1 Oak Ridge National Laboratory, RSIC Computer Code Collection, "SCALE: A Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluations for Workstations and Personal Computers," NUREG/CR-0200, Revision 6, ORNL/NUREG/CSD-2/V2/R6.

6.2 U.S. Nuclear Regulatory Commission, "Criticality Benchmark Guide for Light-Water-Reactor fuel in Transportation and Storage Packages," NUREG/CR-6361, Published March 1997, ORNL/TM-13211.

6.3 U.S. Nuclear Regulatory Commission, "Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages," NUREG/CR-5661, Published April 1997, ORNL/TM-11936.

*6.4 SCALE 6: Modular Code System for Performing Standardized Computer Analyses for Licensing Evaluation for Workstations and Personal Computers, Oak Ridge National Laboratory, Radiation Shielding Information Center Code Package CCC-750, February 2009.*

*P.6.6.4 Type 3 Basket Sensitivity Analysis*

*The Type 3 basket features an alternate design compared to the Type 1 or 2 baskets. The Type 3 basket has a larger minimum compartment width and a higher poison loading than the Type 1 or 2 baskets. It is demonstrated in Table P.6-13 for the Type 1 or 2 baskets that reactivity decreases as the compartment width increases. Therefore, $k_{eff}$ will decrease for the Type 3D basket when compared with the Type 1C/2C basket. All enrichment limits developed for the Type 1C/2C basket may be conservatively applied to the Type 3D basket, and this conclusion is verified with the following sensitivity analysis.*

*Methodology*

*Sensitivity cases are developed for intact, damaged, and failed fuel to explicitly demonstrate that reactivity decreases for the Type 3D basket compared to the Type 1C/2C basket. Because the Type 1C/2C basket analysis was performed with KENO 4.4, which is no longer installed, SCALE 6.0 [6.4] is used in this sensitivity study. To allow a direct comparison between the Type 1C/2C basket and Type 3D basket results without computer code biases, all Type 1C/2C basket cases are first rerun using SCALE 6.0, and the Type 1C/2C basket SCALE 6.0 results are compared to the Type 3D basket SCALE 6.0 results.*

*The CSAS5 (KENO V.a) control module of the SCALE 6.0 program is used to calculate the effective multiplication factor ($k_{eff}$) of the system. The CSAS5 control module allows simplified data input to the functional modules BONAMI, NITAWL, and KENO V.a. These modules process the required cross sections and calculate the $k_{eff}$ of the system. BONAMI performs resonance self-shielding calculations for nuclides that have Bondarenko data associated with their cross sections. NITAWL applies a Nordheim resonance self-shielding correction to nuclides having resonance parameters.*

*Description of the KENO Model for the Type 3 basket*

*This section describes the details of the KENO input used in the analysis. The KENO model of the Type 3 basket is developed based on the design provided in the drawings in Section P.1.5. The material description, KENO V.a parameter data, and unit cells for fuel rods, instrument tubes, and guide tubes are taken from the base cases (described under Section P.6.4.2, K).*

*The poison plates that form the egg crate structure are modeled in such a way that the plates fit together tightly. In reality, the plates have slots to fix the vertical and horizontal plates that are slightly wider than the total plate thickness. These small gaps at the slots are conservatively not considered in the KENO model developed for Type 3 basket since these gaps would be filled with borated water, which would decrease the reactivity. The egg crate is formed by a set of horizontal and vertical plates crossing each other, which forms the wall of the compartment. In this discussion, "horizontal" is parallel to the x-axis, while "vertical" is parallel to the y-axis. The minimum width of the compartment is 8.9 inches.*

*The horizontal plates are modeled as one single length plate whose length is calculated manually. For example, the length of the plates (Al+MMC+SS) that spans 4 compartments, 4 thin (vertical) plates and 1 thick (vertical) plate each is calculated as (4x8.9" + 4x0.945" + 1x1.195") = 40.575 inches (see Figure P.6-27). The full length of the plate that spans all the 6 compartments, with only Al on the peripheral assemblies, is calculated as 59.001 inches. The lengths of the horizontal plates in the model are slightly shorter than the actual plates since the gaps are not considered.*

*The vertical plates are modeled as short segments with their length the same as the compartment width. These segments are then included in between two fuel compartments to form an array. These arrays are then placed as holes in the global unit. The overall length of the vertical plate at the center without considering the thickness of the horizontal plate that runs in between the vertical plates is calculated as (6x8.9" + 2x2.8345") = 59.069 inches. If the thicknesses of the horizontal plates are considered, the total vertical length in the model would be 64.67 inches.*

*The overall lengths of the plates in the KENO model are shorter than the actual plates and hence the total area of the poison plates modeled is reduced compared to the actual plates. This is conservative since the overall poison in the model is reduced compared to the actual basket.*

*The MMC poison plate is modeled as borated aluminum alloy poison, consistent with Type 1 basket. The thickness of the poison plate is 0.164 inches in the Type 3 basket. The poison content is 35 mg B-10/cm$^2$ (poison loading D). 90% credit is taken and hence in the KENO model 31.5 mg B-10/cm$^2$ is modeled. The boron and aluminum ratio in the poison plate is calculated based on this thickness and poison content values.*

*The transition rail is modeled using stainless steel material. This is based on the results of the transition rail region material study using the Type 1 basket, which demonstrated that the use of steel for transition rail material is most reactive. The Type 1 basket transition rail geometry is conservatively applied to the Type 3 basket KENO model. The other materials used for describing the canister and the cask are the same as in the base cases. Water fills the gap between the canister and cask.*

*The axial height modeled is 11.94 inches in the KENO model, with periodic boundary conditions applied to the top and bottom of the model. This boundary condition ensures the model is infinitely long in the axial direction. For failed fuel analysis, the length in the axial direction is changed to match the length used in the failed fuel analysis using the Type 1 basket.*

*In the damaged and failed fuel analysis, it is assumed that the maximum pitch is the optimum pitch value that leads to highest $k_{eff}$. The maximum pitch is calculated using the compartment width (W), the fuel rod's cladding radius (r) value and the number of fuel rods in a row (n). The compartment width value is 8.9 inches; however, for the optimum pitch calculation, 8.85 inches is considered to give a small gap between the peripheral row of fuel rods and the poison plates forming the walls of the compartment to avoid KENO overlap errors. The formula used to compute the maximum pitch value is (W-2r)/(n-1).*

*The material inputs are the same in the Type 3D basket models compared to the Type 1C/2C basket models with the exception of poison loading D, which is provided in Table P.6-8.*

*Sensitivity Evaluation*

*The following assumptions are relevant to the criticality analysis performed with Type 3 basket:*

1. *A conservative assumption of 90% credit is taken for the poison in the KENO model.*

2. *An egg-crate section height of 11.94 inches is modeled. The top and bottom shield plugs are not modeled, and a periodic boundary condition is conservatively applied on the top and bottom.*

3. *The plates forming the egg-crate are assumed to fit together tightly without any gaps. This is a conservative assumption since the presence of gaps would create space for borated water.*

4. *Type 3 basket is a staggered basket. However, the KENO model developed is non-staggered for simplicity because a staggered and non-staggered representation is neutronically equivalent.*

5. *Damaged fuel analysis with the Type 1 basket shows the most reactive damaged case is using optimum (maximum) pitch and guide/instrument tube locations filled with fuel rods. Hence the same configuration is used for the damaged fuel cases in the Type 3 basket analysis.*

6. *Failed fuel analysis with the Type 1 basket illustrates the most reactive failed fuel configuration has fully expanded pitch and the rods shifted 6 inches at the top where they are not covered with poison plates. The same configuration is used in this analysis for failed fuel.*

7. *There are 3 versions of the basket based on their length: 24PTH-S, 24PTH-L, and 24PTH-S-LC. It is assumed that $k_{eff}$ values obtained for the different cases apply to the 24PTH-S, 24PTH-L, 24PTH-S-LC versions of the Type 3 basket since periodic boundary conditions are applied in the Z-direction, making the model infinitely long.*

*For the Type 3 basket analysis, the fuel parameters enrichment, soluble boron, internal moderator density values are the same as in the base cases. The poison concentration in the model is 31.5 mg B-10/cm$^2$. The base cases are described below. For intact fuel analysis, the rod pitch is same as the base case. In the damaged and failed fuel analyses, a larger rod pitch is utilized than the original model because the compartment size is larger.*

*Table P.6-15 tabulates $k_{eff}$ values for various PWR assemblies with varying enrichment, soluble boron, and poison concentration values. It is demonstrated that the most reactive fuel for a given enrichment is B&W 15X15. Hence, the base cases used in the intact fuel analysis are from the intact fuel analysis with the Type 1C/2C basket loaded with B&W 15X15 fuel. Seven most reactive cases are identified under each soluble concentration value:*

1. *B&W 15x15 case with soluble boron at 2100 ppm, enrichment at 4.3 wt.% U-235 and internal moderator density value at 90%.*

2. *B&W 15x15 case with soluble boron at 2200 ppm, enrichment at 4.5 wt.% U-235 and internal moderator density value at 90%.*

3. *B&W 15x15 case with soluble boron at 2300 ppm, enrichment at 4.6 wt.% U-235 and internal moderator density value at 90%.*

4. *B&W 15x15 case with soluble boron at 2400 ppm, enrichment at 4.7 wt.% U-235 and internal moderator density value at 90%.*

5. *B&W 15x15 case with soluble boron at 2500 ppm, enrichment at 4.8 wt.% U-235 and internal moderator density value at 90%.*

6. *B&W 15x15 case with soluble boron at 2600 ppm, enrichment at 4.9 wt.% U-235 and internal moderator density value at 90%.*

7. *B&W 15x15 case with soluble boron at 2700 ppm, enrichment at 5.0 wt.% U-235 and internal moderator density value at 90%.*

