TRANSNUCLEAR
AN AREVA COMPANY

February 25, 2011
E-30554

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
One White Flint North
11555 Rockville Pike
Rockville, MD 20852

Subject: Revision 4 to Transnuclear, Inc. (TN) Application for Amendment 11 to the Standardized NUHOMS® System, Response to Second (Restart) Request for Additional Information (Docket No. 72-1004; TAC No. L24380)

Reference: Letter from B. Jennifer Davis (NRC) to Donis Shaw (TN), "SECOND (RESTART) REQUEST FOR ADDITIONAL INFORMATION FOR REVIEW OF AMENDMENT 11 TO THE STANDARDIZED NUHOMS® SYSTEM (TAC NO. L24380)," February 10, 2011

This submittal provides responses to the request for additional information (RAI) forwarded by the reference above. Enclosure 2 herein provides each of the NRC staff RAI followed by a TN response. Enclosure 3 provides a list of additional changes, not associated with the RAI. Enclosure 4 provides a list of Certificate of Compliance (CoC), Technical Specifications (TS), and updated final safety analysis report (UFSAR) pages associated with Revision 4, with the reasons for change. Enclosure 5 provides page change instructions for CoC, TS and UFSAR pages. Enclosure 6 provides the changed pages.

In the TS and UFSAR, changes made in response to Amendment 11 RAI No. 1, RAI No. 2, (RESTART) RAI No. 1, and new changes based on this current RAI are indicated by revision bars in the right margin and italics for inserted text. The new changes are shaded, to distinguish them from the RAI No. 1, RAI No. 2 and (RESTART) RAI No. 1 changes. Changed UFSAR pages are annotated as Revision 4.

CoC 1004 UFSAR Revisions 10 and 11 were issued on February 1, 2008 and February 1, 2010, respectively, both submittals occurring after the initial application for Amendment 11. Additionally, the update to UFSAR Revision 11 incorporated CoC 1004 Amendment 10, which affected a great many UFSAR pages which are also being proposed for changes under Amendment 11. Based on this history, TN has taken steps to ensure that UFSAR pages with proposed Amendment 11 changes affected by the UFSAR update to Revisions 10 or 11 are included herein and reflect the latest UFSAR changes.

Should the NRC staff require additional information to support review of this application, please do not hesitate to contact Mr. Don Shaw at 410-910-6878 or me at 410-910-6881.



NMSS01

Sincerely,

Jayant Bondre

Jayant Bondre, PhD
Vice President - Engineering

cc: Jennifer Davis (NRC SFST) 11 copies of this cover letter and all Enclosures provided in a separate mailing

Enclosures:

1. Not used
2. RAIs and Responses
3. List of Additional Changes Not Associated with the RAI
4. List of CoC, Technical Specifications, and UFSAR Pages Associated with Amendment 11, Revision 4
5. CoC, Technical Specifications, and UFSAR Page Change Instructions
6. Amendment 11 Revision 4 Changed Certificate of Compliance, Technical Specifications, and UFSAR pages

**CHAPTER 5 Shielding Evaluation, and**
**CHAPTER 8 Radiation Protection Evaluation**

**5-1** Make explicit reference to the Transfer Trailer shielding in the description of the OS197L TC located in Insert A of the CoC. Also include the cask weight limit for the OS197L cask (85 tons).

Insert A of the CoC defines the OS197L TC system, but makes no reference to the Transfer Trailer shielding as mentioned in 3d of the draft CoC.

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-1***

*UFSAR Page W.5-3 provides the following note:*

*"Note that the support skid supplemental shielding is referred to as trailer shielding or trailer area shielding throughout this chapter."*

*Based on this, and for consistency in the CoC, Insert A of the CoC is revised to reference "support skid supplemental shielding" and paragraph 3d of the CoC is revised to reference both "decontamination area shielding" and "support skid supplemental shielding."*

*The OS197L cask weight limit is added to paragraph 3b of the CoC, with clarification that this weight does not include the decontamination area shielding or the support skid supplemental shielding. Note that 90 tons is used as the maximum weight limit of the OS197L cask to account for tolerances in the canister, cask and fuel assembly weights.*

*Also, the maximum loaded weight for the OS197H and OS200 TCs is changed to 125 tons, to be consistent with the UFSAR analysis.*

**5-2** Revise Table W.3-1 to add the word "Nominal" to the description in the last row of the table.

In response to RAI 5-14 (Restart RAI Round #1), clarification was provided which stated, in part, that the nominal loaded weight of the OS197L cask was approximately 85 tons. Table W.3-1 should be revised to specify that the weight listed is for the "Nominal" Loaded OS197L TC.

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-2***

*The UFSAR is revised to add the word "Nominal" to the description in the last row of Appendix W.3, Table W.3-1. A note is added to clarify that this weight does not include the decontamination area shielding or the support skid supplemental shielding.*

**5-3** Provide clarification regarding the impact of the neutron shield on dose rates at the top of the cask.

In response to RAI 5-16 (Restart RAI Round #1), clarification was added to Section W.5.1.3 of the SAR to justify using the axial dose rate results from UFSAR Chapter K.5 and Chapter M.5. Part of this discussion involved the justification for those dose rate values for areas above the cask but within the overall radius of the cask. Section W.5.1.3 states, in part, that... "[i]t is assumed that the water neutron shielding on the side of the cask is lost during the accident. Therefore, accident and normal condition dose rates on top of the cask are not different when radial distances less than the radius of the cask are under consideration." What impact does the neutron shield have on dose rates at the top of the cask?

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-3***

*The discussion in UFSAR Section W.5.1.3 provides justification for the applicability of dose rates calculated with the OS197 TC for the OS197L TC for areas above the cask but within the radius of the cask. The water neutron shielding does not have any impact on dose rates above the cask at radial distances within the radius of the cask. This is because at distances within the radius of the cask, the contribution due to scattering through the radial shielding materials (including the water neutron shield) is minimized.*

*This clarification is added to UFSAR Appendix W.5, Section W.5.1.3.*

**5-4** Confirm the maximum dose rate values discussed in Section W.5.4.8.3 of the SAR.

In response to RAI 5-25 (Restart RAI Round #2), the discussion in Section W.5.4.8.3 was revised to provide the comparison from the results shown in Table W.5-4. However, staff identified values in Section W.5.4.8.3 that were slightly different from those listed in Tables W.5-3 and W.5-12.

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-4***

*The maximum dose rate values shown in UFSAR Section W.5.4.8.3, 9840 mrem/hour and 1550 mrem/hour, are rounded up values of 9835 mrem/hour (Table W.5-3) and 1543 mrem/hour (Table W.5-4), respectively.*

*This clarification is added to the discussion in UFSAR Appendix W.5, Section W.5.4.8.3.*

**5-5** Confirm the bounding total dose rates for the OS197L TC with 32PT DSC and 61BT DSC under normal and accident conditions as specified in Tables W.5-6, W.5-7, W.5-9, and W.5-10 of the SAR.

Tables W.5-6, W.5-7, W.5-9, and W.5-10 list the expected bounding dose rates for a bare OS197L TC under normal and accident conditions. However, each table contains a footnote which states "Note: 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." Guidance found in the shielding section of NUREG-1536 suggests that the SAR should indicate the dose rate at all locations accessible to occupational personnel during cask loading, transport, and maintenance and surveillance operations. It goes on to say that generally these locations include points at or near various cask components and in the immediate vicinity of the cask. This implies that in order to accurately access personnel exposure in such cases the total bounding dose rate should be indicative of the total dose rate to an individual at or near the distances specified in those tables.

This is requested to satisfy the requirements of 10 CFR 72.126.

***Response to 5-5***

*As discussed in UFSAR Appendix W.5, Section W.5.1, the dose rates shown in Table W.5-3, Table W.5-4, and Tables W.5-6 through W.5-14 correspond to "bounding maximum dose rates". This ensures that the total dose rates shown in these tables correspond to the bounding maximum total dose rates for use in the occupational exposure evaluations.*

*This clarification is added to the discussion in Appendix W.5, Section W.5.1. Further, the note shown in Table W.5-3, Table W.5-4, Table W.5-6, Table W.5-7, Table W.5-9, Table W.5-10, Table W.5-12, Table W.5-13 and Table W.5-14 is revised as shown below (changed text is shown as shaded):*

*"Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate."*

**5-6** Provide more detail concerning the amount of water that is in the DSC/TC annulus in Section 5.2.4 of the TS.

Section 5.2.4(e) of the TS states that the DSC/TC annulus is filled with water as part of the configuration used for all TC axial dose rate measurements. The staff concern is that the amount of water present could have a noticeable effect on the measurements. Please provide more detail as to the amount of water that is present in the DSC/TC annulus during the measurements.

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-6***

*As stated in the TS, the DSC/TC annulus is filled with water to such an extent that the water level in the annulus is at least up to the top of the fuel assembly level and is consistent with the geometry employed in the shielding calculations.*

*This requirement is added to TS Section 5.2.4 (e).*

**5-7** In Section 5.2.4(e) of the TS, change the word "approximately," in the sentence, "[i]n addition to the configuration above, decontamination area shielding *approximately* equal to 6 inches of steel is installed in the radial direction only for the OS197L," to either "nominal" or "minimal".

The TS as written lacks precision. Use of wording such as "approximately" does not provide an adequate definition of the tolerances associated with the shielding material mentioned in Section 5.2.4(e).

This is requested to satisfy the requirements of 10 CFR 72.236.

***Response to 5-7***

*In TS Section 5.2.4 (e), the words "decontamination area shielding approximately equal to 6 inches of steel" are changed to "a minimum effective decontamination area shielding equivalent to 6 inches of steel."*

List of Additional Changes Not Associated with the RAI

| Item Number | Discussion/Justification | Areas Affected |
|---|---|---|
| 1 | Technical Specifications<br>(further detailed in Enclosure 4)<br><br>Certain TS were changed to correct editorial items or for consistency with other TS or UFSAR information. | • TS 1.1<br>• TS 1.3<br>• TS 4.1<br>• TS 4.2.4<br>• TS Table 1-1l<br>• TS Table 1-1bb<br>• TS Table 1-1ee<br>• TS Tables 1-6a through 1-6d and the applicable notes<br>• Notes for TS Tables 1-4a to 1-4f<br>• Figures 1-27, 1-29 and 1-30 |
| 2 | Technical Specifications<br>(further detailed in Enclosure 4)<br><br>Certain TS were changed to provide clarification of the requirements. | • TS 4.2.2<br>• TS Table 1-1c<br>• TS Table 1-1j |
| 3 | UFSAR Chapters 3 and 8 have passages which were changed to reflect the limitation of using only the 61BT and 32PT DSCs with the OS197L TC. | UFSAR Section 3.2.5.3<br>UFSAR Chapter 8 second paragraph |

List of Additional Changes Not Associated with the RAI

<table>
<tr><th>Item Number</th><th>Discussion/Justification</th><th>Areas Affected</th></tr>
<tr><td>4</td><td>CoC 1030 Amendment 1, which is in the final stages of Rulemaking, involved many improvements in the area of dry shielded canister (DSC) basket poison testing and acceptance. TN has kept our ongoing licensing actions involving DSCs consistent with those CoC 1030 Amendment 1 changes. In this submittal, UFSAR Appendices K.9, M.9, P.9, T.9 and U.9 are updated to reflect the most recent CoC Amendment 1 changes, plus certain new enhancements are proposed, which are explained below. Based on this, the aforementioned appendices are provided in their entirety, with only these new changes tracked and shaded.<ul><li>In the Borated Aluminum and MMC discussions for Reference 9.5, reference to Chapter 4 of the Aluminum Standards and Data includes the quoted name of that chapter. The name no longer contains the phrase “and Castings”; therefore this phrase was removed.</li><li>At the end of the Thermal Conductivity Testing section changes are made which are similar to CoC 1030 requirements but are specific to the given type of DSC.</li><li>In the discussions of Acceptance Testing of Neutron Absorbers by Neutron Transmission, the passage regarding non-conforming plate thickness is clarified regarding edge effects due to manufacturing operations.</li><li>In the “Boron Carbide / Aluminum Metal Matrix Composites (MMCs) section, the paragraph beginning with “At least 50% by weight of the….” is clarified regarding particles smaller that 40 microns.</li></ul></td><td>UFSAR Appendix K.9<br>UFSAR Appendix M.9<br>UFSAR Appendix P.9<br>UFSAR Appendix T.9<br>UFSAR Appendix U.9</td></tr>
<tr><td>5</td><td>Minor changes are made to ASME Code alternatives tables in UFSAR Appendices K.3, M.3, P.3, T.3, and U.3 for consistency. These are the same changes made in the TS ASME Code alternatives tables.</td><td>UFSAR Table K.3.1-3<br>UFSAR Table M.3.1-2<br>UFSAR Table P.3.1-2<br>UFSAR Table T.3.1-3<br>UFSAR Table U.3.1-2</td></tr>
</table>

**List of CoC, Technical Specifications, and UFSAR Pages Associated with Amendment 11, Revision 4**

| Page number | Reason for change |
|---|---|
| **Certificate of Compliance** | **Certificate of Compliance** |
| CoC page 2 of 3 | RAI Item 5-1 |
| CoC Inserts | RAI Item 5-1 |
| **Technical Specifications** | **Technical Specifications** |
| v | Updated for Table 1-6d |
| vi | Updated for Figures 1-29 and 1-30 titles |
| 1-1 | Definition of HORIZONTAL STORAGE MODULE (HSM) updated to account for the high seismic HSM-HS option.<br><br>Definition of INTACT FUEL ASSEMBLY modified to account for damaged fuel assemblies. |
| 1-5 | Under BACKGROUND, "Completion Times(s)" is changed to "Completion Time(s)". This is an editorial change. |
| 4-2 | Notes (1) through (5) are updated based on the changes to UFSAR Appendices K.9, M.9, P.9, T.9 and U.9.<br><br>In Note (5) an editorial correction is made, changing "here by" to "hereby" |
| 4-4 | Clarification is added that ASME code requirements for basket assemblies apply only to important to safety category A components. Consistent with Appendix A of Regulatory Guide 7.10, the most rigorous industrial materials standards, fabrication controls, and inspection practices, that is, ASME Code Section III jurisdiction, would be applied to level A components, while B components could use ASTM materials, and Level C and NITS materials could be provided by commercial suppliers.<br><br>(Reference Regulatory Guide 7.10, Rev 2, Establishing Quality Assurance Programs for Packaging Used in Transport of Radioactive Material, USNRC 2005) |
| 4-10 | The two table cells in the third column, related to the NB-2130 and NB-4121 rows, are merged into one, as the information applies to both rows. |
| 4-12<br>4-15<br>4-18<br>4-22<br>4-26 | • NG/NF-2130, NG/NF-4121, and NG/NF-8000 rows added to 61BT DSC Basket table for consistency with the UFSAR.<br>• NG-2130 and NG/NF-2130 rows in several tables are changed for consistency. |

**List of CoC, Technical Specifications, and UFSAR Pages Associated with Amendment 11, Revision 4**

| Page number | Reason for change |
|---|---|
| 5-7 | RAI Item 5-6 |
| 5-8 | RAI Item 5-7 |
| T-3 | Note 2 is added for additional requirements if the OS197L transfer cask is employed.<br><br>(Reference UFSAR Tables K.2-1 and W.2-2) |
| T-10<br>T-11 | Note 1 is added for additional requirements if the OS197L transfer cask is employed.<br><br>(Reference UFSAR Tables K.2-1 and W.2-2) |
| T-13 | The fuel damage specification is clarified regarding handling by normal means for consistency. |
| T-28 | The current Amendment 11 TS inadvertently shows outdated values in this table for the rows for 32PTH1-S and 32PTH1-M.<br><br>Therefore, the values are changed to be consistent with the rows for 32PTH1-S and 32PTH1-M from the CoC 1004 Amendment 10 TS. |
| T-34 | The table is revised to be consistent with the UFSAR analysis.<br><br>(Reference UFSAR Tables M.2-2a and U.2-2) |
| T-68 | Clarification on enrichment is added to the note regarding reconstituted fuel assemblies. |
| T-76 | A statement referring to UFSAR Appendix W tables is not needed and is removed.<br><br>The bulleted notes apply to Tables 1-6a and 1-6b. A statement to this effect is added.<br><br>(Reference UFSAR Table W.2-4) |
| T-77 | The title is revised to specify that this table applies to "0.17 kW" assemblies.<br><br>A statement referring to a UFSAR Appendix W table is not needed and is removed.<br><br>The bulleted notes on Table 1-6a apply to Tables 1-6a and 1-6b. A statement to this effect is added.<br><br>(Reference UFSAR Table W.2-5) |

**List of CoC, Technical Specifications, and UFSAR Pages Associated with Amendment 11, Revision 4**

| Page number | Reason for change |
|---|---|
| T-78 | The notes which previously followed this table apply to Tables 1-6c and 1-6d. Those notes are relocated to after Table 1-6d. The statement regarding the notes is revised to this effect.<br><br>(Reference UFSAR Table W.2-7) |
| T-79 | The title is revised to specify that this table applies to "0.4 kW" assemblies.<br><br>The notes which previously preceded this table apply to Tables 1-6c and 1-6d. Those notes are relocated to after this table. The statement regarding the notes is revised to this effect.<br><br>(Reference UFSAR Table W.2-8) |
| T-80 | The notes which previously followed Table 1-6c apply to Tables 1-6c and 1-6d. Those notes are relocated to after Table 1-6d.<br><br>(Reference Table W.2-7) |
| F-27 | The table below the figure had been inadvertently duplicated in the CoC Amendment 11 application. The duplicate information is removed. |
| F-29<br>F-30 | The titles of these two figures are clarified by adding "Contained in an OS197L TC" |
| **UFSAR pages** | **UFSAR pages** |
| 3.2-7<br>8.1-1 | Enclosure 3 Additional Item Number 3 |
| K.3.1-8 | Enclosure 3 Additional Item Number 5 |
| K.9-1 through K.9-15 | Enclosure 3 Additional Item Number 4 |
| M.3.1-8 | Enclosure 3 Additional Item Number 5 |
| M.9-1 through M.9-14 | Enclosure 3 Additional Item Number 4 |
| P.3.1-10 | Enclosure 3 Additional Item Number 5 |
| P.9-1 through P.9-13 | Enclosure 3 Additional Item Number 4 |
| T.3.1-9 | Enclosure 3 Additional Item Number 5 |
| T.9-1 through T.9-14 | Enclosure 3 Additional Item Number 4 |
| U.3.1-10 | Enclosure 3 Additional Item Number 5 |
| U.9-1 through U.9-14 | Enclosure 3 Additional Item Number 4 |

**List of CoC, Technical Specifications, and UFSAR Pages Associated with Amendment 11, Revision 4**

| Page number | Reason for change |
|---|---|
| W.3-7 | RAI Item 5-2 |
| W.5-2 | RAI Item 5-5 |
| W.5-5 | RAI Item 5-3 |
| W.5-23 | RAI Item 5-4 |
| W.5-79 | RAI Item 5-5 |
| W.5-80 | RAI Item 5-5 |
| W.5-82 | RAI Item 5-5 |
| W.5-84 | RAI Item 5-5 |
| W.5-86 | RAI Item 5-5 |
| W.5-87 | RAI Item 5-5 |
| W.5-88 | RAI Item 5-5 |

CoC, Technical Specifications, and UFSAR Page Change Instructions

| Proposed Certificate of Compliance changed pages | |
|---|---|
| Current page number | Replacement page number |
| CoC page 2 of 3 | CoC page 2 of 3 |
| CoC Inserts | CoC Inserts |

| Proposed Technical Specification changed pages | |
|---|---|
| Current page number | Replacement page number |
| v | v |
| vi | vi |
| 1-1 | 1-1 |
| 1-5 | 1-5 |
| 4-2 | 4-2 |
| 4-4 | 4-4 |
| 4-10 | 4-10 |
| 4-12 | 4-12 |
| 4-15 | 4-15 |
| 4-18 | 4-18 |
| 4-22 | 4-22 |
| 4-26 | 4-26 |
| 5-7 | 5-7 |
| 5-8 | 5-8 |
| T-3 | T-3 |
| T-10 | T-10 |
| T-11 | T-11 |
| T-13 | T-13 |
| T-28 | T-28 |
| T-34 | T-34 |
| T-68 | T-68 |
| T-76 | T-76 |
| T-77 | T-77 |
| T-78 | T-78 |
| T-79 | T-79 |
| T-80 | T-80 |
| F-27 | F-27 |
| F-29 | F-29 |
| F-30 | F-30 |

| Proposed UFSAR changed pages | |
|---|---|
| Current page number | Replacement page number |
| Not previously part of Amd. 11 | 3.2-7 |
| Not previously part of Amd. 11 | 8.1-1 |
| K.3.1-8 | K.3.1-8 |

CoC, Technical Specifications, and UFSAR Page Change Instructions

| Proposed UFSAR changed pages | |
|---|---|
| Current page number | Replacement page number |
| Not previously part of Amd. 11 | K.9-1 |
| K.9-2 through K.9-5 | K.9-2 through K.9-5 |
| K.9-5a | K.9-5a |
| Not previously part of Amd. 11 | K.9-6 through K.9-7 |
| K.9-8 through K.9-9 | K.9-8 through K.9-9 |
| Not previously part of Amd. 11 | K.9-10 through K.9-14 |
| K.9-15 | K.9-15 |
| M.3.1-8 | M.3.1-8 |
| Not previously part of Amd. 11 | M.9-1 |
| M.9-2 through M.9-4 | M.9-2 through M.9-4 |
| M.9-4a | M.9-4a |
| Not previously part of Amd. 11 | M.9-5 through M.9-6 |
| M.9-7 through M.9-8 | M.9-7 through M.9-8 |
| Not previously part of Amd. 11 | M.9-9 through M.9-14 |
| P.3.1-10 | P.3.1-10 |
| Not previously part of Amd. 11 | P.9-1 |
| P.9-2 through P.9-5 | P.9-2 through P.9-5 |
| Not previously part of Amd. 11 | P.9-6 through P.9-7 |
| P.9-8 through P.9-9 | P.9-8 through P.9-9 |
| Not previously part of Amd. 11 | P.9-10 through P.9-13 |
| T.3.1-9 | T.3.1-9 |
| Not previously part of Amd. 11 | T.9-1 through T.9-2 |
| T.9-3 through T.9-6 | T.9-3 through T.9-6 |
| Not previously part of Amd. 11 | T.9-7 through T.9-8 |
| T.9-9 through T.9-10 | T.9-9 through T.9-10 |
| Not previously part of Amd. 11 | T.9-11 through T.9-14 |
| U.3.1-10 | U.3.1-10 |
| Not previously part of Amd. 11 | U.9-1 through U.9-2 |
| U.9-3 through U.9-6 | U.9-3 through U.9-6 |
| Not previously part of Amd. 11 | U.9-7 through U.9-8 |
| U.9-9 through U.9-10 | U.9-9 through U.9-10 |
| U.9-11 through U.9-14 | U.9-11 through U.9-14 |
| W.3-7 | W.3-7 |
| W.5-2 | W.5-2 |
| W.5-5 | W.5-5 |
| W.5-23 | W.5-23 |
| W.5-79 | W.5-79 |
| W.5-80 | W.5-80 |
| W.5-82 | W.5-82 |
| W.5-84 | W.5-84 |

CoC, Technical Specifications, and UFSAR Page Change Instructions

| Proposed UFSAR changed pages | |
|---|---|
| Current page number | Replacement page number |
| W.5-86 | W.5-86 |
| W.5-87 | W.5-87 |
| W.5-88 | W.5-88 |

Enclosure 6 to TN E-30554

Amendment 11 Revision 4 Changed Certificate of Compliance, Technical Specifications, and UFSAR pages and steel or aluminum

which provide the transition to the DSC shell,

or grid



The principal component subassemblies of the DSC are the shell with integral bottom cover plate, bottom shield plug or shield plug assemblies, ram/grapple ring, top shield plug or shield plug assemblies, top cover plate, and basket assembly. The shell length is fuel-specific. The internal basket assembly for the 24P, 24PHB, and 52B DSCs is composed of guide sleeves, support rods, and spacer disks. This assembly is designed to hold 24 PWR fuel assemblies or 52 BWR assemblies.

An alternate basket assembly configuration, consisting of assemblies of stainless steel fuel compartments ~~hold in place by~~ basket rails and a holdown ring, is designed to hold 61 BWR assemblies. The 32PT, and 32PTH1 DSC basket assembly configurations are similar, consisting of welded stainless steel plates or tubes that make up a grid of fuel compartments supported by aluminum basket rails, and are designed to accommodate 32 PWR assemblies. The 24 PTH DSC basket assembly configuration consists of stainless steel tubes supported by basket rails and is designed to accommodate 24 PWR assemblies.

The basket assembly aids in the insertion of the fuel assemblies, enhances subcriticality during loading operations, and provides structural support during a hypothetical drop accident. The DSC is designed to slide from the transfer cask into the HSM and back without undue galling, scratching, gouging, or other damage to the sliding surfaces.

multi-walled

comprised of lead and/or steel gamma shield and neutron shield layers,

The HSM is a reinforced concrete unit with penetrations located at the top and bottom of the walls for air flow, and is designed to store DSCs with up to 24.0 kW decay heat. The penetrations are protected from debris intrusions by wire mesh screens during storage operation. The DSC Support Structure, a structural steel frame with rails, is installed within the HSM. An alternate version of the HSM-H design has been provided to allow the use of the NUHOMS® system in locations where higher seismic levels exist.

The TC is designed and fabricated as a lifting device to meet NUREG-0612 and ANSI N14.6 requirements. It is used for transfer operations within the Spent Fuel Pool Building and for transfer operations to/from the HSM. The TC is a cylindrical vessel with a bottom end closure assembly and a bolted top cover plate. Two upper lifting trunnions are located near the top of the cask for downending/uprighting and lifting of the cask in the Spent Fuel Pool Building. The lower trunnions, located near the base of the cask, serve as the axis of rotation during downending/uprighting operations and as supports during transport to/from the Independent Spent Fuel Storage Installation (ISFSI). The 32PT DSC is transferred in a TC with a radial liquid neutron shield.

