TRANSNUCLEAR
AN AREVA COMPANY

January 24, 2006
E-23180

Mr. Joe Sebrosky
Spent Fuel Project Office, NMSS
U. S. Nuclear Regulatory Commission
11555 Rockville Pike M/S 0-6-F-18
Rockville, MD 20852

Subject: Submittal of Formal Revision 4 of the NUHOMS® HD System Safety Analysis Report (TAC NO. L23738).

References:
1. NRC Peer Review Comments dated 12/7/2005 on NUHOMS® HD System.
2. Telecon with the NRC Staff on 11/17/2005 Regarding Helium Leak Testing and Pressure Testing of the NUHOMS® HD System.
3. TN Letter E-22577, Dated August 16, 2005.

Dear Mr. Sebrosky:

Transnuclear, Inc. (TN) herewith submits a formal Revision 4 of the subject SAR to address NRC comments (Reference 1) and to implement staff guidance relating to helium leak testing and pressure testing of the NUHOMS HD System (Reference 2). In addition, as noted in Reference 3, this submittal also provides changed SAR pages resulting from incorporating TN's response to RAI 2. Please note that entire Chapters 8, 12 and 13 are included for replacement, including master table of contents. All other changed pages are provided on a replacement page basis.

Finally, this submittal also implements minor corrections in the SAR. See attached table which lists the replacement SAR pages along with a brief reason for each change. This update does not affect any analysis as presented in the SAR.

Should you or your staff require additional information to support review of this application, please do not hesitate to contact me at 510-744-6053 or Mr. Jayant Bondre at 410-910-6881.

Sincerely,

UBChopra

U. B. Chopra
Licensing Manager

Docket: 72-1030

Enclosures:
1. TN Response to NRC Peer Review Comments on the NUHOMS® HD System.
2. Summary of Changes Implemented in Revision 4 of the NUHOMS® HD SAR.
3. Six Copies of Replacement Pages of Revision 4 of the NUHOMS® HD SAR.

Enclosure 1 to E-23180

TN Response to NRC Peer Review Comments on the NUHOMS® HD System

NUHOMS HD Peer Review Comments
December 7, 2005

Table 1 - Issues for TN to Address/Correct

Item #	Document	Comment	Status
1	Tech Specs	Section 2.1.b fuel types abbreviations are not consistent with other tables in the tech specs a) Westinghouse 17x17 OFA Assembly abbreviated WEO 17x17 in TS 2.1.b, WE 17x17 OFA in TS Table 1, and WEOFA in TS Table 2, b) Framatome 17x17 not abbreviated in section 2.1.b, Table 1 lists it a Framatome MK BW 17x17, and Table 2 abbreviates it as 17x17 MK BW	Abbreviations for the fuel types have been revised in the Technical Specifications (TS) Chapter 12 to eliminate inconsistencies. In addition, other SAR Chapters have also been revised to make them consistent.
2	Tech Specs	Table 7 does not list the Framatome 17x17 fuel assembly	TS Table 12-7 has been revised to add Framatome 17x17 fuel assembly type. In addition, other SAR chapters have also been revised to make them consistent.
3	Tech Specs	2.1.c does not explicitly mention the Framatome 17x17 fuel assembly type	TS 12.2.1.c has been revised to add Framatome 17x17 fuel assembly type. In addition, other SAR chapters have also been revised to make them consistent.
4	Tech Specs	Clarification of TS 3.1.1. Procedure A, B and C provides different time limits for completing vacuum drying. How were these time limits established (ie., what gas does it assume is in the DSC - nitrogen, helium, or vacuum)?	Helium or Air conductivity is used depending upon if nitrogen or helium is used for blowdown. Air is not allowed for blowdown. Use of air conductivity for nitrogen is acceptable because there is little difference between air and nitrogen conductivities at expected temperature. Also there is sufficient conservatism in the models as documented in Chapter 4 of the SAR.
5	Tech Specs and SAR	TS 3.1.1 mentions stepped evacuation. Stepped evacuation is not mentioned in the operating procedures in Chapter 8 of the safety analysis report (SAR). Section 8.1.1.3 step 16 discusses meeting this TS but does not mention stepped evacuation	TS 12.3.1.1 has been revised to delete “stepped” evacuation.

Item #	Document	Comment	Status
6	Tech Specs and SAR	Clarification - What is the basis for the 20 psig limit found in LCO 3.1.1 action statement A.1? Chapter 8 of the SAR appears to have different limits. For example section 8.1.1.3 steps 7 and 13 mention 60 psig maybe applied at the vent port to assist the water pump down (sic). Section 8.1.1.3 step 15 mentions 15 psig as an upper limit. Section 8.2.2 step 14 mentions 20 psig.	Action Statement A.1 of LCO 12.3.1.1 has been revised to 15.0 psig, which is the Design Pressure of the 32PTH DSC for Normal Conditions. SAR Section 8.1.1.3 steps 7 and 13 have been revised to limit the blow down pressure to 15.0 psig. SAR Section 8.2.2, step 14 has also been revised accordingly. In addition, SAR Chapters 3, 8 and 9 have been reviewed and revised to eliminate this inconsistency. The analysis documented in SAR Chapter 3 was conservatively done for a limiting pressure of 60 psig for the blow down operations and 30 psig for normal and off-normal conditions.
7	Tech Specs	Typos a) TS 4.5 states that "limits on the heat load of the DSC's shall.." It should be DSCs b) TS 4.6.3 parameter 5 should be insolation instead of insulation	TS 12.4.5 and 12.4.6.3 have been revised to fix the typo errors.
8	Tech Specs	Why is tech specs 5.2.5.b not located in the section 3 of the tech specs with a corresponding action statement?	TS 12.5.2.5 deals with HSM-H thermal performance monitoring program used to prevent conditions that could lead to exceeding the concrete and fuel cladding temperature. TS 12.5.2.5(b) is for daily visual inspections of front wall and roof bird screen to detect blockage that could lead to adverse effect on concrete or fuel cladding temperature. Therefore it was included under TS 12.5.2.5.
9	SAR Chapter 8	Section 8.1.1.2 step 12 states "up to about 1300 gallons." Remove the word "about" from this sentence.	Corrected SAR Section 8.1.1.2.
10	SAR Chapter 8	Section 8.1.1.3 step 1 states"fill the transfer cask liquid neutron shield if it was drained for weight reduction during preceding operation." There is no mention of draining the neutron shield in section 8.1.1.2	SAR Section 8.1.1.1 has been revised to add a step 14b.
11	SAR Chapter 8	Section 8.1.1.3 step 7 states "up to 60 psig of nitrogen or helium.." Should there be a similar pressure limit in section 8.1.1.2 step 12? Also see comment 6.	SAR Section 8.1.1.3 step 7 and Section 8.1.1.2 step 12 have been revised to reflect a blow down pressure of 15 psig. See response to comment 6 above.
12	SAR Chapter 8	Section 8.1.1.3 step 29 mentions backfilling the transfer cask with helium to TS requirement. Should this be more specific and mention the annulus and should there be a step in the process to check for gross helium leakage from the transfer cask annulus?	SAR Section 8.1.1.3 step 29 has been revised as requested. TS 12.3.1.3 has been revised to either monitor the transfer cask annulus pressure during transfer operation or demonstrate annulus pressure stability for 30 minutes.

Item #	Document	Comment	Status
13	SAR Chapter 8	Section 8.2.1 step 2 mention “ready the transfer cask.” Does this step include filling the neutron shield? If so should this step be more explicit?	SAR Section 8.2.1 step 2 has been revised to explicitly mention filling the neutron shield as requested.
14	SAR Chapter 8	Section 8.2.2 step 9 mentions “covers the annulus.” Should this step mention sealing the annulus as in Section 8.1.1.1 step 10.	SAR Section 8.2.2 step 9 has been revised as requested.
15	SAR Chapter 8	Typos a) Introduction on page 8-1 mentions HSM-H-H, should be HSM-H b) Introduction on page 8-1 defines ALARA incorrectly should be reasonably instead of reasonable c) 8.1 title includes HSM-H-H should be HSM-H d) Step 7 and 13 of 8.1.1.3 mention “water pump” should be “water pump down.” e) Step 7 of 8.1.1.3 mentions “(N.B. step 14 below)” Define N.B. e) step 9 of 8.1.1.3 last sentence mentions “also requires” should be “also required.” f) Table 8-1 under other equipment and instruments in the lift yoke and lifting eyes rows mentions NUREG-0612 2 should this be NUREG-0612 rev 2 in these rows?	SAR Chapter 8 has been revised to address the listed typo errors.
16	SAR Chapter 3	Proposed SAR revision 4 page 3.9.8-19 at the top states that “the highest computed stress intensity factor, K_I of 18.3 ksi in$^{1/2}$...” The value should be 24.2 consistent with the change that was made to the table on the previous page.	SAR Section 3.9.8, page 3.9.8-19 has been revised.
17	TS	NFAH is used as an abbreviation but is not defined in the Tech Specs.	TS 12.2.1 b. has been revised as requested.

Item #	Document	Comment	Status
18	TS	LCO 3.1.1 procedure B (water in the TC cavity/annulus is drained when it exceeds 180F) indicates for a heat load of less than or equal to 16.0 kW there is no time limit. Procedure A (water in the TC cavity/annulus remains below 180F) indicates that there is no limit for heat loads less than 23.2kW. Please explain the basis for the kW limits because it seems procedure A indicates that the water in the annulus won't hit 180F for heat loads less than 23.2 kW.	Procedure A assumes that provisions will be made to keep the temperature of water in TC cavity/annulus below 180°F. Using maximum annulus water temperature of 180°F, thermal analysis in Chapter 4 shows that there is no time limit for heat loads less than 23.2 kW. In Procedure B, there are no provisions made to keep the water temperature below 180°F but it is assumed that water in the annulus is drained after it reaches 180°F and air is assumed in the annulus which is thermally less efficient. Therefore, it takes only 16 kW for no time limit as compared to 23.2 kW for Procedure A.
19	TS	LCO 3.1.2 provides a helium backfill pressure of 2.5 +/- 1 psig after completion of vacuum drying. The cask is hot at this time and will most likely be cooler once its in the HSM or because decay heat goes down. As the cask cools the pressure in the DSC will go down and may result in pressure less than atmospheric. Why is this OK?	The lowest maximum internal pressure calculated in the DSC during storage conditions is 4.8 psig. This will be reduced as the decay heat goes down during the storage period. The temperature inside the DSC will always be higher than ambient due to the decay heat from the assemblies. Even though the decay heat goes down during the storage period, it will not approach zero during the storage period. Therefore, the pressure inside the DSC will always be higher than ambient during the storage period.
20	TS and SAR chapter 8	LCO 3.1.3 has a TS for transfer cask helium during loading operations. Why isn't there a tech spec for helium during unloading operations. If a cask needs to be returned or recovered from the HSM early in its operation helium may need to be provided in the transfer cask in order to remain in an analyzed conditions. Also Chapter 8 of the SAR does not discuss transfer cask helium backfill pressure in the DSC retrieval section (Section 8.2.1).	TS 12.3.1.3 has been revised to include Unloading operations. SAR Section 8.2.1 has also been revised accordingly.
21	TS	LCO 3.1.3 Condition B 18 hour completion time seems to exceed 12 hour thermal calculation that was performed. Why is this OK?	The 12 hours used in the calculation is for the start (initiation) of helium backfill in the annulus. Nine (9) hours are conservatively used in the LCO 12.3.1.3 (A) for this step. It takes very small amounts of helium in the annulus to provide a helium medium for conduction. The 18 hour time limit for LCO 12.3.1.3 (B) is a reasonable amount of time to verify stability of helium pressure which is applicable after LCO 12.3.1.3 (A) where initiation of helium in the annulus is required.
22	TS	LCO 3.1.3 The note under the condition column "Not applicable until SR 3.1.3 is performed" appears to only apply to condition B and not condition A. Why does it appear before condition A?	Agree that the Note in TS 12.3.1.3 is applicable to Condition B and the TS has been revised accordingly.

Item #	Document	Comment	Status
23	TS	TS 4.4.4 NB-4243 refers to Code Case N-595-3. Should refer to ISG-4	TS 12.4.4.4, ASME Code Alternatives for NB-4243 has been revised to delete reference to Code Case N-595-3 and instead reference ISG-15 guidelines. In addition, SAR Chapters are also revised to delete reference to Code Case N-595-3.
24	TS	TS 4.4.4 NB-2531 mentions vent and siphon port cover. Why doesn't this also mention the shield plug weld	This comment was withdrawn by the staff.
25	TS	TS 4.5 allows limits on the heat load of the DSC to be established at a later time for the different heat shield material for the HSM-H. Why is it OK to defer the development of these limits?	TS 12.4.5 has been revised to address this comment.
26	TS	Typos: a)TS 4.4.4 table item NB-4243 under code requirement column should be "This welds shall" should be "These"	TS 12.4.4 Table has been revised to correct the typo error.
27	TS	Typos: a)page ii 5.2.3 Radiological Environmental monitoring Program. "M" should be capitalized in "monitoring." b)page 1.4-1 second paragraph in Description states "..each of the Specifications of Section 3, Surveillance.." Should include entire definition in this sentence (i.e., Section 3.0, Limiting Condition for Operation (LCO) and Surveillance Requirement Applicability."	Listed typos have been corrected.
28	TS	TS 1.3 Completion Times - should be consistent with NUREG-1745 in that prior to listing example 1.3-1 on page 1.3-2 the following words should be inserted "The following examples illustrate the use of Completion Times with different types of Conditions and changing Conditions."	TS 12.1.3 has been revised as requested.
29	TS	Question - why are the completions times in example 1.3-3 higher than the standard tech specs for required action B.1 and B.2? In the standard tech spec the B.2 and B.2 completion times are 6 and 12 hours, respectively, while they are 12 and 36 hours, respectively, in the NUHOMS HD tech specs.	Example 12.1.3-3 has been revised as requested. Revision 3 of SAR Chapter 12 had the 6 and 12 hours, so this does not show as a revision in Revision 4.