*For damaged fuel analysis, the base cases are taken from the Type 1C/2C basket analysis. The damaged analysis is carried out with 12 damaged fuel assemblies loaded in the peripheral locations. Two cases are selected from Table P.6-36. These cases feature fuel rods in the guide/instrument tube locations and fully expanded pitch:*

1. *B&W 15x15 assembly with 4.5 wt.% U-235 enrichment, 2300 ppm of soluble boron concentration, and 90% internal moderator density;*

2. *WE 17x17 assembly with 5.0 wt. % U-235, 2600 ppm soluble boron concentration, and 90% internal moderator density.*

*For failed fuel analysis, the base cases are taken from the Type 1C/2C basket analysis. The failed fuel analysis is performed with 8 failed assemblies loaded at the designated locations along the periphery. These cases feature fully expanded pitch and the rods shifted axially with 6 inch of the fuel rod not covered by the poison plates. The rods are either intact (cladded) or fully/partially de-cladded. The two cases selected here are from Table P.6-40:*

1. *B&W 15x15 case with both intact and failed fuel at 5.0 wt.% U-235 enrichment, 2700 ppm soluble boron concentration, and 80% internal moderator density;*

2. *WE 15x15 case with intact fuel at 4.6 wt.% U-235, failed fuel at 4.5 wt.% U-235, soluble boron concentration at 2100 ppm and internal moderator density at 90%.*

*These base case inputs are converted from SCALE 4.4 to SCALE 6.0 format. SCALE 4.4 uses NITAWL for cross-section processing, so PARM=NITAWL is included in the input before running these cases using SCALE 6.0. For damaged and failed fuel cases, the MOREDATA card in SCALE 4.4 is replaced with explicit LATTICECELL card in SCALE 6.0. The results of the intact, damaged and failed fuel analysis are presented in Table P.6-49, Table P.6-50, and Table P.6-51.*

*The criticality results obtained with the Type 3D basket are compared to the corresponding base case results. The difference between the two is calculated as:*

$$Difference = k_{eff\text{-}T1/2} - k_{eff\text{-}T3}$$

*A positive value of the difference indicates that the Type 1C/2C basket results bound the Type 3D basket results. All difference values presented in Table P.6-49, Table P.6-50, and Table P.6-51 indicate that reactivity decreases for the Type 3D basket. Therefore, all Type 1C/2C enrichment limits are bounding and may be conservatively applied to the Type 3D basket. Reactivity decreases for the Type 3D basket due to the larger poison loading and larger minimum compartment size compared to the Type 1C/2C basket. Therefore, it is concluded that the NUHOMS®-24PTH DSC with the Type 3 basket is compliant with the criticality related portions of 10 CFR Part 72.*

**Table P.6-1**
**Minimum B10 Content in the Neutron Poison Plates**

| Basket Type | Minimum B10 Content for Boral® (mg/cm²) | Minimum B10 Content for B-Al(1) (mg/cm²) | B10 Content Used in Criticality Evaluation (mg/cm²) |
|---|---|---|---|
| 1A or 2A | 9.00 | 7.00 | 6.3 |
| 1B or 2B | 19.0 | 15.0 | 13.5 |
| 1C or 2C | 40.0 | 32.0 | 28.8 |
| *3D* | *N/A* | *35.0* | *31.5* |

Notes:

(1) B-Al = Metal Matrix Composites and Borated Aluminum Alloys.

**Table P.6-8**
**Material Property Data**

| Material | ID | Density g/cm³ | Element | Weight % | Atom Density (atoms/b-cm) |
|---|---|---|---|---|---|
| $UO_2$ (Enrichment - 5.0 wt%) | 1 | 10.686 | U-235 | 4.407 | 1.20673E-03 |
| | | | U-238 | 83.743 | 2.26382E-02 |
| | | | O | 11.850 | 4.76898E-02 |
| Zircaloy-4 | 2 | 6.56 | Zr | 98.23 | 4.2541E-02 |
| | | | Sn | 1.45 | 4.8254E-04 |
| | | | Fe | 0.21 | 1.4856E-04 |
| | | | Cr | 0.10 | 7.5978E-05 |
| | | | Hf | 0.01 | 2.2133E-06 |
| Water (Pellet Clad Gap) | 3 | 0.998 | H | 11.1 | 6.6769E-02 |
| | | | O | 88.9 | 3.3385E-02 |
| Stainless Steel (SS304) | 4 | 7.94 | C | 0.080 | 3.1877E-04 |
| | | | Si | 1.000 | 1.7025E-03 |
| | | | P | 0.045 | 6.9468E-05 |
| | | | Cr | 19.000 | 1.7473E-02 |
| | | | Mn | 2.000 | 1.7407E-03 |
| | | | Fe | 68.375 | 5.8545E-02 |
| | | | Ni | 9.500 | 7.7402E-03 |
| Borated Water (3000 ppm Boron) | 5 | 1.000 | H | 11.159 | 6.67692E-02 |
| | | | O | 88.541 | 3.33846E-02 |
| | | | B10 | 5.522E-02 | 3.32551E-05 |
| | | | B11 | 2.444E-01 | 1.33856E-04 |
| Aluminum | 8 | 2.70 | Al | 100.0 | 6.0307E-02 |
| Aluminum - Boron Poison Plate for Type 1A or 2A Basket (6.30 mg B-10/cm²) | 9 | 2.693 | B10 | 1.224 | 1.98248E-03 |
| | | | B11 | 0.136 | 2.00339E-04 |
| | | | Al | 98.640 | 5.92883E-02 |
| Water | 10 | 0.998 | H | 11.1 | 6.6769E-02 |
| | | | O | 88.9 | 3.3385E-02 |
| Lead | 11 | 11.34 | Pb | 100.0 | 3.2969E-02 |
| $^{11}B_4C$ in CC | 12 | 2.555 | B11 | 78.56 | 1.0988E-01 |
| | | | C | 21.44 | 2.7470E-02 |
| Aluminum - Boron Poison Plate for Type 1B or 2B Basket (13.5 mg B-10/cm² ) | 9 | 2.693 | B10 | 1.6443 | 2.66323E-03 |
| | | | B11 | 0.1827 | 2.69132E-04 |
| | | | Al | 98.173 | 5.90076E-02 |
| Aluminum - Boron Poison Plate for Type 1C or 2C Basket (28.8 mg B-10/cm²) | 9 | 2.693 | B10 | 3.5082 | 5.68213E-03 |
| | | | B11 | 0.3898 | 5.74208E-04 |
| | | | Al | 96.102 | 5.77628E-02 |
| *Aluminum – Boron Poison Plate for Type 3D Basket (31.5 mg B-10/cm²)* | *9* | *2.693* | *B-10* | *2.80* | *4.54761E-03* |
| | | | *B-11* | *0.31* | *4.59558E-04* |
| | | | *Al* | *96.89* | *5.82307E-02* |

***Table P.6-49***
***Comparison of the Intact Fuel Results for Type 3D Basket to Type 1C/2C Basket***

| *Case ID*[(1)] | *Type 3* | | | *Type 1/2*[(2)] | | | *Difference* |
|---|---|---|---|---|---|---|---|
| | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | |
| *24PTH_T3_BW15B21_P35E43_090 bw15b21_p32e43_090* | *0.9144* | *0.0008* | *0.9160* | *0.9321* | *0.0008* | *0.9337* | *0.0177* |
| *24PTH_T3_BW15B22_P35E45_090 bw15b22_p32e45_090* | *0.9180* | *0.0010* | *0.9200* | *0.9340* | *0.0009* | *0.9358* | *0.0158* |
| *24PTH_T3_BW15B23_P35E46_090 bw15b23_p32e46_090* | *0.9176* | *0.0009* | *0.9194* | *0.9348* | *0.0010* | *0.9368* | *0.0174* |
| *24PTH_T3_BW15B24_P35E47_090 bw15b24_p32e47_090* | *0.9159* | *0.0009* | *0.9177* | *0.9345* | *0.0010* | *0.9365* | *0.0188* |
| *24PTH_T3_BW15B25_P35E48_090 bw15b25_p32e48_090* | *0.9165* | *0.0010* | *0.9185* | *0.9331* | *0.0009* | *0.9349* | *0.0164* |
| *24PTH_T3_BW15B26_P35E49_090 bw15b26_p32e49_090* | *0.9166* | *0.0009* | *0.9184* | *0.9338* | *0.0009* | *0.9356* | *0.0172* |
| *24PTH_T3_BW15B27_P35E50_090 bw15b27_p32e50_090* | *0.9155* | *0.0010* | *0.9175* | *0.9329* | *0.0010* | *0.9349* | *0.0174* |

1. *Case ID for Type 3 basket starts with "24PTH_T3", while the other filename beginning with "bw15" is the corresponding base case from intact fuel analysis with the Type 1 or Type 2 basket.*
2. *The results given in the "Type 1/2" column are the results from re-running base intact cases with SCALE 6.0.*

## *Table P.6-50*
## *Comparison of the Damaged Fuel Results for Type 3D Basket to Type 1C/2C Basket*

| ***Case ID*** [1] | ***Type 3*** | | | ***Type 1/2*** [2] | | | ***Difference*** |
|---|---|---|---|---|---|---|---|
| | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | |
| *24PTH_T3_12D_BW15B23_P35E45_090*<br>*bw15_d12e45_090* | *0.9185* | *0.0009* | *0.9203* | *0.9351* | *0.0009* | *0.9369* | *0.0166* |
| *24PTH_T3_12D_WE17B26_P35E50_090*<br>*we17_d12e50_090* | *0.9239* | *0.0010* | *0.9259* | *0.9358* | *0.0008* | *0.9374* | *0.0115* |

1. *Case ID for Type 3 basket starts with "24PTH_T3", while the other filename is the corresponding base case from damaged fuel analysis with Type 1 or Type 2 basket.*
2. *The results given in the "Type 1/2" column are the results from re-running base damaged fuel cases with SCALE 6.0.*