Insert A (attached)

With the exception of the TC, fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the Standardized NUHOMS® System referenced in this Certificate of Compliance (CoC). Such site-specific equipment may include, but is not limited to, special lifting devices, the transfer trailer, and the skid positioning system

c. Drawings

The maximum loaded weight is 110 tons for the Standardized OS197 TC. The maximum loaded weight is 125 tons for the OS197H and OS200 TCs.

The drawings for the Standardized NUHOMS® System are contained in Appendices E, K, M, N, P, T ~~and~~ U of the FSAR.

and W

d. Basic Components

The basic components of the Standardized NUHOMS® System that are important to safety are the DSC, HSM, and TC. These components are described in Section 4.2, Table K.2-8 (Appendix K), Table M.2-18 (Appendix M), Table P.2-17 (Appendix P), Section T.2.3 (Appendix T) ~~and~~ Section U.2.3 (Appendix U) of the FSAR.

and Section W.2.3 (Appendix W)

(including the decontamination area shielding and the support skid supplemental shielding for the OS197L TC)

The maximum loaded weight is 90 tons for the OS197L TC; this weight does not include the decontamination area shielding or the support skid supplemental shielding.

Insert A

The OS197L TC system consists of the bare cask and the upper and lower *decontamination area cask shielding* and the *support skid supplemental shielding*.

Insert B

6. QUALITY ASSURANCE

Activities in the areas of design, purchase, fabrication, assembly, inspection, testing, operation, maintenance, repair, modification of structures, systems and components and decommissioning shall be conducted in accordance with a quality assurance program that satisfies the applicable requirements of 10 CFR Part 72, Subpart G, and that is established, maintained, and executed with regard to the cask system.

7. HEAVY LOADS REQUIREMENTS

Each lift of a DSC and TC must be made in accordance with the existing heavy loads requirements and procedures of the licensed facility at which the lift is made. A plant-specific safety review (under 10 CFR 50.59 or 10 CFR 72.48, if applicable) is required to show operational compliance with NUREG-0612 and/or existing plant-specific heavy loads requirements.

8. PRE-OPERATIONAL TESTING AND TRAINING EXERCISE

A dry run training exercise of the loading, closure, handling, unloading, and transfer of the standardized NUHOMS® System shall be conducted by each licensee prior to the first use of the system to load spent nuclear fuel assemblies. The training exercise shall not be conducted with spent nuclear fuel in the canister. The dry run may be performed in an alternate step sequence from the actual procedural guidelines in the SAR. The dry run shall include but not be limited to the following:

Loading Operations

a. Fuel Loading
b. DSC sealing, drying, and backfilling operations
c. TC downending and transport to the ISFSI
d. DSC transfer to the HSM
e. Use of the remote crane operations and laser/optical systems for targeting if the OS197L TC is to be used for loading.
f. Manual crane operations if the OS197L TC is to be used for loading.

Unloading Operations

a. DSC retrieval from the HSM
b. Flooding of the DSC
c. Opening of the DSC

## List of Figures

# 1.0 USE AND APPLICATION

## 1.1 Definitions

NOTE

*The defined terms of this section appear in capitalized type and are applicable throughout these Technical Specifications and Bases.*

| Term | Definition |
|---|---|
| ACTIONS | ACTIONS shall be that part of a Specification that prescribes Required Actions to be taken under designated Conditions within specified Completion Times. |
| HORIZONTAL STORAGE MODULE (HSM) | The HSM (Standardized HSM, HSM-H, high seismic option for HSM-H or other models enveloped by these designs) is a reinforced concrete structure for storage of a loaded DSC at a spent fuel storage installation. e.g., Standardized HSM includes HSM Model 80, Model 102, Model 152 or Model 202 as described in the UFSAR. *The generic term "HSM-H" refers to HSM-H or high seismic option for HSM-H except where a specific HSM-H configuration is called out.* |
| DRY SHIELDED CANISTER (DSC) | A DSC (Model 24P, 52B, 61BT, 32PT, 24PHB, 24PTH, 61BTH, 32PTH1 or other models enveloped by these designs) is a welded vessel that provides confinement of fuel assemblies in an inert atmosphere. |
| INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI) | *A complex designed and constructed for the interim storage of spent nuclear fuel, solid reactor-related GTCC waste, and other radioactive materials associated with spent fuel and reactor-related GTCC waste storage.* |
| *INTACT FUEL ASSEMBLY, DAMAGED FUEL ASSEMBLY* | *The definitions for intact or damaged fuel assemblies are in the fuel specification tables for each dry shielded canister (DSC) referred to in Technical Specification 2.1.* |
| LOADING OPERATIONS | LOADING OPERATIONS include all licensed activities on a DSC in a TRANSFER CASK while it is being loaded with fuel assemblies. LOADING OPERATIONS begin when the first fuel assembly is placed in the DSC and end when the TRANSFER CASK is ready for TRANSFER OPERATIONS *(i.e., when the cask is in a horizontal position on the trailer). The placement of the Outer Top Trailer Shielding onto the TC is considered part of the LOADING OPERATIONS. LOADING OPERATIONS does not include DSC transfer between the TC and the HSM.* |

*(continued)*

## 1.3 Completion Times

| | |
|---|---|
| PURPOSE | The purpose of this section is to establish the Completion Time convention and to provide guidance for its use. |
| BACKGROUND | Limiting Conditions for Operation (LCOs) specify the lowest functional capability or performance levels of equipment required for safe operation of the facility. The ACTIONS associated with an LCO state Conditions that typically describe the ways in which the requirements of the LCO are not met. Specified with each stated Condition are Required Action(s) and Completion Time(s). |
| DESCRIPTION | The Completion Time is the amount of time allowed for completing a Required Action. It is referenced to the time of discovery of a situation (e.g., equipment or variable not within limits) that requires entering an ACTIONS Condition unless otherwise specified, providing the *Cask System* is in a specified condition stated in the Applicability of the LCO. Required Actions must be completed prior to the expiration of the specified Completion Time. An ACTIONS Condition remains in effect and the Required Actions apply until the Condition no longer exists or the *Cask System* is not within the LCO Applicability.<br><br>Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will <u>not</u> result in separate entry into the Condition unless specifically stated. The Required Actions of the Condition continue to apply to each additional failure, with Completion Times based on initial entry into the Condition. |

*(continued)*

4.1 Canister Criticality Control

The Standardized NUHOMS® DSC models listed below are designed to take credit of the boron content in the neutron absorber plates provided in the DSC basket and/or soluble boron in the spent fuel pool per LCO 3.2. The DSCs have multiple basket configurations, based on the absorber material type (Borated Aluminum alloy, Metal Matrix Composite or Boral®), number of Poison Rod Assemblies or PRAs (for 32PT DSC only) and boron content in the absorber plates, as listed below.

| DSC Model | Basket Type | Minimum B10 Areal Density for Poison Plates |
|---|---|---|
| 61BT(1) | A,B or C | Per Table 1-1k |
| 32PT(2) | A, B, C or D | Per Table 1-1h |
| 24PTH(3) | 1A, 1B, or 1C<br>2A, 2B or 2C | Per Table 1-1 r |
| 61BTH(4) | A, B, C, D, E or F | Per Table 1-1v and Table 1-1w |
| 32PTH1(5) | *1A, 1B, 1C, 1D,* or *1E*<br>*2A, 2B, 2C, 2D,* or *2E* | Per Table 1-1ff |

**NOTES:**

(1) For the 61BT DSC, Borated Aluminum, MMC, or Boral® shall be supplied in accordance with UFSAR Sections K.9.1.7.1, K.9.1.7.2, K.9.1.7.3, K.9.1.7.4, K.9.1.7.*7 (portions of), K.9.1.7.8.3.1, K.9.1.7.8.4, K.9.1.7.8.5, K.9.1.7.9.1* and K.9.1.7.9.2, with the minimum B10 areal density specified in Table 1-1k. These sections of the *U*FSAR are hereby incorporated into the NUHOMS® 1004 CoC.

(2) For the 32PT DSC, Borated Aluminum or MMC shall be supplied in accordance with UFSAR Sections M.9.1.7.1, M.9.1.7.2, M.9.1.7.4, M.9.1.7.*7 (portions of), M.9.1.7.8.3.1, M.9.1.7.8.4, M.9.1.7.8.5, M.9.1.7.9.1*, and M.9.1.7.9.2, with the minimum B10 areal density specified in Table 1-1h. These sections of the *U*FSAR are hereby incorporated into the NUHOMS® 1004 CoC.

(3) For the 24PTH DSC, Borated Aluminum, MMC, or Boral® shall be supplied in accordance with UFSAR Sections P.9.1.7.1, P.9.1.7.2, P.9.1.7.3, P.9.1.7.4, P.9.1.7.*7 (portions of), P.9.1.7.8.3.1, P.9.1.7.8.4, P.9.1.7.8.5, P.9.1.7.9.1* and P.9.1.7.9.2, with the minimum B10 areal density specified in Table 1-1r. These sections of the *U*FSAR are hereby incorporated into the NUHOMS® 1004 CoC.

(4) For the 61BTH DSC, Borated Aluminum, MMCs, or Boral® shall be supplied in accordance with UFSAR Sections T.9.1.7.1, T.9.1.7.2, T.9.1.7.3, T.9.1.7.4, T.9.1.7.*7 (portions of), T.9.1.7.8.3.1, T.9.1.7.8.4, T.9.1.7.8.5, T.9.1.7.9.1* and T.9.1.7.9.2, with the minimum B10 real density specified in Table 1-1v or Table 1-1w. These sections of the UFSAR are hereby incorporated into the NUHOMS® 1004 CoC.

(5) For the 32PTH1 DSC, Borated Aluminum, MMCs, or Boral® shall be supplied in accordance with UFSAR Sections U.9.1.7.1, U.9.1.7.2, U.9.1.7.3, U.9.1.7.4, U.9.1.7.*7 (portions of), U.9.1.7.8.3.1, U.9.1.7.8.4, U.9.1.7.8.5, U.9.1.7.9.1* and U.9.1.7.9.2, with the minimum B10 areal density in Table 1-1ff. These sections of the UFSAR are hereby incorporated into the NUHOMS® 1004 CoC.

*(continued)*

## 4.2 Codes and Standards

### 4.2.1 Horizontal Storage Module (HSM)

The Standardized HSM and HSM-H reinforced concrete are designed to meet the requirements of ACI 349-85 and ACI 349-97 Editions respectively.

Load combinations specified in ANSI 57.9-1984, Section 6.17.3.1 are used for combining normal operating, off-normal, and accident loads for the HSM.

If an independent spent fuel storage installation site is located in a coastal salt water marine atmosphere, then any load-bearing carbon steel DSC support structure rail components of any associated HSM shall be procured with a minimum of 0.20 percent copper content *or stainless steel material shall be used* for corrosion resistance. *For weld filler material used with carbon steel, 1% or more nickel bearing weld material would also be acceptable in lieu of 0.20% copper content.*

### 4.2.2 Dry Shielded Canister (DSC)

The DSCs are designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, Division 1, Subsections NB, NF, and NG for Class 1 components and supports. The ASME code edition years and any addenda *for the various DSC types are provided in the table below. The Code alternatives are discussed in Section 4.2.4.*

*ASME code requirements for basket assemblies apply only to important to safety category A components.*

| ***DSC Type*** | ***Applicable Code*** | ***Edition/Year*** |
|---|---|---|
| *24P/52B/ 24PHB* | *ASME B&PV Code, Section III, Division 1, Subsections NB and NF* | *1983 Edition with Winter 1985 Addenda* |
| *61BT* | *ASME B&PV Code, Section III, Division 1, Subsections NB, NG and NF, including Code Case N-595-1* | *1998 Edition with 1999 Addenda* |
| *32PT, 24PTH* | *ASME B&PV Code, Section III, Division 1, Subsections NB, NG and NF, including Code Case N-595-2* | *1998 Edition with Addenda through 2000* |
| *61BTH, 32PTH1* | *ASME B&PV Code, Section III, Division 1, Subsections NB, NG and NF* | *1998 Edition with Addenda through 2000* |

*(continued)*

**ASME Code Alternatives for the NUHOMS®-61BT DSC Confinement Boundary**

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000. |
| NCA-1140 | Use of Code editions and addenda | Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table.<br>Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction. |
| NB-1100 | Requirements for Code Stamping of Components, Code reports and certificates, etc. | Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NB-1132 | Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component. | Bottom shield plug and outer bottom cover plate are outside code jurisdiction; these components together are much larger than required to provide stiffening for the inner bottom cover plate; the weld that retains the outer bottom cover plate and with it the bottom shield plug is subject to root and final PT examination. |
| NB-2130 | Material must be supplied by ASME approved material suppliers. | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NB-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. |
| NB-4121 | Material Certification by Certificate Holder | |
| NB-4243 and NB-5230 | Category C weld joints in vessels and similar weld joints in other components shall be full penetration joints. These welds shall be examined by UT or RT and either PT or MT | The joints between the top outer and inner cover plates and containment shell are designed and fabricated per ASME Code Case N-595-1. This includes the inner top cover plate weld around the vent and siphon block. The welds are partial penetration welds and the root and final layer are PT examined. The weld between the vent and siphon block and the shell is made at the fabricator's shop and receives a final PT examination. |
| NB-6100 and 6200 | All completed pressure retaining systems shall be pressure tested | The vent and siphon block is not pressure tested due to the manufacturing sequence. The siphon block weld is helium leak tested when fuel is loaded and then covered with the outer top closure plate. |
| NB-7000 | Overpressure Protection | No overpressure protection is provided for the NUHOMS® DSCs. The function of the DSC is to contain radioactive materials under normal, off-normal and hypothetical accident conditions postulated to occur during transportation and storage. The DSC is designed to withstand the maximum possible internal pressure considering 100% fuel rod failure at maximum accident temperature. |

### *ASME Code Alternatives for the NUHOMS®-61BT DSC Basket*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000. |
| NCA-1140 | Use of Code editions and addenda | Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table. Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction. |
| NG/NF-1100 | Requirements for Code Stamping of Components, Code reports and certificates, etc. | Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NG/NF-2000 | Use of ASME Code Material | Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. |
| NG/NF-5520 | NDE Personnel must be qualified to a specific edition of SNT-TC-1A | Permit use of more recent edition of SNT-TC-1A. |
| NG/NF-2130 | Material must be supplied by ASME approved material suppliers. | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. |
| NG/NF-4121 | Material Certification by Certificate Holder | |
| NG/NF-8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program. |

### *Alternatives to the ASME Code Exceptions for the NUHOMS®-32PT DSC Basket Assembly*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table.*<br><br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| *NG-2000* | *Use of ASME Material* | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the solid aluminum rails for use above the Code temperature limits.* |
| *NG-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG-4121* | *Material Certification by Certificate Holder* | |
| *NG -8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| *NG-3000/ Section II, Part D, Table 2A* | *Maximum temperature limit for XM-19 plate material is 800°F* | *Not compliant with ASME Section II Part D Table 2A material temperature limit for XM-19 steel for the postulated transfer accident case (117°F, loss of sunshade, loss of neutron shield). This is a post-drop accident scenario, where the calculated maximum steady state temperature is 852°F, the expected reduction in material strength is small (less than 1 ksi by extrapolation), and the only primary stresses in the basket grid are deadweight stresses. The recovery actions following the postulated drop accident are as described in Section 8.2.5 of the UFSAR.* |
| *NG-5520* | *NDE personnel must be qualified to a specific edition of SNT-TC-1A* | *Permit use of more recent edition of SNT-TC-1A.* |

### *Alternatives to the ASME Code for the NUHOMS®-24PTH DSC Basket Assembly*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000. |
| NCA-1140 | Use of Code editions and addenda | Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table.<br>Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction. |
| NG-1100 | Requirements for Code Stamping of Components, Code reports and certificates, etc. | Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NG-2000 | Use of ASME Material | Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits. |
| NG-2130 | Material must be supplied by ASME approved material suppliers. | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. |
| NG-4121 | Material Certification by Certificate Holder | |
| NG -8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program. |
| NG-3000/ Section II, Part D, Table 2A | Maximum temperature limit for Type 304 plate material is 800°F | Not compliant with ASME Section II Part D Table 2A material temperature limit for Type 304 steel for the postulated transfer accident case (117°F, loss of sunshade, loss of neutron shield). This is a post-drop accident scenario, where the calculated maximum steady state temperature is 862°F, the expected reduction in material strength is small (less than 1 ksi by extrapolation), and the only primary stresses in the basket grid are deadweight stresses. The recovery actions following the postulated drop accident are as described in Section 8.2.5 of the UFSAR. |

### *Alternatives to the ASME Code for the NUHOMS® 32PTH1 DSC Basket Assembly*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table.*<br><br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG -1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| *NG-2000* | *Use of ASME Material* | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits.* |
| *NG-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG -4121* | *Material Certification by Certificate Holder* | |
| *NG-8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| *NG-3000/ Section II, Part D, Table 2A* | *Maximum temperature limit for Type 304 plate material is 800ºF.* | *Not compliant with ASME Section II Part D Table 2A material temperature limit for Type 304 steel for the postulated transfer accident case (117ºF, loss of sunshade, loss of neutron shield) and blocked vent accident (117ºF, 40 hr). The calculated maximum steady state temperatures for transfer accident case and blocked vent accident case are less than 1000°F. The only primary stresses in the basket grid are deadweight stresses. The ASME Code allows use of SA240 Type 304 stainless steel to temperatures up to 1000°F, as shown in ASME Code, Section II, Part D, Table 1A. In the temperature range of interest (near 800°F), the $S_m$ values for SA240 Type 304 shown in ASME Code, Section II Part D, Table 2A are identical to the allowable S values for the same material shown in Section B, Part D, Table 1A. The recovery actions following these accident scenarios are as described in the UFSAR.* |

### *ASME Code Alternatives for the NUHOMS®-61BTH DSC Basket*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section 4.2.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section 4.2.2 table.*<br><br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section 4.2.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG/NF-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| *NG/NF-2000* | *Use of ASME Material* | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits.* |
| *NG/NF-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG/NF-4121* | *Material Certification by Certificate Holder* | |
| *NG-3352* | *Table NG 3352-1 lists the permissible welded joints and quality factors.* | *The fuel compartment tubes may be fabricated from sheet with full penetration seam weldments. Per Table NG-3352-1 a joint efficiency (quality) factor of 0.5 is to be used for full penetration weldments examined in accordance with ASME Section V visual examination (VT). A joint efficiency (quality) factor of 1.0 is utilized for the fuel compartment longitudinal seam welds (if present) with VT examination. This is justified because the compartment seam weld is thin and the weldment is made in one pass; and both surfaces of the weldment (inside and outside) receive 100% VT examination. The 0.5 quality factor, applicable to each surface of the weldment, results is a quality factor of 1.0 since both surfaces are 100% examined. In addition,the fuel compartments have no pressure retaining function and the stainless steel material that comprises the fuel compartment tubes is very ductile.* |
| *NG/NF -8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| *NG/NF-5520* | *NDE personnel must be qualified to a specific edition of SNT-TC-1A* | *Permit use of more recent edition of SNT-TC-1A.* |

If the required limits are not met, any available commercial decontamination technique may be used *on the entire length of the DSC outer surface* to reduce the DSC surface contamination levels to below the required limits. If contamination levels are still not met, remove the fuel assemblies from the DSC and put them back in the fuel pool, *r*emove the DSC from the TC *and decontaminate* as necessary. Insert the clean DSC back in the TC. Check and replace the TC/DSC annulus seal if needed and repeat *the* canister loading process.

e) *The TRANSFER CASK (TC) total dose rate shall be less than or equal to the value specified below for the various DSCs. The dose rates should be measured as soon as possible after the TC is removed from the spent fuel pool when in the configuration defined below but before the TC is downended on the transfer trailer to be transferred to the ISFSI.*

***Dose Rate Limits with TC (except OS197L TC)***

| *DSC Model* | *Axial Surface Dose Rate Limit (mrem/hour)* | *Radial Surface Dose Rate Limit (mrem/hour)* |
|---|---|---|
| *24P* | *700* | *600* |
| *52B* | *700* | *600* |
| *61BT* | *800* | *1200* |
| *32PT* | *900* | *1000* |
| *24PHB* | *1400* | *1200* |
| *24PTH* | *900* | *1500** |
| *61BTH* | *2200* | *1350* |
| *32PTH1* | *800* | *650* |

**For the 24PTH-S-LC, the limit is 600 mrem/hour.*

***Dose Rate Limits with OS197L TC***

| *DSC Model* | *Axial Surface Dose Rate Limit (mrem/hour)* | *Radial Decontamination Area Surface Dose Rate Limit (mrem/hour)* |
|---|---|---|
| *61BT* | *800* | *100* |
| *32PT* | *900* | *100* |

*The following configuration shall be employed for all TC axial dose rate measurements:*

- *Neutron shielding material present in the TC neutron shield cavity*
- *DSC / TC annulus filled with water and water level in the annulus is at least up to the top of the fuel assembly level*
- *Water in the DSC cavity – fuel not fully covered*
- *DSC shield plug installed*
- *DSC inner top cover plate installed*
- *Temporary shielding present above the inner top cover plate – minimum effective equivalent to 3" NS-3 and 1" steel combined*

*(continued)*

*The following locations shall be employed for all TC axial dose rate measurements:*

- *Five locations are chosen within a radius of 10 to 25 inches (diameter of 20 to 50 inches) around the DSC centerline on the top surface of the temporary shielding (as described earlier). None of these measurements shall exceed the dose rate limits given above.*

*The following configuration shall be employed for all TC radial dose rate measurements:*

- *Neutron shielding material present in the TC neutron shield cavity*
- *DSC / TC annulus dry*
- *DSC cavity vacuum drying is complete*
- *DSC outer top cover plate welding completed*
- *TC top lid installed*
- *TC is in a vertical position*

*In addition to the configuration above, a minimum effective decontamination area shielding equivalent to 6 inches of steel is installed in the radial direction only for the OS197L TC.*

*The following locations shall be employed for all TC radial dose rate measurements:*

- *Eight approximately equally spaced locations around the radial surface of the cask at an axial location corresponding to within approximately 24" of the center of the transfer cask.*
- *For the OS197L TC only, dose rate measurements are taken on the surface of the decontamination area shielding. None of these measurements shall exceed the dose rate limits given above.*

*The TC dose rate limits are specified to maintain dose rates as-low-as-reasonably-achievable during DSC TRANSFER OPERATIONS. These dose rate limits are based on the shielding analysis for the various DSCs included in the UFSAR Chapter 7 and Appendix J, Appendix K, Appendix M, Appendix N, Appendix P, Appendix T, Appendix U, and Appendix W with some added margin for uncertainty.*

*If the measured dose rates exceed above values, place temporary shielding around the affected areas of the transfer cask and review plant records of the fuel assemblies which have been placed in the DSC to ensure that they conform to the fuel specification of Technical Specification 2.1 for the applicable DSCs. Submit a letter report to the NRC within 30 days summarizing actions taken and the results of the surveillance, investigation and findings. The report must be submitted using instructions in 10 CFR 72.4 with a copy sent to the administrator of the appropriate NRC regional office.*

**Table 1-1c**
**BWR Fuel Specifications for Fuel to be Stored in the Standardized NUHOMS®-61BT DSC**

| | |
|---|---|
| **Physical Parameters** | |
| Fuel Design | 7x7, 8x8, 9x9, or 10x10 BWR fuel assemblies manufactured by General Electric or equivalent reload fuel that are enveloped by the fuel assembly design characteristics listed in Table 1-1d. |
| Cladding Material | Zircaloy |
| Fuel Damage | Cladding damage in excess of pinhole leaks or hairline cracks is not authorized to be stored as "Intact BWR Fuel." |
| Channels | Fuel may be stored with or without fuel channels |
| Maximum Assembly Length | 176.2 in |
| Nominal Assembly Width (excluding channels) | 5.44 in |
| Maximum Assembly Weight | 705 lbs |
| **Radiological Parameters**(2): No interpolation of Radiological Parameters is permitted between Groups. | |
| Group 1 | |
| Maximum Burnup | 27,000 MWd/MTU |
| Minimum Cooling Time | 5-years |
| Maximum Lattice Average Initial Enrichment | See Minimum Boron Loading below. |
| Minimum Initial Bundle Average Enrichment | 2.0 wt. % U-235 |
| Maximum Initial Uranium Content | 198 kg/assembly |
| Maximum Decay Heat | 300 W/assembly(1) |
| Group 2 | |
| Maximum Burnup | 35,000 MWd/MTU |
| Minimum Cooling Time | 8-years |
| Maximum Lattice Average Initial Enrichment | See Minimum Boron Loading below. |
| Minimum Initial Bundle Average Enrichment | 2.65 wt. % U-235 |
| Maximum Initial Uranium Content | 198 kg/assembly |
| Maximum Decay Heat | 300 W/assembly(1) |
| Group 3 | |
| Maximum Burnup | 37,200 MWd/MTU |
| Minimum Cooling Time | 6.5-years |
| Maximum Lattice Average Initial Enrichment | See Minimum Boron Loading below. |
| Minimum Initial Bundle Average Enrichment | 3.38 wt. % U-235 |
| Maximum Initial Uranium Content | 198 kg/assembly |
| Maximum Decay Heat | 300 W/assembly(1) |
| Group 4 | |
| Maximum Burnup | 40,000 MWd/MTU |
| Minimum Cooling Time | 10-years |
| Maximum Lattice Average Initial Enrichment | See Minimum Boron Loading below. |
| Minimum Initial Bundle Average Enrichment | 3.4 wt. % U-235 |
| Maximum Initial Uranium Content | 198 kg/assembly |
| Maximum Decay Heat | 300 W/assembly(1) |
| **Minimum Boron Loading** | |
| Lattice Average Enrichment (wt. % U-235) | Minimum B-10 Content in Poison Plates |
| 4.4 | Type C Basket |
| 4.1 | Type B Basket |
| 3.7 | Type A Basket |
| **Alternate Radiological Parameters**: | |
| Maximum Initial Enrichment: | See Minimum Boron Loading above |
| Fuel Burnup, Initial Bundle Average Enrichment, and Cooling Time: | See Table 1-2q, *except that for a 61BT DSC contained in an OS197L TC, see Tables 1-6a and 1-6b, and Figure 1-29.* |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly(1) |

(1) For FANP9 9x9-2 fuel assemblies, the maximum decay heat is limited to 0.21 kW/assembly.