Item #	Document	Comment	Status
30	TS	References in the tech specs should be to FSAR not to the SAR (e.g., 4.1.1 and 4.2.2 reference SAR -should be FSAR)	References in TS (Chapter 12) are being maintained as SAR until an FSAR has been docketed following final rulemaking. The proposed TS which use information from Chapter 12 will be revised to say "FSAR".
31	TS	Question - TS 5.4.3.b and 3.c reference dose rates that are much lower than those found in other NUHOMS DSC. Is this correct or an oversight?	The stated values are correct. The differences with other NUHOMS® DSC are due to differences in design basis source terms and DSC geometries.
32	TS and SAR	Reference to ASME Code Case N-595-3 should be removed from the TS and SAR. For example TS 4.4.2, and 4.4.4 (NB-4243 row) refer to this code case. SAR section 9.1.1 also references this code case	Reference to ASME Code Case N-595-3 has been removed as requested from TS 12.4.4.2, 12.4.4.4 and all affected SAR Chapters.
33	TS	Helium leak testing should be added to the TS	TS 12.5.2.4 has been revised to add Helium leak testing as requested.
34	SAR Chapter 9	Section 9.1.2 mentions the pressure test of 18 psig which is not consistent with Chapter 8 values. Specifically use of up to 60 psig pressures are allowed in Chapter 8 while the ASME hydro pressure is 18 psig. Also see comment #6 above	The pressure test value of 18 psig is correct as stated in SAR Section 9.1.2 which bounds the 1.1 x design pressure (1.1x15.0). SAR Chapter 3 and 8 have been revised to eliminate the stated inconsistency. See response to item No. 6 above.
35	SAR Chapter 8	Section 8.1.1.3 step 24 mentions non-destructive examination as required by the tech specs for the vent and drain ports, however, Section 8.1.1.3 step 11, and 26 which mention non-destructive examinations for the top shield plug weld and the other top cover plate, respectively, do not mention tech specs. This appears to be inconsistent	SAR Chapter 8 has been revised to consistently cross reference Technical Specifications where applicable.
36	SAR Chapter 8	Table 8-1 does not mention the pressure test - test pump, or helium leak testing equipment	SAR Table 8-1 has been revised as requested.
37	SAR Chapter 8	Section 8.1.1.3 step 20 mentions suitable pipe thread sealant. Are suitable pipe thread sealants defined anywhere?	This is a level of detail which is to be assessed by individual licensee based on the acceptability for their spent fuel pool.
38	SAR Chapter 8	Section 8.1.1.5 step 5 should include a reference to ALARA	SAR Section 8.1.1.5 step 5 has been revised as requested.

Item #	Document	Comment	Status
39	SAR Chapter 8	Section 8.1.1.5 step 14 - how is it determined or controlled when the DSC reaches the support rail stops at the back of the module?	This is a level of detail which is included in TN's detailed operating procedures.
40	SAR Chapter 8	Section 8.1.1.6 - should site boundary radiation limit periodic verifications be added to this section?	This level of detail normally belongs in the ISFSI requirements of the individual licensee.
41	SAR Chapter 9	Section 9.1.1 contains the following sentence, "non-destructive examination (NDE) requirements for welds are specified on the drawings provided in Chapter 1; acceptance criteria are as specified by the governing code." Are these NDE requirements in accordance with the governing code in all cases? If not, then the NDE requirements should be captured by technical specifications. (If the NDE requirements are in accordance with the governing code they are by default captured by tech spec 4.4.2)	The NDE requirements are in accordance with the governing codes, including alternatives to the codes are specified in Section 3.10 of the SAR. SAR Section 9.1.1 has been revised to add the alternatives to the ASME code.
42	SAR Chapter 9 and tech specs	The staff believes that section 9.5 of the SAR should be incorporated by reference in the tech specs because this component is important to safety and is not ASME code controlled. Incorporating this section into tech specs is consistent with what was done for HI-STORM amendment 2 (see TS 3.2.8 in design features and Section 9.1.5.3 of the HI-STORM FSAR)	Based on discussions with the NRC staff, SAR Chapter 9 has been revised in several areas. SAR Sections 9.1.7.1, 9.1.7.2, 9.1.7.3, 9.5.2, 9.5.3.5 and 9.5.4.3 have Notes indicating that they are incorporated by reference into the TS, and TS 12.4.3 has been revised to include new subsection 12.4.3.1 that discusses and lists these SAR sections that are incorporated by reference. Accordingly, the footnote in TS Table 12-6 has been deleted.
43	TS	Hydrogen monitoring during welding should be captured in the technical specification because of its importance to safety	TN makes a provision for a continuous monitoring of the hydrogen concentration during welding operations. The limit for the initiation of purging with Helium is conservatively set at a concentration limit of 2.4%, which is well below the flammability limit of 4.0 %. In addition, utilities have successfully and safely loaded a large number of DSCs with existing controls in the SAR. Hence, no additional safety benefit is obtained by adding a new TS.

Enclosure 2 to E-23180

Summary of Changes Implemented in Revision 4 of the NUHOMS® HD SAR

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
Table of Contents pages i through ix	Pagination
1-i	Page number due to Pagination
1-ii	Deleted Figure 1-5 (using Figure 7-1 for reference instead)
1-4	Define confinement boundary (Action per 11/18/05 telcon with NRC Staff)
1-5	Define confinement boundary (Action per 11/18/05 telcon with NRC Staff)
1-6	Editorial (remove "-" between OS187H)
1-7	Pagination
1-8	Add pressure and leak tests (Action per 11/18/05 telcon with NRC Staff)
1-9	Consistent for top shield plug call out
1-10	Replace air with nitrogen, add steps of pressure and leak tests (Action per 11/18/05 telcon with NRC Staff), consistent for top shield plug call out, and add note 1
1-11	Pagination
1-12	Consistent with Technical Specifications and consistent fuel type abbreviation call out (comment from Peer Review #1)
1-15	Update reference revisions
Figure 1-5	Deleted (using Figure 7-1 for consistency)
2-1	Consistent with Technical Specifications and consistent fuel type abbreviation call out (comment from Peer Review #1)
2-2	Consistent with Technical Specifications + formatting
2-3	Consistent with Technical Specifications + formatting due to pagination + editorial change
2-8	Remove Code Case N-595-3 (comments from Peer Review #23 and #32)
2-11	Remove Code Case N-595-3 (comments from Peer Review #23 and #32), consistent definition of confinement boundary and add note 1 (Action per 11/18/05 telcon with NRC Staff) + formatting
2-12	Define confinement boundary; Remove ISG-18 (Action per 11/18/05 telcon with NRC Staff) + Technical Specification consistency
2-13	Replace air with nitrogen
2-14	Consistent with Technical Specifications and consistent fuel type abbreviation call out (comment from Peer Review #1)
2-20	Remove referenced Code Case N-595-3 and ISG-18 (comments from Peer Review #23 and #32)
2-21	Update reference revision
Table 2-1	Consistent with Technical Specifications and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 2-2	Consistent with Technical Specifications
Table 2-2 (concluded)	Consistent with Technical Specifications. Originally this Table was in a single page. The same content has been shown in two pages
Table 2-3	Consistent with Technical Specifications
Figure 2-1	Consistent with Technical Specifications
3-ii	Consistent with Technical Specifications
3-iii	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
3-iv	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
3-1	Consistent with Technical Specifications
3-2	Remove Code Case N-595-3 (comments from Peer Review #23 and #32) and consistent definition of confinement boundary (Action per 11/18/05 telcon with NRC Staff)
3-3	Remove Code Case N-595-3 (comments from Peer Review #23 and #32) and add leak test (Action per 11/18/05 telcon with NRC Staff)
3-7	Pagination
3-8	Remove Vyal-b, consistent with revision 2 shielding analysis, and content with Technical Specifications

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
3-10	Consistent with Technical Specifications
3-13	Consistent with shielding analysis
3-27	Typo and add reference 39
3-29	Response to RAI#2
3-36	Replace air with nitrogen and pressure from 60 psig to 15 psig (comments from Peer Review #6, #11, and #34)
3-54	Response to RAI#2 and deleted Code Case N-595-3 & ISG-4 (comments from Peer Review #23 and #32)
3-56	Add references 38 and 39
3-58	Consistent with Technical Specifications, replace Code Case N-595-3 with ISG-15 (comments from Peer Review #23, #26, and #32)
3-59	NB-6000, add pressure and leak test requirements (Action per 11/18/05 telcon with NRC Staff). Remove item number call outs at NB-1132 to be consistent with Technical Specifications
3-60	Consistent with Technical Specifications
Table 3-1	Remove Code Case N-595-3 and ISG-4 (comments from Peer Review #23 and #32)
Table 3-12	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3-13	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-2	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-3	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-4	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-5	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-6	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Figure 3-7	Response to RAI#2 and consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.1-56	Replace Code Case N-595-3 with ISG-15 (comments from Peer Review #23 and #32), typo
3.9.1-91	Replace Code Case N-595-3 with ISG-15 (comments from Peer Review #23 and #32)
Table 3.9.1-9	Define design pressure and pressure used for stress calculation (comment from Peer Review #6, #11, and #34)
3.9.8-ii	Consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.8-2	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.8-10	Consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.8-12	Consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.8-16	Response to addition questions to RAI#1
3.9.8-17	Response to addition questions to RAI#1
3.9.8-18	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
3.9.8-19	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1), Typo (comment from Peer Review #16),
Table 3.9.8-1	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3.9.8-2	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3.9.8-3	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
Table 3.9.8-4	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3.9.8-5	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3.9.8-6	Response to addition questions to RAI#1 and consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 3.9.8-7	Response to addition questions to RAI#1
Table 3.9.8-8	Response to addition questions to RAI#1
3.9.10-15	Typo
4-i	Typo
4-v	Consistent fuel type abbreviation call out (comment from Peer Review #1)
4-2	Typo
4-10, 4-16	Consistent fuel type abbreviation call out (comment from Peer Review #1)
4-18	Consistent with Technical Specifications and consistent fuel type abbreviation call out (comment from Peer Review #1)
4-19, 4-20	Consistent fuel type abbreviation call out (comment from Peer Review #1)
4-29	Replace air with nitrogen
4-30	Typo
4-31	Pagination
4-32	Pagination
4-33	Replace air with nitrogen and comment from Peer Review #4 for conductivities used
4-35, 4-41, 4-42, 4-43, 4-45, 4-46, 4-47, 4-70, 4-71	Consistent fuel type abbreviation call out (comment from Peer Review #1) and for page 4-45, clarification for conductivities used during vacuum drying operation (comment from Peer Review #4)
4-73	Update reference revision
Tables 4-1, 4-12, 4-13, 4-13 continued, 4-13 continued, 4-13 continued, 4-24, 4-25, 4-26	Consistent fuel type abbreviation call out (comment from Peer Review #1)
Figures 4-39, 4-47,	Consistent fuel type abbreviation call out (comment from Peer Review #1)
5-ii	Consistent fuel type abbreviation call out (comment from Peer Review #1), typo
5-1	Consistent fuel type abbreviation call out (comment from Peer Review #1)
5-3	Typo (change ENDFB-IV to ENDF/B-V)
5-4	Consistent with Technical Specifications and fuel type abbreviation call out (comment from Peer Review #1)
5-5	Typo (change ENDFB-IV to ENDF/B-V) and fuel type abbreviation call out (comment from Peer Review #1)
Table 5-7	Consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 5-9	Consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 5-10	Consistent fuel type abbreviation call out (comment from Peer Review #1)
Table 5-13	Consistent fuel type abbreviation call out (comment from Peer Review #1)
6-ii	Typo
Table 6-1	Consistent with Technical Specifications
Table 6-3	Consistent fuel type abbreviation call out (comment from Peer Review #1) and consistent with Technical Specifications
Table 6-4	Consistent with Technical Specifications
Table 6-7	Typo + Consistent with Technical Specifications
7-i	Editorial change
7-1	Define confinement boundary (Action per 11/18/05 telcon with NRC Staff) and remove Code Case N-595-3 (comments from Peer Review #23 and #32), editorial change
7-2	Add pressure and leak test requirements (Action per 11/18/05 telcon with NRC Staff), editorial change

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
7-5	Remove Code Case N-595-3 (comments from Peer Review #23 and #32)
Figure 7-1	Editorial change and add detail description of confinement boundary welds (Action per 11/18/05 telcon with NRC Staff)
8-1	Replace air with nitrogen; response to Peer Review Comment #15, typo
8-2	Response to Peer Review Comments #5 and #10
8-3	Replace air with nitrogen; response to Peer Review Comments #9 and #11; editorial change, add note 1
8-4	Replace air with nitrogen; response to Peer Review Comments #6, #15, and #35; editorial correction; terminology consistency
8-5	Response to Peer Review Comment #6; action per 11/18/05 telcon with NRC Staff for adding pressure test of inner cover/shield plug to shell weld; editorial changes
8-6	Replace air with nitrogen; Action per 11/18/05 telcon with NRC Staff; editorial correction; response to Peer Review Comments # 12 and #35
8-7	Response to Peer Review Comment #38
8-8	Consistent with Technical Specifications
8-9	Response to Peer Review Comments #13 and #20
8-10	Response to Peer Review Comments #13 and #14; editorial correction
8-11	Response to Peer Review Comment #6, editorial change
8-12	Pagination
Table 8-1	Response to Peer Review Comments #15 and #36; editorial change
Figure 8-1	Changed "AIR/HELIUM" to "NITROGEN/HELIUM" and changed "WATER/AIR" to "WATER/NITROGEN/HELIUM," for consistency
Figure 8-1 (concluded)	Typo
9-i	Correct page call out
9-1	Remove Code Case N-595-3 (comments from Peer Review #23 and #32) and add pressure test requirement for inner top cover/shield plug to DSC shell weld (Action per 11/18/05 telcon with NRC Staff)
9-2	Add leak test requirement for inner top cover/shield plug to shell weld including siphon/vent cover welds (Action per 11/18/05 telcon with NRC Staff)
9-3	Pagination; response to Peer Review Comment #42
9-4	Pagination; response to Peer Review Comment #42
9-5	Pagination; response to Peer Review Comment #42
9-6	Pagination
9-7	Pagination
9-8	Pagination; response to Peer Review Comment #42
9-9	Response to Peer Review Comment #42
9-10	Response to Peer Review Comment #42
9-11	Response to Peer Review Comment #42
9-12	Response to Peer Review Comment #42
9-13	Response to Peer Review Comment #42
9-14	Pagination; remove Code Case N-595-3 (comments from Peer Review #23 and #32); response to Peer Review Comment #42
10-1	Editorial change and remove ISG-18 (Action per 11/18/05 telcon with NRC Staff)
10-2	Action per 11/18/05 telcon with NRC Staff
10-8	Typo
11-9	Restoring to the language used in Revision 2
11-26	Consistent with thermal analysis
12-i	Pagination
12-ii	"HSM" changed to "HSM-H" for consistency; consistent with Technical Specifications
12-1	Format change and change to be Consistent with Technical Specifications
12-2	Pagination
12-3	Editorial change and change to be Consistent with Technical Specifications