## *Table P.6-51*
## *Comparison of the Failed Fuel Results for Type 3D Basket to Type 1C/2C Basket*

| ***Case ID*** [1] | ***Type 3*** | | | ***Type 1/2*** [2] | | | ***Difference*** |
|---|---|---|---|---|---|---|---|
| | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | $k_{KENO}$ | $1\sigma$ | $k_{eff}$ | |
| *24PTH_T3_08F_BW15B27_P35E50F50_080*<br>*bw15b27p32e50f50_080* | *0.9158* | *0.0010* | *0.9178* | *0.9322* | *0.0009* | *0.9340* | *0.0162* |
| *24PTH_T3_08F_WE15B21_P35E46F45_090*<br>*we15b21p32e46f45_090* | *0.9178* | *0.0009* | *0.9196* | *0.9370* | *0.0010* | *0.9390* | *0.0194* |

1. *Case ID for Type 3 basket starts with "24PTH_T3", while the other filename is the corresponding base case from failed fuel analysis with Type 1 or Type 2 basket.*
2. *The results given in the "Type 1/2" column are the results from re-running base failed fuel cases with SCALE 6.0.*

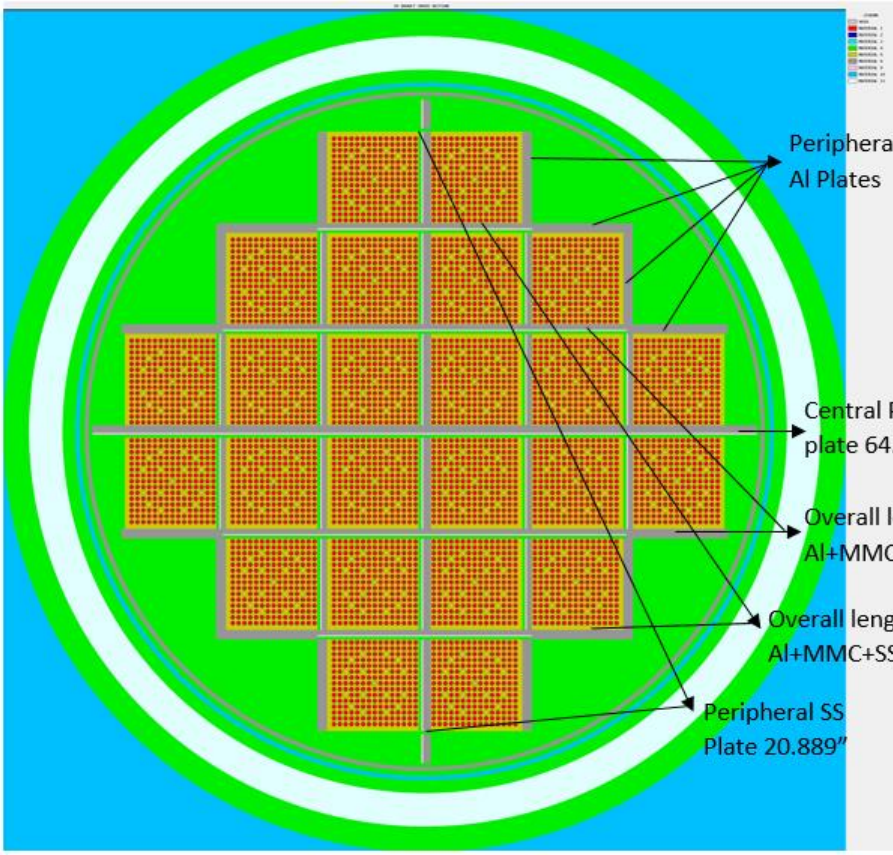



*Figure P.6-27 Poison plate lengths used in the Type 3 KENO model*

5. If a leak is found, remove the outer cover plate root pass, the vent and siphon port plugs and repair the inner cover plate welds. Repeat procedure steps from P.8.1.3 Step 18.

6. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface in accordance with the CoC Appendix A Inspections, Tests, and Evaluations Item 4.3 requirements.

7. Seal weld the prefabricated plug over the outer cover plate test port and perform dye penetrant weld examinations.

8. Remove the automatic welding machine from the DSC.

8a. In accordance with Technical Specification 4.3.2, verify that the NS is filled before the draining operation in Step 9 is initiated and continually monitored during the first five minutes of the draining evolution to ensure the NS remains filled.

9. Open the cask drain port valve and drain the water from the cask/DSC annulus.

10. Rig the cask top cover plate and lower the cover plate onto the TC.

11. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.

    **CAUTION:** Monitor the applicable time limits of Technical Specification 3.1.3 until the completion of DSC transfer Step 6 of Section P.8.1.6.

12. Verify that the TC radial dose rates measured at the surface of the Transfer Cask are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2. The configuration for determining the TC radial surface dose rates shall be in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

P.8.1.5 <u>TC Downending and Transfer to ISFSI</u>

*NOTE: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. If loading with OS197/OS197H/OS197FC TC, drain the TC neutron shield to an acceptable location as required to meet the plant lifting crane capacity limit.

   **CAUTION:** The radiation dose rates around the surface of the transfer cask without water in the neutron shield (through step P.8.1.5.10) are expected to be high. Use proper ALARA practices (e.g., use of temporary shielding, appropriate positioning of personnel, etc.) to minimize personnel exposure.

2. Re-attach the TC lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.

3. Move the scaffolding away from the cask as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transfer trailer.

4. The transfer trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.

## P.8.2 Procedures for Unloading the Cask

### P.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the TC, transfer trailer, and support skid for service and tow the trailer to the HSM. If using the OS200/OS200FC TC to unload, verify that it has been fitted with an internal aluminum sleeve and cask spacer of appropriate height (refer to Drawings NUH-08-8004-SAR and NUH-08-8005-SAR provided in Appendix U.1, Section U.1.5). If using OS197, OS197H or OS197FC TC to unload, verify that it has the appropriate height spacer (see Figure P.4-18).
2. Back the trailer as close to the HSM as compatible with HSM door removal and remove the cask top cover plate.
3. Cut any welds from the door and remove the HSM door using a porta-crane. Remove the DSC drop-in retainer.
4. Using the skid positioning system align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.
5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install and align the hydraulic ram with the cask.
7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.
8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of fifteen inches or greater.

9. Retract ram and pull the DSC into the cask.
10. Retract the ram grapple arms.
11. Disengage the ram from the cask.
12. Remove the cask restraints.
13. Using the skid positioning system, disengage the cask from the HSM.

**Note:** If using the OS200/OS200FC TC to unload, place a sleeve ring spacer at the top of the aluminum sleeve (refer to Drawing NUH-08-8004-SAR provided in Appendix U.1, Section U.1.5).

14. Install the cask top cover plate and ready the trailer for transfer.

15. Replace the door on the HSM.

P.8.2.2 Removal of Fuel from the DSC

When the DSC has been removed from the HSM, there are several potential options for off-site shipment of the fuel. It is preferred to ship the DSC intact to a reprocessing facility, monitored retrievable storage facility or permanent geologic repository in a compatible shipping cask licensed under 10 CFR *Part* 71. *Note that ISG-2, Revision 2 [8.6] also defines ready retrieval or retrievability of spent fuel as the ability to remove a canister (DSC) loaded with spent fuel assemblies from a storage cask/overpack (Option B). DSCs approved for use and loaded from Amendment 18 forward demonstrate fuel retrievability based on Option B.*

If it becomes necessary to remove fuel from the DSC prior to off-site shipment, there are two basic options available at the ISFSI or reactor site. The fuel assemblies could be removed and reloaded into a shipping cask using dry transfer techniques, or if the applicant so desires, the initial fuel loading sequence could be reversed and the plant's spent fuel pool utilized. Procedures for unloading the DSC in a fuel pool are presented here. However, wet or dry unloading procedures are

## P.8.9 References


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

8.2 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 the NUHOMS®-24P and NUHOMS®–7P.

8.3 U.S. Nuclear Regulatory Commission Bulletin 96-04, "Chemical, Galvanic or Other Reactions in Spent Fuel Storage and Transportation Casks," July 5, 1996.

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

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

*8.6 Division of Spent Fuel Management Interim Staff Guidance – 2, Revision 2 (ISG-2) "Fuel Retrievability in Spent Fuel Storage Applications," April 26, 2016.*

## P.9 Acceptance Tests and Maintenance Program

### P.9.1 Acceptance Tests

The pre-operational testing requirements for the NUHOMS®-24PTH system are given in Section 9.0. The NUHOMS®-24PTH DSC has been enhanced to provide leaktight confinement and the basket includes an updated poison plate design. The requirements for the poison plate material acceptance tests and the NUHOMS®-24PTH DSC welds for the 24PTH system are described.

#### P.9.1.1 Visual Inspection

Visual examinations are performed at the fabricator's facility to ensure that the NUHOMS®-24PTH system components conform to the fabrication specifications and drawings.

#### P.9.1.2 Structural Tests

The NUHOMS®-24PTH DSC confinement welds are designed, fabricated, tested and inspected in accordance with ASME B&PV Code Section III, Subsection NB [9.1] with exceptions as listed in Section P.3.1. The following requirements are unique to the NUHOMS®-24PTH DSC:

- The inner bottom cover weld is inspected in accordance with Article NB-5231 when the weld joint design is per Figure NB-4243-1,
- The outer bottom cover weld is penetrant tested, and
- The outer top cover plate weld root and cover are penetrant tested.

The NUHOMS®-24PTH DSC *Type 1 and 2* basket*s are* designed, fabricated, and inspected in accordance with ASME B&PV Code Section III, Subsection NG [9.1] with exceptions as listed in Section P.3.1.