(2) *When the OS197L TC is employed, apply the requirements of Table 1-6a, Table 1-6b and Figure 1-29.*

**Table 1-1j**
**BWR Fuel Specification of Damaged Fuel to be Stored in the Standardized NUHOMS®-61BT DSC**

| | |
|---|---|
| **PHYSICAL PARAMETERS:** | |
| Fuel Design: | 7x7, 8x8 BWR damaged fuel assemblies manufactured by General Electric or Exxon/ANF or equivalent reload fuel that are enveloped by the Fuel assembly design characteristics listed in Table 1-1d for the 7x7 and 8x8 designs only. |
| Cladding Material: | Zircaloy |
| Fuel Damage: | Damaged BWR fuel assemblies are fuel assemblies containing fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. Missing cladding and/or crack size in the fuel pins is to be limited such that a fuel pellet is not able to pass through the gap created by the cladding opening during handling and retrievability is assured following Normal/Off-Normal conditions. Damaged fuel shall be stored with Top and Bottom Caps for Failed Fuel. Damaged fuel may only be stored in the 2x2 compartments of the "Type C" NUHOMS®-61BT Canister. |
| Channels: | Fuel may be stored with or without fuel channels. |
| Maximum Assembly Length (unirradiated) | 176.2 in |
| Nominal Assembly Width (excluding channels) | 5.44 in |
| Maximum Assembly Weight | 705 lbs |
| **RADIOLOGICAL PARAMETERS[1]:** | No interpolation of Radiological Parameters is permitted between groups. |
| **Group 1:** Maximum Burnup: | 27,000 MWd/MTU |
| Minimum Cooling Time: | 5-years |
| Maximum Initial Lattice Average Enrichment: | 4.0 wt. % U-235 |
| Maximum Pellet Enrichment: | 4.4 wt. % U-235 |
| Minimum Initial Bundle Average Enrichment: | 2.0 wt. % U-235 |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly |
| **Group 2:** Maximum Burnup: | 35,000 MWd/MTU |
| Minimum Cooling Time: | 8-years |
| Maximum Initial Lattice Average Enrichment: | 4.0 wt. % U-235 |
| Maximum Pellet Enrichment: | 4.4 wt. % U-235 |
| Minimum Initial Bundle Average Enrichment: | 2.65 wt. % U-235 |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly |
| **Group 3:** Maximum Burnup: | 37,200 MWd/MTU |
| Minimum Cooling Time: | 6.5-years |
| Maximum Initial Lattice Average Enrichment: | 4.0 wt. % U-235 |
| Maximum Pellet Enrichment: | 4.4 wt. % U-235 |
| Minimum Initial Bundle Average Enrichment: | 3.38 wt. % U-235 |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly |

**Table 1-1j**
**BWR Fuel Specification of Damaged Fuel to be Stored in the Standardized NUHOMS®-61BT DSC**

(concluded)

| | |
|---|---|
| **RADIOLOGICAL PARAMETERS:** | |
| **Group 4:** | |
| Maximum Burnup: | 40,000 MWd/MTU |
| Minimum Cooling Time: | 10-years |
| Maximum Initial Lattice Average Enrichment: | 4.0 wt. % U-235 |
| Maximum Pellet Enrichment: | 4.4 wt. % U-235 |
| Minimum Initial Bundle Average Enrichment: | 3.4 wt. % U-235 |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly |
| **ALTERNATE RADIOLOGICAL PARAMETERS:** | |
| Maximum Initial Lattice Average Enrichment: | 4.0 wt. % U-235 |
| Fuel Burnup, Initial Bundle Average Enrichment, and Cooling Time: | See Table 1-2q, *except that for a 61BT DSC contained in an OS197L TC, see Tables 1-6a and 1-6b, and Figure 1-29.* |
| Maximum Pellet Enrichment: | 4.4 wt. % U-235 |
| Maximum Initial Uranium Content: | 198 kg/assembly |
| Maximum Decay Heat: | 300 W/assembly |

(1) *When the OS197L TC is employed, apply the requirements of Table 1-6a, Table 1-6b and Figure 1-29.*

**Table 1-1l**
**PWR Fuel Specification for the Fuel to be Stored in the NUHOMS®-24PTH DSC**

| | |
|---|---|
| **PHYSICAL PARAMETERS:** | |
| Fuel Class | Intact or damaged unconsolidated B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14 and WE 14x14 class PWR assemblies (with or without control components) that are enveloped by the fuel assembly design characteristics listed in Table 1-1m. Equivalent reload fuel manufactured by other vendors but enveloped by the design characteristics listed in Table 1-1m is also acceptable. |
| Fuel Damage | 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 cladding damage in the fuel rods is to be limited such that a fuel assembly needs to be handled by normal means. |
| Partial Length Shield Assemblies (PLSAs) | WE 15x15 class PLSAs which have only ever been irradiated in peripheral core locations with following characteristics are authorized:<br>• Maximum burnup, 40 GWd/MTU<br>• Minimum cooling time, 6.5 years<br>• Maximum decay heat, 900 watts |
| **Reconstituted Fuel Assemblies:**<br>• Maximum No. of Reconstituted Assemblies per DSC with Irradiated Stainless Steel Rods<br>• Maximum No. of Irradiated Stainless Steel Rods per Reconstituted Fuel Assembly<br>• Maximum No. of Reconstituted Assemblies per DSC with unlimited number of low enriched $UO_2$ rods and/or Unirradiated Stainless Steel Rods and/or Zr Rods or Zr Pellets | <br>4<br>10<br>24 |
| Control Components (CCs) | • Up to 24 CCs are authorized for storage in 24PTH-L, *24PTH-S,* and 24PTH-S-LC DSCs only.<br>• Authorized CCs include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Assembly Rods (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources.<br>• Design basis thermal and radiological characteristics for the CCs are listed in Table 1-1n. |
| Nominal Assembly Width | 8.536 inches |
| No. of Intact Assemblies | ≤24 |
| No. and Location of Damaged Assemblies | Maximum of 12 damaged fuel assemblies. Balance may be intact fuel assemblies, empty slots, or dummy assemblies depending on the specific heat load zoning configuration.<br><br>Damaged fuel assemblies are to be placed in Location A and/or B as shown in Figure 1-16. The DSC basket cells which store damaged fuel assemblies are provided with top and bottom end caps to assure retrievability. |
| Maximum Assembly plus CC Weight | 1682 lbs |

**Table 1-1bb**
**PWR Fuel Assembly Design Characteristics for the NUHOMS®-32PTH1 DSC**

| Assembly Class | | B&W 15x15 | WE 17x17 | CE 15x15 | WE 15x15 | CE 14x14 | WE 14x14 | CE 16x16 |
|---|---|---|---|---|---|---|---|---|
| Max Unirradiated Length (in)[(1)] | 32PTH1-S | 162.6 | 162.6 | 162.6 | 162.6 | 162.6 | 162.6 | 162.6 |
| | 32PTH1-M | 170.0 | 170.0 | 170.0 | 170.0 | 170.0 | 170.0 | 170.0 |
| | 32PTH1-L | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 | 178.3 |
| Fissile Material | | $UO_2$ | $UO_2$ | $UO_2$ | $UO_2$ | $UO_2$ | $UO_2$ | $UO_2$ |
| Maximum MTU/Assembly[(2)] | | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 | 0.49 |
| Maximum Number of Fuel Rods | | 208 | 264 | 216 | 204 | 176 | 179 | 236 |
| Maximum Number of Guide/ Instrument Tubes | | 17 | 25 | 9 | 21 | 5 | 17 | 5 |

Notes:
(1) Maximum Assembly + Control Component Length (unirradiated)
(2) The maximum MTU/assembly is based on the shielding analysis. The listed value is higher than the actual.

**Table 1-1ee**
**Thermal and Radiological Characteristics for Control Components Stored in the NUHOMS®-32PT and NUHOMS®-32PTH1 DSCs**

| Parameter | BPRAs, NSAs, CRAs, RCCAs, VSIs, Neutron Sources, and APSRAs | TPAs and ORAs |
|---|---|---|
| Maximum Gamma Source (γ/sec/Assembly) | 3.97E+13 | 4.1E+12 |
| Decay Heat (Watts/Assembly) | 8 | 8 |

**Notes: Tables 1-4a through 1-4f:**

- Burnup = Assembly Average burnup.
- *Use burnup and enrichment to lookup minimum cooling time in years. Licensee is responsible for ensuring that* uncertainties in fuel enrichment and burnup are correctly accounted for during fuel qualification.
- Round burnup UP to next higher entry, round enrichments DOWN to next lower entry.
- Fuel with an lattice average initial enrichment less than 0.9 (or less than the minimum provided above for each burnup) or greater than 5.0 wt.% U-235 is unacceptable for storage.
- Fuel with a burnup greater than 62 GWd/MTU is unacceptable for storage.
- Fuel with a burnup less than 10 GWd/MTU is acceptable for storage after 3-years cooling.
- See Figure 1-17 through Figure 1-24 for a description of the zones.
- For reconstituted fuel assemblies with $UO_2$ rods and/or Zr rods or Zr pellets and/or stainless steel rods, use the *lattice* average equivalent enrichment to determine the minimum cooling time.
- The cooling times for damaged and intact assemblies are identical.
- *Example*: An intact fuel assembly, with a decay heat load of 0.22 kW or less, an initial enrichment of 3.65 wt. % U-235 and a burnup of 41.5 GWd/MTU is acceptable for storage after a 24 year cooling time as defined by 3.6 wt. % U-235 (rounding down) and 42 GWd/MTU (rounding up) in Table 1-4a.

## Table 1-6a

**Fuel Qualification Table for 0.3 kW BWR FAs in Zone 1 of a NUHOMS®-61BT DSC Contained in an OS197L TC**

*(Minimum required years of cooling time after reactor core discharge)*

| Burn-Up, GWD/MTU | Maximum Assembly Average Initial U-235 Enrichment, wt % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 |
| 10 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 15 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 20 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 25 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 | 4 | 4 |
| 28 | Not Analyzed Domain | | | | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 30 | | | | | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 32 | | | | | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| 34 | | | | | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| 36 | | | | | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| 38 | | | | | 14 | 13 | 13 | 12 | 12 | 12 | 12 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |
| 39 | | | | | 15 | 14 | 14 | 14 | 13 | 13 | 13 | 12 | 12 | 12 | 12 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 9 | 9 | 9 |
| 40 | | | | | 16 | 16 | 15 | 15 | 15 | 14 | 14 | 14 | 13 | 13 | 13 | 12 | 12 | 12 | 12 | 12 | 11 | 11 | 11 | 11 | 11 | 10 | 10 | 10 | 10 | 10 | 10 |

Notes for Tables 1-6a and 1-6b:

- Use burnup and enrichment to lookup minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are conservatively applied in determination of actual values for these two parameters.
- Round burnup UP to next higher entry, round enrichments DOWN to next lower entry.
- Fuel with an initial enrichment less than 1.4 and greater than 4.4 wt. % U-235 is unacceptable for storage.
- Fuel with a burnup greater than 40 GWd/MTU is unacceptable for storage
- Fuel with a burnup less than 10 GWd/MTU is acceptable for storage after 4 years cooling.
- Example: An assembly with an initial enrichment of 3.75 wt. % U-235 and a burnup of 39.5 GWd/MTU is acceptable for storage after a eleven-year cooling time as defined by 3.7 wt. % U-235 (rounding down) and 40 GWd/MTU (rounding up) on the qualification table.

**Table 1-6b**

**Fuel Qualification Table for 0.17 kW BWR FAs in Zone 2 of a NUHOMS®-61BT DSC Contained in an OS197L TC**

*(Minimum required years of cooling time after reactor core discharge)*

| Burn-Up, GWD/MTU | Maximum Assembly Average Initial U-235 Enrichment, wt % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 |
| 10 | 21.5 | 20.5 | 20.5 | 20.5 | 20.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 11 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| 12 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 |
| 13 | 24.0 | 24.0 | 24.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 |
| 14 | 25.0 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 |
| 15 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |
| 16 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 |
| 17 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.0 |
| 18 | 28.0 | 28.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 |
| 19 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| 20 | 29.0 | 29.0 | 29.0 | 29.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| 21 | 30.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| 22 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 28.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 |
| 23 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 27.5 | 27.5 | 27.5 | 27.5 |
| 24 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 |
| 25 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 |
| 26 | | | | | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 |
| 27 | | | | | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 |
| 28 | | | | | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 |
| 29 | | | | | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 |
| 30 | | | | | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 |
| 31 | | | | | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 |
| 32 | Not Analyzed Domain | | | | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 |
| 33 | | | | | 35.5 | 35.5 | 35.5 | 35.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 |
| 34 | | | | | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 |
| 35 | | | | | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 |
| 36 | | | | | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 |
| 37 | | | | | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 | 35.5 |
| 38 | | | | | 37.5 | 37.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 |
| 39 | | | | | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 | 36.5 |
| 40 | | | | | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 |

Note: The explanatory notes and limitations provided for Table 1-6a are also applicable to this table.

**Table 1-6c**

**Fuel Qualification Table for 0.6 kW PWR FAs in Zone 1 of a NUHOMS®-32PT DSC Contained in an OS197L TC**

*(Minimum required years of cooling time after reactor core discharge)*

| Burn-Up GWD/ MTU | Maximum Assembly Average Initial U-235 Enrichment, wt % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1 | 1.2 | 1.4 | 1.6 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 | 4.7 | 4.8 | 4.9 | 5.0 |
| 6 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 8 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 10 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 15 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 20 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 25 | 6.5 | 6.5 | 6.5 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| 28 | 8.0 | 8.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| 30 | 9.0 | 9.0 | 9.0 | 9.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 | 7.0 |
| 32 | 10.5 | 10.5 | 9.5 | 9.5 | 9.5 | 9.5 | 9.5 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 | 8.0 |
| 34 | 12.0 | 12.0 | 12.0 | 11.5 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 |
| 36 | 14.5 | 14.5 | 14.0 | 14.0 | 13.5 | 13.5 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 12.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 | 11.0 |
| 38 | 17.5 | 17.5 | 16.5 | 16.5 | 16.5 | 16.0 | 16.0 | 15.5 | 15.5 | 15.0 | 15.0 | 15.0 | 15.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 | 13.0 |
| 39 | 19.5 | 19.0 | 18.5 | 18.0 | 17.0 | 16.5 | 16.5 | 16.5 | 16.5 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 | 14.0 |
| 40 | 20.5 | 20.0 | 20.0 | 19.0 | 19.0 | 18.5 | 18.5 | 18.5 | 18.0 | 18.0 | 18.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 16.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 | 15.0 |
| 41 | 22.5 | 21.5 | 21.0 | 21.0 | 20.0 | 20.0 | 19.5 | 19.5 | 19.5 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 17.0 | 16.0 |
| 42 | 24.0 | 22.5 | 22.5 | 21.5 | 21.5 | 21.5 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 | 18.0 |
| 43 | 25.0 | 24.5 | 24.5 | 23.5 | 23.5 | 23.0 | 22.0 | 22.0 | 22.0 | 21.5 | 21.5 | 21.5 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 20.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 |
| 44 | 26.5 | 26.5 | 25.0 | 25.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.5 | 23.5 | 23.5 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.0 | 20.0 |
| 45 | 27.5 | 27.5 | 27.0 | 26.0 | 26.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.5 | 24.5 | 24.5 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 |

*Note: The page that follows Table 1-6d provides the explanatory notes and limitations regarding the use of this table.*

## *Table 1-6d*
## *Fuel Qualification Table for 0.4 kW PWR FAs in Zone 2 of a NUHOMS®-32PT DSC Contained in an OS197L TC*
*(Minimum required years of cooling time after reactor core discharge)*

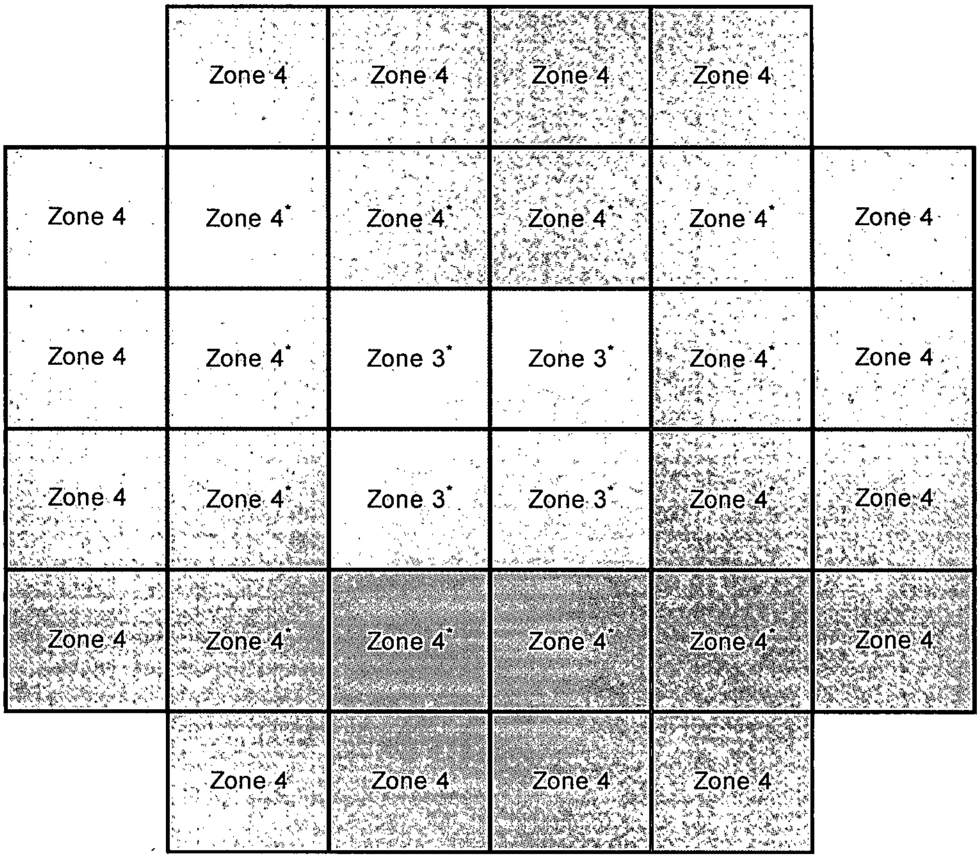
| Burn-up, GWD/ MTU | Maximum Assembly Average Initial U-235 Enrichment, wt % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1.1 | 1.2 | 1.3 | 1.4 | 1.5 | 1.6 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 | 4.3 | 4.4 | 4.5 | 4.6 | 4.7 | 4.8 | 4.9 | 5.0 |
| 10 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 11 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 12 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 13 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 14 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 15 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 16 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 17 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 18 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 19 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 20 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 21 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 22 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 23 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 24 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 25 | 18.5 | 18.0 | 18.0 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 26 | 19.0 | 18.5 | 18.5 | 18.0 | 18.0 | 18.0 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 27 | 19.5 | 19.0 | 19.0 | 19.0 | 18.5 | 18.5 | 18.5 | 18.0 | 18.0 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 28 | 19.0 | 19.0 | 19.0 | 18.5 | 18.5 | 18.5 | 18.5 | 18.0 | 18.0 | 18.0 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 29 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 19.0 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 18.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 | 17.5 |
| 30 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 21.0 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.5 | 20.0 | 20.0 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 | 19.5 |
| 31 | 23.5 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 23.0 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.5 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 22.0 | 21.5 | 21.5 | 21.5 | 21.5 | 21.5 | 21.5 | 21.5 | 21.5 | 21.5 |
| 32 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.5 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 24.0 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.5 | 23.0 |
| 33 | 28.0 | 28.0 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 26.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.5 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| 34 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 28.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.5 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 | 27.0 |
| 35 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 31.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.5 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 | 29.0 |
| 36 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 32.0 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.5 | 30.0 |
| 37 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 34.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.5 | 33.0 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 32.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 | 31.5 |
| 38 | 36.0 | 36.0 | 36.0 | 35.5 | 35.5 | 35.5 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 35.0 | 34.5 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 34.0 | 33.0 | 33.0 | 33.0 |
| 39 | 37.5 | 37.5 | 37.5 | 37.5 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 37.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 36.0 | 35.0 |
| 40 | 39.5 | 39.0 | 39.0 | 39.0 | 39.0 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 38.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 | 37.5 |
| 41 | 41.0 | 41.0 | 40.5 | 40.5 | 40.5 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 | 39.0 |
| 42 | 42.5 | 42.5 | 42.5 | 42.5 | 42.5 | 42.5 | 42.5 | 42.5 | 42.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 41.5 | 40.5 | 40.5 | 40.5 | 40.5 | 40.5 | 40.5 | 40.5 | 40.5 |
| 43 | 44.0 | 44.0 | 43.5 | 43.5 | 43.5 | 43.5 | 43.5 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 43.0 | 42.0 | 42.0 | 42.0 | 42.0 | 42.0 | 42.0 | 42.0 | 42.0 |
| 44 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 | 44.0 |
| 45 | 47.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 46.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 | 45.5 |

*Explanatory notes and limitations regarding the use of this table follow.*

*Notes for Tables 1-6c and 1-6d:*

- *Use burnup and enrichment to lookup minimum cooling time in years. Licensee is responsible for ensuring that uncertainties in fuel enrichment and burnup are correctly accounted for during fuel qualification.*
- *For fuel assemblies with CCs, increase the indicated cooling time by 1.5 years. This applies to 0.6 kW FAs only.*
- *For fuel assemblies reconstituted with up to 10 stainless steel rods, increase the indicated cooling time by 1.5 years. If more than 10 stainless steel rods are present, increase the indicated cooling time by 6 years.*
- *Round burnup UP to next higher entry, round enrichments DOWN to next lower entry.*
- *Fuel with an initial enrichment less than 1.1 and greater than 5.0 wt.% U-235 is unacceptable for storage.*
- *Fuel with a burnup greater than 45 GWd/MTU is unacceptable for storage.*
- *Fuel with a burnup less than 10 GWd/MTU is acceptable for storage after 5-years cooling.*

*Example: An assembly with an initial enrichment of 3.75 wt. % U-235 and a burnup of 41.5 GWd/MTU is acceptable for storage after a nineteen-year cooling time as defined by 3.7 wt. % U-235 (rounding down) and 42 GWd/MTU (rounding up) on the qualification table.*




* denotes location where intact or damaged fuel assembly can be stored.

| | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 | Zone 6 |
|---|---|---|---|---|---|---|
| Max. Decay Heat / FA (kW) | N/A | N/A | 0.96$^{(2)}$ | 0.98$^{(2)}$ | N/A | N/A |
| Max. Decay Heat / Zone (kW) | N/A | N/A | 3.84 | 27.44 | N/A | N/A |
| Max. Decay Heat / DSC (kW) | 31.2$^{(1)}$ | | | | | |

Notes:

1: Adjust payload to maintain 31.2 kW heat load.

2: The fuel qualification table corresponding to 1.0 kW/FA shall be used to determine burnup, cooling time, and enrichments corresponding to these heat loads.

**Figure 1-27**
**Heat Load Zoning Configuration No. 2 for 32PTH1-S, 32PTH1-M and 32PTH1-L DSCs (Type 1 or Type 2 Baskets)**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2 | 2 | 2 | | | |
| | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| | 2 | 2 | 2 | 1 | 2 | 2 | 2 | |
| 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| 2 | 2 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| 2 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | 2 |
| | 2 | 2 | 2 | 1 | 2 | 2 | 2 | |
| | 2 | 2 | 2 | 2 | 2 | 2 | 2 | |
| | | | 2 | 2 | 2 | | | |

| ***Heat Zone Level*** | ***Zone 1*** | ***Zone 2*** |
|---|---|---|
| *Max. Decay Heat/FA (kW)* | *0.3* | *0.17* |
| *Number of FAs/Zone* | *13* | *48* |
| *Max. Decay Heat/Zone (kW)* | *3.9* | *8.2* |
| *Max. Decay Heat/DSC (kW)* | ***12.0*** | |

***Figure 1-29***
***Heat Load Zone Configuration for the 61BT DSC Contained in an OS197L TC***

| | | | | | |
|---|---|---|---|---|---|
| | 2 | 2 | 2 | 2 | |
| 2 | 2 | 1 | 1 | 2 | 2 |
| 2 | 1 | 1 | 1 | 1 | 2 |
| 2 | 1 | 1 | 1 | 1 | 2 |
| 2 | 2 | 1 | 1 | 2 | 2 |
| | 2 | 2 | 2 | 2 | |

| ***Heat Zone Level*** | ***Zone 1*** | ***Zone 2*** |
|---|---|---|
| *Max. Decay Heat/FA (kW)* | *0.6* | *0.4* |
| *Number of FAs/Zone* | *12* | *20* |
| *Max. Decay Heat/Zone (kW)* | *7.2* | *8.0* |
| *Max. Decay Heat/DSC (kW)* | ***13.0*** [(1)] | |

*(1) Maximum decay heat load allowed in the OS197L TC.*

***Figure 1-30***
***Heat Load Zone Configuration for the 32PT DSC Contained in an OS197L TC***

summarizes the stress criteria for DSC non-pressure boundary components (except for support rods). The spacer discs are designed using the component stress criteria from ASME Code Subsection NB (for Service Levels A, B, C) and ASME Code Appendix F (Service Level D, Elastic and Elastic/Plastic analysis). The support rods are designed using the criteria of ASME Code Subsection NF for linear type component supports (for Service levels A, B, C) and ASME Code Appendix F (for Service Level D stress or stability criteria). For Service Level A the limits of NF-3322 are used. For Service Levels B and C the factors of Table NF-3523(b)-1 are used. For Service Level D, the criteria from Appendix F is used. The 24P guide sleeves and oversleeves are designed using the stress criteria of ASME Code Subsection NB and ASME Code Appendix F, and the stability criteria of Subsection NF and Appendix F, as applicable. All non-pressure boundary partial penetration and fillet welds are designed using the stress criteria of ASME Code Subsection NF and ASME Code Appendix F.