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
12-4	Consistent with Technical Specifications
12-5	Consistent with Technical Specifications
12-6	Response to Peer Review Comment #28; consistent with Technical Specifications
12-7	Consistent with Technical Specifications
12-8	Response to Peer Review Comment #27; consistent with Technical Specifications
12-9	Editorial change and changes to be Consistent with Technical Specifications
12-10	Consistent with Technical Specifications
12-11	Editorial change and change to be Consistent with Technical Specifications
12-12	Response to Peer Review Comments #1 and #17; consistent with Technical Specifications
12-13	Editorial, response to Peer Review Comment #3, and consistent with Technical Specifications
12-14	Editorial change and change to be Consistent with Technical Specifications
12-15	Consistent with Technical Specifications
12-16	Consistent with Technical Specifications
12-17	Consistent with Technical Specifications; consistent terminology; response to Peer Review Comment #5
12-18	Consistent with Technical Specifications; response to Peer Review Comment #6; consistent terminology
12-19	Consistent with Technical Specifications
12-20	Editorial; response to Peer Review Comments #12, #20 and #22; consistent with Technical Specifications
12-21	Pagination
12-22	Editorial; consistent with Technical Specifications; pagination
12-23	Consistent with Technical Specifications; response to Peer Review Comments #32 and #41; editorial; pagination
12-24	Response to Peer Review Comments #23 and #26; pagination
12-25	Change per 11/18/05 telcon with NRC Staff; pagination
12-26	Consistent with Technical Specifications; pagination
12-27	Consistent with Technical Specifications; response to Peer Review Comment #25; pagination
12-28	Consistent with Technical Specifications; response to Peer Review Comment #7; pagination
12-29	Pagination
12-30	Consistent with Technical Specifications; pagination
12-31	Consistent with Technical Specifications; pagination
12-32	Response to Peer Review Comment #33; consistent with Technical Specifications; pagination
12-33	Consistent with Technical Specifications; pagination
12-34	Consistent with Technical Specifications; pagination
12-35	Consistent with Technical Specifications; pagination
12-36	Consistent terminology; editorial; pagination
12-37	Consistent with Technical Specifications; pagination
Table 12-1	Response to Peer Review Comment #1; consistent with Technical Specifications
Table 12-2	Response to Peer Review Comment #1; consistent with Technical Specifications; editorial
Table 12-3	Response to Peer Review Comment #1; editorial
Table 12-4	Consistent with Technical Specifications
Table 12-4 (concluded)	Consistent with Technical Specifications
Table 12-5 and Table 12-6	Consistent with Technical Specifications; editorial
Table 12-7	Consistent with Technical Specifications; response to Peer Review Comment #1; clarity; formatting
Figure 12-1	Revised to Revision 4, without change, to bring all pages to Revision 4 status

Summary of Changes Implemented in SAR Revision 4 and Supporting Reason for Change

Page Number	Change Description and Reason for Change
Figure 12-2	Consistent with Technical Specifications
B12-9	Replace air with nitrogen
B12-10	Response to Peer Review Comment #6
B12-11	Replace air with nitrogen and clarity regarding "inner top cover/shield plug" for consistency
B12-13	"/Annulus" deleted for consistency, an editorial correction, and clarity regarding "inner top cover/shield plug"
B12-14	"/Annulus" deleted for consistency
Chapter 13 pages 13-i, 13-1, 13-2, 13-3, 13-5 through 13-8, 13-10, and Table 13-1	Consistent with current Quality Assurance Program Description Manual

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Six Copies of Replacement Pages of Revision 4 of the NUHOMS® HD SAR

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CHAPTER 1
GENERAL INFORMATION

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transfer trailer, and other auxiliary equipment that is described in this SAR. Similar equipment was previously licensed under C of C 72-1004 [5]. Sufficient information for the transfer system and auxiliary equipment is included in this SAR to demonstrate that means for safe operation of the system are provided.

1.2 General Description of the NUHOMS® HD System

The NUHOMS® HD System provides for the horizontal, dry storage of canisterized Spent Fuel Assemblies (SFAs) in a concrete HSM-H. The storage system components consist of a reinforced concrete HSM-H and a stainless steel 32PTH DSC confinement vessel which holds the SFAs. The general arrangement of the NUHOMS® HD System components is shown in Figure 1-3 and Figure 1-4. The confinement boundary is defined in Section 7.1 of Chapter 7 and is shown in Figure 7-1. This SAR addresses the design and analysis of the storage system components, including the 32PTH DSC, the OS187H TC, and the HSM-H, which are important to safety in accordance with 10CFR 72.

In addition to these storage system components, the NUHOMS® HD System also utilizes transfer equipment to move the 32PTH DSCs from the plant's fuel/reactor building, where they are loaded with SFAs and readied for storage, to the HSM-Hs where they are stored. This transfer system consists of a transfer cask, a lifting yoke, a hydraulic ram system, a prime mover for towing, a transfer trailer, a cask support skid, and a skid positioning system. This transfer system interfaces with the existing plant fuel pool, the cask handling crane, the site infrastructure (i.e. roadways and topography) and other site specific conditions and procedural requirements. Auxiliary equipment such as a cask/canister annulus seal, a vacuum drying system and a welding system are also used to facilitate canister loading, draining, drying, inerting, and sealing operations. Similar transfer system and auxiliary equipment have been previously licensed under C of C 72-1004 [5].

During dry storage of the spent fuel, no active systems are required for the removal and dissipation of the decay heat from the fuel. The NUHOMS® HD System is designed to transfer the decay heat from the fuel to the canister and from the canister to the surrounding air by conduction, radiation and natural convection.

Each canister is identified by a Model Number, XXX-32PTH-YYY-Z, where XXX identifies the site for which the 32PTH DSC was fabricated, Z designates the basket type, and YYY is a sequential number corresponding to a specific canister. The basket types are described in SAR drawing no. 10494-72-10.

The NUHOMS® HD System components do not include receptacles, valves, sampling ports, impact limiters, protrusions, or pressure relief systems.

1.2.1 NUHOMS® HD System Characteristics

1.2.1.1 Dry Shielded Canister (32PTH DSC)

The key design parameters of the 32PTH DSC are listed in Table 1-1. The cylindrical shell, the inner top cover/shield plug[1] (including vent and siphon cover plates), and shell bottom form the pressure retaining confinement boundary for the spent fuel. The inner top cover/shield plug[1] and shell bottom provide shielding for the 32PTH DSC so that occupational doses at the ends are minimized during drying, sealing, handling, and transfer operations.

[1] See Chapter 1 drawings for option 2 and option 3 designs and Chapter 7 for confinement boundary definitions.

The cylindrical shell and inner bottom cover plate confinement boundary welds are fully compliant to Subsection NB of the ASME Code and are made during fabrication. The confinement boundary weld between the shell and the inner top cover/shield plug[1] (including siphon/vent cover welds) and structural attachment weld between the shell and the outer top cover plate are in accordance with Alternatives to the ASME code as described in Section 3.10.

Both siphon and vent covers are welded after drying operations are complete. There are no credible accidents which could breach the confinement boundary of the 32PTH DSC as documented in Chapters 3 and 11.

The 32PTH DSC is designed for a maximum heat load of 34.8 kW. The internal basket assembly contains a storage position for each fuel assembly. The criticality analysis credits the fixed borated neutron absorbing material placed between the fuel assemblies. The analysis takes credit for soluble boron during loading operations. Sub-criticality during wet loading, drying, sealing, transfer, and storage operations is maintained through the geometric separation of the fuel assemblies by the basket assembly, the boron loading of the pool water, and the neutron absorbing capability of the 32PTH DSC materials, as applicable. Based on poison material and boron loading, several basket types are provided, as shown on drawing 10494-70-11 and described in Chapter 6.

Structural support for the PWR fuel is provided by the basket fuel compartments and support strips. The support strips are located periodically over the full length of the basket with allowance provided for thermal growth. Stainless steel transition rails are provided at the basket periphery for support and heat transfer.

Dimensions of the 32PTH DSC components described in the text and provided in figures and tables of this SAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.5.2 of this SAR. For a discussion of the contents authorized to be stored in this DSC, see Section 2.1.1 of this SAR.

1.2.1.2 Horizontal Storage Module (HSM-H)

Each HSM-H provides a self-contained modular structure for storage of spent fuel canisterized in a 32PTH DSC. The HSM-H is constructed from reinforced concrete and structural steel. The thick concrete roof and walls provide substantial neutron and gamma shielding. Contact doses for the HSM-H are designed to be ALARA. The key design parameters of the HSM-H are listed in Table 1-1.

The nominal thickness of the HSM-H roof is four feet for biological shielding. Separate shield walls at the end of a module row in conjunction with the module wall, provide a minimum thickness of four feet for shielding. Similarly, an additional shield wall is used at the rear of the module if the ISFSI is configured as single module arrays. Sufficient shielding is provided by thick concrete side walls between HSM-Hs in an array to minimize doses in adjacent HSMs during loading and retrieval operations.

[1] See Chapter 1 drawings for option 2 and option 3 designs and Chapter 7 for confinement boundary definitions.

The HSM-Hs provide an independent, passive system with substantial structural capacity to ensure the safe dry storage of SFAs. To this end, the HSM-Hs are designed to ensure that normal transfer operations and postulated accidents or natural phenomena do not impair the 32PTH DSC or pose a hazard to the public or plant personnel.

The HSM-H provides a means of removing spent fuel decay heat by a combination of radiation, conduction and convection. Ambient air enters the HSM-H through ventilation inlet openings located on both sides of the lower front wall of the HSM-H and circulates around the 32PTH DSC and the heat shields. Air exits through air outlet openings located on each side of the top of the HSM-H. The HSM-H is designed to remove up to 34.8 kW of decay heat from the 32PTH DSC.

Decay heat is rejected from the 32PTH DSC to the HSM-H air space by convection and then removed from the HSM-H by natural circulation air flow. Heat is also radiated from the 32PTH DSC surface to the heat shields and HSM-H walls where the natural convection air flow and conduction through the walls aids in the removal of the decay heat. The passive cooling system for the HSM-H is designed to assure that SFA peak cladding temperatures during long term storage remain below acceptable limits to ensure fuel cladding integrity.

The HSM-Hs are installed on a load bearing foundation which consists of a reinforced concrete basemat on a subgrade suitable to support the loads. The HSM-Hs are not tied to the basemat.

Dimensions of the HSM-H components described in the text and provided in figures and tables of this SAR are nominal dimensions for general system description purposes. Actual design dimensions are contained in the drawings in Section 1.5.2 of this SAR.

1.2.1.3 Transfer Systems

1.2.1.3.1 OS187H On-Site Transfer Cask

The OS187H transfer cask (TC) used in the NUHOMS® HD System provides shielding and protection from potential hazards during 32PTH DSC loading and closure operations and transfer to the HSM-H. The key design parameters of the TC are listed in Table 1-1. The TC included in this SAR is the NUHOMS® cask which is limited to on-site use under 10CFR 72. The OS187H transfer cask is very similar to the OS197 and OS197H transfer casks described in the FSAR for the Standard NUHOMS® Storage System [5].

The OS187H TC has a 186.6 inch cavity length, a 70.5 inch inside diameter and a payload capacity of 121,000 pounds (wet) and 109,000 pounds (dry). The TC is designed to meet the requirements of 10CFR72 for on-site transfer of the DSC from the plant's fuel pool to the HSM-H. As shown in Figure 1-6, the TC is constructed from two concentric stainless steel shells with a bolted and gasketed top cover plate and a welded bottom end assembly. The TC also includes an outer steel jacket which is filled with water to provide neutron shielding. The top and bottom end assemblies also incorporate a solid neutron shield material.

The TC is designed to provide sufficient shielding to ensure dose rates are ALARA. Two top lifting trunnions are provided for handling the TC using a lifting yoke and overhead crane. Lower trunnions are provided for rotating the cask from/to the vertical and horizontal positions on the

support skid/transport trailer. A gasketed cover plate is provided to seal the bottom hydraulic ram access penetration of the cask during loading. The TC lid is also provided with gaskets so that a helium environment can be maintained during DSC transfer operations.

1.2.1.3.2 Transfer Equipment

Transfer Trailer: The typical transfer trailer for the NUHOMS® HD System consists of a heavy industrial trailer used to transfer the empty cask, support skid and the loaded transfer cask between the plant's fuel/reactor building and the ISFSI. The trailer is designed to ride as low to the ground as possible to minimize the overall HSM-H height and the transfer cask height during 32PTH DSC transfer operations. The trailer is equipped with four hydraulic leveling jacks to provide vertical alignment of the cask with the HSM-H. The trailer is towed by a conventional heavy haul truck tractor or other suitable prime mover. Figure 1-7 shows the typical trailer.