#### P.9.1.3 Leak Tests

The NUHOMS®-24PTH DSC confinement boundary is leak tested to verify that it is leaktight in accordance with the criteria of ANSI N14.5 [9.2]. The personnel performing the leak test are qualified in accordance with SNT-TC-1A [9.8].

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

#### P.9.1.4 Component Tests

The NUHOMS® system does not include any components such as valves, rupture discs, pumps, or blowers. No other components of the NUHOMS® system require testing, except as discussed in this chapter.

### P.9.1.5 Shielding Integrity Tests

The transfer cask poured lead shielding integrity will be confirmed via gamma scanning prior to first use. The detector and examination grid will be matched to provide coverage of the entire lead-shielded surface area. The acceptance criterion is attenuation greater than or equal to that of a test block matching the cask through-wall configuration with lead and steel thicknesses equal to the design minima less 5%.

The radial neutron shielding is provided by filling the neutron shield shell with water during operations. No testing is necessary. The neutron shield material in the lid and bottom end is a cementitious grout, NS-3. The shielding performance of this material will be assured by written procedures.

The gamma and neutron shielding materials of the storage system itself are limited to concrete HSM components and steel shield plugs in the DSC. The integrity of these shielding materials is ensured by the control of their fabrication in accordance with the appropriate ASME, ASTM or ACI criteria. No additional acceptance testing is required.

### P.9.1.6 Thermal Acceptance Tests

No thermal acceptance testing is required to verify the performance of each storage unit other than that specified in the Technical Specifications for initial loading.

The heat transfer analysis for the basket includes credit for the thermal conductivity of neutron-absorbing materials. *Requirements for Type 1 and 2 baskets are specified in Section P.4.3. For Type 3 baskets, the minimum acceptable thermal conductivity is* [ ] Because these materials do not have publicly documented values for thermal conductivity, testing of such materials will be performed in accordance with Section P.9.1.7.6.

### P.9.1.7 Poison Acceptance

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

a) Borated aluminum *(Basket Types 1 and 2 only)*

b) Boron carbide/aluminum metal matrix composite (MMC) *(All basket types)*

c) BORAL® *(Basket Types 1 and 2 only)*

P.9.1.7.6 Thermal Conductivity Testing of Poison Plates

Acceptance testing shall conform to ASTM E1225[1], ASTM E1461[2], or equivalent method, performed at room temperature on coupons taken from the rolled or extruded production material. Initial sampling shall be one test per lot, and may be reduced if the first five tests meet the specified minimum thermal conductivity. For cast products, the lot shall be defined by the heat or ingot. For other products, the lot shall be defined as material produced in a single production campaign using the same heat or lots of aluminum and boron carbide feed materials.

If a thermal conductivity test result is below the specified minimum, at least four additional tests shall be performed on the material from that lot. If the mean value of those tests, including the original test, falls below the specified minimum, the associated lot shall be rejected.

After twenty five tests of a single type of material, with the same aluminum alloy matrix, the same boron content, and the same primary boron phase, e.g., $B_4C$, $TiB_2$, or $AlB_2$, if the mean value of all the test results less two standard deviations meets the specified thermal conductivity, no further testing of that material is required. This exemption may also be applied to the same type of material if the matrix of the material changes to a more thermally conductive alloy (e.g., from 6000 to 1000 series aluminum), or if the boron content is reduced without changing the boron phase.

The measured thermal conductivity values shall satisfy the minimum required conductivities as specified in Section P.4.3 *for Type 1 and 2 baskets. For Type 3 baskets, the minimum acceptable thermal conductivity is as described in Section P.9.1.6.*

The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.

[1] ASTM E1225, "Thermal Conductivity of Solids by Means of the Guarded-Comparative-Longitudinal Heat Flow Technique"

[2] ASTM E1461, "Thermal Diffusivity of Solids by the Flash Method"

*P.9.1.8 High-Strength Low-Alloy Steel for Basket Type 3*

*The basket structural material is the same as is qualified and tested for the EOS-37PTH under CoC 1042 [9.11]. The structural steel grid plate shall be a High-Strength Low-Alloy (HSLA) steel meeting one of the following requirements A, B, or C:*

*A. ASTM A829 Gr 4130 [9-13] or AMS 6345 SAE 4130, quenched and tempered at not less than 1050 °F, 103.6 ksi minimum yield strength, and 123.1 ksi minimum ultimate strength. This material is qualified as described in [9.12].*

*B. ASME Code edition 2010 with 2011 addenda, SA-517 Gr A, B, E, F, or P. This material is qualified by the material properties at elevated temperature in ASME Section II, Part D [9.14], which exceed the values of yield and ultimate strength in UFSAR Table P.3.3-10.*

*C. Other HSLA steel, with the specified heat treatment, meeting these qualification and acceptance criteria:*

*i. If quenched and tempered, the tempering temperature shall be at no less than 1000 °F,*

*ii. Qualified prior to first use by testing at least two lots and demonstrating that the fracture toughness value $K_{JIc} \geq 150$ ksi √in at -40 °F with 95% confidence based on the methodology in Reference [9.12] for HSLA steel.*

*iii. Qualified prior to first use by testing at least two lots and demonstrating that the 95% lower tolerance limit of yield and ultimate strengths ≥ the values in UFSAR Table P.3.3-10 based on the methodology in Reference [9.12] for HSLA steel.*

*iv. Meet production acceptance criteria based on the 95% lower tolerance limit of yield strength and ultimate strength at room temperature as determined by qualification testing described in Section 9.1.8.iii.*

*As discussed in the Response to RSI 8-6 of [9.19], the 103.6 ksi yield and 123.1 ksi ultimate strength requirements only apply to the A829 Gr 4130 material and are not necessary for SA-517 because the mechanical properties from ASME Section II Part D exceed the design requirements of Table P.3.3-10 at all temperatures. The rationale for applying these acceptance criteria to A829 Gr 4130 is explained in the Response to RSI 8-5 of [9.19]. The impact testing acceptance criteria provide an alternate means of demonstrating sufficiently ductile behavior at the minimum service temperature as explained in RSI 8-6 of [9.19].*

*The basket HSLA material shall also meet the following production acceptance criteria:*

- *Weld repair shall not be permitted.*
- *Impact testing shall be performed at -40 °F*
  - *Charpy testing per ASTM A370 [9.15], minimum absorbed energy 25 ft-lb average, 20 ft-lb lowest of three (modify these acceptance criteria for sub-size specimens per A370-17 Table 9), or*
  - *Dynamic tear testing per ASTM E604 [9.16] with acceptance criterion of a minimum 80% shear fracture appearance.*

- *Test specimen location, orientation, and sampling rate per ASTM A6 [9.17] or ASTM A20 [9.18] for production acceptance testing.*

[ ]

## P.9.3 References


9.1 ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition including 2000 addenda.

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

9.3 Deleted.

9.4 Deleted.

9.5 "Aluminum Standards and Data, 2003" The Aluminum Association.

9.6 Natrella, "Experimental Statistics," Dover, 2005.

9.7 Deleted.

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

9.9 Deleted.

9.10 Deleted.

*9.11 CoC 1042, "Updated Final Safety Analysis Report (UFSAR) for the NUHOMS® EOS System, Revision 3," June 2020.*

*9.12* [ ]

*9.13 ASTM A829, "Standard Specification for Alloy Structural Steel Plates," ASTM International, West Conshohocken, PA, 2014.*

*9.14 ASME Boiler and Pressure Vessel Code, Section II, Materials Specifications, Part D, 2010 Edition with 2011 Addenda.*

*9.15 ASTM A370, "Standard Test Methods and Definitions for Mechanical Testing of Steel Products," ASTM International, West Conshohocken, PA, 2021.*

*9.16 ASTM E604, "Standard Test Method for Dynamic Tear Testing of Metallic Materials," ASTM International, West Conshohocken, PA, 2018.*

*9.17 ASTM A6, "Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling" ASTM International, West Conshohocken, PA, 2016.*

*9.18 ASTM A20, Standard Specification for General Requirements for Steel Plates for Pressure Vessels, ASTM International, West Conshohocken, PA, 2020.*

*9.19 Acceptance Review of TN Americas LLC Application for Certificate of Compliance No. 1042, Amendment No. 1, to the NUHOMS® EOS System, Revision 1 – Response to Request for Supplemental Information (Docket No. 72-1042, CAC No. 001028, EPID: L-2018-LLA-0043), ML18178A029.*

**Table P.9-1**
**B10 Specification for the NUHOMS®-24PTH Poison Plates**

| Poison Type | 24PTH Basket Type | Minimum Poison Loading (B10 mg/cm$^2$) | % Credit Used in Criticality Analysis |
|---|---|---|---|
| Borated Aluminum[(1)] /MMC | 1A or 2A | 7 | 90 |
| | 1B or 2B | 15 | |
| | 1C or 2C | 32 | |
| | *3D* | *35* | |
| BORAL® | 1A or 2A | 9 | 75 |
| | 1B or 2B | 19 | |
| | 1C or 2C | 40 | |

*Notes:*
*(1) Borated Aluminum is not an option for the Type 3 basket*

## P.10.1 Occupational Exposure

The occupational exposure results shown herein do not account for loading of 0.380 MTU fuel, which is described in Section P.5.4.11. Loading 0.380 MTU fuel results in an increase in occupational exposure of 10%.