Other components of the DSC include the support ring, the lifting lugs, the shield plugs, the grapple ring and grapple ring support plate, and all welds associated with these components. The support ring is designed using the ASME Code Subsection NB criteria. The associated weld to the DSC shell is a partial penetration weld evaluated to the ASME Code Subsection NF and Appendix F requirements, as applicable. The lifting lugs and associated welds are designed using Subsection NF allowables. The grapple ring, grapple ring support plates and associated welds are designed using the ASME Code Subsection NB design criteria. The shield plugs are non-pressure boundary components and need only to maintain their structural integrity. The shield plugs are evaluated using Subsection NB primary stress limits. The shield plugs stiffener welds in the long cavity basket are full penetration welds designed to Subsection NF.

#### 3.2.5.3 On-site Transfer Cask

The on-site transfer cask is a non-pressure retaining component which conservatively is designed by analysis to meet the stress allowables of the ASME Code (3.14) Subsection NC for Class 2 components. The cask is conservatively designed by utilizing linear elastic analysis methods. The load combinations considered for the transfer cask normal, off-normal, and postulated accident loadings are shown in Table 3.2-7. Service Levels A and B allowables are used for all normal operating and off-normal loadings. Service Levels C and D allowables are used for load combinations which include postulated accident loadings. Allowable stress limits for the upper lifting trunnions and upper trunnion sleeves are conservatively developed to meet the requirements of ANSI N14.6-1993 (3.37) for a non-redundant lifting device for all cask movements within the fuel/reactor building. The maximum shear stress theory is used to calculate principal stresses in the cask structural shell. The appropriate dead load and thermal stresses are combined with the calculated drop accident scenario stresses to determine the worst case design stresses. The transfer cask structural design criteria are summarized in Table 3.2-11 and Table 3.2-12. The transfer cask accident analyses are presented in Section 8.2. The effects of fatigue on the transfer cask due to thermal cycling are addressed in Section 8.2.10. Appendices K, L, and N address the effects of handling the NUHOMS®-61BT, 24PT2, and 24PHB DSC in the *standardized* transfer cask, respectively. The effects of handling the *61BT and 32PT DSCs* in the OS197L TC are addressed in Appendix W. The effects of handling the NUHOMS®-32PT, 24PTH and 61BTH DSC in the OS197 or OS197H transfer cask are addressed in Appendices M, P and T, respectively. Appendix U addresses the OS200 transfer cask.

# 8. ANALYSIS OF DESIGN EVENTS

In previous chapters of this SAR, the features of the standardized NUHOMS® system which are important to safety have been identified and discussed. The purpose of this chapter is to present the engineering analyses for normal and off-normal operating conditions, and to establish and qualify the system for a range of credible and hypothetical accidents. As stated in Chapter 1, the analyses presented in this section are applicable to the standard length 24P and 52B canisters. An evaluation of the long cavity 24P canister, for the same design criteria, is provided in Appendix H and J. Appendices K, L, M, N, P, T and U, provide the evaluation for the NUHOMS®-61BT 24PT2, 32PT, 24PHB 24PTH, 61BTH and 32PTH1 DSCs, respectively. Also, as noted in Chapter 1, the structural, thermal, and shielding evaluations for the HSM-H, HSM Model 152, and HSM Model 202 are provided in Appendices P, R, and V, respectively. Evaluations for other canisters and modules may be included as additional appendices at a later time.

The structural and thermal analysis of the *61BT and 32PT DSCs* when transferred in OS197L TC are provided in Appendix W.3 and W.4, respectively.

In accordance with NRC Regulatory Guide 3.48 (8.1), the design events identified by ANSI/ANS 57.9-1984, (8.2) form the basis for the accident analyses performed for the standardized NUHOMS® system. Four categories of design events are defined. Design event Types I and II cover normal and off-normal events and are addressed in Section 8.1. Design event Types III and IV cover a range of postulated accident events and are addressed in Section 8.2. These events provide a means of establishing that the NUHOMS® system design satisfies the applicable operational and safety acceptance criteria as delineated herein.

It is important to note that, given the generic nature of this SAR, the majority of the analyses presented throughout this chapter are based on bounding conservative assumptions and methodologies, with the objective of establishing upper bound values for the responses of the primary components and structures of the standardized NUHOMS® system for the design basis events. Because of the conservative approach adopted herein, the reported temperatures and stresses in this chapter envelope the actual temperatures or states of stress for the various operating and postulated accident conditions. More rigorous and detailed analyses and/or more realistic assumptions and loading conditions would result in temperatures and states of stress which are significantly lower than the reported values.

## 8.1 Normal and Off-Normal Operations

Normal operating design conditions consist of a set of events that occur regularly, or frequently, in the course of normal operation of the NUHOMS® system. These normal operating conditions are addressed in Section 8.1.1. Off-normal operating design conditions are events that could occur with moderate frequency, possibly once during any calendar year of operation. These off-normal operating conditions are addressed in Section 8.1.2. The thermal-hydraulic, structural, and radiological analyses associated with these events are presented in the sections which follow.

## Table K.3.1-3
### *ASME Code Alternatives for the NUHOMS®-61BT DSC Basket*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section K.2 may be used for construction, but in no case earlier than 3 years before that specified in Section K.2.*<br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section K.2 may be used, so long the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG/NF-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| *NG/NF-2000* | *Use of ASME Code Material* | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness.* |
| *NG/NF-5520* | *NDE personnel must be qualified to a specific edition of SNT-TC-1A* | *Permit use of more recent edition of SNT-TC-1A.* |
| *NG/NF-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG/NF-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG/NF-4121* | *Material Certification by Certificate Holder* | |
| *NG/NF-8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |

## K.9 Tests and Maintenance Program

### K.9.1 Acceptance Tests

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

#### K.9.1.1 Visual Inspection

No change.

#### K.9.1.2 Structural.

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

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

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

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

#### K.9.1.3 Leak Tests

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

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

K.9.1.4 Components

The Standardized NUHOMS® system does not include any components such as valves, rupture discs, pumps, or blowers. The gaskets in the transfer cask do not require acceptance testing other than the leak testing cited above. No other components of the Standardized NUHOMS® system require testing, except as discussed in this Appendix.

K.9.1.5 Shielding Integrity

No change to Section 4.3.9 and Appendix U, Section U.9.1.5.

K.9.1.6 Thermal Acceptance

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, as specified in Section K.4.3. Because these materials do not have publicly documented values for thermal conductivity, testing of such materials will be performed in accordance with Section K.9.1.7.6.

K.9.1.7 Poison Acceptance

| ***CAUTION*** |
|---|
| *Sections K.9.1.7.1 through K.9.1.7.4 below are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 1) and shall not be deleted or altered in any way without approval from the NRC. The text of these sections is shown in bold type to distinguish it from other sections.* |

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

(a) Borated aluminum

(b) Boron carbide/aluminum metal matrix composite (MMC)

(c) BORAL®

The 61BT DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content of these three types of materials is given in Table K.9-1.

References to metal matrix composites throughout this Appendix are not intended to refer to BORAL®, which is described later in this section.

K.9.1.7.1 **Borated Aluminum**

**See the Caution in Section K.9.1.7 before deletion or modification to this section.**

**The material is produced by direct chill (DC) or permanent mold casting with boron precipitating primarily as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of aluminum or aluminum alloy (other boron compounds, such as $AlB_{12}$, can also occur). For extruded products, the $TiB_2$ form of the alloy shall be used. For rolled products, either the $AlB_2$, the $TiB_2$, or a hybrid may be used.**

**Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product. The amount required to achieve the specified minimum B10 areal density will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. In no case shall the boron content in the aluminum or aluminum alloy exceed 5% by weight.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which shall be as specified in Section K.9.1.7.7. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

K.9.1.7.2 Boron Carbide / Aluminum Metal Matrix Composites (MMCs)

**See the Caution in Section K.9.1.7 before deletion or modification to this section.**

**The material is a composite of fine boron carbide particles in an aluminum or aluminum alloy matrix. The material shall be produced by either direct chill casting, permanent mold casting, powder metallurgy, or thermal spray techniques. The boron carbide content shall not exceed 40% by volume. The boron carbide content for MMCs with an integral aluminum cladding shall not exceed 50% by volume.**

**The final MMC product shall have density greater than 98% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity. For MMC with an integral cladding, the final density of the core shall be greater than 97% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity of the core and cladding as a unit of the final product.**

*At least 50% by weight of the $B_4C$ particles in MMCs shall be smaller than 40 microns. No more than 10% of the particles shall be over 60 microns.*

**Prior to use in the 61BT DSC, MMCs shall pass the qualification testing specified in Section K.9.1.7.8, and shall subsequently be subject to the process controls specified in Section K.9.1.7.9.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of MMCs. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section K.9.1.7.7. The specified acceptance testing assures that at any location**

**in the final product, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

K.9.1.7.3 **BORAL®**

**See the Caution in Section K.9.1.7 before deletion or modification to this section.**

**This material consists of a core of aluminum and boron carbide powders between two outer layers of aluminum, mechanically bonded by hot-rolling an "ingot" consisting of an aluminum box filled with blended boron carbide and aluminum powders. The core, which is exposed at the edges of the sheet, is slightly porous. Before rolling, at least 80% by weight of the $B_4C$ particles in BORAL® shall be smaller than 200 microns. The nominal boron carbide content shall be limited to 65% (+ 2% tolerance limit) of the core by weight.**

**The criticality calculations take credit for 75% of the minimum specified B10 areal density of BORAL®. B10 areal density will be verified by chemical analysis and by certification of the B10 isotopic fraction for the boron carbide powder, or by neutron transmission testing. Areal density testing is performed on a coupon taken from the sheet produced from each ingot. If the measured areal density is below that specified, all the material produced from that ingot will be either rejected, or accepted only on the basis of alternate verification of B10 areal density for each of the final pieces produced from that ingot.**

K.9.1.7.4 Visual Inspections of Neutron Absorbers

**See the Caution in Section K.9.1.7 before deletion or modification to this section.**

**Neutron absorbers shall be 100% visually inspected in accordance with the Certificate Holder's QA procedures. Material that does not meet the following acceptance criteria shall be reworked, repaired, or scrapped. Blisters shall be treated as non-conforming. Inspection of MMCs with an integral aluminum cladding shall also include verification that the matrix is not exposed through the faces of the aluminum cladding and that solid aluminum is not present at the edges. For Boral, visual inspection shall verify that there are no cracks through the cladding, exposed core on the face of the sheet, or solid aluminum at the edge of the sheet.**

K.9.1.7.5 Other Visual Inspections Criteria (non-Technical Specifications)

For borated aluminum and MMCs, visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products" [9.5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable. 1

K.9.1.7.6 Thermal Conductivity Testing

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. Previous

[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"

testing of borated aluminum and metal matrix composite shows that thermal conductivity increases slightly with temperature. Initial sampling shall be one test per lot, defined by the heat or ingot, and may be reduced if the first five tests meet the specified minimum thermal conductivity.

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 K.4.3*

*In cases where the specified thickness of the neutron absorber may vary, the equations introduced in Section K.4.3 shall be used to determine the minimum required effective thermal conductivity.*

*The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.*

K.9.1.7.7 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

***CAUTION***

*Portions of Section K.9.1.7.7 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 1) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

**a) Neutron Transmission acceptance testing procedures shall be subject to approval by the Certificate Holder. Test coupons shall be removed from the rolled or extruded production material at locations that are systematically or probabilistically distributed throughout the lot. Test coupons shall not exhibit physical defects that would not be acceptable in the finished product, or that would preclude an accurate measurement of the coupon's physical thickness.**

**A lot is defined as all the pieces produced from a single ingot or heat or from a group of billets from the same heat. If this definition results in lot size too small to provide a meaningful statistical analysis of results, an alternate larger lot definition may be used, so long as it results in accumulating material that is uniform for sampling purposes.**

**The sampling rate for neutron transmission measurements shall be such that there is at least one neutron transmission measurement for each 2000 square inches of final product in each lot.**

**The B10 areal density is measured using a collimated thermal neutron beam up to 1.1 inch diameter.**

**The neutron transmission through the test coupons is converted to B10 areal density by comparison with transmission through calibrated standards. These standards are composed of a homogeneous boron compound without other significant neutron absorbers. For example, boron carbide, zirconium diboride or titanium diboride sheets are acceptable standards. These standards are paired with aluminum shims sized to match the effect of neutron scattering by aluminum in the test coupons. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to provide neutron attenuation equivalent to a homogeneous standard.**

**Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross section of B10 at that energy.**

**Alternatively, digital image analysis may be used to compare neutron radioscopic images of the test coupon to images of the standards. The area of image analysis shall be no more than 0.75 sq. inch.**

**The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. If a goodness-of-fit test demonstrates that the sample comes from a normal population, the one-sided tolerance limit for a normal distribution may be used for this purpose. Otherwise, a non-parametric (distribution-free) method of determining the one-sided tolerance limit may be used. Demonstration of the one-sided tolerance limit shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

b) The following illustrates one acceptable method and is intended to be utilized as an example. Therefore, the following text is not part of the Technical Specifications. The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The B10 areal densities determined by neutron transmission are converted to volume density, i.e., the B10 areal density is divided by the thickness at the location of the neutron transmission measurement or the maximum thickness of the coupon. The lower tolerance limit of B10 volume density is then determined, defined as the mean value of B10 volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor with 95% probability and 95% confidence [9.6].

Finally, the minimum specified value of B10 areal density is divided by the lower tolerance limit of B10 volume density to arrive at the minimum plate thickness which provides the specified B10 areal density.

**Any plate which is thinner than the statistically derived minimum thickness from K.9.1.7.7 a) or the minimum design thickness, whichever is greater, shall be treated as non-**

**conforming, with the following exception. Local depressions are acceptable, so long as they total no more than 0.5% of the area on any given plate, and the thickness at their location is not less than 90% of the minimum design thickness.** ***Edge effects due to manufacturing operations such as shearing, deburring, and chamfering need not be included in this determination.***

**Non-conforming material shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

K.9.1.7.8 Specification for Qualification Testing of Metal Matrix Composites

> ***CAUTION***
>
> *Section K.9.1.7.8.3.1, Section K.9.1.7.8.4 and Section K.9.1.7.8.5 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 1) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

K.9.1.7.8.1 Applicability and Scope

MMCs acceptable for use in the 61BT DSC are described in Section K.9.1.7.2.

Prior to initial use in a spent fuel dry storage or transport system, such MMCs shall be subjected to qualification testing that will verify that the product satisfies the design function. Key process controls shall be identified per Section K.9.1.7.9 so that the production material is equivalent to or better than the qualification test material. Changes to key processes shall be subject to qualification before use of such material in a spent fuel dry storage or transport system.

ASTM test methods and practices are referenced below for guidance. Alternative methods may be used with the approval of the Certificate Holder.

K.9.1.7.8.2 Design Requirements

In order to perform its design functions the product must have at a minimum sufficient strength and ductility for manufacturing and for the normal and accident conditions of the storage/ transport system. This is demonstrated by the tests in Section K.9.1.7.8.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section K.9.1.7.8.5.

K.9.1.7.8.3 Durability

There is no need to include accelerated radiation damage testing in the qualification. Such testing has already been performed on MMCs, and the results confirm what would be expected of materials that fall within the limits of applicability cited above. Metals and ceramics do not experience measurable changes in mechanical properties due to fast neutron fluences typical over the lifetime of spent fuel storage, about $10^{15}$ neutrons/cm$^2$.

Thermal damage and corrosion (hydrogen generation) testing shall be performed unless such tests on materials of the same chemical composition have already been performed and found acceptable. The following paragraphs illustrate two cases where such testing is not required.

Thermal damage testing is not required for unclad MMCs consisting only of boron carbide in an aluminum 1100 matrix, because there is no reaction between aluminum and boron carbide below 842°F, well above the basket temperature under normal conditions of storage or transport[3].

Corrosion testing is not required for MMCs (clad or unclad) consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

K.9.1.7.8.3.1 **Delamination Testing of Clad MMC**

**Clad MMCs shall be subjected to thermal damage testing following water immersion to ensure that delamination does not occur under normal conditions of storage.**

K.9.1.7.8.4 **Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity**

**At least three samples, one each from approximately the two ends and middle of the qualification material run shall be subject to:**

**a) room temperature tensile testing (ASTM- B557[5]) demonstrating that the material has the following tensile properties:**

- **Minimum yield strength, 0.2% offset: 1.5 ksi**
- **Minimum ultimate strength: 5 ksi**
- **Minimum elongation in 2 inches: 0.5%**

**As an alternative to the elongation requirement, ductility may be demonstrated by bend testing per ASTM E290[6]. The radius of the pin or mandrel shall be no greater than three times the material thickness, and the material shall be bent at least 90 degrees without complete fracture,**

**b) Testing to verify more than 98% of theoretical density for non-clad MMCs and 97% for the matrix of clad MMCs. Testing or examination for interconnected porosity on the faces and edges of unclad MMC, and on the edges of clad MMC shall be performed by a means to be approved by the Certificate Holder. The maximum interconnected porosity is 0.5 volume %,**

**and for at least one sample,**

3 Sung, C., "Microstructural Observation of Thermally Aged and Irradiated Aluminum/Boron Carbide ($B_4C$) Metal Matrix Composite by Transmission and Scanning Electron Microscope," 1998.

4 Boralyn testing submitted to the NRC under docket 71-1027, 1998.

5 ASTM B557 Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products

6 ASTM E290, Standard Methods for Bend Testing of Materials for Ductility

**c) For MMCs with an integral aluminum cladding, thermal durability testing demonstrating that after a minimum 24 hour soak in either pure or borated water, then insertion into a preheated oven at approximately 825°F for a minimum of 24 hours, the specimens are free of blisters and delamination and pass the mechanical testing requirements described in test 'a' of this section.**

K.9.1.7.8.5 **Required Tests and Examinations to Demonstrate B10 Uniformity**

**Uniformity of the boron distribution shall be verified either by:**

**a) Neutron radioscopy or radiography (ASTM E94[7], E142[8], and E545[9]) of material from the ends and middle of the test material production run, verifying no more than 10% difference between the minimum and maximum B10 areal density, or**

**b) Quantitative testing for the B10 areal density, B10 density, or the boron carbide weight fraction, on locations distributed over the test material production run, verifying that one standard deviation in the sample is less than 10% of the sample mean. Testing may be performed by a neutron transmission method similar to that specified in Section K.9.1.7.7, or by chemical analysis for boron carbide content in the composite.**

K.9.1.7.8.6 Approval of Procedures

Qualification procedures shall be subject to approval by the Certificate Holder.

K.9.1.7.9 Specification for Process Controls for Metal Matrix Composites

| *CAUTION* |
| --- |
| *Sections K.9.1.7.9.1 and K.9.1.7.9.2 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications (paragraph 4.1 (Note 1)) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

K.9.1.7.9.1 **Applicability and Scope**

**Key processing changes shall be subject to qualification prior to use of the material produced by the revised process. The Certificate Holder shall determine whether a complete or partial re-qualification program per Section K.9.1.7.8 is required, depending on the characteristics of the material that could be affected by the process change.**

K.9.1.7.9.2 **Definition of Key Process Changes**

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7 ASTM E94, Recommended Practice for Radiographic Testing

8 ASTM E142, Controlling Quality of Radiographic Testing

9 ASTM E545, Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing

**Key process changes are those which could adversely affect the uniform distribution of the boron carbide in the aluminum, reduce density, reduce corrosion resistance, reduce the mechanical strength or ductility of the MMC.**

K.9.1.7.9.3 Identification and Control of Key Process Changes

The manufacturer shall provide the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer shall identify key process changes as defined in Section K.9.1.7.9.2.

An increase in nominal boron carbide content over that previously qualified shall always be regarded as a key process change. The following are examples of other changes that are established as key process changes, as determined by the Certificate Holder's review of the specific applications and production processes:

a) Changes in the boron carbide particle size specification that increase the average particle size by more than 5 microns or that increase the amount of particles larger than 60 microns from the previously qualified material by more than 5% of the total distribution but less than the 10% limit,

b) Change of the billet production process, e.g., from vacuum hot pressing to cold isostatic pressing followed by vacuum sintering,

c) Change in the nominal matrix alloy,

d) Changes in mechanical processing that could result in reduced density of the final product, e.g., for PM or thermal spray MMCs that were qualified with extruded material, a change to direct rolling from the billet,

e) For MMCs using a magnesium-alloyed aluminum matrix, changes in the billet formation process that could increase the likelihood of magnesium reaction with the boron carbide, such as an increase in the maximum temperature or time at maximum temperature,

f) Changes in powder blending or melt stirring processes that could result in less uniform distribution of boron carbide, e.g., change in duration of powder blending, and

g) For MMCs with an integral aluminum cladding, a change greater than 25% in the ratio of the nominal aluminum cladding thickness (sum of two sides of cladding) and the nominal matrix thickness could result in changes in the mechanical properties of the final product.

In no case shall process changes be accepted if they result in a product outside the limits in Sections 9.5.3.1 and 9.5.3.4.

### K.9.2 Maintenance Program

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

## K.9.3 References


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

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

9.3 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 Deleted.

9.9 Deleted.

**Table K.9-1**
**B10 Specification for the NUHOMS® 61BT Poison Plates**

| Basket Type | Specified Minimum B10 Areal Density for Borated Aluminum/MMC for 90% credit (g/cm$^2$) | Specified Minimum B10 Areal Density for BORAL® for 75% credit (g/cm$^2$) |
|---|---|---|
| **Type 1 DSC** | | |
| A | 0.021 | 0.025 |
| B | 0.032 | 0.038 |
| C | 0.040 | 0.048 |
| **For Damaged Fuel** | | |
| C | 0.040 | 0.048 |

**Table K.9-2**

# DELETED

Table K.9-3

# DELETED

# Table M.3.1-2
## Alternatives to the ASME Code Exceptions for the NUHOMS®-32PT DSC Basket Assembly

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section M.2 may be used for construction, but in no case earlier than 3 years before that specified in the Section M.2.*<br><br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section M.2 may be used, so long the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| NG-2000 | Use of ASME Material | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness.* Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the solid aluminum rails for use above the Code temperature limits. |
| *NG-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG-4121* | *Material Certification by Certificate Holder* | |
| *NG -8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| NG-3000/ Section II, Part D, Table 2A | Maximum temperature limit for XM-19 plate material is 800°F | Not compliant with ASME Section II Part D Table 2A material temperature limit for XM-19 steel for the postulated transfer accident case (117°F, loss of sunshade, loss of neutron shield). This is a post-drop accident scenario, where the calculated maximum steady state temperature is 852°F, the expected reduction in material strength is small (less than 1 ksi by extrapolation), and the only primary stresses in the basket grid are deadweight stresses. The recovery actions following the postulated drop accident are as described in Section 8.2.5 of the FSAR. |
| *NG-5520* | *NDE personnel must be qualified to a specific edition of SNT-TC-1A* | *Permit use of more recent edition of SNT-TC-1A.* |

## M.9 Acceptance Tests and Maintenance Program

### M.9.1 Acceptance Tests

The acceptance requirements for the NUHOMS®-32PT system are given in the UFSAR except as described in the following sections. The NUHOMS®-32PT DSC has been enhanced to provide leaktight confinement and the basket includes an updated poison plate design. Additional acceptance testing of the NUHOMS®-32PT DSC welds and poison plates are described.

#### M.9.1.1 Visual Inspection

Visual examinations are performed at the fabricator's facility to ensure that the NUHOMS®-32PT system components conform to the fabrication specifications and drawings.

Visual examination of all finished absorber plates and rods are done to ensure that they are free of cracks, porosity, blisters, or foreign substances. Dimensional inspections of the plates and rods are done to ensure that their functional requirements listed in M.9.17.1 are met.

#### M.9.1.2 Structural Tests

The NUHOMS®-32PT 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 M.3.1. The following requirements are unique to the NUHOMS®-32PT DSC:

- The inner bottom cover weld is inspected in accordance with Article NB-5231,
- The outer bottom cover weld root and cover are penetrant tested, and
- The outer top cover plate weld root and cover are penetrant tested.

The NUHOMS®-32PT DSC basket is designed, fabricated, and inspected in accordance with ASME B&PV Code Section III, Subsection NG [9.1] with exceptions as listed in Section M.3.1. The following requirement is unique to the NUHOMS®-32PT DSC basket:

- The fuel compartment welds are inspected in accordance with Article NG-5260.

#### M.9.1.3 Leak Tests

The NUHOMS®-32PT DSC confinement boundary is leak tested to verify that it is leaktight in accordance with ANSI N14.5 [9.2]. The personnel performing the leak test are qualified in accordance with SNT-TC-1A [9.14].

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

#### M.9.1.4 Component Tests

The Standardized NUHOMS® system does not include any components such as valves, rupture discs, pumps, or blowers. The gaskets in the transfer cask do not require acceptance testing other than the leak testing cited above. No other components of the Standardized NUHOMS® system require testing, except as discussed in this Appendix.

M.9.1.5 Shielding Integrity Tests

No changes to Section 4.3.9 and Appendix U, Section U.9.1.5.

M.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, as specified in Section M.4.3. Because these materials do not have publicly documented values for thermal conductivity, testing of such materials will be performed in accordance with Section M.9.1.7.6.

M.9.1.7 Poison Acceptance

***CAUTION***

*Sections M.9.1.7.1 through M.9.1.7.4 are below are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 2) and shall not be deleted or altered in any way without approval from the NRC. The text of these sections is shown in bold type to distinguish it from other sections.*

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

(a) Borated aluminum

(b) Boron carbide/aluminum metal matrix composite (MMC)

The 32PT DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content for these materials is given in Table M.9-1.