Cask Support Skid: The cask support skid for the NUHOMS® HD System is shown in Figure 1-8 and is essentially the same as described in the FSAR [5] for the standard NUHOMS® System. Key design features include:

The skid is mounted on a surface with sliding support bearings and hydraulic positioners to provide alignment of the cask with the HSM-H. Brackets with locking bolts are provided to prevent movement during trailer towing.

The hydraulic ram may be mounted on the skid or, as an option, the ram can be set-up using a frame structure bolted to the cask bottom and a rear support tripod.

The cask support skid is mounted on a low profile heavy haul industrial trailer.

The plant's fuel/reactor building crane or other suitable lifting device is used to lower the cask onto the support skid which is secured to the transfer trailer. Specific details of this operation and the fuel/reactor building arrangement are covered by the provisions of the plant's 10CFR 50 operating license.

Hydraulic Ram: The hydraulic ram system consists of a hydraulic cylinder with a capacity and a reach sufficient for 32PTH DSC insertion into and retrieval from the HSM-H. The design of the ram support system provides a direct load path for the hydraulic ram reaction forces during 32PTH DSC insertion and retrieval. The system uses a rear ram support for alignment of the ram to the 32PTH DSC, and trunnions as the front support. The design provides positive alignment of the major components during 32PTH DSC insertion and retrieval.

1.2.2 Operational Features

This section provides a discussion of the sequence of operations involving the NUHOMS® HD System components.

1.2.2.1 Dry Run Operations

A dry run utilizing a 32PTH DSC loaded with mock-up fuel assemblies will be performed prior to loading the first canister by each licensee to demonstrate the adequacy of training, familiarity of system components and operational procedures. Mock-up fuel assemblies shall provide a representation of the maximum fuel assembly cross sectional envelope and provide a reasonable approximation of fuel assembly length and weight. The licensee shall determine the quantity of mock-up fuel assemblies required for the dry run to demonstrate that the loading and unloading processes are sound and the operations personnel are adequately trained.

The loading and unloading operations which have an impact on safety will be verified and recorded according to the requirements detailed in Chapter 8. The operations include loading and identifying fuel assemblies, ensuring the fuel assemblies meet the fuel acceptance criteria, drying, backfilling and pressurizing the canister, gas sampling and transferring the loaded canister to the HSM-H. Additionally, the ability to weld the top cover plates and open a sealed canister shall be demonstrated.

1.2.2.2 SFA Loading Operations

The primary operations (in sequence of occurrence) for the NUHOMS® HD System are:

1. Transfer Cask Preparation
2. 32PTH DSC Preparation
3. Place 32PTH DSC in Transfer Cask
4. Fill Transfer Cask/32PTH DSC Annulus with Clean Water and Seal
5. Fill 32PTH DSC Cavity with Fuel Pool Water (may be accomplished in step 6)
6. Lift Transfer Cask and Place in Fuel Pool
7. Spent Fuel Loading
8. Top Shield Plug Placement
9. Lifting Transfer Cask from Pool (DSC water may be drained)
10. Top Shield Plug Sealing
11. Vacuum Drying and Backfilling
12. Pressure Test
13. Leak Test
14. Outer Top Cover Plate Sealing

15. Transfer Cask/32PTH DSC Annulus Draining and Transfer Cask Top Cover Plate Placement
16. Backfill Transfer Cask Cavity with Helium
17. Place Loaded Transfer Cask on Transfer Skid/Trailer
18. Move Loaded Transfer Cask to HSM-H
19. Transfer Cask/HSM-H Preparation and Alignment
20. Insertion of 32PTH DSC into HSM-H
21. HSM-H Closure

These operations are described in the following paragraphs. The descriptions are intended to be generic and are described in greater detail in Chapter 8. Plant specific requirements may affect these operations and are to be addressed by the licensee.

Transfer Cask Preparation: Transfer cask preparation includes exterior washdown and interior decontamination. These operations are performed on the decontamination pad/pit outside the fuel pool area. The operations are similar to those for a shipping cask which are performed by plant personnel using existing procedures.

32PTH DSC Preparation: The internals and externals of the 32PTH DSC are inspected and cleaned if necessary. This ensures that the 32PTH DSC will meet plant cleanliness requirements for placement in the spent fuel pool.

Place 32PTH DSC in Transfer Cask: The empty 32PTH DSC is inserted into the transfer cask.

Fill Transfer Cask/32PTH DSC Annulus with Water and Seal: The transfer cask/32PTH DSC annulus is filled with uncontaminated water and is then sealed prior to placement in the pool. This prevents contamination of the 32PTH DSC outer surface and the transfer cask inner surface by the pool water.

Fill 32PTH DSC Cavity with Water: The 32PTH DSC cavity is filled with pool water to prevent an in-rush of water as the transfer cask is lowered into the pool.

Lift Transfer Cask and Place in Fuel Pool: The transfer cask, with the water-filled 32PTH DSC inside, is then lowered into the fuel pool. The transfer cask liquid neutron shield, if provided, may be left unfilled to meet hook weight limitations.

Spent Fuel Loading: Spent fuel assemblies are placed into the 32PTH DSC. This operation is identical to that presently used at plants for shipping cask loading.

Inner Top Cover/Shield Plug Placement: This operation consists of placing the inner top cover/shield plug into the 32PTH DSC using the plant's crane or other suitable lifting device.

Lifting Transfer Cask from Pool: The loaded transfer cask is lifted out of the pool and placed (in the vertical position) on the drying pad in the decontamination pit. This operation is similar to that used for shipping cask handling operations.

Inner Top Cover/Shield Plug[1] Sealing: The water contained in the space above the inner top cover plate/shield plug[1] is drained. The inner top cover plate/shield plug[1] is welded to the shell. This weld provides the top (confinement) seal for the 32PTH DSC.

Vacuum Drying and Backfilling: The initial blowdown of the 32PTH DSC is accomplished by pressurizing the vent port with nitrogen or helium. The water in the cavity is forced out of the siphon tube and routed back to the fuel pool or to the plant's liquid radwaste processing system via appropriate size flexible hose or pipe, as appropriate. The cavity water may also be removed by pumping out the water using the siphon port/tube and replaced by helium or nitrogen. The 32PTH DSC is then evacuated to remove the residual liquid water and water vapor, nitrogen or helium in the cavity. When the system pressure has stabilized, the 32PTH DSC is backfilled with helium.

Pressure Test: Perform a pressure test of inner top cover/shield plug[1] weld by backfilling the DSC cavity with helium.

After the pressure test, remove the helium lines then the vent and siphon cover plates are installed and welded to the inner top cover/shield plug[1].

Leak Test: Perform a leak test of the inner top cover/shield plug[1] to the DSC shell weld and siphon/vent cover welds using a temporary test head or any other alternative means.

Outer Top Cover Plate Sealing: After helium backfilling, the 32PTH DSC outer top cover plate is installed by using a partial penetration weld between the outer top cover plate and the DSC shell.

The outer cover plate to shell weld and inner top cover plate/shield plug[1] weld provide redundant seals at the upper end of the 32PTH DSC.

Transfer Cask/32PTH DSC Annulus Draining and Transfer Cask Top Cover Plate Placement: The transfer cask/32PTH DSC annulus is drained. A swipe is then taken over the 32PTH DSC exterior at the top cover plate and the upper portion of the shell. Demineralized water is flushed through the transfer cask/32PTH DSC annulus, as required, to remove any contamination left on the 32PTH DSC exterior. The transfer cask top cover plate is installed, using the plant's crane or other suitable lifting device, and bolted closed.

Backfill Transfer Cask Cavity with Helium: The TC cavity is evacuated and the cavity/annulus is backfilled to a positive pressure with helium.

Place Loaded Transfer Cask on Transfer Skid/Trailer: The transfer cask is lifted onto the transfer cask support skid and downended onto the transfer trailer from the vertical to horizontal position. The transfer cask is secured to the skid.

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[1] See Chapter 1 drawings for option 2 and option 3 designs and Chapter 7 for confinement boundary definitions.

Move Loaded Transfer Cask to HSM: Once loaded and secured, the transfer trailer is towed to the ISFSI along a predetermined route on a prepared road surface. Upon entering the ISFSI the cask is positioned and aligned with the designated HSM-H into which the 32PTH DSC is to be transferred.

Transfer Cask/HSM Preparation and Alignment: At the ISFSI with the cask positioned in front of the HSM-H, the transfer cask top cover plate is removed. The HSM-H door is removed and the transfer trailer is then backed into close proximity with the HSM-H. The skid positioning system is then used for the final alignment and docking of the transfer cask with the HSM-H and the cask restraint installed.

Insertion of 32PTH DSC into HSM: After final alignment of the transfer cask, HSM-H, and hydraulic ram, the 32PTH DSC is pushed into the HSM-H by the hydraulic ram.

HSM Closure: Install 32PTH DSC axial retainer and install HSM-H door.

1.2.2.3 Identification of Subjects for Safety and Reliability Analysis

1.2.2.3.1 Criticality Prevention

Criticality is controlled by utilizing the fixed borated neutron absorbing material in the 32PTH DSC basket and the pool water boron loading. During storage, with the cavity dry and sealed from the environment, criticality control measures within the installation are not necessary because water cannot enter the canister during storage.

1.2.2.3.2 Chemical Safety

There are no chemical safety hazards associated with operations of the NUHOMS® HD System. The coating materials used in the design of the 32PTH DSC are chosen to minimize hydrogen generation. Hydrogen monitoring is required during sealing operations to ensure hydrogen concentration levels remain within acceptable limits.

1.2.2.3.3 Operation Shutdown Modes

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

1.2.2.3.4 Instrumentation

The NUHOMS® HD System is a totally passive system. No safety-related instrumentation is necessary. The maximum temperatures and pressures are conservatively bounded by analyses. Therefore, there is no need for monitoring the internal cavity of the 32PTH DSC for pressure or temperature during normal operations. The 32PTH DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and accident conditions.

1.2.2.3.5 Maintenance and Surveillance

All maintenance and surveillance tasks are described in Chapter 9.

1.2.3 32PTH DSC Contents

The 32PTH DSC is designed to store up to 32 intact PWR Westinghouse 15x15 (WE 15x15 and WES 15x15), Westinghouse 17x17 (WE 17x17, WEV 17x17 and WEO 17x17), Framatome ANP Advanced MK BW 17x17 (MK BW 17x17) and/or Combustion Engineering 14x14 (CE 14x14) fuel assemblies. Non-Fuel Assembly Hardware (NFAHs) likeVibration Suppressor Inserts (VSI), Burnable Poison Rod Assemblies (BPRAs), or Thimble Plug Assemblies (TPAs) are allowed for these fuel assemblies except for CE 14x14 fuel assemblies. The 32PTH DSC is also designed for storage of up to 16 damaged fuel assemblies, and remaining intact assemblies, utilizing top and bottom end caps. A description of the fuel assemblies including the damaged fuel assemblies is provided in Chapter 2.

The maximum allowable assembly average initial enrichment of the fuel to be stored is 5.00 weight % U-235 and the maximum assembly average burnup is 60,000 MWd/MTU. The fuel must be cooled at least 5 years prior to storage.

The criticality control features of the NUHOMS® HD System are designed to maintain the neutron multiplication factor k-effective (including uncertainties and calculational bias) at less than 0.95 under normal, off-normal, and accident conditions.

The quantity and type of radionuclides in the SFAs are described and tabulated in Chapter 5. Chapter 6 covers the criticality safety of the NUHOMS® HD System and its parameters. These parameters include rod pitch, rod outside diameter, material densities, moderator ratios, and geometric configurations. The maximum pressure buildup in the 32PTH DSC cavity is addressed in Chapter 4.

1.5 Supplemental Data

1.5.1 References

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

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

3. U.S. Nuclear Regulatory Commission, "Standard Review Plan for Dry Cask Storage Systems," NUREG 1536, U.S. NRC, January 1997.

4. NRC Certificate of Compliance 72-1004, NUHOMS® General License Spent Fuel Storage System, Amendment No. 8, December, 2005.

5. TN West, Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel, Revision 8, June 2004, File NUH003.0103, USNRC Docket No. 72-1004.

6. Title 10, Code of Federal Regulations, Part 50, "Domestic Licensing of Production and Utilization Facilities".

7. Application for Amendment No. 8 of the NUHOMS® Certificate of Compliance 72-1004, Revision 4, January 2005.

1.5.2 Drawings

- 32PTH DSC: 10494-72-(1 to 12), Rev 0 (PROPRIETARY)
- OS187H: 10494-72-(15 to 21), Rev 0 (PROPRIETARY)
- HSM-H: 10494-72-(100 to 109) Rev. 0 (PROPRIETARY)
- Damaged Fuel End Caps: 10494-72-30, Rev 0 (PROPRIETARY)

THIS FIGURE HAS BEEN DELETED

Figure 1-5

2. PRINCIPAL DESIGN CRITERIA

2.1 Spent Fuel to be Stored

The NUHOMS® HD System components have currently been designed for the storage of 32 intact and or up to 16 damaged with remaining intact, Westinghouse 15x15 (WE 15x15 and WES 15x15), Westinghouse 17x17 (WE 17x17, WEV 17x17 and WEO 17x17), Framatome ANP Advanced 17x17 MK BW (MK BW 17x17), and/or Combustion Engineering 14x14 (CE 14x14) PWR fuel assemblies. Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed in Table 2-1 for a given assembly class are also acceptable. Additional payloads may be defined in future amendments to this application.

The thermal and radiological characteristics for the PWR spent fuel were generated using the SCALE computer code package [1]. The physical characteristics for the PWR fuel assembly types are shown in Table 2-1. Free volume in the 32PTH DSC cavity is addressed in Chapter 4. Specific gamma and neutron source spectra are given in Chapter 5.

Although analyses in this SAR are performed only for the design basis fuel, any other intact or damaged PWR fuel which falls within the geometric, thermal, and nuclear limits established for the design basis fuel can be stored in the 32PTH DSC.