The expected occupational dose for placing a canister of spent fuel into dry storage is based on the operational steps outlined in Table 7.4-1. The total exposure for the occupational dose due to placing a single NUHOMS®-24PTH-L DSC into storage is conservatively estimated to be *4.5* person-rem. This value bounds the exposure for loading either a 24PTH-S or 24PTH-S-LC DSC into storage. This is a very conservative estimate because the dose rates on and around the 24PTH DSC's used in these calculations are based on very conservative assumptions for the design-basis source terms and analyses models (Configuration 2 from Section P.2). The calculated exposures are due mainly to the expected gamma dose rate during preparation for welding. 72.48

*The exposure calculation is based on the 24PTH-L Type 2 DSC, which bounds the 24PTH-L Type 1 DSC. As noted in Chapter P.5, the 24PTH-L Type 3 DSC has lower cask side dose rates and higher cask end dose rates than the 24PTH-L Type 2 DSC. The net effect on occupational exposure is an increase of 3% for the 24PTH-L Type 3 DSC, which is negligible and within the uncertainty of the methodology.*

*Measured occupational exposures are usually significantly less than calculated values and are provided for multiple past loading campaigns in Table P.10-1a. The average measured occupational exposures range from 0.17 person-rem to 0.36 person-rem and are significantly lower than the computed value of 4.5 person-rem. This result implies large conservatism in the computed exposure.*

The NUHOMS®-24PTH System loading operations, the number of workers required for each operation, and the amount of time required for each operation are presented in Table P.10-1. This information is used as the basis for estimating the total occupational exposure associated with one fuel load. This evaluation is performed for the storage of one design-basis NUHOMS®-24PTH-L DSC in an HSM-H. The loading operations are identical for the 24PTH-S and 24PTH-S-LC DSC. The dose rates applicable for each operation are based on the results presented in Section P.5.4 for loading operations. Engineering judgment and operational experience are used to estimate dose rates that were not explicitly evaluated. This evaluation assumes that a transfer trailer/skid with an integral ram is used for the DSC transfer operations. Licensees may elect to use different equipment and/or different procedures. Each Licensee must evaluate any such changes in accordance with its ALARA program.

Unique steps are sometimes necessary at the individual site to load the canister, complete closure operations and place the canister in the HSM. Specifically, the licensee may choose to modify the sequence of operations in order to achieve reduced dose rates for a larger number of steps, with the end result of reduced total exposure. The only requirement is that the licensee practice ALARA with respect to the total exposure received for a loading campaign. These estimated durations, manloading and dose rates are not limits.

The amount of time required to complete some operations as identified in Table P.10-1 may be greater than the actual amount of time spent in a radiation field. The process of vacuum drying the DSC includes setting up the vacuum drying system (VDS), verifying that the VDS is operating correctly, evacuating the DSC cavity, monitoring the DSC pressure, and disconnecting the VDS from the DSC. Of these tasks, only setup and removal of the VDS require a worker to spend time near the DSC. The most time consuming task, evacuating the DSC, does not require anyone to be present near DSC at all. The total exposure calculated for each task is therefore not necessarily equal to the number of workers multiplied by the total time required, multiplied by a dose rate. The exposure estimation for each task correctly accounts for cases such as vacuum drying assumes that good ALARA practices are followed.

The results of the evaluations of the 24PTH-L are presented in Table P.10-1.

***Table P.10-1a***
***Measured Occupational Exposures***

| ***Loading Campaign*** | ***HSM*** | ***DSC*** | ***Average DSC Heat Load (kW)*** | ***Average Occupational Exposure (person-rem)*** |
|---|---|---|---|---|
| *1* | *HSM Model 102* | *24PTH-S-LC* | *22.3* | *0.34* |
| *2* | *HSM Model 102* | *24PTH-S-LC* | *22.4* | *0.31* |
| *3* | *HSM Model 102* | *24PTH-S-LC* | *22.8* | *0.36* |
| *4* | *HSM-H* | *24PTH-L* | *25.8* | *0.23* |
| *5* | *HSM-H* | *24PTH-L* | *26.6* | *0.34* |
| *6* | *HSM-H* | *24PTH-L* | *29.0* | *0.24* |
| *7* | *HSM-H* | *24PTH-L* | *28.0* | *0.17* |
| *8* | *HSM-H* | *24PTH-L* | *29.3* | *0.17* |

P.11.1.2 Extreme Temperatures

No change. The off-normal maximum ambient temperature of 125°F is used in Section 8.1.2.2. For the NUHOMS®-24PTH system, a maximum ambient temperature of 117°F is used. Therefore, the analyses in Section 8.1.2.2 bound TCs and HSM Model 102 used in the NUHOMS®-24PTH system.

P.11.1.2.1 Postulated Cause of Event

No change. See Section 8.1.2.2.

P.11.1.2.2 Detection of Event

No change to Section 8.1.2.2.

P.11.1.2.3 Analysis of Effects and Consequences

The thermal evaluation of the NUHOMS®-24PTH system for off-normal conditions is presented in Section P.4. The 100ºF normal condition with insolation bounds the 117ºF case without insolation for the DSC in the TC. Therefore the normal condition maximum temperatures are bounding. The 117ºF case with the DSC in the HSM-H is not bounded by the normal conditions and therefore evaluated in Section P.4.

The NUHOMS® standardized TC and HSM Model 102 were evaluated for a maximum heat load of 24 kW and maximum off-normal ambient temperature of 125ºF. The maximum heat load of the 24PTH-S-LC DSC in standardized TC or HSM Model 102 is limited to 24 kW. Therefore the evaluation presented in Section 8.1.2.2 is bounding for these components.

The structural evaluation of the 24PTH DSC for off-normal temperature conditions is presented in Section P.3.6.2.2. The structural evaluation of the basket due to off-normal thermal conditions is presented in Section P.3.6.1.3 *for the Types 1 and 2 basket. The Type 3 basket is evaluated considering the bounding normal and off-normal thermal conditions in Section P.3.8*. The structural evaluation of HSM-H and OS197FC Transfer Cask for off-normal conditions with 24PTH DSC are presented in Section P.3.6.

As indicated in Section P.3.6, the structural evaluation of the HSM-HS and OS200/OS200FC Transfer Cask, as presented in Chapter U.3, Section U.3.6.2.3 and Chapter U.3, Section U.3.6.2.4, respectively, are not affected when loaded with the 24PTH DSC.

P.11.1.2.4 Corrective Actions

Restrictions for onsite handling of the TC with a loaded DSC under extreme temperature conditions are presented in Technical Specifications 4.4.1.A and 4.4.1.B. There is no change to this requirement as a result of addition of the NUHOMS®-24PTH DSC.

remain sealed in the DSC and, therefore, will not contaminate the encroaching flood water. See also Section 8.2.4.3.

P.11.2.4.4 Corrective Actions

No change to Section 8.2.4.4.

P.11.2.5 Accidental TC Drop

P.11.2.5.1 Cause of Accident

See Section P.3.7.4.

P.11.2.5.2 Accident Analysis

The evaluation of the NUHOMS®-24PTH DSC shell and basket assemblies due to an accidental drop is presented in Section P.3.7.4 *for the Types 1 and 2 basket and in Section P.3.8 for the Type 3 basket.* As documented in Chapter P.3.7, the TCs have been evaluated for a payload that bounds the 24PTH DSC payload, and therefore is not affected by the 24PTH DSC. As shown in Section P.3.7.4, the DSC shell and *Types 1 and 2* basket stress intensities are within the appropriate ASME Code Service Level D allowable limits and maintains their structural integrity. *The Type 3 basket grid plate plastic strains meet the strain criteria for high-strength low-alloy steel as shown in Section P.3.8.7.3.*

For the standardized TC with solid neutron shield, complete loss of neutron shield during cask drop events is not credible. For the case of a liquid neutron shield, a complete loss of neutron shield was evaluated at the 100ºF ambient condition with full solar load in Section P.4. It is conservatively assumed that the neutron shield jacket is still present but all the liquid is lost. The maximum DSC shell temperature is 685ºF. The maximum OS197/OS197H/OS197FC cask inner liner, OS197/OS197H/OS197FC cask outer shell, and OS197/OS197H/OS197FC cask neutron shield jacket temperatures are 530ºF, 488ºF and 325ºF respectively for 24PTH DSC with 40.8 kW decay heat load as shown in Table P.4-12. The fuel cladding temperatures are below their limit as shown in Table P.4-25. Accident thermal conditions, such as loss of the liquid neutron shield, need not be considered in the load combination evaluation. Rather the peak stresses resulting from the accident thermal conditions must be less than the allowable fatigue stress limit for 10 cycles from the appropriate fatigue design curves in Appendix I of the ASME Code. Similar analyses of other NUHOMS® TCs have shown that fatigue is not a concern. Therefore, these thermal stresses in a TC with a liquid neutron shield need not be evaluated for the accident condition.

As documented in Section U.3.3.7.4, the OS200 transfer cask has been evaluated for the 32PTH1 DSC payload, which bounds that for the 24PTH DSC.

For the OS200 transfer cask, the assessment of a complete loss of neutron shield, presented in Section U.11.2.5.2, is not changed.

5. If a leak is found, remove the outer cover plate root pass (if not using test head), the vent and siphon port plugs and repair the inner cover plate welds. Then install the strongback (if used) and repeat procedure steps from T.8.1.3 step 21.

6. Perform dye penetrant examination of the root pass weld. Weld out the outer top cover plate to the DSC shell and perform dye penetrant examination on the weld surface in accordance with the CoC Appendix A Inspections, Tests, and Evaluations Item 4.3 requirements.

7. Install and seal weld the prefabricated plug, if applicable, over the outer cover plate test port and perform dye penetrant weld examinations in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 4.3 requirements.

8. Remove the automatic welding machine from the DSC.

8a. In accordance with Technical Specification 4.3.2, verify that the NS is filled before the draining operation in Step 9 is initiated and continually monitored during the first five minutes of the draining evolution to ensure the NS remains filled.

9. Open the cask drain port valve and drain the water from the cask/DSC annulus.

10. Rig the cask top cover plate and lower the cover plate onto the transfer cask. *If using the two-piece lid option on the OS197FC-B TC to load the 61BTH Type 2 DSC, rig the interior lid only.* 72.48

11. If using the OS200/OS200FC TC to load, place a sleeve ring spacer at the top of the aluminum sleeve (refer to Drawing NUH-08-8004-SAR provided in Appendix U.1, Section U.1.5).

12. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.

    CAUTION: Monitor the applicable time limits of Technical Specification 3.1.3 until the completion of DSC transfer step 6 of Section T.8.1.6, if loading Type 2 61BTH DSC.

13. Verify that the TC radial dose rates measured at the surface of the Transfer Cask are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2. The configuration for determining the TC radial surface dose rates shall be in accordance with CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

T.8.1.5 <u>Transfer Cask Downending and Transfer to ISFSI</u>

*NOTE:*
*Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

NOTE:
Alternate Procedure for Downending of Transfer Cask: Some plants have limited floor hatch openings above the cask/trailer/skid, which limit crane travel (within the hatch opening) that would be needed in order to downend the TC with the trailer/skid in a stationary position. For these situations, alternate procedures are to be developed on a plant-specific basis, with detailed steps for downending.

1. Re-attach the transfer cask lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.

### T.8.2 Procedures for Unloading the Cask

#### T.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the transfer cask, transfer trailer, and support skid for service and tow the trailer to the HSM. If using the OS200/OS200FC TC to unload, verify that it has been fitted with an internal aluminum sleeve and a cask spacer of appropriate height (refer to Drawings NUH-08-8004-SAR and NUH-08-8005-SAR provided in Appendix U.1, Section U.1.5).

2. Back the trailer to within a few feet of the HSM and remove the cask top cover plate.

*2a. If using the two-piece lid option, remove the combined interior and exterior top lid assembly.* 72.48

CAUTION: High dose rates are expected in the HSM cavity after removal of HSM door. Proper ALARA practices should be followed.

3. Remove the HSM door using a porta-crane. Remove the DSC axial retainer.

4. Continue to back the transfer trailer within a few inches of the HSM. Using the skid positioning system, align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.

5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install (if required) and align the hydraulic ram with the cask.

7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.

8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of 15 inches or greater.

9. Retract ram and pull the DSC into the cask.

10. Retract the ram grapple arms.

11. Disengage the ram from the cask. Install the ram access penetration cover plate.

If it becomes necessary to remove fuel from the DSC prior to off-site shipment, there are two basic options available at the ISFSI or reactor site. The fuel assemblies could be removed and reloaded into a shipping cask using dry transfer techniques, or if the applicant so desires, the initial fuel loading sequence could be reversed and the plant's spent fuel pool utilized. Procedures for unloading the DSC in a fuel pool are presented here. However, wet or dry unloading procedures are essentially identical to those of DSC loading through the DSC weld removal (beginning of preparation for placement of the cask in the fuel pool). Prior to opening the DSC, the following operations are to be performed.

1. The cask may now be transferred to the cask handling area inside the plant's fuel/reactor building.

2. Position and ready the trailer for access by the crane.

*2a. If using the two-piece lid option, remove the exterior top lid.*

3. Attach the lifting yoke to the crane hook.

4. Engage the lifting yoke with the trunnions of the cask.

5. Visually inspect the yoke lifting hooks to insure that they are properly aligned and engaged onto the cask trunnions.

6. Lift the cask approximately one inch off the trunnion supports.

7. Move the crane backward in a horizontal motion while simultaneously raising the crane hook vertically and lift the cask off the trailer. Move the cask to the cask decon area.

8. Lower the cask into the cask decon area in the vertical position.

9. Wash the cask to remove any dirt which may have accumulated on the cask during the DSC loading and transfer operations.

10. Place scaffolding around the cask so that any point on the surface of the cask is easily accessible to personnel.

11. Unbolt the cask top cover plate.

12. Connect the rigging cables to the cask top cover plate and lift the cover plate from the cask. Set the cask cover plate aside and disconnect the lid lifting cables.

*12a. If using the two-piece lid option, remove the interior top lid.*

13. Install temporary shielding to reduce personnel exposure as required. Fill the TC/DSC annulus with clean demineralized water and place a protective cover over the annulus.

The process of DSC unloading is similar to that used for DSC loading. DSC opening operations described below are to be carefully controlled in accordance with plant procedures. This operation is to be performed under the site's standard health physics guidelines for welding, grinding, and handling of potentially highly contaminated equipment. These are to include the use of prudent housekeeping measures and monitoring of airborne particulates. Procedures may require personnel to perform the work using respirators or supplied air.

U.8.1.5 TC Downending and Transfer to ISFSI

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

Note: Alternate Procedure for Downending of Transfer Cask: Some plants have limited floor hatch openings above the cask/trailer/skid, which limit crane travel (within the hatch opening) that would be needed in order to downend the TC with the trailer/skid in a stationary position. For these situations, alternate procedures are to be developed on a plant-specific basis, with detailed steps for downending.

1. Re-attach the TC lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.
2. Move the scaffolding away from the cask as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transfer trailer.
3. The transfer trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.
4. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.
5. Move the crane forward while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.
6. Inspect the positioning of the cask to insure that the cask and trunnion pillow blocks are properly aligned.
7. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.
8. Inspect the trunnions to ensure that they are properly seated onto the skid and install the trunnion tower closure plates, if required.
9. Remove the bottom ram access cover plate from the cask if integral rem/trailer is not used. Install the two-piece temporary neutron/gamma shield plug to cover the bottom ram access. Install the ram trunnion support frame on the bottom of the TC. (The temporary shield plug and ram trunnion support frame are not required with integral ram/trailer.)

U.8.1.6 DSC Transfer to the HSM

1. Prior to transferring the cask to the ISFSI or prior to positioning the transfer cask at the HSM designated for storage, remove the HSM door using a porta-crane, inspect the cavity of the HSM, removing any debris and ready the HSM to receive a DSC. The doors on adjacent HSMs should remain in place.

   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.

## U.8.2 Procedures for Unloading the Cask

### U.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the TC, transfer trailer, and support skid for service and tow the trailer to the HSM.
2. Back the trailer to within a few feet of the HSM and remove the cask top cover plate.

   CAUTION: High dose rates are expected in the HSM cavity after removal of HSM door. Proper ALARA practices should be followed.

3. Remove the HSM door using a crane. Remove the DSC axial retainer.
4. Continue to back the transfer trailer within a few inches of the HSM. Using the skid positioning system align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.
5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install (if required) and align the hydraulic ram with the cask.
7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.
8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of 15 inches or greater.

9. Retract ram and pull the DSC into the cask.
10. Retract the ram grapple arms.
11. Disengage the ram from the cask. Install the ram access penetration cover plate.
12. Remove the cask restraints.
13. Using the skid positioning system, disengage the cask from the HSM.
14. Install the cask top cover plate and ready the trailer for transfer.
15. Replace the door on the HSM.

8. Remove the automated welding machine from the DSC.
9. Open the cask drain port valve and drain the water from the cask/DSC annulus.

   CAUTION: If the DSC decay heat load is greater than 24.0 kW, monitor the applicable time limits of Technical Specification 3.1.3 until the completion of DSC transfer step 15 of Section Y.8.1.6.

   If the TC is in a horizontal orientation on the transfer skid, and the required time limit for completion of a DSC transfer specified in Technical Specification 3.1.3 are not met, initiate air circulation in the TC/DSC annulus by starting one of the blowers provided on the transfer skid and continue blower operation for a minimum duration of 36 hours.

   When transfer operations are ready to continue secure air circulation and either complete the DSC insertion OR return the TC/DSC to an upright configuration and fill with clean demineralized water within the applicable time limits of Technical Specification 3.1.3.
10. Rig the cask top cover plate and lower the cover plate onto the transfer cask.
11. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.
12. Verify that the TC dose rates are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

### Y.8.1.5 Transfer Cask Downending and Transfer to ISFSI

*NOTE: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

NOTE: **Alternate procedure for downending of transfer cask:** Some plants have limited floor hatch openings above the cask/trailer/skid, or other conditions which limit crane travel in the direction that would be needed in order to downend the TC with the trailer/skid in a stationary position. For these situations, alternate procedures are to be developed on a plant-specific basis, with detailed steps for downending.

1. Re-attach the transfer cask lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.
2. Move the scaffolding away from the cask, as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transfer trailer.
3. The transfer trailer should be positioned so that the cask support skid is accessible to the crane with the trailer supported on the vertical jacks.
4. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.
5. Move the crane forward while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.
6. Inspect the positioning of the cask to ensure that the cask and trunnion pillow blocks are properly aligned.
7. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.
8. Inspect the trunnions to ensure that they are properly seated onto the skid and install the trunnion tower closure plates, if required.
9. Remove the bottom ram access cover plate from the cask if integral ram/trailer is not used. Install the two-piece temporary neutron/gamma shield plug to cover the bottom ram access. Install the ram trunnion support frame on the bottom of the transfer cask.

## Y.8.2 Procedures for Unloading the Cask

### Y.8.2.1 DSC Retrieval from the HSM

*Note: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the transfer cask, transfer trailer, and support skid for service and tow the trailer to the HSM.

2. Back the trailer to within a few feet of the HSM and remove the cask top cover plate.

   CAUTION: High dose rates are expected in the HSM cavity after removal of HSM door. Proper ALARA practices should be followed.

3. Remove the HSM door using a porta-crane. Remove the DSC axial retainer.

4. Continue to back the trailer within a few inches of the HSM. Using the skid positioning system, align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.

5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install (if required) and align the hydraulic ram with the cask.

7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.

8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of fifteen inches or greater.

9. Retract ram and pull the DSC into the cask.

10. Retract the ram grapple arms.

11. Disengage the ram from the cask. Install the ram access penetration cover plate.

12. Remove the cask restraints.

13. Using the skid positioning system, disengage the cask from the HSM.

air circulation in the TC/DSC annulus by starting one of the blowers provided on the transfer skid and continue blower operation for a minimum duration of 36 hours.