**M.9.1.7.1 Borated Aluminum**

**See the Caution in Section M.9.1.7 before deletion or modification to this section.**

**The material is produced by direct chill (DC) or permanent mold casting with boron precipitating primarily as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of aluminum or aluminum alloy (other boron compounds, such as $AlB_{12}$, can also**

**occur). For extruded products, the $TiB_2$ form of the alloy shall be used. For rolled products, either the $AlB_2$, the $TiB_2$, or a hybrid may be used.**

**Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product. The amount required to achieve the specified minimum B10 areal density will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. In no case shall the boron content in the aluminum or aluminum alloy exceed 5% by weight.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which shall be as specified in Section M.9.1.7.7. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

### M.9.1.7.2 Boron Carbide/Aluminum Metal Matrix Composites (MMCs)

**See the Caution in Section M.9.1.7 before deletion or modification to this section.**

**The material is a composite of fine boron carbide particles in an aluminum or aluminum alloy matrix. The material shall be produced by either direct chill casting, permanent mold casting, powder metallurgy, or thermal spray techniques. The boron carbide content shall not exceed 40% by volume. The boron carbide content for MMCs with an integral aluminum cladding shall not exceed 50% by volume.**

**The final MMC product shall have density greater than 98% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity. For MMC with an integral cladding, the final density of the core shall be greater than 97% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity of the core and cladding as a unit of the final product.**

***At least 50% by weight of the $B_4C$ particles in MMCs shall be smaller than 40 microns. No more than 10% of the particles shall be over 60 microns.***

**Prior to use in the 32PT DSC, MMCs shall pass the qualification testing specified in Section M.9.1.7.8, and shall subsequently be subject to the process controls specified in Section M.9.1.7.9.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of MMCs. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section M.9.1.7.7. The specified acceptance testing assures that at any location in the final product, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

### M.9.1.7.3 Not Used

### M.9.1.7.4 Visual Inspections of Neutron Absorbers

**See the Caution in Section M.9.1.7 before deletion or modification to this section.**

**Neutron absorbers shall be 100% visually inspected in accordance with the Certificate Holder's QA procedures. Material that does not meet the following acceptance criteria shall be reworked, repaired, or scrapped. Blisters shall be treated as non-conforming. Inspection of MMCs with an integral aluminum cladding shall also include verification that the matrix is not exposed through the faces of the aluminum cladding and that solid aluminum is not present at the edges. For Boral, visual inspection shall verify that there are no cracks through the cladding, exposed core on the face of the sheet, or solid aluminum at the edge of the sheet.**

M.9.1.7.5 Other Visual Inspections Criteria (non-Technical Specifications)

For borated aluminum and MMCs, visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products" [9.5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable.

M.9.1.7.6 Thermal Conductivity Testing of Poison Plates

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. Previous testing of borated aluminum and metal matrix composite shows that thermal conductivity increases slightly with temperature. Initial sampling shall be one test per lot, defined by the heat or ingot, and may be reduced if the first five tests meet the specified minimum thermal conductivity.

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 M.4.3.*

*In cases where the specified thickness of the neutron absorber may vary, the equations introduced in Section M.4.3 shall be used to determine the minimum required effective thermal conductivity.*

*The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.*

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[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"

M.9.1.7.7 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

> ***CAUTION***
>
> *Portions of Section M.9.1.7.7 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 2) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

**a) Neutron Transmission acceptance testing procedures shall be subject to approval by the Certificate Holder. Test coupons shall be removed from the rolled or extruded production material at locations that are systematically or probabilistically distributed throughout the lot. Test coupons shall not exhibit physical defects that would not be acceptable in the finished product, or that would preclude an accurate measurement of the coupon's physical thickness.**

**A lot is defined as all the pieces produced from a single ingot or heat or from a group of billets from the same heat. If this definition results in lot size too small to provide a meaningful statistical analysis of results, an alternate larger lot definition may be used, so long as it results in accumulating material that is uniform for sampling purposes.**

**The sampling rate for neutron transmission measurements shall be such that there is at least one neutron transmission measurement for each 2000 square inches of final product in each lot.**

**The B10 areal density is measured using a collimated thermal neutron beam up to 1.1 inch diameter.**

**The neutron transmission through the test coupons is converted to B10 areal density by comparison with transmission through calibrated standards. These standards are composed of a homogeneous boron compound without other significant neutron absorbers. For example, boron carbide, zirconium diboride or titanium diboride sheets are acceptable standards. These standards are paired with aluminum shims sized to match the effect of neutron scattering by aluminum in the test coupons. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to provide neutron attenuation equivalent to a homogeneous standard. Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross section of B10 at that energy.**

**Alternatively, digital image analysis may be used to compare neutron radioscopic images of the test coupon to images of the standards. The area of image analysis shall be no more than 0.75 sq. inch. The method shall demonstrate sufficient sensitivity to distinguish between areal density at the specified minimum, 1% above, and 1% below.**

**The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. If a goodness-of-fit test demonstrates that the sample comes**

**from a normal population, the one-sided tolerance limit for a normal distribution may be used for this purpose. Otherwise, a non-parametric (distribution-free) method of determining the one-sided tolerance limit may be used. Demonstration of the one-sided tolerance limit shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

b) The following illustrates one acceptable method and is intended to be utilized as an example. Therefore, the following text is not part of the Technical Specifications. The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The B10 areal densities determined by neutron transmission are converted to volume density, i.e., the B10 areal density is divided by the thickness at the location of the neutron transmission measurement or the maximum thickness of the coupon. The lower tolerance limit of B10 volume density is then determined, defined as the mean value of B10 volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor with 95% probability and 95% confidence [9.12].

Finally, the minimum specified value of B10 areal density is divided by the lower tolerance limit of B10 volume density to arrive at the minimum plate thickness which provides the specified B10 areal density.

**Any plate which is thinner than the statistically derived minimum thickness from M.9.1.7.7 a) or the minimum design thickness, whichever is greater, shall be treated as non-conforming, with the following exception. Local depressions are acceptable, so long as they total no more than 0.5% of the area on any given plate, and the thickness at their location is not less than 90% of the minimum design thickness.** ***Edge effects due to manufacturing operations such as shearing, deburring, and chamfering need not be included in this determination.***

**Non-conforming material shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

M.9.1.7.8 Specification for Qualification Testing of Metal Matrix Composites

| *CAUTION* |
| --- |
| *Section M.9.1.7.8.3.1, Section M.9.1.7.8.4 and Section M.9.1.7.8.5 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 2) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

M.9.1.7.8.1 Applicability and Scope

MMCs acceptable for use in the 32PT DSC are described in Section M.9.1.7.2.

Prior to initial use in a spent fuel dry storage or transport system, such MMCs shall be subjected to qualification testing that will verify that the product satisfies the design function. Key process controls shall be identified per Section M.9.1.7.9 so that the production material is equivalent to or better than the qualification test material. Changes to key processes shall be subject to qualification before use of such material in a spent fuel dry storage or transport system.

ASTM test methods and practices are referenced below for guidance. Alternative methods may be used with the approval of the Certificate Holder.

M.9.1.7.8.2 Design Requirements

In order to perform its design functions the product must have at a minimum sufficient strength and ductility for manufacturing and for the normal and accident conditions of the storage/ transport system. This is demonstrated by the tests in Section M.9.1.7.8.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section M.9.1.7.8.5.

M.9.1.7.8.3 Durability

There is no need to include accelerated radiation damage testing in the qualification. Such testing has already been performed on MMCs, and the results confirm what would be expected of materials that fall within the limits of applicability cited above. Metals and ceramics do not experience measurable changes in mechanical properties due to fast neutron fluences typical over the lifetime of spent fuel storage, about $10^{15}$ neutrons/cm$^2$.

Thermal damage and corrosion (hydrogen generation) testing shall be performed unless such tests on materials of the same chemical composition have already been performed and found acceptable. The following paragraphs illustrate two cases where such testing is not required.

Thermal damage testing is not required for unclad MMCs consisting only of boron carbide in an aluminum 1100 matrix, because there is no reaction between aluminum and boron carbide below 842°F, well above the basket temperature under normal conditions of storage or transport[3].

Corrosion testing is not required for MMCs (clad or unclad) consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

M.9.1.7.8.3.1 **Delamination Testing of Clad MMC**

**Clad MMCs shall be subjected to thermal damage testing following water immersion to ensure that delamination does not occur under normal conditions of storage.**

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3 Sung, C., "Microstructural Observation of Thermally Aged and Irradiated Aluminum/Boron Carbide ($B_4C$) Metal Matrix Composite by Transmission and Scanning Electron Microscope," 1998.

4 Boralyn testing submitted to the NRC under docket 71-1027, 1998.

M.9.1.7.8.4 **Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity**

**At least three samples, one each from approximately the two ends and middle of the qualification material run shall be subject to:**

**a) room temperature tensile testing (ASTM- B557[5]) demonstrating that the material has the following tensile properties:**

- **Minimum yield strength, 0.2% offset: 1.5 ksi**
- **Minimum ultimate strength: 5 ksi**
- **Minimum elongation in 2 inches: 0.5%**

**As an alternative to the elongation requirement, ductility may be demonstrated by bend testing per ASTM E290[6]. The radius of the pin or mandrel shall be no greater than three times the material thickness, and the material shall be bent at least 90 degrees without complete fracture,**

**b) Testing to verify more than 98% of theoretical density for non-clad MMCs and 97% for the matrix of clad MMCs. Testing or examination for interconnected porosity on the faces and edges of unclad MMC, and on the edges of clad MMC shall be performed by a means to be approved by the Certificate Holder. The maximum interconnected porosity is 0.5 volume %,**

**and for at least one sample,**

**c) For MMCs with an integral aluminum cladding, thermal durability testing demonstrating that after a minimum 24 hour soak in either pure or borated water, then insertion into a preheated oven at approximately 825°F for a minimum of 24 hours, the specimens are free of blisters and delamination and pass the mechanical testing requirements described in test 'a' of this section.**

M.9.1.7.8.5 **Required Tests and Examinations to Demonstrate B10 Uniformity**

**Uniformity of the boron distribution shall be verified either by:**

**a) Neutron radioscopy or radiography (ASTM E94[7], E142[8], and E545[9]) of material from the ends and middle of the test material production run, verifying no more than 10% difference between the minimum and maximum B10 areal density, or**

**b) Quantitative testing for the B10 areal density, B10 density, or the boron carbide weight fraction, on locations distributed over the test material production run,**

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[5] ASTM B557 Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products
[6] ASTM E290, Standard Methods for Bend Testing of Materials for Ductility
[7] ASTM E94, Recommended Practice for Radiographic Testing
[8] ASTM E142, Controlling Quality of Radiographic Testing
[9] ASTM E545, Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing

**verifying that one standard deviation in the sample is less than 10% of the sample mean. Testing may be performed by a neutron transmission method similar to that specified in Section M.9.1.7.7, or by chemical analysis for boron carbide content in the composite.**

M.9.1.7.8.6 Approval of Procedures

Qualification procedures shall be subject to approval by the Certificate Holder.

M.9.1.7.9 Specification for Process Controls for Metal Matrix Composites

| ***CAUTION*** |
|---|
| *Sections M.9.1.7.9.1 and M.9.1.7.9.2 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 2) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

M.9.1.7.9.1 **Applicability and Scope**

**Key processing changes shall be subject to qualification prior to use of the material produced by the revised process. The Certificate Holder shall determine whether a complete or partial re-qualification program per Section M.9.1.7.8 is required, depending on the characteristics of the material that could be affected by the process change.**

M.9.1.7.9.2 **Definition of Key Process Changes**

**Key process changes are those which could adversely affect the uniform distribution of the boron carbide in the aluminum, reduce density, reduce corrosion resistance, reduce the mechanical strength or ductility of the MMC.**

M.9.1.7.9.3 Identification and Control of Key Process Changes

The manufacturer shall provide the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer shall identify key process changes as defined in Section M.9.1.7.9.2.

An increase in nominal boron carbide content over that previously qualified shall always be regarded as a key process change. The following are examples of other changes that are established as key process changes, as determined by the Certificate Holder's review of the specific applications and production processes:

a) Changes in the boron carbide particle size specification that increase the average particle size by more than 5 microns or that increase the amount of particles larger than 60 microns from the previously qualified material by more than 5% of the total distribution but less than the 10% limit,

b) Change of the billet production process, e.g., from vacuum hot pressing to cold isostatic pressing followed by vacuum sintering,

c) Change in the nominal matrix alloy,

d) Changes in mechanical processing that could result in reduced density of the final product, e.g., for PM or thermal spray MMCs that were qualified with extruded material, a change to direct rolling from the billet,

e) For MMCs using a magnesium-alloyed aluminum matrix, changes in the billet formation process that could increase the likelihood of magnesium reaction with the boron carbide, such as an increase in the maximum temperature or time at maximum temperature,

f) Changes in powder blending or melt stirring processes that could result in less uniform distribution of boron carbide, e.g., change in duration of powder blending, and

g) For MMCs with an integral aluminum cladding, a change greater than 25% in the ratio of the nominal aluminum cladding thickness (sum of two sides of cladding) and the nominal matrix thickness could result in changes in the mechanical properties of the final product.

In no case shall process changes be accepted if they result in a product outside the limits in Sections 9.5.3.1 and 9.5.3.4.

M.9.1.7.10 <u>$B^4C$ Linear Density Testing for Poison Rod Assemblies (PRAs)</u>

The PRAs are shown in Figure M.1-2, and additional physical requirements are listed in Table M.2-4. The $B_4C$ poison is inserted into the stainless steel tubes shown in Figure M.1-2. Table M.2-4 specifies the minimum $B_4C$ content per unit length in the axial direction of the rods for the various PRA designs. The minimum $B_4C$ content per unit length is consistent with the criticality analysis (Section M.6) with an additional 25% margin.

Pellets or powder representing each powder lot shall be tested per ASTM C751 [9.6] or ASTM C750 (Type 2) [9.7] (or equivalent). Density and diameter shall be measured to verify conformance to the specification requirements.

Deviations from the specified dimensions or density may be accepted, so long as the resulting minimum $B_4C$ mass per unit length is maintained.

<u>Justification for Durability of $B_4C$ Pellets:</u>

$B_4C$ is essentially inert and will not be attacked even by hot hydrofluoric or nitric acids[9.8]. It is insoluble in water [9.9], resistant to steam at temperatures of 200 to 300°C [9.10] and has a melting point of 2450°C [9.10]. Mechanically, $B_4C$ is extremely hard (Mohs hardness of 9.3 vs. 10 for diamond) and is used in abrasion- and wear-resistant applications and in bullet-proof tiles. It has a compressive strength of 398,000 psi In the PRAs, the $B_4C$ pellets are sealed within stainless steel. With this configuration there is nothing that could cause the material to degrade. In the unlikely event that a pellet were to crack or break, the total mass would be confined by the steel to the same dimensions.

The irradiation-induced swelling is due to neutron capture by the $^{10}B$ isotope. Using data from [9.11] and by determining the neutron absorption in the $B_4C$ ($^{10}B$ capture) from the shielding analyses, the swelling is determined to be negligible ~ 0.00002%. Finally, according to [9.11], the first intergranular cracks do not start to appear until fluences are 5.5 orders of magnitude greater than those calculated for 50 year operation.

### M.9.2 Maintenance Program

NUHOMS®-32PT system is a totally passive system and therefore requires little, if any, maintenance over the lifetime of the ISFSI. Typical NUHOMS®-32PT system maintenance tasks are performed in accordance with the UFSAR.

## M.9.3 References


9.1 ASME Boiler and Pressure Vessel Code, Section III, 2004 Edition through 2006 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 ASTM C751, "Standard Specification for Nuclear-Grade Boron Carbide Pellets."

9.7 ASTM C750, "Standard Specification for Nuclear-Grade Boron Carbide Powder."

9.8 The Merck Index, *9th edition, Merck & Co., 1976.*

9.9 *Grant (ed.),* Hackh's Chemical Dictionary, *4th edition, McGraw-Hill, 1969.*

9.10 *Lipp, A., "Boron Carbide: Production, Properties, Application," Reprint from* Technische Rundschau, *Nos. 14, 28, 33 (1995) and 7 (1966).*

9.11 *Stoto, T. et al., "Swelling and Microcracking of Boron Carbide Subjected to Fast Neutron Irradiations,"* Journal of Applied Physics, *Vol. 68, No.7, October 1, 1990, pp. 3198-3206.*

9.12 Natrella, "Experimental Statistics," Dover, 2005.

9.13 Not Used.

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

**Table M.9-1**
**B10 Specification for the NUHOMS® - 32PT Poison Plates**

| Poison Type | 32PT Basket Type | Minimum Poison Loading (B10 g/cm$^2$) | % Credit Used in Criticality Analysis |
|---|---|---|---|
| Borated Aluminum /MMC | A/B/C/D | 0.007 | 90 |
| Borated Aluminum /MMC | A1 | 0.015 | 90 |
| Borated Aluminum /MMC | A2 | 0.020 | 90 |

**Table P.3.1-2**
**Alternatives to the ASME Code for the NUHOMS®-24PTH DSC Basket Assembly**

*(Part 1 of 2)*

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section P.2 may be used for construction, but in no case earlier than 3 years before that specified in Section P.2.*<br>*Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section P.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| NG-2000 | Use of ASME Material | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness.* Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits. |
| *NG-2130* | *Material must be supplied by ASME approved material suppliers.* | *Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to NG-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program.* |
| *NG-4121* | *Material Certification by Certificate Holder* | |
| *NG -8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| NG-3000/ Section II, Part D, Table 2A | Maximum temperature limit for Type 304 plate material is 800°F | Not compliant with ASME Section II Part D Table 2A material temperature limit for Type 304 steel for the postulated transfer accident case (117°F, loss of sunshade, loss of neutron shield). This is a post-drop accident scenario, where the calculated maximum steady state temperature is 862°F, the expected reduction in material strength is small (less than 1 ksi by extrapolation), and the only primary stresses in the basket grid are deadweight stresses. The recovery actions following the postulated drop accident are as described in Section 8.2.5 of the FSAR. |

## P.9 Acceptance Tests and Maintenance Program

### P.9.1 Acceptance Tests

The acceptance requirements for the NUHOMS®-24PTH system are given in the UFSAR except as described in the following sections. 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 basket is 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. The gaskets in the transfer cask do not require acceptance testing other than the leak testing cited above. 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. For example, for a 6"x 6" grid, the detector will encompass a 6" x 6" square. 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 proprietary polymer resin. The shielding performance of the resin will be assured by written procedures controlling temperature, measuring, and mixing of the components, degassing of the resin, and verification of the mass or volume of resin installed.

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, as specified in Section P.4.3. 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

| ***CAUTION*** |
|---|
| *Sections P.9.1.7.1 through P.9.1.7.4 below are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 3) and shall not be deleted or altered in any way without approval from the NRC. The text of these sections is shown in bold type to distinguish it from other sections.* |

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

(a) Borated aluminum

(b) Boron carbide/aluminum metal matrix composite (MMC)

(c) BORAL®

The 24PTH DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content for these materials is given in Table P.9-1.

References to metal matrix composites throughout this chapter are not intended to refer to BORAL®, which is described later in this section.

P.9.1.7.1 **Borated Aluminum**

**See the Caution in Section P.9.1.7 before deletion or modification to this section.**

**The material is produced by direct chill (DC) or permanent mold casting with boron precipitating primarily as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of aluminum or aluminum alloy (other boron compounds, such as $AlB_{12}$, can also occur). For extruded products, the $TiB_2$ form of the alloy shall be used. For rolled products, either the $AlB_2$, the $TiB_2$, or a hybrid may be used.**

**Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product. The amount required to achieve the specified minimum B10 areal density will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. In no case shall the boron content in the aluminum or aluminum alloy exceed 5% by weight.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which shall be as specified in Section P.9.1.7.7. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

P.9.1.7.2 **Boron Carbide/Aluminum Metal Matrix Composites (MMC)**

**See the Caution in Section P.9.1.7 before deletion or modification to this section.**

**The material is a composite of fine boron carbide particles in an aluminum or aluminum alloy matrix. The material shall be produced by either direct chill casting, permanent mold casting, powder metallurgy, or thermal spray techniques. The boron carbide content shall not exceed 40% by volume. The boron carbide content for MMCs with an integral aluminum cladding shall not exceed 50% by volume.**

**The final MMC product shall have density greater than 98% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity. For MMC with an integral cladding, the final density of the core shall be greater than 97% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity of the core and cladding as a unit of the final product.**

***At least 50% by weight of the $B_4C$ particles in MMCs shall be smaller than 40 microns. No more than 10% of the particles shall be over 60 microns.***

**Prior to use in the 24PTH DSC, MMCs shall pass the qualification testing specified in Section P.9.1.7.8, and shall subsequently be subject to the process controls specified in Section P.9.1.7.9.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of MMCs. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section P.9.1.7.7. The specified acceptance testing assures that at any location in the final product, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

P.9.1.7.3 <u>**BORAL®**</u>

**See the Caution in Section P.9.1.7 before deletion or modification to this section.**

**This material consists of a core of aluminum and boron carbide powders between two outer layers of aluminum, mechanically bonded by hot-rolling an "ingot" consisting of an aluminum box filled with blended boron carbide and aluminum powders. The core, which is exposed at the edges of the sheet, is slightly porous. Before rolling, at least 80% by weight of the $B_4C$ particles in BORAL® shall be smaller than 200 microns. The nominal boron carbide content shall be limited to 65% (+ 2% tolerance limit) of the core by weight.**

**The criticality calculations take credit for 75% of the minimum specified B10 areal density of BORAL®. B10 areal density will be verified by chemical analysis and by certification of the B10 isotopic fraction for the boron carbide powder, or by neutron transmission testing. Areal density testing is performed on a coupon taken from the sheet produced from each ingot. If the measured areal density is below that specified, all the material produced from that ingot will be either rejected, or accepted only on the basis of alternate verification of B10 areal density for each of the final pieces produced from that ingot.**

P.9.1.7.4 <u>**Visual Inspections of Neutron Absorbers**</u>

**See the Caution in Section P.9.1.7 before deletion or modification to this section.**

**Neutron absorbers shall be 100% visually inspected in accordance with the Certificate Holder's QA procedures. Material that does not meet the following acceptance criteria shall be reworked, repaired, or scrapped. Blisters shall be treated as non-conforming. Inspection of MMCs with an integral aluminum cladding shall also include verification that the matrix is not exposed through the faces of the aluminum cladding and that solid aluminum is not present at the edges. For Boral, visual inspection shall verify that there are no cracks through the cladding, exposed core on the face of the sheet, or solid aluminum at the edge of the sheet.**

P.9.1.7.5 <u>Other Visual Inspections Criteria (non-Technical Specifications)</u>

For borated aluminum and MMCs, visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products" [9.5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable. 1

P.9.1.7.6 Thermal Conductivity Testing of Poison Plates

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. Previous testing of borated aluminum and metal matrix composite shows that thermal conductivity increases slightly with temperature. Initial sampling shall be one test per lot, defined by the heat or ingot, and may be reduced if the first five tests meet the specified minimum thermal conductivity.

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*

*In cases where the specified thickness of the neutron absorber may vary, the equations introduced in Section P.4.3 shall be used to determine the minimum required effective thermal conductivity.*

*The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.*

P.9.1.7.7 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

| ***CAUTION*** |
| --- |
| *Portions of Section P.9.1.7.7 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 3) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

**a) Neutron Transmission acceptance testing procedures shall be subject to approval by the Certificate Holder. Test coupons shall be removed from the rolled or extruded production material at locations that are systematically or probabilistically distributed throughout the lot. Test coupons shall not exhibit physical defects that would not be acceptable in the**

[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"

**finished product, or that would preclude an accurate measurement of the coupon's physical thickness.**

**A lot is defined as all the pieces produced from a single ingot or heat or from a group of billets from the same heat. If this definition results in lot size too small to provide a meaningful statistical analysis of results, an alternate larger lot definition may be used, so long as it results in accumulating material that is uniform for sampling purposes.**

**The sampling rate for neutron transmission measurements shall be such that there is at least one neutron transmission measurement for each 2000 square inches of final product in each lot.**

**The B10 areal density is measured using a collimated thermal neutron beam up to 1.1 inch diameter.**

**The neutron transmission through the test coupons is converted to B10 areal density by comparison with transmission through calibrated standards. These standards are composed of a homogeneous boron compound without other significant neutron absorbers. For example, boron carbide, zirconium diboride or titanium diboride sheets are acceptable standards. These standards are paired with aluminum shims sized to match the effect of neutron scattering by aluminum in the test coupons. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to provide neutron attenuation equivalent to a homogeneous standard. Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross section of B10 at that energy.**

**Alternatively, digital image analysis may be used to compare neutron radioscopic images of the test coupon to images of the standards. The area of image analysis shall be no more than 0.75 sq. inch.**

**The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. If a goodness-of-fit test demonstrates that the sample comes from a normal population, the one-sided tolerance limit for a normal distribution may be used for this purpose. Otherwise, a non-parametric (distribution-free) method of determining the one-sided tolerance limit may be used. Demonstration of the one-sided tolerance limit shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

b) The following illustrates one acceptable method and is intended to be utilized as an example. Therefore, the following text is not part of the Technical Specifications. The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The B10 areal densities determined by neutron transmission are converted to volume density, i.e., the B10 areal density is divided by the thickness at the location of the neutron transmission measurement or the maximum thickness of the coupon. The lower tolerance limit of B10 volume density is then determined, defined as the mean value of B10 volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor for a normal distribution with 95% probability and 95% confidence [9.6].

Finally, the minimum specified value of B10 areal density is divided by the lower tolerance limit of B10 volume density to arrive at the minimum plate thickness which provides the specified B10 areal density.