2.1.1 Detailed Payload Description

This payload consists of 32 PWR UO_2 fuel assemblies with or without Non-Fuel Assembly Hardware (NFAH) which includes Burnable Poison Rod Assemblies, (BPRAs), Vibration Suppression Inserts (VSI) or Thimble Plug Assemblies (TPAs). CE 14x14 fuel assemblies are to be stored without NFAHs. Each 32PTH DSC can accommodate a maximum of sixteen damaged fuel assemblies, with the remaining assemblies intact. The fuel to be stored in the 32PTH DSC is limited to fuel with a maximum assembly average initial enrichment of 5.00 weight % U-235. The maximum allowable burnup is given as a function of initial fuel enrichment but does not exceed 60,000 MWd/MTU. The minimum cooling time is five years.

The 32PTH DSC may store up to 32 PWR fuel assemblies arranged in accordance with a heat load zoning configuration as shown in Figure 2-1, with a maximum decay heat of 1.5 kW per assembly and a maximum heat load of 34.8 kW per DSC, (33.8 kW per DSC for CE 14x14).

The 32PTH DSC can accommodate up to 16 damaged fuel assemblies as defined in Chapter 12. Damaged fuel assemblies shall be placed into the sixteen inner most basket fuel compartments, as shown in Figure 2-2, which contain top and bottom end caps that confine any loose material and gross fuel particles to a known, sub-critical volume during normal, off-normal and accident conditions and to facilitate handling and retrievability. Reactor records, visual/videotape records, fuel sipping, ultrasonic examination, and radio chemistry are examples of techniques utilized by utilities to identify damaged fuel.

The end caps are sized to fit inside the fuel compartment (see drawing 10494-72-30). The bottom end cap is slid into the fuel compartment before loading the fuel, utilizing a special tool.

After fuel loading, a top end cap is placed into the fuel compartment. The end caps are not "attached" to the basket, but are a slip/friction fit into the basket compartment. The fuel assembly is thus enclosed/confined by the fuel compartment walls and the end caps. The DSC inner top cover prevents any significant movement of the top end cap. The damaged fuel assemblies can be retrieved simply by removing the top end cap and grappling the fuel assembly by normal means.

The NUHOMS®-32TH DSC basket is designed with three alternate poison materials: Borated Aluminum alloy, Boron Carbide/Aluminum Metal Matrix Composite (MMC) and Boral®.

The NUHOMS®-32PTH DSC basket is analyzed for seven alternate basket configurations, depending on the boron loadings and poison materials.

A summary of the alternate poison loadings considered for each poison material as a function of basket types is presented below:

NUHOMS®-32PTH DSC Basket Type	**Minimum B10 Areal Density, g/cm²**	
	Natural or Enriched Boron Aluminum Alloy / Metal Matrix Composite (MMC) (Type I)	Boral® (Type II)
A	0.007	0.009
B	0.015	0.019
C	0.020	0.025
D	0.032	N/A
E	0.050	N/A

Table 2-2 shows a parametric equation that can be utilized to qualify spent fuel assemblies for the defined decay heat load zones. The decay heat load can be calculated based on a fuel assembly's burnup, cool time, and initial enrichment parameters. This table ensures that the fuel assembly decay heat load is within the appropriate zone. The development of this equation is provided in Appendix 4.16.2.

The maximum fuel cladding temperature limit of 400°C (752°F) is applicable to normal conditions of storage and all short term operations from spent fuel pool to ISFSI pad including vacuum drying and helium backfilling of the NUHOMS®-32PTH DSC per Interim Staff Guidance (ISG) No. 11, Revision 2 [15]. In addition, ISG-11 restricts the change in fuel cladding temperature to less than 65°C (117°F) and limits the numbers of cycles to less than 10 during DSC drying, backfilling and transfer operations.

The maximum fuel cladding temperature limit of 570°C (1058°F) is applicable to accidents or off-normal thermal transients [15].

Calculations were performed to determine the fuel assembly type which was most limiting for each of the analyses including shielding, criticality, thermal and confinement. These evaluations are performed in Chapters 5 and 6. The fuel assembly classes considered are listed in Table 2-1. It was determined that the MK BW 17x17 is the enveloping fuel design for the shielding, thermal and confinement source term calculation because of its total assembly weight and highest initial heavy metal loading. The bounding source term for shielding analysis is given in Table 2-3. Table 2-4 presents the thermal and radiological source terms for the NFAH.

These values are consistent with the cumulative exposures and cooling times of the fuel assemblies. The gamma spectra for the bounding fuel assembly and NFAH are presented in Chapter 5.

The shielding evaluation is performed assuming 32 fuel assemblies with the parameters (1.5kW) shown in Table 2-3. Any fuel assembly that is thermally qualified by Table 2-2 is also acceptable from a shielding perspective since the maximum decay heat load is 1.5 kW and only eight (8) are allowed in the 32PTH DSC. The shielding analysis assumes 32, 1.5 kW assemblies are in the 32PTH DSC. Minimum initial enrichments are defined for each of the zones to assure the shielding evaluation is bounding.

For criticality safety, the WE 17x17 is the most reactive assembly type for a given enrichment. This assembly is used to determine the most reactive configuration in the DSC. Using this most reactive configuration, criticality analysis for all other fuel assembly classes is performed to determine the maximum enrichment allowed as a function of the soluble boron concentration and fixed poison plate loading. The analyses results are presented in Chapter 6.

For calculating the maximum internal pressure in the NUHOMS®-32PTH DSC, it is assumed that 1% of the fuel rods are damaged for normal conditions, up to 10% of the fuel rods are damaged for off normal conditions, and 100% of the fuel rods will be damaged following a design basis accident event. A minimum of 100% of the fill gas and 30% of the fission gases within the ruptured fuel rods are assumed to be available for release into the DSC cavity, consistent with NUREG-1536 [17].

The maximum internal pressures used in the structural analysis for the NUHOMS®-32PTH DSC are 15 and 20 psig for normal and off-normal storage and transfer conditions respectively and 120 and 70 psig during transfer and storage accident conditions respectively.

The structural integrity of the fuel cladding due to the side drop is analyzed in Section 3.5.3. The end and corner drops are not considered credible during storage and transfer. The structural integrity of the fuel cladding due to these loads will be addressed by the users under their site license (10CFR50).

2.2 Design Criteria for Environmental Conditions and Natural Phenomena

The 32PTH DSC and HSM-H form a self-contained, independent, passive system, which does not rely on any other systems or components for its operation. The criterion used in the design of the 32PTH DSC and HSM-H ensures that their exposure to credible site hazards does not impair their safety functions.

The design criteria satisfy the requirements of 10CFR Part 72 [2]. They include the effects of normal operation, natural phenomena and postulated man-made accidents. The criteria are defined in terms of loading conditions imposed on the 32PTH DSC. The loading conditions are evaluated to determine the type and magnitude of loads induced on the 32PTH DSC. The combinations of these loads are then established based on the conditions that can be superimposed. The load combinations are classified by Service Level consistent with Section III of the ASME Boiler and Pressure Vessel Code [3]. The stresses resulting from the application of these loads are then evaluated based on the rules for a Class I nuclear component prescribed by Subsection NB of the Code for the 32PTH DSC Shell Assembly important to safety components. Subsections NG and NF of the Code apply to the 32PTH DSC Basket Assembly. The HSM-H loads and load combinations are developed in accordance with the requirements of ANSI 57.9 [4] and ASCE 7-95 [5]. The HSM-H component stresses are evaluated based on the applicable ACI and AISC standards specified.

2.2.1 Tornado and Wind Loadings

The NUHOMS® HD System is designed to resist the most severe tornado and wind loads specified by NRC Regulatory Guide 1.76 [6] and NUREG-0800 [7]. The HSM-H is designed to safely withstand tornado missiles as defined by 10CFR 72.122(b) (2). Extreme wind effects are much less severe than the specified design basis tornado wind forces, which are used in load combinations specifying extreme wind for the design of the HSM-H.

There are no credible wind loads applied to the 32PTH DSC as the HSM-H and transfer cask provide the required environmental protection. The case of the canister inside the HSM-H is evaluated in Chapter 3 for the associated pressure drop condition.

Since the NUHOMS® HD System on-site transfer cask (TC) is used infrequently and for short durations, the possibility of a tornado funnel cloud enveloping the TC/32PTH DSC during transit to the HSM-H is a low probability event. Nevertheless, the TC is designed for the effects of tornadoes, in accordance with 10CFR 72.122 which includes design for the effects of worst case tornado winds and missiles [7]. Analyses are presented in Chapter 11.

2.2.1.1 Applicable Design Parameters

The design basis tornado (DBT) intensities used for the HSM-H are obtained from NRC Regulatory Guide 1.76 [6]. Region I intensities are utilized since they result in the most severe loading parameters. The maximum wind speed is 360 mph which is the sum of the rotational speed of 290 mph plus the maximum translational speed of 70 mph. The radius of the maximum rotational speed is 150 feet, the pressure drop across the tornado is 3.0 psi, and the rate of pressure drop is 2.0 psi per second.

2.2.3 Seismic Design

Seismic design criteria are dependent on the specific site location. These criteria are established based on the general requirements as stated in 10CFR Part 72.102.

The design earthquake (DE) for use in the design of the casks must be equivalent to the safe shutdown earthquake (SSE) for a co-located nuclear power plant, the site of which has been evaluated under the criteria of 10CFR 100, Appendix A[8].

2.2.3.1 Input Criteria

The seismic design criteria for the HSM-H is based on the NRC Regulatory Guide 1.60 (R.G.) [9]. The response spectra is anchored to a maximum ground acceleration of 0.30g for the horizontal components and 0.20g for the vertical component. The results of the frequency analysis of the HSM-H structure (which includes a simplified model of the DSC) yield a lowest frequency of 23.2 Hz in the transverse direction and 28.4 Hz in the longitudinal direction. The lowest vertical frequency exceeds 33 Hz. Thus, based on the R.G. 1.60 response spectra amplifications, the corresponding seismic accelerations used for the design of the HSM-H are 0.37g and 0.33g in the transverse and longitudinal directions respectively and 0.20g in the vertical direction. The corresponding accelerations applicable to the DSC are 0.41g and 0.36g in the transverse and longitudinal directions, respectively, and 0.20g in the vertical direction.

2.2.4 Snow and Ice Loadings

Snow and ice loads for the HSM-H are derived from ASCE 7-95 [5]. The maximum 100 year roof snow load, specified for most areas of the continental United States for an unheated structure, of 110 psf is assumed. There are no credible snow and ice loads applied to the 32PTH DSC as the HSM-H and TC provide the environmental protection. Snow and ice loads for the TC with a loaded 32PTH DSC are negligible due to the smooth curved surface of the cask, the heat rejection of the SFAs, and the infrequent short term use of the cask.

2.2.5 Tsunami

Specific analyses including analyses for tip-over are not done for tsunamis as they are typically bounded by the tornado, wind and flooding load conditions. The licensee should evaluate site specific impacts of a tsunami.

2.2.6 Lightning

A lightning strike will not cause a significant thermal effect on the HSM-H or stored 32PTH DSC. The effects on the HSM-H resulting from a lightning strike are discussed in Chapter 11.

2.2.7 Combined Load Criteria

2.2.7.1 Horizontal Storage Module

The reinforced concrete HSM-H is designed to meet the requirements of ACI 349-97 [10]. The alternate temperature criteria of NUREG-1536 will be utilized as discussed in Chapters 3 (Appendix 3.9.9) and 11. The ultimate strength method of analysis is utilized with the appropriate strength reduction factors as described in Chapter 3 (Appendix 3.9.9). The load combinations specified in ANSI 57.9-1984 [4] are used for combining normal operating, off-normal, and accident loads for the HSM-H. All seven load combinations specified are considered and the governing combinations and the appropriate load factors are presented in Chapter 3 (Appendix 3.9.9).

The resulting HSM-H load combinations and load factors are also presented in Chapter 3 (Appendix 3.9.9). The effects of duty cycle on the HSM-H are considered and found to have negligible effect on the design. The corresponding structural design evaluation for the 32PTH DSC support structure is presented in Chapter 3 (Appendix 3.9.9).

2.2.7.2 32PTH DSC

The 32PTH DSC is designed by analysis to meet the stress intensity allowables of the ASME Boiler and Pressure Vessel Code (1998 Edition with 2000 Addenda) Section III, Division I, Subsection NB including alternatives to ASME code specified in SAR Section 3.10, NG and NF for Class 1 components and supports [3]. The 32PTH DSC is conservatively designed by utilizing linear elastic or non-linear elastic-plastic analysis methods. The load combinations considered for the 32PTH DSC normal, off-normal and postulated accident loadings are described in Chapter 3. ASME Code Service Level A allowables are used for normal and off-normal operating conditions. Service Level D allowables are used for accident conditions such as a postulated cask drop accident. Using these acceptance criteria ensures that in the event of a design basis drop accident, the 32PTH DSC confinement boundary is not breached. Normal operational stresses are combined with the appropriate off-normal and accident stresses. It is assumed that only one postulated accident condition occurs at any one time. The structural evaluation for the 32PTH DSC is documented in Chapter 3.

2.2.7.3 Transfer Cask

The on-site transfer cask is a pressure retaining component (maintain helium backfill) and is designed by analysis to meet the stress allowables of the ASME Code, Subsection NC for Class 2 components. The cask is designed by utilizing linear elastic analysis methods. The load combinations considered for the transfer cask, normal, off-normal, and postulated accident loadings are defined in Chapter 3. Service Level A allowables are used for all normal operating and off-normal conditions. Service Level D allowables are used for load combinations which include postulated accident loadings. Allowable stress limits for upper lifting trunnions are developed to meet the requirements of ANSI N14.6 [11] for non-redundant lifting. 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 analyses are presented in Chapter 3.

2.3 Safety Protection Systems

2.3.1 General

The NUHOMS® HD System is designed to provide long term storage of spent fuel. The canister materials are selected such that degradation is not expected during the storage period. The 32PTH DSC shell and bottom end assembly confinement boundary weld is made during fabrication of the 32PTH DSC in accordance with the subsection NB of the ASME code. The top shield plug and bottom provide shielding for the 32PTH DSC so that occupational doses are minimized during drying, sealing, and handling operations. The confinement boundary weld between the DSC shell and inner top cover/shield plug[1] (including siphon/vent cover welds) and structural attachment weld between the DSC shell and outer top cover plate are in accordance with alternatives to the ASME code as described in SAR Section 3.10.