When transfer operations are ready to continue secure air circulation and either complete the DSC insertion OR return the TC/DSC to an upright configuration and fill with clean demineralized water within the applicable time limits of Technical Specification 3.1.3.

10. Rig the cask top cover plate and lower the cover plate onto the TC.
11. Bolt the cask cover plate into place, tightening the bolts to the required torque in a star pattern.
12. Verify that the transfer cask dose rates are compliant with limits specified in CoC Appendix A Inspections, Tests, and Evaluations Item 3.2.

Z.8.1.5 TC Downending and Transfer to ISFSI

*NOTE: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

NOTE: **Alternate Procedure for Downending of Transfer Cask:** Some plants have limited floor hatch openings above the cask/trailer/skid, or other conditions which limit crane travel in the direction that would be needed in order to downend the TC with the trailer/skid in a stationary position. For these situations, alternate procedures are to be developed on a plant-specific basis, with detailed steps for downending.

1. Re-attach the TC lifting yoke to the crane hook, as necessary. Ready the transfer trailer and cask support skid for service.
2. Move the scaffolding away from the cask, as necessary. Engage the lifting yoke and lift the cask over the cask support skid on the transfer trailer.
3. The transfer trailer should be positioned so that cask support skid is accessible to the crane with the trailer supported on the vertical jacks.
4. Position the cask lower trunnions onto the transfer trailer support skid pillow blocks.
5. Move the crane forward while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks.
6. Inspect the positioning of the cask to ensure that the cask and trunnion pillow blocks are properly aligned.
7. Lower the cask onto the skid until the weight of the cask is distributed to the trunnion pillow blocks.
8. Inspect the trunnions to ensure that they are properly seated onto the skid and install the trunnion tower closure plates, if required.
9. Remove the bottom ram access cover plate from the cask if integral ram/trailer is not used. Install the two-piece temporary neutron/gamma shield plug to cover the bottom ram access. Install the ram trunnion support frame on the bottom of the transfer cask. (The temporary shield plug and ram trunnion support frame are not required with the integral ram/trailer.)

### Z.8.2 Procedures for Unloading the Cask

#### Z.8.2.1 DSC Retrieval from the HSM

*NOTE: Ensure the administrative controls detailed in Section 5.1.1.5 are being implemented.*

1. Ready the TC, transfer trailer, and support skid for service and tow the trailer to the HSM.

NOTE: Verify that a cask spacer of appropriate height (refer to Drawing NUH-08-8005-SAR provided in Appendix U, Section U.1.5) is placed at the location of the TC.

2. Back the trailer to within a few feet of the HSM and remove the cask top cover plate.

   CAUTION: High dose rates are expected in the HSM cavity after removal of the HSM door. Proper ALARA practices should be followed.

3. Remove the HSM door using a crane. Remove the DSC axial retainer.

4. Continue to back the trailer within a few inches of the HSM. Using the skid positioning system align the cask with the HSM and position the skid until the cask is docked with the HSM access opening.

5. Using optical survey equipment, verify alignment of the cask with respect to the HSM. The TC shall be aligned with respect to the HSM such that the longitudinal centerline of the DSC in the TC is within ± ⅛ inch of its true position when the TC is docked with the HSM front access opening.

   If the alignment tolerance is exceeded, the following actions should be taken:

   a. Confirm that the transfer system is properly configured,

   b. Check and repair the alignment equipment, or

   c. Confirm the locations of the alignment targets on the TC and HSM.

5a. Install the cask restraints.

6. Install (if required) and align the hydraulic ram with the cask.

7. Extend the ram through the cask into the HSM until it is inserted in the DSC grapple ring.

8. Activate the arms on the ram grapple mechanism with the DSC grapple ring.

8a. From this point, until fuel has been removed from the DSC or the DSC has been removed from the TC, the DSC will be inspected for damage after any TC drop of 15 inches or greater.

9. Retract ram and pull the DSC into the cask.

10. Retract the ram grapple arms.

11. Disengage the ram from the cask. Install the ram access penetration cover plate.

# Amendment 18 to NUHOMS® CoC No. 1004

## Impacts on CoC 1004 Renewal

## CONTENTS



## LIST OF TABLES

# 1 Purpose

As required by certificate of compliance (CoC) Condition III.2, this enclosure evaluates impacts to aging management activities (i.e., time-limited aging analyses (TLAAs) and aging management programs (AMPs)) to ensure that they remain adequate for any changes to structures, systems, and components (SSCs) within the scope of renewal [1] due to Amendment 18. Since this Amendment is adding new structures, systems, and components (SSCs) to CoC 1004, the evaluation of the new SSCs will follow the renewal process outlined in NUREG-1927 Rev. 1, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance" [2].

## 1.1 Scoping Evaluation

Amendment 18 does not make any changes to SSCs external to the DSC and, thus, has no impact on the aging management review or activities associated with other CoC 1004 SSCs, (e.g., HSM, transfer cask, spent fuel). Thus, the evaluation of the impacts to aging management activities identified in the renewed CoC 1004 is limited to the subcomponents of the 24PTH Type 3 basket. A review of the SAR drawings for the Type 3 basket determined that all subcomponents would be in-scope for renewal (i.e., either important-to-safety or whose failure would prevent fulfillment of an intended safety function). Note that the retrievability safety function is based on the ability to remove a canister loaded with spent fuel assemblies from the storage overpack, i.e., option B in Revision 2 of Interim Staff Guidance - 2 [3].

## 1.2 Aging Management Review

### 1.2.1 Methodology

The Aging Management Review (AMR) follows the methodology recommended in NUREG-1927 [2]. The AMR provides an assessment of the aging effects that could adversely affect the ability of the SSCs to perform their intended functions during the period of extended operation.

The AMR process involves the following major steps:

- Identification of materials and environments,
- Identification of aging effects and mechanisms requiring management,
- Determination of the activities required to manage the effects and mechanisms of aging. This involves the identification of time-limited aging analyses (TLAAs), or aging management programs (AMPs) for managing the effects of aging.

For each 24PTH Type 3 basket subcomponent, the material of construction and the environment to which each subcomponent is exposed are determined. The subcomponent environments are determined based on the location of the component within the storage system. NUREG-2214, “Managing Aging Processes in Storage (MAPS) Report” [4], (which is based on engineering literature, related research and industry information, and existing operating experience) was reviewed to identify potential aging degradation mechanisms for different material/environment combinations.

### 1.2.2 Identification of Materials and Environments

The first step in the AMR process is to identify the materials of construction for each subcomponent of the in-scope SSCs and the environments to which those materials are exposed during normal storage conditions. The combinations of materials and environments are used to identify the potential aging effects that require management during the period of extended operation.

Materials

The materials of construction were identified through a review of the UFSAR drawings listed in UFSAR Section P.1.5 and are provided in Table 1

Environments

The environments to which SSCs and associated subcomponents are exposed play a critical role in the determination of potential aging mechanisms and effects.

Amendment 18 to CoC 1004 proposes to add a third type of a basket for use in the 24PTH DSC. Since, the new SSCs and subcomponents are confined to the interior of the DSC shell during storage; these subcomponents are exposed to the helium fill gas inside the canister and trace quantities of other gases, such as nitrogen, oxygen, argon, and fission product gases.

### 1.2.3 Identification of Aging Mechanisms and Aging Effects

The AMR for the 24PTH Type 3 basket subcomponents was performed by relying upon the AMR conducted by the NRC in NUREG-2214 [4]. NUREG-2214 grouped various material of construction into material groups as defined in Table 2-1 of the NUREG and then addressed potential aging mechanism/effects based on the material group/environment combination. The various materials of construction for the 24PTH Type 3 basket are assigned to the applicable NUREG-2214 material group as summarized in Table 1.

Table 3-2 thru 3-6 of NUREG-2214 summarizes the aging mechanism evaluations performed by the NRC for the various material grouping environment combinations. For a given material group, the table lists the environment where the aging mechanism is credible or if the aging mechanism is non-credible within the given environment.

For the carbon steel, stainless steel, and aluminum material in a helium environment, Table 3-2 of NUREG-2214 indicates there are no credible aging mechanisms, except that the fatigue aging mechanism must be evaluated per the design code if applicable. Fatigue evaluation of the 24PTH DSC, presented in UFSAR Section 12.2.1, considers cyclic loads caused by ambient daily and seasonal fluctuations in the pressure and temperature. The basket components are less susceptible than the DSC to ambient fluctuations of the external environment because they are inside the DSC. Therefore, no additional fatigue evaluation of the 24PTH Type 3 basket is required for the carbon steel, stainless steel, and aluminum material. For the stainless steel material, thermal aging for precipitation-hardened martensitic stainless steel must be evaluated as well. For the subcomponents made of precipitation-hardened martensitic stainless steel, (i.e., the tie rods and associated flat head screws and hex nuts made of ASTM A564 Type 630 H1100 stainless steel) see Section 1.2.4 below for the evaluation of thermal aging. For the aluminum material, an analysis is also required for creep and thermal aging if the component is load bearing. The load-bearing aluminum components in the 24PTH Type 3 basket are the R45 and R90 Rails. See Section 1.2.5 for the evaluation of creep and Section 1.2.6 for the evaluation of thermal aging.

For the Aluminum–Based Composite (i.e., Metal Matrix Composite) in a helium environment, Table 3-4 of NUREG-2214 indicates that there are no credible aging mechanisms, unless the material is load-bearing. For the 24PTH Type 3 basket, the MMC material is not load-bearing. Therefore, there are no credible aging mechanisms.

### 1.2.4 Thermal aging of precipitation-hardened martensitic stainless steel subcomponent

Precipitation-hardened martensitic stainless steel operating at high temperatures may be susceptible to thermal embrittlement depending on several factors including the alloy composition within the allowable specifications, the initial heat treatment and the operating temperature. For operating temperatures between 243°C and 316°C [470°F to 600°F] Section 3.2.2.8 of NUREG-2214 recommends an evaluation of conditions on a per-component basis considering operating temperature, exposure time, operating environment, stress levels, and material composition.