**Any plate which is thinner than the statistically derived minimum thickness from P.9.1.7.7 a) or the minimum design thickness, whichever is greater, shall be treated as non-conforming, with the following exception. Local depressions are acceptable, so long as they total no more than 0.5% of the area on any given plate, and the thickness at their location is not less than 90% of the minimum design thickness.** ***Edge effects due to manufacturing operations such as shearing, deburring, and chamfering need not be included in this determination.***

**Non-conforming material shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

P.9.1.7.8 Specification for Qualification Testing of Metal Matrix Composites

| ***CAUTION*** |
|---|
| *Section P.9.1.7.8.3.1, Section P.9.1.7.8.4 and Section P.9.1.7.8.5 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 3) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

P.9.1.7.8.1 Applicability and Scope

Metal matrix composites (MMCs) acceptable for use in the 24PTH DSC are described in Section P.9.1.7.2.

Prior to initial use in a spent fuel dry storage or transport system, such MMCs shall be subjected to qualification testing that will verify that the product satisfies the design function. Key process controls shall be identified per Section P.9.1.7.9 so that the production material is equivalent to or better than the qualification test material. Changes to key processes shall be subject to qualification before use of such material in a spent fuel dry storage or transport system.

ASTM test methods and practices are referenced below for guidance. Alternative methods may be used with the approval of the Certificate Holder.

P.9.1.7.8.2 Design Requirements

In order to perform its design functions the product must have at a minimum sufficient strength and ductility for manufacturing and for the normal and accident conditions of the storage/ transport system. This is demonstrated by the tests in Section P.9.1.7.8.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section P.9.1.7.8.5.

P.9.1.7.8.3 Durability

There is no need to include accelerated radiation damage testing in the qualification. Such testing has already been performed on MMCs, and the results confirm what would be expected of materials that fall within the limits of applicability cited above. Metals and ceramics do not experience measurable changes in mechanical properties due to fast neutron fluences typical over the lifetime of spent fuel storage, about $10^{15}$ neutrons/cm$^2$.

Thermal damage and corrosion (hydrogen generation) testing shall be performed unless such tests on materials of the same chemical composition have already been performed and found acceptable. The following paragraphs illustrate two cases where such testing is not required.

Thermal damage testing is not required for unclad MMCs consisting only of boron carbide in an aluminum 1100 matrix, because there is no reaction between aluminum and boron carbide below 842°F, well above the basket temperature under normal conditions of storage or transport[3].

Corrosion testing is not required for MMCs (clad or unclad) consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

P.9.1.7.8.3.1 **Delamination Testing of Clad MMC**

**Clad MMCs shall be subjected to thermal damage testing following water immersion to ensure that delamination does not occur under normal conditions of storage.**

P.9.1.7.8.4 **Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity**

**At least three samples, one each from approximately the two ends and middle of the qualification material run shall be subject to:**

**a) room temperature tensile testing (ASTM- B557[5]) demonstrating that the material has the following tensile properties:**

- **Minimum yield strength, 0.2% offset: 1.5 ksi**
- **Minimum ultimate strength: 5 ksi**
- **Minimum elongation in 2 inches: 0.5%**

**As an alternative to the elongation requirement, ductility may be demonstrated by bend testing per ASTM E290[6]. The radius of the pin or mandrel shall be no greater than three times the material thickness, and the material shall be bent at least 90 degrees without complete fracture,**

**b) Testing to verify more than 98% of theoretical density for non-clad MMCs and 97% for the matrix of clad MMCs. Testing or examination for interconnected porosity on the faces and edges of unclad MMC, and on the edges of clad MMC shall be performed by a means to be approved by the Certificate Holder. The maximum interconnected porosity is 0.5 volume %,**

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3 Sung, C., "Microstructural Observation of Thermally Aged and Irradiated Aluminum/Boron Carbide ($B_4C$) Metal Matrix Composite by Transmission and Scanning Electron Microscope," 1998.

4 Boralyn testing submitted to the NRC under docket 71-1027, 1998.

5 ASTM B557 Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products

6 ASTM E290, Standard Methods for Bend Testing of Materials for Ductility

**and for at least one sample,**

**c) For MMCs with an integral aluminum cladding, thermal durability testing demonstrating that after a minimum 24 hour soak in either pure or borated water, then insertion into a preheated oven at approximately 825°F for a minimum of 24 hours, the specimens are free of blisters and delamination and pass the mechanical testing requirements described in test 'a' of this section.**

P.9.1.7.8.5 **Required Tests and Examinations to Demonstrate B10 Uniformity**

**Uniformity of the boron distribution shall be verified either by:**

**a) Neutron radioscopy or radiography (ASTM E94[7], E142[8], and E545[9]) of material from the ends and middle of the test material production run, verifying no more than 10% difference between the minimum and maximum B10 areal density, or**

**b) Quantitative testing for the B10 areal density, B10 density, or the boron carbide weight fraction, on locations distributed over the test material production run, verifying that one standard deviation in the sample is less than 10% of the sample mean. Testing may be performed by a neutron transmission method similar to that specified in Section P.9.1.7.7, or by chemical analysis for boron carbide content in the composite.**

P.9.1.7.8.6 Approval of Procedures

Qualification procedures shall be subject to approval by the Certificate Holder.

P.9.1.7.9 Specification for Process Controls for Metal Matrix Composites

***CAUTION***

*Sections P.9.1.7.9.1 and P.9.1.7.9.2 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specifications 4.1 (Note 3) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

P.9.1.7.9.1 **Applicability and Scope**

**Key processing changes shall be subject to qualification prior to use of the material produced by the revised process. The Certificate Holder shall determine whether a complete or partial re-qualification program per Section P.9.1.7.8 is required, depending on the characteristics of the material that could be affected by the process change.**

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7 ASTM E94, Recommended Practice for Radiographic Testing
8 ASTM E142, Controlling Quality of Radiographic Testing
9 ASTM E545, Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing

P.9.1.7.9.2 **Definition of Key Process Changes**

**Key process changes are those which could adversely affect the uniform distribution of the boron carbide in the aluminum, reduce density, reduce corrosion resistance, reduce the mechanical strength or ductility of the MMC.**

P.9.1.7.9.3 Identification and Control of Key Process Changes

The manufacturer shall provide the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer shall identify key process changes as defined in Section P.9.1.7.9.2.

An increase in nominal boron carbide content over that previously qualified shall always be regarded as a key process change. The following are examples of other changes that are established as key process changes, as determined by the Certificate Holder's review of the specific applications and production processes:

a) Changes in the boron carbide particle size specification that increase the average particle size by more than 5 microns or that increase the amount of particles larger than 60 microns from the previously qualified material by more than 5% of the total distribution but less than the 10% limit,

b) Change of the billet production process, e.g., from vacuum hot pressing to cold isostatic pressing followed by vacuum sintering,

c) Change in the nominal matrix alloy,

d) Changes in mechanical processing that could result in reduced density of the final product, e.g., for PM or thermal spray MMCs that were qualified with extruded material, a change to direct rolling from the billet,

e) For MMCs using a magnesium-alloyed aluminum matrix, changes in the billet formation process that could increase the likelihood of magnesium reaction with the boron carbide, such as an increase in the maximum temperature or time at maximum temperature,

f) Changes in powder blending or melt stirring processes that could result in less uniform distribution of boron carbide, e.g., change in duration of powder blending, and

g) For MMCs with an integral aluminum cladding, a change greater than 25% in the ratio of the nominal aluminum cladding thickness (sum of two sides of cladding) and the nominal matrix thickness could result in changes in the mechanical properties of the final product.

In no case shall process changes be accepted if they result in a product outside the limits in Sections 9.5.3.1 and 9.5.3.4.

### P.9.2 Maintenance Program

NUHOMS®-24PTH system is a totally passive system and therefore requires little, if any, maintenance over the lifetime of the ISFSI. Typical NUHOMS®-24PTH system maintenance tasks are performed in accordance with the UFSAR.

## 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.

## 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 /MMC | 1A or 2A | 7 | 90 |
| | 1B or 2B | 15 | |
| | 1C or 2C | 32 | |
| BORAL® | 1A or 2A | 9 | 75 |
| | 1B or 2B | 19 | |
| | 1C or 2C | 40 | |

## Table T.3.1-3
## ASME Code Alternatives for the NUHOMS®-61BTH DSC Basket

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| *NCA* | *All* | *Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000.* |
| *NCA-1140* | *Use of Code editions and addenda* | *Code edition and addenda other than those specified in Section T.2 may be used for construction, but in no case earlier than 3 years before that specified in Section T.2.* *Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section T.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction.* |
| *NG/NF-1100* | *Requirements for Code Stamping of Components, Code reports and certificates, etc.* | *Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified.* |
| NG/*NF*-2000 | Use of ASME Material | *Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness.* Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits. |
| NG/NF-2130 | Material must be supplied by ASME approved material suppliers. | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to *NG/NF*-2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. |
| NG/NF-4121 | Material Certification by Certificate Holder | |
| NG-3352 | Table NG 3352-1 lists the permissible welded joints and quality factors. | The fuel compartment tubes may be fabricated from sheet with full penetration seam weldments. Per Table NG-3352-1 a joint efficiency (quality) factor of 0.5 is to be used for full penetration weldments examined in accordance with ASME Section V visual examination (VT). A joint efficiency (quality) factor of 1.0 is utilized for the fuel compartment longitudinal seam welds (if present) with VT examination. This is justified because the compartment seam weld is thin and the weldment is made in one pass; and both surfaces of the weldment (inside and outside) receive 100% VT examination. The 0.5 quality factor, applicable to each surface of the weldment, results is a quality factor of 1.0 since both surfaces are 100% examined. In addition,the fuel compartments have no pressure retaining function and the stainless steel material that comprises the fuel compartment tubes is very ductile. |
| *NG/NF-8000* | *Requirements for nameplates, stamping & reports per NCA-8000* | *The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program.* |
| *NG/NF-5520* | *NDE personnel must be qualified to a specific edition of SNT-TC-1A* | *Permit use of more recent edition of SNT-TC-1A* |

## T.9 Acceptance Tests and Maintenance Program

### T.9.1 Acceptance Tests

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

#### T.9.1.1 Visual Inspection

Visual inspections are performed at the fabricator's facility to ensure that the DSC, the Transfer Cask and the HSM conform to the drawings and specifications. The visual inspections include weld, dimensional, surface finish, and cleanliness inspections. Visual inspections specified by codes applicable to a component are performed in accordance with the requirements and acceptance criteria of those codes.

All weld inspection is performed using qualified processes and qualified personnel according to the applicable code requirements, e.g., ASME or AWS. Non-destructive examination (NDE) requirements for welds are specified on the drawings provided in Chapter T.1; acceptance criteria are as specified by the governing code. NDE personnel are qualified in accordance with SNT-TC-1A [9.2].

The confinement welds on the DSC are inspected in accordance with ASME B&PV Code Subsection NB [9.1] including alternatives to ASME Code specified in Section T.3.1.2.3.

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

#### T.9.1.2 Structural

The DSC confinement boundary except the inner top cover/shield plug to the DSC shell weld is pressure tested at the fabricator's shop in accordance with ASME Article NB-6300. The test pressure is set between 16.5 to 18.0 psig for 61BTH DSC with Type 1 basket for future 10CFR71 application. This bounds the 1.1xDSC design pressure of 10 psig. The test pressure is set between 22.5 to 24.0 psig for 61BTH DSC with Type 2 basket for future 10CFR71 application. This bounds the 1.1xDSC design pressure of 15 psig.

The inner top cover/shield plug to the DSC shell weld is also pressure tested between 16.5 to 18.0 psig for 61BTH DSC with Type 1 basket and between 22.5 to 24.0 psig for 61BTH DSC with Type 2 basket. This pressure test is performed at the field after the fuel assemblies are loaded in the DSC. This test is in accordance with the alternatives to the ASME Code specified in Section T.3.1.2.3.

HSM-H reinforcement and concrete are tested as described in Section 3.4.2.

### T.9.1.3 Leak Tests

DSC confinement welds in the DSC shell and bottom are leak tested at the fabricator's shop to an acceptance criterion of $1x10^{-7}$ ref $cm^3/s$, i.e., "leaktight" as defined in ANSI N14.5 [9.4]. Personnel performing the leak test are qualified in accordance with SNT-TC-1A [9.2].

The weld between the DSC shell and inner top cover and the siphon/vent cover welds are also leak tested to an acceptance criteria of $1 \times 10^{-7}$ ref $cm^3/s$ in the field after the fuel assemblies are loaded in the canister.

### T.9.1.4 Components

The Standardized NUHOMS® system does not include any components such as valves, rupture discs, pumps, or blowers. The gaskets in the Transfer Cask do not require acceptance testing other than the leak testing cited above. No other components of the NUHOMS® system require testing, except as discussed in this chapter.

### T.9.1.5 Shielding Integrity

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. For example, for a 6" × 6" grid, the detector will encompass a 6" × 6" square. 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 proprietary polymer resin. The shielding performance of the resin will be assured by written procedures controlling temperature, measuring, and mixing of the components, degassing of the resin, and verification of the mass or volume of resin installed.

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.

### T.9.1.6 Thermal Acceptance

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, as specified in Section T.4.3. Because these materials do not have publicly documented values for thermal conductivity, testing of such materials will be performed in accordance with Section T.9.1.7.6

T.9.1.7 Poison Acceptance

> ***CAUTION***
>
> *Sections T.9.1.7.1 through T.9.1.7.4 below are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 4) and shall not be deleted or altered in any way without approval from the NRC. The text of these sections is shown in bold type to distinguish it from other sections.*

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

(a) Borated aluminum

(b) Boron carbide/aluminum metal matrix composite (MMC)

(c) BORAL®

The 61BTH DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content of these three types of materials is given in Table T.9-1.

References to metal matrix composites throughout this chapter are not intended to refer to BORAL®, which is described later in this section.

T.9.1.7.1 **Borated Aluminum**

**See the Caution in Section T.9.1.7 before deletion or modification to this section.**

**The material is produced by direct chill (DC) or permanent mold casting with boron precipitating primarily as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of aluminum or aluminum alloy (other boron compounds, such as $AlB_{12}$, can also occur). For extruded products, the $TiB_2$ form of the alloy shall be used. For rolled products, either the $AlB_2$, the $TiB_2$, or a hybrid may be used.**

**Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product. The amount required to achieve the specified minimum B10 areal density will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. In no case shall the boron content in the aluminum or aluminum alloy exceed 5% by weight.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which shall be as specified in Section T.9.1.7.7. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

T.9.1.7.2 Boron Carbide / Aluminum Metal Matrix Composites (MMC)

**See the Caution in Section T.9.1.7 before deletion or modification to this section.**

**The material is a composite of fine boron carbide particles in an aluminum or aluminum alloy matrix. The material shall be produced by either direct chill casting, permanent mold casting, powder metallurgy, or thermal spray techniques. The boron carbide content shall not exceed 40% by volume. The boron carbide content for MMCs with an integral aluminum cladding shall not exceed 50% by volume.**

**The final MMC product shall have density greater than 98% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity. For MMC with an integral cladding, the final density of the core shall be greater than 97% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity of the core and cladding as a unit of the final product.**

*At least 50% by weight of the $B_4C$ particles in MMCs shall be smaller than 40 microns. No more than 10% of the particles shall be over 60 microns.*

**Prior to use in the 61BTH DSC, MMCs shall pass the qualification testing specified in Section T.9.1.7.8, and shall subsequently be subject to the process controls specified in Section T.9.1.7.9.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of MMCs. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section T.9.1.7.7. The specified acceptance testing assures that at any location in the final product, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

T.9.1.7.3 BORAL®

**See the Caution in Section T.9.1.7 before deletion or modification to this section.**

**This material consists of a core of aluminum and boron carbide powders between two outer layers of aluminum, mechanically bonded by hot-rolling an "ingot" consisting of an aluminum box filled with blended boron carbide and aluminum powders. The core, which is exposed at the edges of the sheet, is slightly porous. Before rolling, at least 80% by weight of the $B_4C$ particles in BORAL® shall be smaller than 200 microns. The nominal boron carbide content shall be limited to 65% (+ 2% tolerance limit) of the core by weight.**

**The criticality calculations take credit for 75% of the minimum specified B10 areal density of BORAL®. B10 areal density will be verified by chemical analysis and by certification of the B10 isotopic fraction for the boron carbide powder, or by neutron transmission testing. Areal density testing is performed on a coupon taken from the sheet produced from each ingot. If the measured areal density is below that specified, all the material produced from that ingot will be either rejected, or accepted only on the basis of alternate verification of B10 areal density for each of the final pieces produced from that ingot.**

T.9.1.7.4 Visual Inspections of Neutron Absorbers

**See the Caution in Section T.9.1.7.7 before deletion or modification to this section.**

**Neutron absorbers shall be 100% visually inspected in accordance with the Certificate Holder's QA procedures. Material that does not meet the following acceptance criteria shall be reworked, repaired, or scrapped. Blisters shall be treated as non-conforming. Inspection of MMCs with an integral aluminum cladding shall also include verification that the matrix is not exposed through the faces of the aluminum cladding and that solid aluminum is not present at the edges. For Boral, visual inspection shall verify that there are no cracks through the cladding, exposed core on the face of the sheet, or solid aluminum at the edge of the sheet.**

T.9.1.7.5 Other Visual Inspections Criteria (non-Technical Specifications)

For borated aluminum and MMCs, visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products" [9.5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable.

T.9.1.7.6 Thermal Conductivity Testing

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. Previous testing of borated aluminum and metal matrix composite shows that thermal conductivity increases slightly with temperature. Initial sampling shall be one test per lot, defined by the heat or ingot, and may be reduced if the first five tests meet the specified minimum thermal conductivity.

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 T.4.3*

*In cases where the specified thickness of the neutron absorber may vary, the equations introduced in Section T.4.3 shall be used to determine the minimum required effective thermal conductivity.*

[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"

*The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.*

T.9.1.7.7 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

| CAUTION |
| --- |
| *Portions of T.9.1.7.7 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 4) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

**a) Neutron Transmission acceptance testing procedures shall be subject to approval by the Certificate Holder. Test coupons shall be removed from the rolled or extruded production material at locations that are systematically or probabilistically distributed throughout the lot. Test coupons shall not exhibit physical defects that would not be acceptable in the finished product, or that would preclude an accurate measurement of the coupon's physical thickness.**

**A lot is defined as all the pieces produced from a single ingot or heat or from a group of billets from the same heat. If this definition results in lot size too small to provide a meaningful statistical analysis of results, an alternate larger lot definition may be used, so long as it results in accumulating material that is uniform for sampling purposes.**

**The sampling rate for neutron transmission measurements shall be such that there is at least one neutron transmission measurement for each 2000 square inches of final product in each lot.**

**The B10 areal density is measured using a collimated thermal neutron beam up to 1.1 inch diameter.**

**The neutron transmission through the test coupons is converted to B10 areal density by comparison with transmission through calibrated standards. These standards are composed of a homogeneous boron compound without other significant neutron absorbers. For example, boron carbide, zirconium diboride or titanium diboride sheets are acceptable standards. These standards are paired with aluminum shims sized to match the effect of neutron scattering by aluminum in the test coupons. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to provide neutron attenuation equivalent to a homogeneous standard. Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross section of B10 at that energy.**

**Alternatively, digital image analysis may be used to compare neutron radioscopic images of the test coupon to images of the standards. The area of image analysis shall be no more than 0.75 sq. inch.**

**The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. If a goodness-of-fit test demonstrates that the sample comes from a normal population, the one-sided tolerance limit for a normal distribution may be used for this purpose. Otherwise, a non-parametric (distribution-free) method of determining the one-sided tolerance limit may be used. Demonstration of the one-sided tolerance limit shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

b) The following illustrates one acceptable method and is intended to be utilized as an example. Therefore, the following text is not part of the Technical Specifications. The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The B10 areal densities determined by neutron transmission are converted to volume density, i.e., the B10 areal density is divided by the thickness at the location of the neutron transmission measurement or the maximum thickness of the coupon. The lower tolerance limit of B10 volume density is then determined, defined as the mean value of B10 volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor with 95% probability and 95% confidence [9.6].

Finally, the minimum specified value of B10 areal density is divided by the lower tolerance limit of B10 volume density to arrive at the minimum plate thickness which provides the specified B10 areal density.

**Any plate which is thinner than the statistically derived minimum thickness from T.9.1.7.7 a) or the minimum design thickness, whichever is greater, shall be treated as non-conforming, with the following exception. Local depressions are acceptable, so long as they total no more than 0.5% of the area on any given plate, and the thickness at their location is not less than 90% of the minimum design thickness.** ***Edge effects due to manufacturing operations such as shearing, deburring, and chamfering need not be included in this determination.***

**Non-conforming material shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

T.9.1.7.8 Specification for Qualification Testing of Metal Matrix Composites

*CAUTION*

*Section T.9.1.7.8.3.1, Section T.9.1.7.8.4 and Section T.9.1.7.8.5 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 4) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

T.9.1.7.8.1 Applicability and Scope

Metal matrix composites (MMCs) acceptable for use in the 61BTH DSC are described in Section T.9.1.7.2.

Prior to initial use in a spent fuel dry storage or transport system, such MMCs shall be subjected to qualification testing that will verify that the product satisfies the design function. Key process controls shall be identified per Section T.9.1.7.9 so that the production material is equivalent to or better than the qualification test material. Changes to key processes shall be subject to qualification before use of such material in a spent fuel dry storage or transport system.

ASTM test methods and practices are referenced below for guidance. Alternative methods may be used with the approval of the Certificate Holder.

T.9.1.7.8.2 Design Requirements

In order to perform its design functions the product must have at a minimum sufficient strength and ductility for manufacturing and for the normal and accident conditions of the storage/ transport system. This is demonstrated by the tests in Section T.9.1.7.8.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section T.9.1.7.8.5.

T.9.1.7.8.3 Durability

There is no need to include accelerated radiation damage testing in the qualification. Such testing has already been performed on MMCs, and the results confirm what would be expected of materials that fall within the limits of applicability cited above. Metals and ceramics do not experience measurable changes in mechanical properties due to fast neutron fluences typical over the lifetime of spent fuel storage, about $10^{15}$ neutrons/cm$^2$.

Thermal damage and corrosion (hydrogen generation) testing shall be performed unless such tests on materials of the same chemical composition have already been performed and found acceptable. The following paragraphs illustrate two cases where such testing is not required.

Thermal damage testing is not required for unclad MMCs consisting only of boron carbide in an aluminum 1100 matrix, because there is no reaction between aluminum and boron carbide below 842°F, well above the basket temperature under normal conditions of storage or transport[3].

Corrosion testing is not required for MMCs (clad or unclad) consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

**T.9.1.7.8.3.1 Delamination Testing of Clad MMC**

**Clad MMCs shall be subjected to thermal damage testing following water immersion to ensure that delamination does not occur under normal conditions of storage.**

[3] Sung, C., "Microstructural Observation of Thermally Aged and Irradiated Aluminum/Boron Carbide ($B_4C$) Metal Matrix Composite by Transmission and Scanning Electron Microscope," 1998.

[4] Boralyn testing submitted to the NRC under docket 71-1027, 1998.

T.9.1.7.8.4 **Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity**

**At least three samples, one each from approximately the two ends and middle of the qualification material run shall be subject to:**

**a) room temperature tensile testing (ASTM- B557[5]) demonstrating that the material has the following tensile properties:**

- **Minimum yield strength, 0.2% offset: 1.5 ksi**
- **Minimum ultimate strength: 5 ksi**
- **Minimum elongation in 2 inches: 0.5%**

**As an alternative to the elongation requirement, ductility may be demonstrated by bend testing per ASTM E290[6]. The radius of the pin or mandrel shall be no greater than three times the material thickness, and the material shall be bent at least 90 degrees without complete fracture,**

**b) Testing to verify more than 98% of theoretical density for non-clad MMCs and 97% for the matrix of clad MMCs. Testing or examination for interconnected porosity on the faces and edges of unclad MMC, and on the edges of clad MMC shall be performed by a means to be approved by the Certificate Holder. The maximum interconnected porosity is 0.5 volume %,**

**and for at least one sample,**

**c) For MMCs with an integral aluminum cladding, thermal durability testing demonstrating that after a minimum 24 hour soak in either pure or borated water, then insertion into a preheated oven at approximately 825°F for a minimum of 24 hours, the specimens are free of blisters and delamination and pass the mechanical testing requirements described in test 'a' of this section.**

T.9.1.7.8.5 **Required Tests and Examinations to Demonstrate B10 Uniformity**

**Uniformity of the boron distribution shall be verified either by:**

**a) Neutron radioscopy or radiography (ASTM E94[7], E142[8], and E545[9]) of material from the ends and middle of the test material production run, verifying no more than 10% difference between the minimum and maximum B10 areal density, or**

**b) Quantitative testing for the B10 areal density, B10 density, or the boron carbide weight fraction, on locations distributed over the test material production run, verifying that one standard deviation in the sample is less than 10% of the sample mean. Testing may be performed by a neutron transmission method similar to that specified in Section T.9.1.7.7, or by chemical analysis for boron carbide content in the composite.**

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[5] ASTM B557 Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products

[6] ASTM E290, Standard Methods for Bend Testing of Materials for Ductility

[7] ASTM E94, Recommended Practice for Radiographic Testing

[8] ASTM E142, Controlling Quality of Radiographic Testing

[9] ASTM E545, Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing

T.9.1.7.8.6 Approval of Procedures

Qualification procedures shall be subject to approval by the Certificate Holder.

T.9.1.7.9 Specification for Process Controls for Metal Matrix Composites

> ***CAUTION***
>
> *Sections T.9.1.7.9.1 and T.9.1.7.9.2 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 4) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

T.9.1.7.9.1 **Applicability and Scope**

**Key processing changes shall be subject to qualification prior to use of the material produced by the revised process. The Certificate Holder shall determine whether a complete or partial re-qualification program per Section T.9.1.7.8 is required, depending on the characteristics of the material that could be affected by the process change.**

T.9.1.7.9.2 **Definition of Key Process Changes**

**Key process changes are those which could adversely affect the uniform distribution of the boron carbide in the aluminum, reduce density, reduce corrosion resistance, reduce the mechanical strength or ductility of the MMC.**

T.9.1.7.9.3 Identification and Control of Key Process Changes

The manufacturer shall provide the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer shall identify key process changes as defined in Section T.9.1.7.9.2.