The NUHOMS® HD System is designed for safe and secure, long-term confinement and dry storage of SFAs. The key elements of the NUHOMS® HD System and their operation which require special design consideration are:

A. Minimizing the contamination of the 32PTH DSC exterior by fuel pool water.

B. The 32PTH DSC confinement boundaries and welds as defined in SAR Section 7.1.

C. Minimizing personnel radiation exposure during 32PTH DSC loading, closure, and transfer operations.

D. Design of the HSM-H, OS187H TC, and 32PTH DSC for postulated accidents.

E. Design of the HSM-H passive ventilation system for effective decay heat removal to ensure the integrity of the fuel cladding. The HSM-H is designed with no active safety systems.

F. Design of the 32PTH DSC to ensure subcriticality.

G. Design of the OS187H TC for shielding, protection, and efficient operability.

2.3.2 Protection by Multiple Confinement Barriers and Systems

2.3.2.1 Confinement Barriers and Systems

The radioactive material which the NUHOMS® HD System confines is the spent fuel assemblies and the associated contaminated or activated materials.

During fuel loading operations, the radioactive material in the plant's fuel pool is prevented from contacting the 32PTH DSC exterior by filling the cask/32PTH DSC annulus with uncontaminated, demineralized water prior to placing the cask and 32PTH DSC in the fuel pool. In addition, the cask/32PTH DSC annulus opening at the top of the cask is sealed using an inflatable seal to prevent pool water from entering the annulus. This procedure minimizes the likelihood of contaminating the 32PTH DSC exterior surface. The combination of the above operations assures that the 32PTH

[1] See Chapter 1 drawings for option 2 and option 3 designs and Chapter 7 for confinement boundary definitions.

DSC surface loose contamination levels are within those required for shipping cask externals. Compliance with these contamination limits is assured by taking surface swipes of the upper end of the 32PTH DSC before transferring the cask from the fuel building.

Once inside the 32PTH DSC, the SFAs are confined by the 32PTH DSC confinement boundary. The fuel cladding integrity is ensured by maintaining the storage cladding temperatures below levels which are known to cause degradation of the cladding. In addition, the SFAs are stored in an inert atmosphere to prevent degradation of the cladding, specifically cladding rupture due to oxidation and its resulting volumetric expansion of the fuel. Thus, a helium atmosphere for the 32PTH DSC is incorporated in the design to protect the fuel cladding integrity by inhibiting the ingress of oxygen into the cavity.

Helium is known to leak through valves, mechanical seals, and escape through very small passages because it has a small atomic diameter, is an inert element, and exists in a monatomic species. Helium will not, to any practical extent, diffuse through stainless steel. For this reason the 32PTH DSC has been designed as a welded confinement pressure vessel with no mechanical or electrical penetrations and meets the leak-tight criteria as described in Chapter 9. See Chapter 7 for a detailed discussion of the confinement boundary design.

The 32PTH DSC itself has a series of barriers to ensure the confinement of radioactive materials. The cylindrical shell is fabricated from rolled ASME stainless steel plate which is joined with full penetration welds that are 100% inspected by non-destructive examination. All top and bottom end closure welds are multiple-layer welds. This effectively eliminates any pinhole leaks which might occur in a single pass weld, since the chance of pinholes being in alignment on successive weld passes is not credible. Furthermore, the cover plates are sealed by separate, redundant closure welds. Pressure boundary welds and welders are qualified in accordance with Section IX of the ASME B&PV Code and inspected according to the appropriate articles of Section III, Division 1, Subsection NB including alternatives to ASME Code as specified in SAR Section 3.10. These criteria ensure that the as-deposited weld filler metal is as sound as the parent metal of the pressure vessel.

Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and by its presence compromise the integrity of the 32PTH DSC design. The shell and welded cover plates provide total confinement of radioactive materials. Once the 32PTH DSC is sealed, there are no credible events, as discussed in Chapter 11, which could fail the cylindrical shell or the closure plates which form the confinement boundary.

2.3.2.2 32PTH DSC Cooling

The HSM-H provides a means of removing spent fuel decay heat by a combination of radiation, conduction, and natural convection. The passive convective ventilation system is driven by the pressure difference due to the stack buoyancy effect (ΔP_s) provided by the temperature difference between the 32PTH DSC and the ambient air outlet. This pressure difference is larger than the flow pressure drop (ΔP_f) at the design air inlet and outlet temperatures.

There are no radioactive releases of effluents during normal and off-normal storage operations. Also, there are no credible accidents which cause releases of radioactive effluents from the 32PTH DSC. Therefore, an off-gas monitoring system is not required for the HSM-H. The only time an off-gas system is required is during 32PTH DSC drying operations. During this operation, the spent fuel pool or plant's radwaste system is used to process the nitrogen and helium evacuated from the 32PTH DSC.

During transfer of the DSC from the reactor building to the HSM, cooling of the DSC is maintained by utilizing a helium environment inside the transfer cask.

2.3.3 Protection by Equipment and Instrumentation Selection

2.3.3.1 Equipment

The HSM-H, 32PTH DSC, and transfer cask encompass equipment which is important to safety. Other equipment important to safety associated with the NUHOMS® 32PTH System includes the equipment required for handling operations within the plant's fuel/reactor building. This equipment is regulated by the plant's 10CFR 50 [16] operating license.

2.3.3.2 Instrumentation

The NUHOMS® HD System is a totally passive system. No safety-related instrumentation is necessary for monitoring the 32PTH DSC. The maximum temperatures and pressures are conservatively bounded by analyses. Therefore, there is no need for monitoring the internal cavity of the 32PTH DSC for pressure or temperature during normal operations. The 32PTH DSC is conservatively designed to perform its confinement function during all worst case normal, off-normal, and postulated accident conditions.

2.3.4 Nuclear Criticality Safety

2.3.4.1 Control Methods for Prevention of Criticality

The design criteria for criticality is that an upper sub-critical limit (USL) of 0.95 minus statistical uncertainties and bias, shall be limiting for all postulated arrangements of fuel within the canister. The 32PTH DSC incorporates borated aluminum material(s) as fixed neutron absorbing materials to provide criticality control. Criticality control is discussed in Chapter 6.

The 32PTH DSC is designed to assure an ample margin of safety against criticality under the conditions of fresh fuel (fuel without burnup credit) in a canister flooded with borated pool water. The methods of criticality control are in accordance with the requirements of 10CFR 72.124 [2].

Criticality analysis is performed using the SCALE computer code package [1] which is widely used for criticality analysis of shipping casks, fuel storage pools and storage systems. Benchmark problems are run to verify the codes, methodology and cross section library and to determine calculational bias and uncertainties. Chapter 6 of the SAR presents the NUHOMS® HD System criticality analyses.

In the criticality calculation, the fuel assemblies and canister geometries are explicitly modeled. Each fuel pin and each guide tube is represented within each assembly.

Reactivity analyses were performed for CE 14x14, WE 15x15, WES 15x15, WE 17x17, WEV 17x17, WEO 17x17 and MK BW 17x17 fuel assemblies. These analyses do not credit the neutron absorption capability of the NFAH where applicable.

2.3.4.2 Error Contingency Criteria

Provision for error contingency is built into the criterion used in Section 2.3.4.1. The criterion is common practice for licensing submittals. Because conservative assumptions are made in modeling, it is not necessary to introduce additional contingency for error.

2.3.4.3 Verification Analysis-Benchmarking

Evaluation and verification against critical benchmarking experiments are described in Chapter 6, Section 6.5.

2.3.5 Radiological Protection

The NUHOMS® HD System ISFSI is designed to maintain on-site and off-site doses as low as reasonably achievable (ALARA) during transfer operations and long-term storage conditions. ISFSI operating procedures, shielding design, and access controls provide the necessary radiological protection to assure radiological exposures to station personnel and the public are ALARA. Further details concerning on-site and off-site dose rates resulting from NUHOMS® 32PTH HD System, ISFSI operations and the ISFSI ALARA evaluation are provided in Chapter 10.

2.3.5.1 Access Control

The NUHOMS® HD System ISFSI will typically be located within the owner controlled area of an operating plant. A separate protected area consisting of a double fenced, double gated, lighted area may be installed around the ISFSI. Access is then controlled by locked gates, and guards are stationed when the gates are open. The licensee's Security Plan must describe the devices employed to detect unauthorized access to the facility. The specific procedures for controlling access to the ISFSI site and the restricted area within the site per 10CFR 72, Subpart H shall be addressed by the licensee's physical security and safeguards contingency plans. The system will not require the continuous presence of operators or maintenance personnel.

2.5.3 ISFSI Basemat and Approach Slabs

The ISFSI basemat and approach slabs are considered NITS and are designed, constructed, maintained, and tested as commercial grade items.

Licensees are required to perform an assessment to confirm that the license seismic criteria described in Section 2.2.3 are met.

2.5.4 Transfer Equipment

2.5.4.1 Transfer Cask and Yoke

The on-site transfer cask OS-187H is ITS since it protects the spent fuel canister (32PTH DSC) during handling and is part of the primary load path used while handling the 32PTH DSC in the fuel/reactor building. An accidental drop of a loaded transfer cask (weighing approximately 115 tons) has the potential for creating conditions in the plant which must be evaluated. These possible drop conditions are evaluated with respect to the impact on the 32PTH DSC in Chapters 3 and 11. Therefore, the transfer cask is designed, constructed, and tested in accordance with a QA program incorporating a graded quality approach for ITS requirements as defined by 10CFR 72, Subpart G, paragraph 72.140(b) and described in Chapter 13.

A lifting yoke is used for handling the transfer cask within the fuel/reactor building and it is used by the licensee (utility) under their 10CFR 50 [16] program requirement.

Due to site unique requirements, rigid or sling lifting members may be used to augment the lifting yoke. These members shall be designed, fabricated and tested in accordance with the same requirements as the cask lifting yoke.

2.5.4.2 Other Transfer Equipment

The NUHOMS® HD System transfer equipment (i.e., ram, skid, transfer trailer) are necessary for the successful loading of the 32PTH DSC into the HSM-H. However, the analyses described in Chapter 11 demonstrate that the performance of these items are not required to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Therefore, these components are considered NITS and need not comply with the requirements of 10CFR 72. These components are designed, constructed, and tested in accordance with good industry practices.

2.5.5 Auxiliary Equipment

The vacuum drying system and the automated welding system are NITS. Performance of these items is not required to provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Failure of any part of these systems may result in a delay of operations, but will not result in a hazard to the public or operating personnel. These components are designed, constructed, and tested in accordance with good industry practices.

2.6 References

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2. U.S. Government, "Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)," Title 10 Code of Federal Regulations, Part 72, Office of the Federal Register, Washington, D.C.

3. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1998 Edition through 2000 Addenda.

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

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

6. U.S. Atomic Energy Commission, "Design Basis Tornado for Nuclear Power Plants," Regulatory Guide 1.76 (1974).

7. NUREG-0800, Standard Review Plan, Section 3.3.1, "Wind Loading" and Section 3.5.1.4 "Missiles Generated by Natural Phenomenon".

8. U.S. Government, "Reactor Site Criteria," Title 10 Code of Federal Regulations, Part 100, Office of the Federal Register, Washington, D.C.

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

10. American Concrete Institute, Code Requirements for Nuclear Safety Related Concrete Structures and Commentary, ACI 349-97. and ACI 349R-97, American Concrete Institute, Detroit, Michigan.

11. American National Standards Institute, ANSI N14.6-1993, American National Standard for Special Lifting Device for Shipping Containers Weighing 10,000 lbs. or More for Nuclear Materials.

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13. U.S. Government, "Packaging and Transportation of Radioactive Material" Title 10 Code of Federal Regulations, Part 71, Office of the Federal Register, Washington, D.C.

14. American Concrete Institute, “Building Code Requirements for Reinforced Concrete,” ACI-318, 199789 (92).

15. US NRC, Interim Staff Guidance, ISG-11, Rev 3, “Cladding Considerations for the Transportation and storage of Spent Fuel.”

16. U.S. Government, “Domestic Licensing of Production and Utilization Facilities,” Title 10 Code of Federal Regulations, Part 50, Office of the Federal Register, Washington, D.C.

17. NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems," 1997.

Table 2-1
Spent Fuel Assembly Physical Characteristics

Parameter	WE &WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Maximum Assembly Average Initial Enrichment, wt % U235 (max)	5.00	5.00	5.00	5.00	5.00	5.00
Clad Material	Zr-4/Zirlo	Zr-4/Zirlo	M5	Zr-4/Zirlo	Zr-4/Zirlo	Zr-4/Zirlo
No of fuel rods	204	264	264	264	264	176
No of guide/instrument tubes	21	25	25	25	25	5
Assembly Length(4)	162.2	162.4	162.4	162.4	162.4	159.5
Max Uranium Loading (MTU)	467	467	476	467	467	385
Assembly Cross Section	8.424 x 8.424	8.426 x 8.426	8.425 x 8.425	8.426 x 8.426	8.426 x 8.426	8.25 x 8.25
Max Assembly Weight with Insert components(5)	1528	1575	1554	1533	1533	1450(6)

(1) Nominal values shown unless stated otherwise
(2) All dimensions are inches
(3) Deleted
(4) Includes allowance for irradiation growth
(5) Weights of TPAs and VSIs are enveloped by BPRAs
(6) Without NFAHs

Table 2-2

Fuel Qualification Table(s)

The Decay Heat (DH) in watts is expressed as:

$$F1 = A + B*X1 + C*X2 + D*X1^2 + E*X1*X2 + F*X2^2$$
$$DH = F1*Exp(\{[1-(5/X3)]*G\}*[(X3/X1)^H]*[(X2/X1)^I])$$

where,

- F1 Intermediate Function, basically the Thermal source at 5 year cooling
- X1 Assembly Burnup in GWD/MTU
- X2 Maximum Assembly Average Initial Enrichment in wt. % U-235 (max 5%, min: Zone 1- 1.5%, Zone 2 -1.6% Zone 3- 2.5%)
- X3 Cooling Time in Years (min 5 yrs)

A=13.69479 B= 25.79539 C= -3.547739 D= 0.307917 E= -3.809025
F= 14.00256 G= -0.831522 H= 0.078607 I= -0.095900

Examples for Zone 1a -1050 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.50	32.8	37.2	40.7	43.7	48.1	55.2
2.50	34.7	39.2	42.7	45.6	50.0	57.0
3.00	35.5	40.1	43.6	46.5	51.0	57.9
3.50	36.2	40.9	44.5	47.4	52.0	58.9
4.00	36.8	41.5	45.3	48.3	52.8	59.9
4.50	37.2	42.1	45.9	49.0	53.7	60.0

Examples for Zone 1b -800 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.50	26.3	30.0	32.9	35.4	39.2	45.2
2.00	27.1	30.8	33.8	36.2	40.0	46.0
2.50	27.7	31.5	34.5	37.0	40.8	46.7
3.00	28.2	32.1	35.2	37.7	41.5	47.5
3.50	28.5	32.5	35.7	38.3	42.2	48.3
4.00	28.5	32.9	36.2	38.8	42.8	49.0
4.50	28.5	33.0	36.4	39.2	43.3	49.7

Table 2-2

Fuel Qualification Table(s) (concluded)

Examples for Zone 2 -1100 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.60	34.2	39.8	42.4	45.4	50.0	57.3
2.50	36.0	40.6	44.2	47.2	51.7	58.9
3.00	36.9	41.5	45.2	48.2	52.8	59.9
3.50	37.6	42.4	46.1	49.1	53.7	60.0
4.00	38.3	43.1	46.9	50.0	54.7	60.0
4.50	38.7	43.8	47.7	50.8	55.6	60.0

Examples for Zone 3 -1500 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years
3.50	47.9	53.5	57.8	60.0
4.00	48.9	54.6	59.0	60.0
4.25	49.4	55.1	59.5	60.0
4.50	49.9	55.6	60.0	60.0

Table 2-3
Bounding Spent Fuel Assembly Thermal and Radiological Characteristics

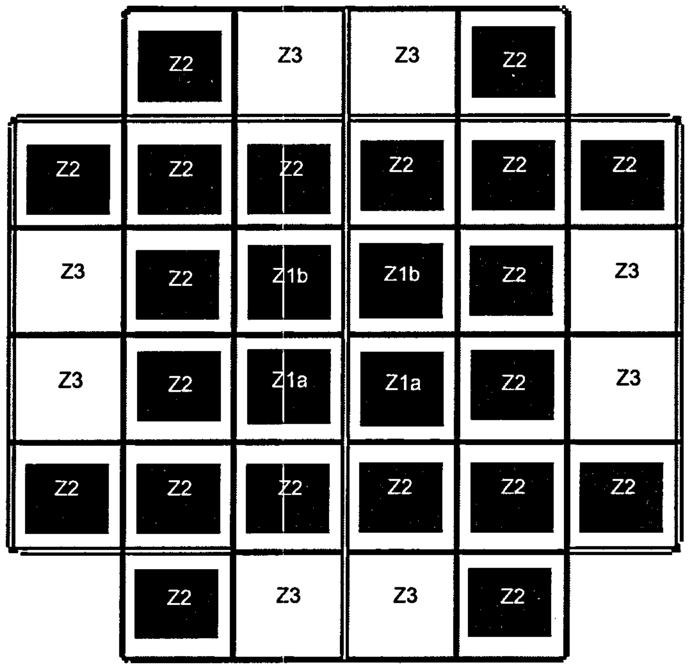
Parameter	MK BW 17x17
Enrichment (%wt U-235)	4.0(3)
Burnup (MWd/MTU)	60,000
Minimum Cooling Time (years)	7
Decay Heat (kW/assy)	1.5(1) or less
Gamma Source (γ/sec/DSC)(2)	2.22E+17
Neutron Source (n/sec/DSC)(2)	3.52E+10

(1) Decay heat for fuel assembly excluding control components. Decay heat for control components (0.009 kW per assembly maximum) is specified in Table 2-4
(2) Gamma/neutron source spectrum by energy group per fuel assembly is presented in Chapter 5.
(3) For criticality max enrichment is 5.0%wt.

Table 2-4
Non-Fuel Assembly Hardware Thermal and Radiological Characteristics

Parameter	BPRA (Bounding)
Gamma Source(1) (γ/sec/assy)	2.30E+14
Decay heat (Watts/assy)(2)	9

(1) Four days cooled, 30 GWD/MTU source.
(2) Five years cooled, 30 GWD/MTU source.
(3) Gamma source by energy group is presented in Chapter 5



For CE 14x14 Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 33.8 kW
- 4 fuel assemblies in zone 1 with $Q_{z1} \leq 0.775$ kW
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.068$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

For other Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat ≤ 3.2 kW
  - $Q_{z1a} \leq 1.05$ kW in the lower compartments
  - $Q_{z1b} \leq 0.8$ kW in the upper compartments
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.1$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

Figure 2-1
Heat Load Zones

CHAPTER 3
STRUCTURAL EVALUATION

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3. STRUCTURAL EVALUATION

3.1 Structural Design

This chapter, including its appendices, presents the structural evaluation of the NUHOMS® HD System.

The NUHOMS® HD system consists of the 32PTH DSC basket and shell assemblies, the HSM-H, and the OS187H Transfer Cask. The 32PTH DSC is a new dual purpose canister that is designed to accommodate up to 32 intact PWR fuel assemblies (or up to 16 damaged assemblies, with the remaining intact) with total heat load of up to 34.8 kw. The HSM-H is an enhanced version of the NUHOMS® Standardized HSM and incorporates design features to enable storage of the higher heat load 32PTH DSC. The OS187H is the modified version of OS197 transfer cask with a redesigned shielding panel to improve the thermal performance, shortened the cavity length and increased inside diameter to accommodate the larger diameter of 32PTH DSC.

The overall design bases for the NUHOMS® HD system are described in Chapters 1 and 2. This Chapter discusses the structural design criteria and associated design bases applicable to the 32PTH DSC, HSM-H, and OS187H transfer cask. This Chapter also describes the ability of these components to perform their design function during normal and off-normal operating conditions, as well as under postulated accident conditions and extreme natural phenomena events.

3.1.1 Discussion

The NUHOMS® HD system consists of the 32PTH DSC, a high-integrity stainless steel dry shielded canister that provides for the dry storage of spent fuel assemblies in an inert atmosphere; the HSM-H, a massive reinforced concrete storage module that houses and provides environmental protection and shielding to the 32PTH DSC; and the OS187H transfer cask, a stainless steel cask, with lead shielding, that handles and protects the 32PTH DSC during transfer to and from the HSM-H.

Multiple HSM-Hs are grouped together to form arrays in single or double rows to provide storage capacity consistent with available site space and reactor SFA discharge rates. The HSM-H is placed next to, and in contact with, adjacent module(s) to form a continuous single or double row arrays.

For purposes of the structural analyses and agreement with the criteria set forth in Regulatory Guide 3.61 [1] and NUREG 1536 [2], a single NUHOMS® HD System 32PTH DSC plus an HSM-H form the "cask" cited in [1] and [2].

The codes and standards used for the design, fabrication, and construction of the NUHOMS® HD system components, equipment, and structures are summarized in Table 3-1 and are identified throughout the SAR. Alternatives to the ASME Code [4] are provided in Section 3.10.

3.1.1.1 General Description of the 32PTH DSC

The principal characteristics of the 32PTH DSC are described in Chapter 1, Section 1.2.1. The drawings in Section 1.5 provide the principal dimensions and design parameters of the 32PTH DSC. For purposes of the structural analysis, the 32PTH DSC is divided into the 32PTH DSC shell assembly and the internal basket assembly.

A. DSC Canister (Shell) Assembly Description

The canister shell assembly and details are shown on drawings 10494-72-2 through 10494-72-7 in Chapter 1, Section 1.5. The shell assembly is a high integrity stainless steel (SA-240 Type 304) welded pressure vessel that provides confinement of radioactive materials, encapsulates the fuel in an inert atmosphere (the canister is backfilled with Helium before being seal welded closed), and provides biological shielding (in axial direction).

The remaining 32PTH DSC shell assembly components include the solid stainless steel top shield plug, the grapple ring assembly, support ring, and the lifting blocks. The outer top cover, top shield plug and shell bottom provide biological shielding during fuel loading operations and storage of a loaded 32PTH DSC. The grapple ring assembly is welded to the shell bottom or outer bottom cover plate for the purpose of inserting/extracting the 32PTH DSC to and from the Horizontal Storage Module (HSM-H). The support ring, welded to the cylindrical shell, supports the top shield plug. Four lifting blocks are welded to the inside of the shell bottom and are used in conjunction with a lifting fixture to lift the unloaded 32PTH DSC into the transfer cask prior to fuel loading operations.

All primary components of the 32PTH DSC are constructed from Type 304 stainless steel. The 32PTH DSC cylindrical shell and shell bottom assembly (which includes the shell bottom and the grapple ring assembly), and the internal basket assembly, are shop-fabricated (and assembled) components. The top shield plug and outer top cover plate is installed at the plant after the spent fuel assemblies have been loaded into the 32PTH DSC internal basket.

The 32PTH DSC shell assembly is designed, fabricated, examined and tested in accordance with the requirements of Subsection NB of the ASME Code including alternatives to ASME code specified in Section 3.10. The circumferential and longitudinal shell plate weld seams are multi-layer full penetration butt welds. The butt weld joints are fully radiographed and inspected according to the requirements of NB-5000 of the ASME Boiler and Pressure Vessel Code. The full penetration inner bottom cover plate to shell weld is inspected to the same Code standards.

The 32PTH DSC top closure is designed, fabricated and inspected using alternatives to ASME code specified in Section 3.10. The outer top cover plate and inner top cover/shield plug (including option 2 or option 3 inner top cover as described in Chapter 1 drawings) are sealed by separate, redundant closure welds. The inner top cover/shield plug (including option 2 or option 3 design welds as described in Chapter 1 drawings) is welded to the 32PTH DSC shell to form the confinement boundary at the top end of the 32PTH DSC, as shown in Chapter 7, Figure 7-1.

The outer top cover plate provides structural support to the confinement boundary. All closure welds are multiple layer welds. This effectively eliminates any pinhole leaks which may occur in a single-pass weld, since the chance of pinholes being in alignment on successive weld passes is negligibly small. Also, both welds are examined by multi-level liquid penetrant to effectively eliminate through wall leaks.

The top shield plug of the 32PTH DSC incorporates a vent and a siphon port, with two small-diameter tubing penetrations into the 32PTH DSC cavity for draining and filling operations. One penetration, the vent port, is terminated at the bottom of the shield plug assembly. The other port is attached to a siphon tube, which continues to the bottom of the 32PTH DSC cavity. The vent and siphon ports terminate in normally closed quick-connect fittings. Both ports are used to remove water from the 32PTH DSC during the drying and sealing operations.

During fabrication, the 32PTH DSC shell and bottom assemblies are leak tested to an acceptance criterion of 1×10^{-7} ref. cm^3/sec as defined in ANSI N14.5 [6]. The welds between the DSC shell and the inner top cover/shield plug (including siphon/vent cover and option 2 or option 3 inner top cover welds as described in Chapter 1 drawings) are also leak tested to an acceptance criteria of 1×10^{-7} ref. cm^3/sec at the field after the fuel assemblies are loaded into the canister.

The stringent design and fabrication requirements described above ensure that the pressure retaining confinement function is maintained for the design life of the 32PTH DSC. Pressure monitoring instrumentation is not used since penetration of the pressure boundary would be required. The penetration itself would then become a potential leakage path and, by its presence, compromise the leaktightness of the 32PTH DSC design.

During draining, backfilling, and leak testing, a "Strongback Device" may be installed to minimize deformation of the inner top cover plate during blowdown. The strongback is bolted to the top flange of the transfer cask and provides support to the inner cover plate during those operations that may involve significant pressurization of the 32PTH DSC cavity.

Transfer of the 32PTH DSC from the transfer cask into the HSM-H is performed using a hydraulic ram that applies a load to the bottom cover plate assembly, at the center of the DSC.

Frictional loads during 32PTH DSC transfer are reduced by application of a dry film lubricant to the hardened nitronic surface on the support rails of the HSM-H and the transfer cask. The lubricant chosen for this application is a tightly adhering inorganic lubricant with an inorganic binder. The dry film lubricant provides a thin, clean, dry, layer of lubricating solids that is intended to reduce wear, and prevent galling in metals. It is applied as a thin sprayed coating, similar to paint, using a carefully controlled process. The lubricant is not affected by water and is designed to be highly resistant to aggressive chemicals. This product is designed for radiation service and has a low coefficient of sliding friction for stainless steel.

B. <u>Fuel Basket Assembly Description</u>

The details of the 32PTH DSC basket are shown in drawings 10494-72-8 through 10494-72-12 on Chapter 1, Section 1.5. The 32PTH DSC basket is a welded assembly of stainless steel fuel

compartment boxes, and designed to accommodate 32 PWR fuel assemblies. The sections of the stainless steel fuel compartments are fusion welded to Type 304 stainless steel structural plates, sandwiched between the box sections. The fusion welds are spaced intermittently along the box sections. Neutron poison plates, composed of a boron-aluminum alloy (or a boron carbide aluminum metal matrix composite), are sandwiched between the sections of the stainless steel walls of the adjacent box and the adjacent stainless steel plates. The Type 304 stainless steel members are the primary structural components. The neutron poison plates provide criticality control and a heat conduction path from the fuel assemblies to the canister shell. The bottom rows of plates which are 304 SST (no poison) are also sandwiched between the fuel compartment box sections, and provide structural support to the basket.

Stainless steel rails are oriented parallel to the axis of the canister and attached to the periphery of the basket to establish and maintain basket orientation and to support the basket.