The only 24PTH Type 3 basket components made of precipitation-hardened martensitic stainless steel (ASTM A564 Type 630) are the tie rods and associated flat head screws and hex nuts. For normal storage conditions these components have a maximum temperature of 481°F based on thermal analysis. The maximum component temperatures are below the reported threshold temperature of 500°F in EPRI report TR-1012081 [5].

Therefore, thermal aging embrittlement is unlikely to affect the mechanical properties of the precipitation-hardened martensitic stainless steel during the Period of Extended Operations and, thus, is not considered a credible aging mechanism.

### 1.2.5 Creep of Aluminum Material

UFSAR Section P.3.8 demonstrated that the bearing stress on the aluminum rails is less than that necessary to limit creep strain to 0.01 after 80 years of storage. UFSAR Section

P.3.8.7.2 showed such a large margin between actual average aluminum bearing stress and the allowable creep stress that it is concluded that the aluminum components in the 24PTH Type 3 basket will continue to perform their intended function through the end of the period of extended operation.

### 1.2.6 Thermal Aging of Aluminum Material

The Type 3 basket's ASTM B209 Alloy 1100 Aluminum subcomponents serve no structural function; therefore, thermal aging is only considered for the Aluminum 6061 subcomponents. As shown in UFSAR Table P.3.3-12, the temperature dependent material properties used in the stress evaluations for the Aluminum 6061 material is based on the annealed condition.

The use of properties based on annealed condition (no credit taken for enhanced properties obtained by heat treatment) in the stress qualification eliminates any changes in strength that may occur under exposure to elevated temperatures and ensures no adverse impact on the properties used in the design.

Therefore, thermal aging of the aluminum material is not credible in a helium environment.

## 2 Conclusions

The review of the potential aging mechanisms/effects of the 24PTH Type 3 basket materials/environment combinations determined that there are no credible aging effects or that the design analyses demonstrate that the subcomponents will continue to perform their intended function through the end of the period of extended operation. Therefore, no additional aging management activities are required.

The scope of Amendment 18 does not impact the renewed CoC 1004 aging management activities (i.e., TLAAs and AMPs). These aging management activities remain adequate for those SSCs within the scope of renewal.

## 3 References

1. Letter from Jayant Bondre (AREVA) to NRC Document Control Desk, "Response to Re-Issue of Second Request for Additional Information - AREVA Inc. Renewal Application for the Standardized NUHOMS® System - CoC 1004 (Docket No. 72-1004, CAC No. L24964)," dated September 29, 2016 (ML16279A367).

2. NUREG 1927 Rev. 1, Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance, June 2016.

3. Division of Spent Fuel Management Interim Staff Guidance – 2, Revision 2, "Fuel Retrievability in Spent Fuel Storage Applications," April 26, 2016.

4. NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report", July 2019.

5. EPRI Technical Report TR-1012081, "Materials Reliability Program: PWR Internals Material Aging Degradation Mechanism Screening and Threshold Values (MRP-175)", 2005.

**Table 1**
**24PTH Type 3 Basket Material Grouping**

| Material Grouping | 24PTH Type 3 Basket Material of Construction |
|---|---|
| Steel | HSLA STEEL |
| | ASTM A516 GR. 70 |
| Stainless Steel | ASME SA-240 TYPE 304 |
| | ASTM A240 TYPE 304 |
| | ASTM A564 TYPE 630 H1100 |
| | STAINLESS STEEL |
| | STAINLESS STEEL 302 |
| | STAINLESS STEEL 304 |
| Aluminum | ASTM B221 ALLOY 6061 |
| | ASTM B209 ALLOY 6061 |
| | ASTM B209 ALLOY 1100 |
| Metal Matrix Composite | MMC |

Listing of Computer Files Contained in Enclosure 11

| Disk ID No. (size) | Discipline | System/Component | File Series (topics) | Number of files |
|---|---|---|---|---|
| Enclosure 11<br>Hard drive<br>**Structural Folder**<br>(4.18 GB) | **Structural** | **24PTH Type 3 Basket** | Appendix P.3.8 24PTH Type 3 Basket Structural Analysis – Normal/Off-Normal Conditions<br>**Folder: \Structural\normal\handling**<br>Input and output files for ANSYS analysis of handling load case - 180° orientation with adjusted gap between basket and DSC | 6 |
| | | | Appendix P.3.8 24PTH Type 3 Basket Structural Analysis – Normal/Off-Normal Conditions<br>**Folder: \Structural\normal\thermal**<br>Input and output files for ANSYS analysis of thermal load case (restraint at y=0) | 6 |
| | | | Appendix P.3.8 24PTH Type 3 Basket Structural Analysis – Normal/Off-Normal Conditions<br>**Folder: \Structural\normal\load_combination**<br>Input and output files for ANSYS load combination - 180° orientation with adjusted gap and thermal load case (restraint at y=0) | 8 |
| | | | Appendix P.3.8 24PTH Type 3 Basket Structural Analysis – Accident Conditions<br>**Folder: \Structural\accident\with_bolt_tierod**<br>Input and output files for ANSYS analysis of accident side drop - 210° orientation with bolts and tie rods | 6 |
| | | | Appendix P.3.8 24PTH Type 3 Basket Structural Analysis – Accident Conditions<br>**Folder: \Structural\accident\without_bolt_tierod**<br>Input and output files for ANSYS analysis of accident side drop - 210° orientation without bolts and tie rods | 6 |
| Enclosure 11<br>Hard drive<br>**Thermal Folder**<br>(86.3 GB) | **Thermal** | **24PTH Type 3 DSC in HSM-H** | **Appendix P.4.12.1 (LC S-1 of Table P.4-44)**<br>**Folder: \Thermal\P.4.12.1\1-24PTH_HSM-H_HLZC1_LC_S-1**<br>Input and output files for the bounding storage condition of 24PTH Type 3 DSC in HSM-H during normal storage conditions with HLZC 1 using the coarse mesh.<br>(ANSYS FLUENT Evaluation) | 4 |

Listing of Computer Files Contained in Enclosure 11

| Disk ID No. (size) | Discipline | System/Component | File Series (topics) | Number of files |
|---|---|---|---|---|
| | | | **Appendix P.4.12.1 (LC S-1f of Table P.4-44)**<br>**Folder: \Thermal\P.4.12.1\2-24PTH_HSM-H_HLZC1_LC_S-1f**<br>Input and output files for the bounding storage condition of 24PTH Type 3 DSC in HSM-H during normal storage conditions with HLZC 1 using the fine mesh.<br>(ANSYS FLUENT Evaluation) | 4 |
| | | **24PTH Type 3 DSC in OS197** | **Appendix P.4.12.2 (LC T-1A of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\1-24PTH_OS197FC-TC_HLZC1_LC_T-1A**<br>Input and output files for the bounding steady state normal indoor transfer evaluation with no air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 1.<br>(ANSYS FLUENT Evaluation) | 11 |
| | | | **Appendix P.4.12.2 (LC T-1 of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\2-24PTH_OS197FC-TC_HLZC1_LC_T-1**<br>Input and output files for the bounding normal outdoor transfer evaluation with no air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 1 @ 11.5 hours.<br>(ANSYS FLUENT Evaluation) | 11 |
| | | | **Appendix P.4.12.2 (LC T-2 of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\3-24PTH_OS197FC-TC_HLZC1_LC_T-2**<br>Input and output files for the bounding normal outdoor transfer evaluation with air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 1 @ 8 hours after end of LC T-1.<br>(ANSYS FLUENT Evaluation) | 11 |

Listing of Computer Files Contained in Enclosure 11

| Disk ID No. (size) | Discipline | System/Component | File Series (topics) | Number of files |
|---|---|---|---|---|
| | | | **Appendix P.4.12.2 (LC T-3 of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\4-24PTH_OS197FC-TC_HLZC1_LC_T-3**<br>Input and output files for the bounding normal outdoor transfer evaluation with no air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 1 @ 4 hours after end of LC T-2.<br>(ANSYS FLUENT Evaluation) | 11 |
| | | | **Appendix P.4.12.2 (LC T-4 of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\5-24PTH_OS197FC-TC_HLZC4_LC_T-4**<br>Input and output files for the bounding steady state normal outdoor transfer evaluation with no air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 4.<br>(ANSYS FLUENT Evaluation) | 11 |
| | | | **Appendix P.4.12.2 (LC T-4f of Table P.4-61)**<br>**Folder: \Thermal\ P.4.12.2\6-24PTH_OS197FC-TC_HLZC4_LC_T-4f**<br>Input and output files for the bounding steady state normal outdoor transfer evaluation with no air circulation for the 24PTH Type 3 DSC in OS197FC TC with HLZC 4.<br>(ANSYS FLUENT Evaluation) | 11 |
| Hard drive<br>**Shielding Folder**<br>(1.09 GB) | **Shielding** | 24PTH-L Type 3 DSC in OS197 transfer cask | Table P.5-3a: Transfer | 12 |
| | | | Table P.5-4a: Decontamination | 12 |
| | | | Table P.5-4a: Welding | 12 |
| | | 24PTH-S-LC Type 3 DSC in Standardized transfer cask | Table P.5-5a: Transfer | 12 |

Listing of Computer Files Contained in Enclosure 11

| **Disk ID No. (size)** | **Discipline** | **System/Component** | **File Series (topics)** | **Number of files** |
|---|---|---|---|---|
| Hard drive<br>**Criticality Folder**<br>(10.1 MB) | **Criticality** | 24PTH Type 3 DSC Sensitivity Study | Table P.6-49: Intact fuel | 28 |
| | | | Table P.6-50: Damaged fuel | 8 |
| | | | Table P.6-51: Failed fuel | 8 |