An increase in nominal boron carbide content over that previously qualified shall always be regarded as a key process change. The following are examples of other changes that are established as key process changes, as determined by the Certificate Holder's review of the specific applications and production processes:

a) Changes in the boron carbide particle size specification that increase the average particle size by more than 5 microns or that increase the amount of particles larger than 60 microns from the previously qualified material by more than 5% of the total distribution but less than the 10% limit,

b) Change of the billet production process, e.g., from vacuum hot pressing to cold isostatic pressing followed by vacuum sintering,

c) Change in the nominal matrix alloy,

d) Changes in mechanical processing that could result in reduced density of the final product, e.g., for PM or thermal spray MMCs that were qualified with extruded material, a change to direct rolling from the billet,

e) For MMCs using a magnesium-alloyed aluminum matrix, changes in the billet formation process that could increase the likelihood of magnesium reaction with the boron carbide, such as an increase in the maximum temperature or time at maximum temperature,

f) Changes in powder blending or melt stirring processes that could result in less uniform distribution of boron carbide, e.g., change in duration of powder blending, and

g) For MMCs with an integral aluminum cladding, a change greater than 25% in the ratio of the nominal aluminum cladding thickness (sum of two sides of cladding) and the nominal matrix thickness could result in changes in the mechanical properties of the final product.

In no case shall process changes be accepted if they result in a product outside the limits in Sections 9.5.3.1 and 9.5.3.4.

## T.9.2 Maintenance Program

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

## T.9.3 References


9.1 ASME Boiler and Pressure Vessel Code, Section III, 2004 Edition with 2006 Addenda.

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

9.3 Deleted

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

9.5 "Aluminum Standards and Data, 2003" The Aluminum Association.

9.6 Natrella, "Experimental Statistics," Dover, 2005.

9.7 Deleted

9.8 Deleted

9.9 Deleted

9.10 Deleted

## Table T.9-1
## B10 Specification for the NUHOMS® 61BTH Poison Plates

| Basket Type | Specified Minimum B10 Areal Density for Borated Aluminum/MMC for 90% Credit ($g/cm^2$) | Specified Minimum B10 Areal Density for BORAL® for 75% Credit ($g/cm^2$) |
|---|---|---|
| Type 1 DSC | | |
| A | 0.021 | 0.025 |
| B | 0.032 | 0.038 |
| C | 0.040 | 0.048 |
| D | 0.048 | 0.058 |
| E | 0.055 | 0.066 |
| F | 0.062 | 0.075 |
| Type 2 DSC | | |
| A | 0.022 | 0.027 |
| B | 0.032 | 0.038 |
| C | 0.042 | 0.050 |
| D | 0.048 | 0.058 |
| E | 0.055 | 0.066 |
| F | 0.062 | 0.075 |

## Table U.3.1-2
## Alternatives to the ASME Code for the NUHOMS® 32PTH1 DSC Basket Assembly

(Part 1 of 2)

| Reference ASME Code Section/Article | Code Requirement | Alternatives, Justification & Compensatory Measures |
|---|---|---|
| NCA | All | Not compliant with NCA. Quality Assurance is provided according to 10 CFR 72 Subpart G in lieu of NCA-4000. |
| NCA-1140 | Use of Code editions and addenda | Code edition and addenda other than those specified in Section U.2 may be used for construction, but in no case earlier than 3 years before that specified in Section U.2.<br>Materials produced and certified in accordance with ASME Section II material specification from Code Editions and Addenda other than those specified in Section U.2 may be used, so long as the materials meet all the requirements of Article 2000 of the applicable Subsection of the Section III Edition and Addenda used for construction. |
| NG-1100 | Requirements for Code Stamping of Components, Code reports and certificates, etc. | Code Stamping is not required. As Code Stamping is not required, the fabricator is not required to hold an ASME "N" or "NPT" stamp, or to be ASME Certified. |
| NG-2000 | Use of ASME Material | Some baskets include neutron absorber and aluminum plates that are not ASME Code Class 1 material. They are used for criticality safety and heat transfer, and are only credited in the structural analysis with supporting their own weight and transmitting bearing loads through their thickness. Material properties in the ASME Code for Type 6061 aluminum are limited to 400°F to preclude the potential for annealing out the hardening properties. Annealed properties (as published by the Aluminum Association and the American Society of Metals) are conservatively assumed for the aluminum transition rails for use above the Code temperature limits. |
| NG-2130 | Material must be supplied by ASME approved material suppliers. | Material is certified to meet all ASME Code criteria but is not eligible for certification or Code Stamping if a non-ASME fabricator is used. As the fabricator is not required to be ASME certified, material certification to $\boxed{NG}$ -2130 is not possible. Material traceability and certification are maintained in accordance with TN's NRC approved QA program. |
| NG-4121 | Material Certification by Certificate Holder | |
| NG-8000 | Requirements for nameplates, stamping & reports per NCA-8000 | The NUHOMS® DSC nameplate provides the information required by 10CFR71, 49CFR173 and 10CFR72 as appropriate. Code stamping is not required for the DSC. QA data packages are prepared in accordance with the requirements of TN's approved QA program. |
| NG-3000/ Section II, Part D, Table 2A | Maximum temperature limit for Type 304 plate material is 800°F. | Not compliant with ASME Section II Part D Table 2A material temperature limit for Type 304 steel for the postulated transfer accident case (117°F, loss of sunshade, loss of neutron shield) and blocked vent accident (117°F, 40 hr). The calculated maximum steady state temperatures for transfer accident case and blocked vent accident case are less than 1000°F. The only primary stresses in the basket grid are deadweight stresses. The ASME Code allows use of SA240 Type 304 stainless steel to temperatures up to 1000°F, as shown in ASME Code, Section II, Part D, Table 1A. In the temperature range of interest (near 800°F), the $S_m$ values for SA240 Type 304 shown in ASME Code, Section II Part D, Table 2A are identical to the allowable S values for the same material shown in Section B, Part D, Table 1A. The recovery actions following these accident scenarios are as described in the UFSAR. |

## U.9 Acceptance Tests and Maintenance Program

### U.9.1 Acceptance Tests

The pre-operational testing requirements for the NUHOMS® system are given in Chapter 9.0, with the exceptions described in the following sections. The NUHOMS®-32PTH1 DSC has been enhanced to provide leaktight confinement and the basket includes an updated poison plate design. Additional acceptance testing of the NUHOMS®-32PTH1 DSC welds and of the poison plates are described.

#### U.9.1.1 Visual Inspection

Visual inspections are performed at the fabricator's facility to ensure that the DSC, the Transfer Cask and the HSM conform to the drawings and specifications. The visual inspections include weld, dimensional, surface finish, and cleanliness inspections. Visual inspections specified by codes applicable to a component are performed in accordance with the requirements and acceptance criteria of those codes.

All weld inspection is performed using qualified processes and qualified personnel according to the applicable code requirements, e.g., ASME or AWS. Non-destructive examination (NDE) requirements for welds are specified on the drawings provided in Chapter U.1; acceptance criteria are as specified by the governing code. NDE personnel are qualified in accordance with SNT-TC-1A [9.2].

The confinement welds on the DSC are inspected in accordance with ASME B&PV Code Subsection NB [9.1] including alternatives to ASME Code specified in Section U.3.1.2.3.

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

#### U.9.1.2 Structural

The DSC confinement boundary except the inner top cover/shield plug to the DSC shell weld is pressure tested at the fabricator's shop in accordance with ASME Article NB-6300. The test pressure is set between 22.5 to 24.0 psig for 32PTH1 DSC for future 10CFR71 application. This bounds the 1.1xDSC design pressure of 15 psig.

The inner top cover/shield plug to the DSC shell weld is also pressure tested between 22.5 to 24.0 psig for 32PTH1 DSC at the field after the fuel assemblies are loaded in the DSC. This test is in accordance with the alternatives to the ASME Code specified in Section U.3.1.2.3.

HSM-H reinforcement and concrete are tested as described in Section U.3.4.2.

#### U.9.1.3 Leak Tests

DSC confinement welds in the DSC shell and bottom are leak tested at the fabricator's shop to an acceptance criterion of $1 \times 10^{-7}$ ref $cm^3/s$, i.e., "leaktight" as defined in ANSI N14.5 [9.4].

Personnel performing the leak test are qualified in accordance with SNT-TC-1A [9.2].

The weld between the DSC shell and inner top cover and the siphon/vent cover welds are also leak tested to an acceptance criteria of 1 x $10^{-7}$ ref $cm^3/s$ in the field after the fuel assemblies are loaded in the canister.

U.9.1.4 Components

The NUHOMS® System does not include any components such as valves, rupture discs, pumps, or blowers. The gaskets in the Transfer Cask do not require acceptance testing other than the leak testing cited above. No other components of the NUHOMS® System require testing, except as discussed in this chapter.

U.9.1.5 Shielding Integrity

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. For example, for a 6" × 6" grid, the detector will encompass a 6" × 6" square. 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 proprietary polymer resin. The shielding performance of the resin will be assured by written procedures controlling temperature, measuring, and mixing of the components, degassing of the resin, and verification of the mass or volume of resin installed.

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.

U.9.1.6 Thermal Acceptance

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, as specified in Section U.4.3. Because these materials do not have publicly documented values for thermal conductivity, testing of such materials will be performed in accordance with Section U.9.1.7.6.

U.9.1.7 Poison Acceptance

| |
|---|
| ***CAUTION*** |
| *Sections U.9.1.7.1 through U.9.1.7.4 below are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 5) and shall not be deleted or altered in any way without approval from the NRC. The text of these sections is shown in bold type to distinguish it from other sections.* |

The neutron absorber used for criticality control in the DSC basket may consist any of the following types of material:

(a) Borated aluminum

(b) Boron carbide/aluminum metal matrix composite (MMC)

(c) BORAL®

The 32PTH1 DSC safety analyses do not rely upon the tensile strength of these materials. The radiation and temperature environment in the cask is not sufficiently severe to damage these metallic/ceramic materials. To assure performance of the neutron absorber's design function only the presence of B10 and the uniformity of its distribution need to be verified, with testing requirements specific to each material. The boron content for these materials is given in Table U.9-1.

References to metal matrix composites throughout this chapter are not intended to refer to BORAL®, which is described later in this section.

U.9.1.7.1 **Borated Aluminum**

**See the Caution in Section U.9.1.7 before deletion or modification to this section.**

**The material is produced by direct chill (DC) or permanent mold casting with boron precipitating primarily as a uniform fine dispersion of discrete $AlB_2$ or $TiB_2$ particles in the matrix of aluminum or aluminum alloy (other boron compounds, such as $AlB_{12}$, can also occur). For extruded products, the $TiB_2$ form of the alloy shall be used. For rolled products, either the $AlB_2$, the $TiB_2$, or a hybrid may be used.**

**Boron is added to the aluminum in the quantity necessary to provide the specified minimum B10 areal density in the final product. The amount required to achieve the specified minimum B10 areal density will depend on whether boron with the natural isotopic distribution of the isotopes B10 and B11, or boron enriched in B10 is used. In no case shall the boron content in the aluminum or aluminum alloy exceed 5% by weight.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of borated aluminum. The basis for this credit is the B10 areal density acceptance testing, which shall be as specified in Section U.9.1.7.7. The specified acceptance testing assures that at any location in the material, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

U.9.1.7.2 **Boron Carbide/Aluminum Metal Matrix Composites (MMC)**

**See the Caution in Section U.9.1.7 before deletion or modification to this section.**

**The material is a composite of fine boron carbide particles in an aluminum or aluminum alloy matrix. The material shall be produced by either direct chill casting, permanent mold casting, powder metallurgy, or thermal spray techniques. The boron carbide content shall not exceed 40% by volume. The boron carbide content for MMCs with an integral aluminum cladding shall not exceed 50% by volume.**

**The final MMC product shall have density greater than 98% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity. For MMC with an integral cladding, the final density of the core shall be greater than 97% of theoretical density demonstrated by qualification testing, with no more than 0.5 volume % interconnected porosity of the core and cladding as a unit of the final product.**

***At least 50% by weight of the $B_4C$ particles in MMCs shall be smaller than 40 microns. No more than 10% of the particles shall be over 60 microns.***

**Prior to use in the 32PTH1 DSC, MMCs shall pass the qualification testing specified in Section U.9.1.7.8, and shall subsequently be subject to the process controls specified in Section U.9.1.7.9.**

**The criticality calculations take credit for 90% of the minimum specified B10 areal density of MMCs. The basis for this credit is the B10 areal density acceptance testing, which is specified in Section U.9.1.7.7. The specified acceptance testing assures that at any location in the final product, the minimum specified areal density of B10 will be found with 95% probability and 95% confidence.**

U.9.1.7.3 **BORAL®**

**See the Caution in Section U.9.1.7 before deletion or modification to this section.**

**This material consists of a core of aluminum and boron carbide powders between two outer layers of aluminum, mechanically bonded by hot-rolling an "ingot" consisting of an aluminum box filled with blended boron carbide and aluminum powders. The core, which is exposed at the edges of the sheet, is slightly porous. Before rolling, at least 80% by weight of the $B_4C$ particles in BORAL® shall be smaller than 200 microns. The nominal boron carbide content shall be limited to 65% (+ 2% tolerance limit) of the core by weight.**

**The criticality calculations take credit for 75% of the minimum specified B10 areal density of BORAL®. B10 areal density will be verified by chemical analysis and by certification of the B10 isotopic fraction for the boron carbide powder, or by neutron transmission testing. Areal density testing is performed on a coupon taken from the sheet produced from each ingot. If the measured areal density is below that specified, all the material produced from that ingot will be either rejected, or accepted only on the basis of alternate verification of B10 areal density for each of the final pieces produced from that ingot.**

U.9.1.7.4 **Visual Inspections of Neutron Absorbers**

**See the Caution in Section U.9.1.7 before deletion or modification to this section.**

**Neutron absorbers shall be 100% visually inspected in accordance with the Certificate Holder's QA procedures. Material that does not meet the following acceptance criteria shall be reworked, repaired, or scrapped. Blisters shall be treated as non-conforming. Inspection of MMCs with an integral aluminum cladding shall also include verification that the matrix is not exposed through the faces of the aluminum cladding and that solid aluminum is not present at the edges. For Boral, visual inspection shall verify that there are no cracks through the cladding, exposed core on the face of the sheet, or solid aluminum at the edge of the sheet.**

U.9.1.7.5 Other Visual Inspections Criteria (non-Technical Specifications)

For borated aluminum and MMCs, visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4, "Quality Control, Visual Inspection of Aluminum Mill Products" [9.5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable.

U.9.1.7.6 Thermal Conductivity Testing

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. Previous testing of borated aluminum and metal matrix composite shows that thermal conductivity increases slightly with temperature. Initial sampling shall be one test per lot, defined by the heat or ingot, and may be reduced if the first five tests meet the specified minimum thermal conductivity.

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 U.4.3*

*In cases where the specified thickness of the neutron absorber may vary, the equations*

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[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"**

*introduced in Section U.4.3 shall be used to determine the minimum required effective thermal conductivity.*

*The thermal conductivity test requirement does not apply to aluminum that is paired with the neutron absorber.*

U.9.1.7.7 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

> ***CAUTION***
>
> *Portions of Section U.9.1.7.7 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 5) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.*

**a) Neutron Transmission acceptance testing procedures shall be subject to approval by the Certificate Holder. Test coupons shall be removed from the rolled or extruded production material at locations that are systematically or probabilistically distributed throughout the lot. Test coupons shall not exhibit physical defects that would not be acceptable in the finished product, or that would preclude an accurate measurement of the coupon's physical thickness.**

**A lot is defined as all the pieces produced from a single ingot or heat or from a group of billets from the same heat. If this definition results in lot size too small to provide a meaningful statistical analysis of results, an alternate larger lot definition may be used, so long as it results in accumulating material that is uniform for sampling purposes.**

**The sampling rate for neutron transmission measurements shall be such that there is at least one neutron transmission measurement for each 2000 square inches of final product in each lot.**

**The B10 areal density is measured using a collimated thermal neutron beam up to 1.1 inch diameter.**

**The neutron transmission through the test coupons is converted to B10 areal density by comparison with transmission through calibrated standards. These standards are composed of a homogeneous boron compound without other significant neutron absorbers. For example, boron carbide, zirconium diboride or titanium diboride sheets are acceptable standards. These standards are paired with aluminum shims sized to match the effect of neutron scattering by aluminum in the test coupons. Uniform but non-homogeneous materials such as metal matrix composites may be used for standards, provided that testing shows them to provide neutron attenuation equivalent to a homogeneous standard. Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross section of B10 at that energy.**

**Alternatively, digital image analysis may be used to compare neutron radioscopic images of**

**the test coupon to images of the standards. The area of image analysis shall be no more than 0.75 sq. inch.**

**The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. If a goodness-of-fit test demonstrates that the sample comes from a normal population, the one-sided tolerance limit for a normal distribution may be used for this purpose. Otherwise, a non-parametric (distribution-free) method of determining the one-sided tolerance limit may be used. Demonstration of the one-sided tolerance limit shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

b) The following illustrates one acceptable method and is intended to be utilized as an example. Therefore, the following text is not part of the Technical Specifications. The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The B10 areal densities determined by neutron transmission are converted to volume density, i.e., the B10 areal density is divided by the thickness at the location of the neutron transmission measurement or the maximum thickness of the coupon. The lower tolerance limit of B10 volume density is then determined, defined as the mean value of B10 volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor with 95% probability and 95% confidence [9.6].

Finally, the minimum specified value of B10 areal density is divided by the lower tolerance limit of B10 volume density to arrive at the minimum plate thickness which provides the specified B10 areal density.

**Any plate which is thinner than the statistically derived minimum thickness from U.9.1.7.7 a) or the minimum design thickness, whichever is greater, shall be treated as non-conforming, with the following exception. Local depressions are acceptable, so long as they total no more than 0.5% of the area on any given plate, and the thickness at their location is not less than 90% of the minimum design thickness. *Edge effects due to manufacturing operations such as shearing, deburring, and chamfering need not be included in this determination.***

**Non-conforming material shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.**

U.9.1.7.8 Specification for Qualification Testing of Metal Matrix Composites

| ***CAUTION*** |
|---|
| Section U.9.1.7.8.3.1, Section U.9.1.7.8.4, and Section U.9.1.7.8.5, are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 5) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections. |

U.9.1.7.8.1 Applicability and Scope

Metal matrix composites (MMCs) acceptable for use in the 32PTH1 DSC are described in Section U.9.1.7.2.

Prior to initial use in a spent fuel dry storage or transport system, such MMCs shall be subjected to qualification testing that will verify that the product satisfies the design function. Key process controls shall be identified per Section U.9.1.7.9 so that the production material is equivalent to or better than the qualification test material. Changes to key processes shall be subject to qualification before use of such material in a spent fuel dry storage or transport system.

ASTM test methods and practices are referenced below for guidance. Alternative methods may be used with the approval of the Certificate Holder.

U.9.1.7.8.2 Design Requirements

In order to perform its design functions the product must have at a minimum sufficient strength and ductility for manufacturing and for the normal and accident conditions of the storage/ transport system. This is demonstrated by the tests in Section U.9.1.7.8.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section U.9.1.7.8.5.

U.9.1.7.8.3 Durability

There is no need to include accelerated radiation damage testing in the qualification. Such testing has already been performed on MMCs, and the results confirm what would be expected of materials that fall within the limits of applicability cited above. Metals and ceramics do not experience measurable changes in mechanical properties due to fast neutron fluences typical over the lifetime of spent fuel storage, about $10^{15}$ neutrons/cm$^2$.

Thermal damage and corrosion (hydrogen generation) testing shall be performed unless such tests on materials of the same chemical composition have already been performed and found acceptable. The following paragraphs illustrate two cases where such testing is not required.

Thermal damage testing is not required for unclad MMCs consisting only of boron carbide in an aluminum 1100 matrix, because there is no reaction between aluminum and boron carbide below

842°F, well above the basket temperature under normal conditions of storage or transport[3].

Corrosion testing is not required for MMCs (clad or unclad) consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

U.9.1.7.8.3.1 Delamination Testing of Clad MMC

**Clad MMCs shall be subjected to thermal damage testing following water immersion to ensure that delamination does not occur under normal conditions of storage.**

U.9.1.7.8.4 **Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity**

**At least three samples, one each from approximately the two ends and middle of the qualification material run shall be subject to:**

a) **room temperature tensile testing (ASTM- B557[5]) demonstrating that the material has the following tensile properties:**
   - **Minimum yield strength, 0.2% offset: 1.5 ksi**
   - **Minimum ultimate strength: 5 ksi**
   - **Minimum elongation in 2 inches: 0.5%**

   **As an alternative to the elongation requirement, ductility may be demonstrated by bend testing per ASTM E290[6]. The radius of the pin or mandrel shall be no greater than three times the material thickness, and the material shall be bent at least 90 degrees without complete fracture,**

b) **Testing to verify more than 98% of theoretical density for non-clad MMCs and 97% for the matrix of clad MMCs. Testing or examination for interconnected porosity on the faces and edges of unclad MMC, and on the edges of clad MMC shall be performed by a means to be approved by the Certificate Holder. The maximum interconnected porosity is 0.5 volume %,**

**and for at least one sample,**

c) **For MMCs with an integral aluminum cladding, thermal durability testing demonstrating that after a minimum 24 hour soak in either pure or borated water, then insertion into a preheated oven at approximately 825°F for a minimum of 24 hours, the specimens are free of blisters and delamination and pass the mechanical testing requirements described in test 'a' of this section.**

U.9.1.7.8.5 **Required Tests and Examinations to Demonstrate B10 Uniformity**

**Uniformity of the boron distribution shall be verified either by:**

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3 Sung, C., "Microstructural Observation of Thermally Aged and Irradiated Aluminum/Boron Carbide ($B_4C$) Metal Matrix Composite by Transmission and Scanning Electron Microscope," 1998.

4 Boralyn testing submitted to the NRC under docket 71-1027, 1998.

5 **ASTM B557 Standard Test Methods of Tension Testing Wrought and Cast Aluminum and Magnesium-Alloy Products**

6 **ASTM E290, Standard Methods for Bend Testing of Materials for Ductility**

a) **Neutron radioscopy or radiography (ASTM E94[7], E142[8], and E545[9] of material from the ends and middle of the test material production run, verifying no more than 10% difference between the minimum and maximum B10 areal density, or**

b) **Quantitative testing for the B10 areal density, B10 density, or the boron carbide weight fraction, on locations distributed over the test material production run, verifying that one standard deviation in the sample is less than 10% of the sample mean. Testing may be performed by a neutron transmission method similar to that specified in Section U.9.1.7.7, or by chemical analysis for boron carbide content in the composite.**

U.9.1.7.8.6 Approval of Procedures

Qualification procedures shall be subject to approval by the Certificate Holder.

U.9.1.7.9 Specification for Process Controls for Metal Matrix Composites

| *CAUTION* |
|---|
| *Sections U.9.1.7.9.1 and U.9.1.7.9.2 are incorporated by reference into the NUHOMS® CoC 1004 Technical Specification 4.1 (Note 5) and shall not be deleted or altered in any way without approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.* |

U.9.1.7.9.1 **Applicability and Scope**

**Key processing changes shall be subject to qualification prior to use of the material produced by the revised process. The Certificate Holder shall determine whether a complete or partial re-qualification program per Section U.9.1.7.8 is required, depending on the characteristics of the material that could be affected by the process change.**

U.9.1.7.9.2 **Definition of Key Process Changes**

**Key process changes are those which could adversely affect the uniform distribution of the boron carbide in the aluminum, reduce density, reduce corrosion resistance, reduce the mechanical strength or ductility of the MMC.**

U.9.1.7.9.3 Identification and Control of Key Process Changes

The manufacturer shall provide the Certificate Holder with a description of materials and process controls used in producing the MMC. The Certificate Holder and manufacturer shall identify key process changes as defined in Section U.9.1.7.9.2.

An increase in nominal boron carbide content over that previously qualified shall always be regarded as a key process change. The following are examples of other changes that are

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[7] **ASTM E94, Recommended Practice for Radiographic Testing**

[8] **ASTM E142, Controlling Quality of Radiographic Testing**

[9] **ASTM E545, Standard Method for Determining Image Quality in Thermal Neutron Radiographic Testing**

established as key process changes, as determined by the Certificate Holder's review of the specific applications and production processes:

a) Changes in the boron carbide particle size specification that increase the average particle size by more than 5 microns or that increase the amount of particles larger than 60 microns from the previously qualified material by more than 5% of the total distribution but less than the 10% limit,

b) Change of the billet production process, e.g., from vacuum hot pressing to cold isostatic pressing followed by vacuum sintering,

c) Change in the nominal matrix alloy,

d) Changes in mechanical processing that could result in reduced density of the final product, e.g., for PM or thermal spray MMCs that were qualified with extruded material, a change to direct rolling from the billet,

e) For MMCs using a magnesium-alloyed aluminum matrix, changes in the billet formation process that could increase the likelihood of magnesium reaction with the boron carbide, such as an increase in the maximum temperature or time at maximum temperature,

f) Changes in powder blending or melt stirring processes that could result in less uniform distribution of boron carbide, e.g., change in duration of powder blending, and

g) For MMCs with an integral aluminum cladding, a change greater than 25% in the ratio of the nominal aluminum cladding thickness (sum of two sides of cladding) and the nominal matrix thickness could result in changes in the mechanical properties of the final product.

In no case shall process changes be accepted if they result in a product outside the limits in Sections 9.5.3.1 and 9.5.3.4

### U.9.2 Maintenance Program

The NUHOMS®-32PTH1 system is a totally passive system and therefore will require little, if any, maintenance over the lifetime of the ISFSI. Typical NUHOMS®-32PTH1 system maintenance tasks will be performed in accordance with the UFSAR.

## U.9.3 References


9.1 ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition through 2000 Addenda.

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

9.3 Deleted.

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

9.5 "Aluminum Standards and Data, 2003," The Aluminum Association.

9.6 Natrella, "Experimental Statistics," Dover, 2005.

9.7 Deleted.

9.8 Deleted.

9.9 Deleted.

9.10 Deleted.

**Table U.9-1**
**B10 Specification for the NUHOMS® 32PTH1 Poison Plates**

| Poison Type | 32PTH1 Basket Type | Minimum Poison Loading (B10 mg/cm$^2$) | % Credit Used in Criticality Analysis |
|---|---|---|---|
| Borated Aluminum MMC | 1A or 2A | 7 | 90 |
| | 1B or 2B | 15 | |
| | 1C or 2C | 20 | |
| | 1D or 2D | 32 | |
| | 1E or 2E | 50 | |
| BORAL® | 1A or 2A | 9 | 75 |
| | 1B or 2B | 19 | |
| | 1C or 2C | 25 | |
| | 1D or 2D | N/A | |
| | 1E or 2E | N/A | |

**Table W.3-1**
**Summary of OS197L TC Weights**

| *Item* | *Weight Configuration* | |
|---|---|---|
| | ***Wet (lbs)*** | ***Dry (lbs)*** |
| *OS197L Cask Body with Neutron Shield Assembly* | *52,236* | *52,236* |
| *Neutron Shield Water* | *4,606* | *4,606* |
| *Top Cask Lid* | *-* | *5,147* |
| *Water in DSC and DSC/TC Annulus* | *12,708* | *-* |
| *Bounding Nominal Payload* (1) | *99,133* | *102,222* |
| *Loaded OS197L TC Total Nominal Weight* (2) | *168,683* (84.3 tons) | *164,211* (82.1 tons) |

*Notes:*

(1) *Bounding of 32PT and 61BT DSCs*

(2) *The weight does not include the decontamination area shielding or the support skid supplemental shielding*

DSC. These tables also provide assurance that single fuel assembly decay heat limits shown in Appendix W.2, Figure W.2-1 and *Figure* W.2-2 are not exceeded.

### W.5.1 Discussion and Results

A summary of the bounding maximum dose rates on and around the OS197L TC with the 61BT or 32PT DSC during loading and transfer operations during normal and accident conditions are shown in Table W.5-3 and Table W.5-4, respectively. The bounding maximum dose rates *for* various shielding configurations of the OS197L TC with the 61BT or 32PT DSC during the various operational evolutions for normal, off-normal and accident conditions, at various locations are shown in Table W.5-6 through Table W.5-14. *The total dose rates shown in these tables correspond to the maximum dose rates for the various shielding configurations.* A brief description of the various shielding configurations evaluated herein for various loading and transfer operations is provided *in* Figure W.5-1 and in Section W.5.4.10.

A discussion of the method used to determine the bounding source terms for this evaluation is included in Section W.5.2. The shielding material densities are given in Section W.5.3. The *model specification and the* method used to determine the dose rates due to 32 PWR or 61 BWR allowed fuel assemblies in the various OS197L TC design configurations with 32PT DSC and 61BT DSC payload is provided in Section W.5.4. The radiological source terms are calculated with the SAS2H/ORIGEN-S modules of SCALE 4.4 [5.1] for the spent fuel contents. The shielding evaluation is performed with the MCNP5 [5.2] code with the ENDF/B-VI cross section library.

#### W.5.1.1 Dose Rates Near Shielding Configurations Containing 32PT and 61BT DSC

In general, *the* intensity and shape of *the* radiation field distribution around a shielding configuration is determined by two factors: *(*1) *the* intensity and spatial distribution of radiological sources, and *(*2) *the* shielding properties and spatial configuration of shielding materials. Also note that the maximum of gamma and neutron radiation dose rates may occur at different locations. Therefore the maximum of total dose rate is not necessarily equal to the sum of the maximum gamma and maximum neutron dose rates.

The bounding radiological source terms employed herein are shown in Table W.5-1 and Table W.5-2 for the 32PT DSC and 61BT DSC, respectively. Such sources result in bounding dose rates from 32PT and 61BT DSC contents of the cask when compared with other radiological sources at various burnup, enrichment, and cooling time combinations shown in *the FQTs*. Neutron radiation dose rates near the OS197L bare cask containing a 32PT DSC bounding sources are bounding for the neutron radiation dose rates from the cask containing the 61BT DSC bounding sources.

The data presented in Tables W.5-6 through Table W.5-14 are based on MCNP calculated dose rates. There is always a statistical uncertainty in the results obtained using a Monte Carlo method like MCNP.

Because of axial symmetry of the shielding materials distribution on the side of the cask and the DSCs and in the distribution of radiological sources, it is convenient to consider dose rate distribution along the cask side in a cylindrical coordinate system with an axis that coincides with the axis of the cask/DSC. In general, dose rate is dependent on all three coordinates: axial,

### W.5.1.3 Bounding Dose Rates as a Function of Axial Distance

For the dose rates on top of the cask, two radial regions need to be considered: within and beyond the cask radius. These radial regions are depicted in Figure W.5-3. Dose rates beyond the cask radius are *due* to radiation from the side of the cask and through shielding on its top. Because there is substantially less shielding and sources are stronger (because of the in-core region) on the side, the contribution by radiation from the side is dominating. On the other hand, dose rates just over the ends of the cask at radial distances within the cask radius are contributed *due* to radiation through shielding over the ends of fuel assemblies. *Further, the contribution to the top end dose rates due to scattering through the radial shielding layers, including the water neutron shield, is minimized at distances within the radius of the cask.* It is assumed that the water neutron shielding on the side of the cask is lost during the accident. Therefore, accident and normal condition dose rates on top of the cask are not different when radial distances less than the radius of the cask are under consideration. Hence, the dose rates on the TC axis (r=0) and at r<= TC radius are applicable for both normal and accident conditions at "short" or relatively "closer" axial distances. Here the axial distance is the distance from the cask end when dose rate distribution becomes uniform (i.e., maximum and average dose rates are *approximately the same*). For the axial dose rates, this occurs at distances greater than 10.0 meters. Because shielding properties on the top of the various configurations are identical, dose rates at these axial distances are the same for various shielding configurations when radial distances less than the cask radius are considered.

When the cask is ready for transfer to the ISFSI, there is at least 12.1" of steel and 2.0" of NS3 over the top of the fuel assemblies for the 32PT DSC. The shielding of steel on top of the 61BT DSC is 1.5" thinner. At the same time, primary gamma and neutron radiation sources (in the two energy groups that are the dominant contributors to the *PGR* dose rates, 1.00 to 1.33 and 1.33 to 1.66 MeV) are by a factor of ~3.1 and 4.8 stronger in the central compartments of the 32PT DSC, respectively. It is established in the shielding analysis that such a difference makes the TC dose rates with the 32PT DSC source, bounding. Also, dose rates in *Chapter* M.5, Table M.5-5 are calculated with a model having the geometry depicted in Figure M.5-24. The model uses 2.45" of NS3 but only 9.75" of steel. The model distributes 32PT DSC design basis *(DB)* radiological sources from 1.2 kW/FA assemblies *(conservatively)* in 16 peripheral fuel compartments instead of 8 peripheral compartments at the corners of the DSC basket structural grid.

This makes the total top dose rates predicted with the shielding model of UFSAR Appendix M very conservative. For the OS197L TC, the dose rates on top of the cask depicted on Figure M.5-24 and presented in Table M.5-5 are bounding for the dose rates on top of the OS197L cask containing a 32PT DSC when radial locations bounded by the bare cask radius are under consideration. Therefore, dose rates *on the* top of the reference shielding configuration presented in Table M.5-5 are bounding for dose rates on the top of the OS197L containing a *61BT* or *32PT* DSC *with contents bounded by* source *term*s presented in Table W.5-1 and Table W.5-2, *respectively.*

### W.5.2 Source Specification

The radiological source terms are calculated with the SAS2H/ORIGEN-S modules of SCALE 4.4 [5.1] for the fuel. The computational model of the *DB* PWR fuel from Appendix M.5 is directly utilized, as appropriate, to calculate the bounding radiological source *term*s due to modification above, the cask surface dose rate is dominated by gamma. *T*he presence of steel will result in a net reduction in the total dose rate in the vicinity of the seams.

The seam between the two halves of the neutron shield is 1.5 inches wide and is "filled" with 3 inches of steel instead of water. The calculational MCNP model did not explicitly include the seam between the two halves of the neutron shield. *Instead,* the neutron shield shell is modeled as if it was continuous. This is conservative as the region around the weld seams represents an area of dose *rate* depression due to superior gamma shielding. The justification for such a representation is provided below.

The maximum dose rate at the surface of the OS197L cask with water in the neutron shield, from Table W.5-3 *(Case #3-3),* is approximately 9,840 mrem/*hr* (320 mrem/hr neutron and 9520 mrem/hr gamma). The maximum dose rate at the surface of the OS197L cask in the vicinity of the seams, from Table W.5-*4 (Case #4-4),* is approximately *1550* mrem/hr *(1470* mrem/hr neutron and *540* mrem/hr gamma). *Note that the dose rate values shown herein are rounded up from those shown in Table W.5-3 and Table W.5-4.* This dose rate is not calculated using an explicit model of the weld seams but calculated with an equivalent (conservative) model. For this model, the OS197L cask model includes no water in the annulus and neutron shield shell and also includes *a* 2.50" thick steel shell. This is *a conservative* representati*on* of the weld seam region with no water and a thickness of 3.00" of steel. These results are conservative since the thickness of the seam is 3.00" instead of 2.50" employed in the model. These results demonstrate that there is a substantial dose rate reduction in the vicinity of the seams since the dose rate distribution on and around the cask *is* dominated (>95%) by gamma sources.

#### W.5.4.9 Accident Models

Accident condition models are those where the OS197L cask and its contents (32PT or 61BT DSC with design basis fuel) are modeled with loss of shielding arising out of hypothetical accident conditions. Loss of water in the neutron shielding is the most common consequence of these accidents. The accident condition MCNP models are similar to the normal condition MCNP models except that the *water in the neutron shield* is replaced with air.

The radial dose rates as a function of distance for selected distances are summarized in Table W.5-4. The bounding axial dose rates are discussed in Section W.5.1.3. These accident configurations are described below:

- The first configuration involves the OS197L cask in the supplemental trailer shielding with loss of water in the neutron shield. Dose rate*s* at certain radial distances for this configuration are shown in Table W.5-4 *(Case #4-3) (*see data related to OS197L TC (with *s*upplemental *i*nner & *o*uter *trailer s*hielding)*).*

- The second configuration involves the OS197L cask in the supplemental trailer shielding with*out the* outer top supplemental *trailer* shielding and *without* water in the neutron shield. Dose rate*s* at certain radial distances for this configuration are shown in Table W.5-4 *(Case #4-4) (*see data related to OS197L TC (with *s*upplemental *i*nner *trailer s*hielding *only*)*).*

## Table W.5-3
## Summary *of* OS197L TC Normal Condition Bounding Dose Rates

| *Case #* | Transfer Cask Configuration | Dose Rate[(5)] Component | Dose Rates (mrem/hr) at Different Distances from Side Surface Normal Condition–Water in Neutron Shield: On Side Surface | 4.57 meters (15') | 100 meters | 609.9 meters (2000') |
|---|---|---|---|---|---|---|
| *3-1* | UFSAR (Table M.5-5 and Section M.11.2.5.3) | Neutron | 261 | Not calc. | Not calc. | Not calc. |
| | | Gamma | 784 | Not calc. | Not calc. | Not calc. |
| | | Total | 950 | Not calc. | Not calc. | 0.01 |
| 3-2 | OS197 TC[(1)] *Results are directly shown in this table.* | Neutron | 102 | 7.20 | 0.006 | 7.09e-6 |
| | | Gamma | 248 | 20.3 | 0.03 | 5.29e-5 |
| | | Total | 346 | 25.9 | 0.03 | 5.67e-5 |
| 3-3 | OS197L TC bare cask *(Maximum from Table W.5-6 and Table W.5-9)* | Neutron | 323 | 22..4 | 0.022 | 1.51e-5 |
| | | Gamma | 9,521 | 824 | 1.41 | 1.45e-3 |
| | | Total | 9,835 | 845 | 1.42 | 1.46e-3 |
| 3-4 | OS197L TC with decontamination area *cask* or supplemental trailer shielding[(2,4)] *Table W.5-13* | Neutron | *27.9* | 4.00 | 0.02 | 1.32e-5 |
| | | Gamma | *39.5* | 25.0 | 0.08 | 1.83e-4 |
| | | Total | *60.6* | 29.0 | 0.10 | 1.96e-4 |
| 3-5 | OS197L TC without the outer top supplemental trailer shielding[(3,4)] *Table W.5-12* | Neutron | *58.6* | 4.30 | 0.02 | 8.20e-5 |
| | | Gamma | 336 | *36.7* | 0.17 | 6.32e-4 |
| | | Total | 394 | *40.8* | 0.20 | 7.14e-4 |

(1) Dose rates are due to 32PT DSC design basis radiological sources. *These are calculated to compare against those shown for the OS197 TC in the UFSAR, shown in this table as Case #3-1.*

(2) The dose rates are also applicable to the cask on trailer at vertical elevations above the trailer support skid. These are dose rates a person could potentially be exposed when doing manual operations at altitudes above the trunnions level; for example, traversing the crane bridge above the OS197L. Use data in *Table W.5-14* for dose rates below the trailer support skid.

(3) The dose rates are applicable for radial locations over *the* 2.5" thick inner top supplemental trailer shielding *prior to the installation of the outer top trailer shielding. These dose rates do not reflect those at radial distances from the side of the trailer.* Use data in *Table W.5-14* for dose rates below the trailer support skid.

*(4) Table W.5-14 dose rates below the trailer support skid do not account for shielding from the trailer gear boxes, wheels assembly that may provide substantial shielding at certain locations near the trailer platform. Therefore, they represent a conservative estimate.*

*(5) Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-4**
**Summary *of* OS197L TC Accident Condition Bounding Dose Rates**

| Case # | Transfer Cask Configuration | Dose Rate[(5)] Component | Dose Rates (mrem/hr) at Different Distances from Side Surface Accident Condition–No Water in Neutron Shield — On Side Surface | 4.57 meters (15') | 100 meters | 609.9 meters (2000') |
|---|---|---|---|---|---|---|
| *4-1* | UFSAR (*Table M.5-3,* Table M.11-2) | Neutron | 3,780 | Not calc. | Not calc. | Not calc. |
| | | Gamma | 1,070 | Not calc. | Not calc. | Not calc. |
| | | Total | 4,640 | Not calc. | Not calc. | < 0.02 |
| *4-2* | *UFSAR (Table K.5-2, Table K.11-4)* | Neutron | *3,700* | *Not calc.* | *Not calc.* | *Not calc.* |
| | | Gamma | *4,820* | *Not calc.* | *Not calc.* | *Not calc* |
| | | Total | *8,520* | *Not calc* | *Not calc* | *< 0.02* |
| *4-3* | OS197L TC[(1, 3)] (with supplemental inner & outer trailer shielding) *Results are directly shown in this table.* | Neutron | 727 | 79.0 | 0.32 | 2.31e-4 |
| | | Gamma | 134 | 40.0 | 0.14 | 3.04e-4 |
| | | Total | 791 | 104 | 0.46 | 5.34e-4 |
| *4-4* | OS197L TC[(1, 4)] (with supplemental inner trailer shielding only) *Results are directly shown in this table.* | Neutron | 1466 | 87.0 | 0.48 | 7.36e-4 |
| | | Gamma | 540 | 59.0 | 0.29 | 1.07e-3 |
| | | Total | 1543 | 129 | 0.77 | 1.81e-3 |
| *4-5* | OS197L TC[(1)] (bare cask) *(Maximum from Table W.5-7 and Table W.5-10)* | Neutron | 4,194 | 175 | 0.20 | 4.97e-5 |
| | | Gamma | 15,305 | 1,332 | 2.30 | 2.43e-3 |
| | | Total | 18,210 | 1,438 | 2.48 | 2.46e-3 |
| *4-6* | OS197 TC[(2)] *Results are directly shown in this table.* | Neutron | 1,282 | 66.0 | 0.07 | 1.87e-5 |
| | | Gamma | 291 | 30.0 | 0.04 | 5.14e-5 |
| | | Total | 1573 | 84.0 | 0.10 | 6.48e-5 |

[(1)] 0.19" thick neutron shield shell(s) *are* credited in the calculations. To obtain a rough and conservative estimates for dose rates without the neutron shield shells one can scale the dose rates by the factor of $\exp(\ln(2)*0.19/0.85)=1.17$, where 0.85" is a half layer thickness of steel for Co-60 radiation.

[(2)] Dose rates are due to 32PT DSC design basis radiological sources. Those sources would result in nearly 87 rem/hr maximum dose rate on *the* side of the bare *OS197L* cask without water in *the* neutron shield. *These are calculated to compare against those shown for the OS197 TC, shown in this table as Case #4-1.*

[(3)] The dose rates are also applicable to the cask on *the* trailer at vertical elevations above the trailer support skid.

[(4)] The dose rates are applicable for radial locations *around the* 2.5" thick inner top supplemental trailer shielding *prior to the installation of the outer top supplemental trailer shielding. These dose rates do not reflect those at radial distances from the side of the trailer.*

[(5)] *Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

## Table W.5-6
## Bounding Radial Dose Rates for the Bare OS197L TC with 32PT DSC (Normal Condition, Water in Neutron Shield)

| Distance from TC Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | *323* | 0.010 | *9,521* | 0.004 | *9,835* | 0.004 |
| 1 | *136* | 0.003 | *4,022* | 0.002 | *4,158* | 0.002 |
| 2 | *71.8* | 0.003 | *2,306* | 0.002 | *2,378* | 0.002 |
| 3 | *42.7* | 0.003 | *1,463* | 0.002 | *1,506* | 0.003 |
| 4.57 (15') | *22.4* | 0.005 | *824* | 0.003 | *845* | 0.007 |
| 10 | *5.63* | 0.005 | *217* | 0.003 | *223* | 0.010 |
| 50.8 (2000") | *0.16* | 0.010 | *7.52* | 0.010 | *7.67* | 0.010 |
| 100 | *0.02* | 0.020 | *0.98* | 0.010 | *1.01* | 0.010 |
| 200 | *2.30E-03* | 0.070 | *0.11* | 0.020 | *0.11* | 0.020 |
| 300 | *5.02E-04* | 0.130 | *0.02* | 0.030 | *0.02* | 0.030 |
| 609.6 (2000') | *1.51E-05* | 0.290 | *6.37E-04* | 0.060 | *6.45E-04* | 0.060 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

## Table W.5-7
## Bounding Radial Dose Rates for the Bare OS197L TC with 32PT DSC (Accident Condition, No Water in Neutron Shield)

| Distance from TC Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | *2,904* | 0.003 | *15,305* | 0.010 | *18,210* | 0.008 |
| 1 | *968* | 0.002 | *6,522* | 0.004 | *7,491* | 0.003 |
| 2 | *470* | 0.002 | *3,755* | 0.004 | *4,225* | 0.004 |
| 3 | *271* | 0.002 | *2,378* | 0.004 | *2,649* | 0.010 |
| 4.57 (15') | *141* | 0.003 | *1,333* | 0.010 | *1,430* | 0.011 |
| 10 | *34.6* | 0.003 | *351* | 0.010 | *386* | 0.010 |
| 50.8 (2000") | *0.99* | 0.010 | *12.2* | 0.030 | *13.2* | 0.030 |
| 100 | *0.14* | 0.010 | *1.56* | 0.020 | *1.70* | 0.020 |
| 200 | *1.22E-02* | 0.020 | *0.19* | 0.080 | *0.21* | 0.076 |
| 300 | *2.02E-03* | 0.030 | *0.04* | 0.040 | *0.04* | 0.040 |
| 609.6 (2000') | *3.85E-05* | 0.120 | *9.53E-04* | 0.100 | *9.88E-04* | 0.100 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-9**
**Bounding Radial Dose Rates for the Bare OS197L TC with 61BT DSC**
**(Normal Condition, Water in Neutron Shield)**

| Distance from TC Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | *311* | 0.010 | *8,817* | 0.010 | *9,129* | 0.010 |
| 1 | *116* | <0.01 | *3,566* | <0.01 | *3,682* | 0.010 |
| 2 | *56.5* | <0.01 | *2,030* | <0.01 | *2,083* | 0.010 |
| 3 | *32.6* | <0.01 | *1,326* | <0.01 | *1,357* | 0.010 |
| 4.57 (15') | *14.3* | 0.006 | *621* | 0.010 | *641* | 0.013 |
| 10 | *4.16* | 0.010 | *222* | 0.010 | *226* | 0.010 |
| 50.8 (2000") | *0.12* | 0.020 | *8.00* | 0.020 | *8.12* | 0.020 |
| 100 | *0.02* | 0.040 | *1.41* | 0.020 | *1.42* | 0.020 |
| 200 | *2.05E-03* | 0.120 | *0.18* | 0.050 | *0.18* | 0.050 |
| 300 | *3.98E-04* | 0.090 | *0.04* | 0.080 | *0.04* | 0.078 |
| 609.6 (2000') | *1.50E-05* | 0.280 | *1.45E-03* | 0.140 | *1.46E-03* | 0.140 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-10**
**Bounding Radial Dose Rates for the Bare OS197L TC with 61BT DSC**
**(Accident Condition, No Water in Neutron Shield)**

| Distance from TC Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | *4,194* | 0.004 | *14,816* | 0.010 | *18,141* | 0.008 |
| 1 | *1279* | 0.003 | *6,080* | 0.003 | *7,359* | 0.003 |
| 2 | *596* | 0.003 | *3,444* | 0.003 | *4,038* | 0.003 |
| 3 | *339* | 0.003 | *2,228* | 0.004 | *2,559* | 0.010 |
| 4.57 (15') | *175* | 0.005 | *1,304* | 0.010 | *1,438* | 0.010 |
| 10 | *42.7* | 0.005 | *366* | 0.010 | *408* | 0.010 |
| 50.8 (2000") | *1.26* | 0.010 | *13.4* | 0.020 | *14.7* | 0.020 |
| 100 | *0.20* | 0.010 | *2.30* | 0.030 | *2.48* | 0.030 |
| 200 | *1.68E-02* | 0.030 | *0.28* | 0.050 | *0.29* | 0.050 |
| 300 | *2.89E-03* | 0.040 | *0.06* | 0.080 | *0.07* | 0.080 |
| 609.6 (2000') | *4.97E-05* | 0.140 | *2.43E-03* | 0.190 | *2.46E-03* | 0.190 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-12**
**OS197L TC Radial Dose Rates over 2.5" Inner Top Trailer Area Shielding**
**(Normal Condition, Water in Neutron Shield)**

| Distance from Inner Top Trailer Area Shielding Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | 58.6 | 0.010 | 336 | 0.010 | 394 | 0.010 |
| 1 | 22.2 | 0.010 | 156 | 0.004 | 178 | 0.004 |
| 2 | 12.0 | 0.010 | 94.4 | 0.004 | 106 | 0.004 |
| 3 | 7.60 | 0.010 | 62.9 | 0.005 | 70.2 | 0.005 |
| 4.57 (15') | 4.30 | 0.010 | 36.7 | 0.010 | 40.8 | 0.010 |
| 10 | 1.30 | 0.010 | 11.0 | 0.010 | 12.2 | 0.010 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-13**
**OS197L TC Radial Dose Rates with 5.5" Trailer Area Shielding**
**(Normal Condition, Water in Neutron Shield)**

| Distance from Outer Top Trailer Area Shielding Side, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | 27.9 | 0.010 | 39.5 | 0.004 | 60.6 | 0.010 |
| 1 | 17.4 | 0.010 | 81.9 | 0.010 | 97.3 | 0.009 |
| 2 | 10.6 | 0.010 | 52.6 | 0.010 | 63.0 | 0.009 |
| 3 | 6.90 | 0.010 | 39.3 | 0.010 | 46.2 | 0.010 |
| 4.57 (15') | 4.00 | 0.020 | 25.0 | 0.010 | 29.0 | 0.010 |
| 10 | 1.10 | 0.030 | 7.10 | 0.020 | 8.20 | 0.020 |

Note: Dose rates presented are bounding for OS197 L TC radial dose rates above cask support skid. There is no shielding underneath in the computation model used for determination of the dose rates presented in the tables except for only 0.25" thick steel plate on top of the trailer platform. Geometry of the model is depicted on sketches of Figure W.5-5. Contribution of scattered radiation is pronounced at short (less than 2 meters) radial distances. The presented maximum values of the dose *rate* are determined at vertical elevations above the cask support skid and they account for radiation scattered from concrete at grade level. *Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*

**Table W.5-14**
**OS197L TC Radial Dose Rates below Cask Support Skid**
**(Prior to Installation of Outer Top Trailer Area Shielding, Water in Neutron Shielding)**

| Distance in horizontal direction from side of 5.5" thick Side Shielding Plates, m | Neutron Radiation | | Gamma Radiation | | Total Radiation | |
|---|---|---|---|---|---|---|
| | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error | Dose Rate, mrem/hr | Relative Error |
| 0 | 56.8 | 0.010 | 1878 | 0.006 | 1934.3 | 0.01 |
| 1 | 20.1 | 0.020 | 475 | 0.010 | 494.0 | 0.01 |
| 2 | 8.50 | 0.010 | 79.3 | 0.010 | 87.7 | 0.01 |
| 3 | 5.50 | 0.010 | 31.2 | 0.010 | 36.3 | 0.01 |
| 4.57 (15') | 3.20 | 0.020 | 14.2 | 0.010 | 17.3 | 0.01 |
| 10 | 1.00 | 0.030 | 4.50 | 0.020 | 5.50 | 0.02 |

*Note: Gamma and neutron dose rate peaks do not always occur at the same location; therefore, the maximum total dose rate (as reported) is not always the sum of the maximum gamma plus maximum neutron dose rate.*