The nominal open dimension of each fuel compartment cell is 8.70 inches × 8.70 inches, which provides clearance around the fuel assemblies. The overall length of the fuel basket is 162.00 inches, which is less than the canister cavity length of the canister (164.50 inches minimum) to allow for thermal expansion, tolerances, and access to the top of the fuel assemblies.

The basket structure is open at each end. Therefore, longitudinal fuel assembly loads are applied directly on the DSC body and not on the fuel basket structure. The fuel assemblies are laterally supported by the stainless steel fuel compartments and structural plates, and the fuel basket is laterally supported by the rails and the canister shell.

The circumferential orientation of the basket, relative to the canister shell, is maintained by the four lifting blocks attached to the bottom closure assembly of the canister. The four canister lifting blocks mate with the hollow portions of the basket outer support rails, without interfering with the spent fuel assemblies. During normal transfer conditions, the DSC rests on four transfer support rails, attached to the inside surface of the NUHOMS®-OS187H Transfer Cask.

3.1.1.2 General Description of the HSM-H

The details of the HSM-H module are shown in drawings 10494-72-100 through 10494-72-109 on Chapter 1, Section 1.5. The HSM-H is a free standing reinforced concrete structure designed to provide environmental protection and radiological shielding for the 32PTH DSC. Each HSM-H provides a self contained modular structure for the storage of a 32PTH DSC containing up to 32 PWR fuel assemblies. The HSM-H provides heat rejection from the spent fuel decay heat by a combination of radiation, conduction and convection.

The HSM-H is a reinforced concrete structure consisting of two separate units: a base storage unit, where the 32PTH canister is stored, and a top shield block that serves to provide environmental protection and radiation shielding. The top shield block is attached to the base unit by vertical ties. Three-foot thick shield walls are installed behind each HSM-H (single row array only) and at the ends of each row to provide additional shielding.

is provided to seal the bottom hydraulic ram access penetration of the cask (by 12-1/2 in. high strength bolts with O-ring) during fuel loading and transferring the canister to the ISFSI. Drawing 10494-72-15 provides the part list for the NUHOMS®-OS187H transfer cask. Drawing 10494-72-16 shows the overall configuration of the NUHOMS®-OS187H transfer cask. Drawing 10494-72-17 shows the details of the transfer cask top cover. The remaining drawings (10494-72-18 through 10494-72-21) show the details of the remaining individual components that make up the transfer cask.

The following sections provide physical and functional descriptions of each major component of the transfer cask. Detail drawings showing dimensions of significance to the safety analyses, welding and NDE information, as well as a complete materials list are provided in Chapter 1, Section 1.5. Reference to these drawings is made in the following physical description sections, and in general, throughout this SAR.

A. Transfer Cask Body and Structural Components

The shell or cask body cylinder assembly is an open ended (at the top) cylindrical unit with an integral closed bottom end. This assembly consists of concentric inner shell and outer shell (both SA-240 Type 304), welded to massive closure flanges (SA-240 Gr. Type 304) at the top and bottom ends. The inner shell is 0.50 inches thick and has a 70.50 inch inside diameter. The outer shell is the primary structural shell and is 1.5 inches to 2.0 inches thick, and has an 82.70 inch outside diameter. The annulus between the shells is filled with lead shielding. The lead gamma shield is 3.60 inch thick and is poured into the annulus in a molten state using a carefully controlled procedure.

The transfer cask bottom end assembly consists of a 2.00 inch bottom end plate and a 0.75 inch bottom neutron shield plate, that sandwich a 2.25 inch think resin neutron shield. The RAM access penetration at the center of the bottom end assembly is used during insertion/removal operations to and from the HSM-H. The RAM access penetration is four inches thick in the radial direction and 4.25 inches thick in the axial direction. A cover plate is provided to seal the bottom hydraulic ram access penetration of the cask (by 12-1/2 in. high strength bolts with O-ring) during fuel loading and transferring the canister to the ISFSI.

The transfer cask top cover consists of a 3 inch thick structural plate constructed from SA-240, Type XM-19, and a top radial neutron shield constructed from resin encased in a 0.25 inch thick SA-240 Type 304 stainless steel shell. The top cover is fastened to the top flange of the transfer cask body with 24-1.5 inch diameter SA-540 Grade B24 Class 1 high strength steel bolts. The top closure is designed to maintain confinement of the 32PTH DSC inside the transfer cask during all normal, off normal and hypothetical accident conditions.

The transfer cask body provides additional radiation shielding and structural support for the 32PTH DSC. It also maintains an inert atmosphere (helium) in the cask cavity. Helium assists in heat removal during transfer operations and provides a non-reactive environment. To preclude air in-leakage, the cask cavity is pressurized with helium to above atmospheric pressure.

The NUHOMS®-OS187H transfer cask is designed, fabricated, examined and tested in accordance with the requirements of Subsection NC [7] of the ASME Code to the maximum practical extent. Alternatives to the ASME Code are discussed in Section 3.10.

B. Gamma and Radial Neutron Shielding

The lead and steel shells of the transfer cask provide shielding between the DSC and the exterior surface of the package for the attenuation of gamma radiation.

Axial neutron shielding is primarily provided by a borated polyester resin compound. The resin compound is cast into stainless steel cavities on the outside surface of the top closure and bottom assembly.

The resin material is an unsaturated polyester cross-linked with styrene, with about 50% weight mineral and fiberglass reinforcement. The components are polyester resin, styrene monomer, alpha methyl styrene, aluminum oxide, zinc borate, and chopped fiberglass which produce the elemental resin composition is shown in Chapter 5, Table 5-17.

Radial neutron shielding is primarily provided by liquid water enclosed in a radial outer stainless steel shield shell. The shield shell around the neutron shield consists of a cylindrical shell section, with closure plates at each end. The closure plates are welded to the outer surface of the structural shell of the cask body. The outer shield shell has no structural function other than to provide an enclosure for the neutron shield water. The shell is made of SA-240 Type 304 stainless steel.

C. Tiedown and Lifting Devices

There are four trunnions welded to the exterior of the structural shell of the transfer cask. There are two front trunnions located on opposite sides of the cask near the top closure, and two rear trunnions located similarly, near the bottom of the cask. The two top trunnions are used to first lift the cask, containing a canister and an empty basket, into a fuel pool for loading of the spent fuel. After the spent fuel has been loaded into the basket, the cask is lifted to a decontamination area. After draining and drying of the pool water, welding of the canister cover, and bolting of the cask cover, the cask is placed in a trailer for transfer to ISFSI. The cask is vertically lifted onto the trailer and is initially supported by the bottom trunnions which are mated to transfer trailer. Then the cask is allowed to pivot about the bottom trunnions, into a horizontal position until the top trunnions rest on their supports in the trailer. The trunnions are secured to the skid's trunnion tower.

Appendix 3.9.2

This appendix describes the detail analysis of the TC for all the loading conditions. For the drop loads, the TC is analyzed for the 75g side and end drops. The results for the TC corner drop using LS-DYNA is reported in Appendix 3.9.10 (page 3.9.10-14).

Appendix 3.9.3

This appendix describes the detail analysis of the TC top cover bolt and ram cover bolt due to the 22g corner drop. The stress analysis is performed in accordance with NUREG/CR-6007.

Appendix 3.9.4

This appendix describes the detailed analysis of the TC lead slump and inner shell buckling analysis. A 75g end drop load is used for these analyses.

Appendix 3.9.8

This appendix describes the detailed structural analysis of the fuel cladding due to the following loads.

10CFR72 (Normal & Off-Normal loads):

1g down (dead weight), transfer loads (1g longitudinal, 1g transverse, and 1g vertical).

10CFR71 (Normal loads): 30g (1 foot side drop)
1 foot end drop will be addressed in the 10CFR71 application.

3.1.2 Design Criteria

This section specifies the design requirements of the NUHOMS® HD system. The system consists of the Transportable Dry Shielded Canister (DSC), the Horizontal Storage Module, HSM-H and the OS-187H onsite transfer cask. The system is designed for high burnup fuel, up to 60 GWD/MTU, with a maximum assembly average initial enrichment of 5 wt. % U-235. The design will be based on the NUHOMS® design concept of horizontal storage, and is intended for use with a compatible transport cask.

General design requirements include structural, thermal, nuclear criticality safety, confinement/containment, and radiological protection criteria.

The overall storage system consists of three major components:

- 32PTH Dry Storage Container
- 32PTH Horizontal Storage Module
- OS187H Transfer Cask

The reinforced concrete 32PTH HSM-H, including the 32PTH-DSC support structure, the 32PTH-DSC, and the structural components of the OS187H transfer cask are important to safety of NUHOMS® HD System components. Consequently, they are designed and analyzed to perform their intended functions under the extreme environmental and natural phenomena specified in 10CFR 72.122 [3] and ANSI 57.9 [9]. These include tornado and wind, seismic, and flood design criteria.

This section addresses component specific design criteria, loads, and load combinations for the structural analyses of the 32PTH DSC, 32PTH HSM-H and the OS187H Transfer Cask.

3.2 Weights

The nominal DSC, HSM-H and OS187H Transfer Cask geometry is used to compute the weights of the NUHOMS® HD system components.

The following densities are used to compute the component weights.

NUHOMS® HD Component Material Densities

Material	Density (lb./in^3.)	Reference
Stainless Steel	0.29	10
Aluminum	0.098	10
Water	0.0361	10
Lead	0.41	10
Resin (neutron shield)	0.057	Table 5-17, Chapter 5

3.2.1 32PTH DSC Weight

The total weight of the loaded 32PTH DSC is 108.76 kips (54.38 tons). The weights of the major individual subassemblies are listed in following table.

32PTH DSC Summary of Nominal Component Weights

Component	Nominal Weight (lbs. x 1000)
Canister Shell	5.86
Outer Top Cover Plate	2.14
Top Shield Plug and Support Ring	10.71
Bottom Shield Plug	9.42
Grapple Ring	0.06
Total Canister Assembly	**28.19**
Fuel Compartments (32)	10.02
Aluminum Plates	3.73
Poison Plates	0.55
Stainless Steel Plates	1.94
Small Support Rails (4)	3.24
½ Large Support Rails (8)	10.38
Total Fuel Basket	**29.85**
Total Empty DSC (Basket & Canister)	**58.04**
Fuel Assembly Weight (32) @ 1585 lbs/assembly	50.72
Total Loaded DSC Weight	**108.76**

3.5 Fuel Rods General Standards for 32PTH DSC

This section provides the temperature criteria used in the 32PTH DSC thermal evaluation for the safe storage and handling of SFA's in accordance with the requirements of 10CFR 72. This section also contains the analysis of the thermal and irradiation growth of the fuel assemblies to ensure adequate space exists within the 32PTH DSC cavity for the fuel assemblies to grow thermally under all conditions.

In addition, this section provides an evaluation of the fuel rod stresses and critical buckling loads due to accident drop loads.

3.5.1 Fuel Rod Temperature Limits

The fuel rod temperature limits during transfer operation and storage are defined by Interim Staff Guidance, ISG-11, revision 3 [39]. The temperature limits are summarized in the following table.

Transfer		Storage	
Normal/Off Normal	Accident	Normal	Off Normal/Accident
752°F	1058°F	752°F	1058°F

3.5.2 Fuel Assembly Thermal and Irradiation Growth

The thermal and irradiation growth of the fuel assemblies were calculated to ensure there is adequate space for the fuel assemblies to grow within the 32PTH DSC canister cavity. Detail thermal expansion evaluations of canister cavity versus lengths of basket and fuel assembly, canister ID vs. basket OD, canister OD vs. transfer cask ID, and overall length of canister vs. transfer cask cavity length are included in Appendix 3.9.1, Section 3.9.1.4.

The extreme metal temperatures for the fuel cladding and canister under different cases are obtained from Chapter 4 for computation of the differential length growth. These temperatures are conservatively rounded and used in this calculation as listed in the following table.

Thermal Expansion Evaluation Cases

Cases \ Component Temperature	Length Growth Between Fuel Cladding and Canister	
	Fuel Cladding Temp. (°F)	**Canister (DSC Shell) Temp. (°F)**
Vacuum Drying	750	210
Transfer	730	390
Storage – Off Normal	700	310
Storage – Blocked Vent	810	500

The following table summaries the minimum gap between the canister cavity and the fuel assembly in the above thermal cases.

	Thermal Load Cases			
	Vacuum Drying	Transfer	Storage – Off Normal	Storage – Blocked Vent
Fuel assembly length	162.4 in.	162.4 in.	162.4 in.	162.4 in.
Total thermal growth	0.4 in.	0.38 in.	0.36 in.	0.43 in.
Irradiation growth	1.25 in.	1.25 in.	1.25 in.	1.25 in.
Total fuel assembly length after thermal growth	**164.05 in.**	**164.03 in.**	**164.01 in.**	**164.08 in.**
Min. canister cavity length	164.5 in.	164.5 in.	164.5 in.	164.5 in.
Canister thermal growth	0.2 in.	0.5 in.	0.3 in.	0.69 in.
Canister cavity length after thermal growth	**164.7 in.**	**165.0 in.**	**164.8 in.**	**165.19 in.**
Min. calculated gap	**0.65 in.**	**0.97 in.**	**0.79 in.**	**1.11 in.**

Based on the evaluations, there is adequate space within the 32PTH DSC cavity for thermal and irradiation growth of the fuel assemblies and spacers.

3.5.3 Fuel Rod Integrity During Drop Scenario

The purpose of this section is to calculate zircaloy clad fuel cladding stresses due to a transfer cask side drop.

3.5.3.1 Side Drop

The fuel rod side impact stresses are computed by treating the fuel rod as a continuous beam supported at locations of spacer grids. Continuous beam theory is used to determine the maximum bending moment in the entire beam. An ANSYS [33] finite element model of the fuel rod is created for each fuel type, using PIPE16 elements. The details of the finite element model geometry and equivalent densities are given computed in Table 3-12. The dimensions (lengths) of the fuel cladding for each fuel type are taken from reference [11]. The weight of fuel pellets is incorporated in the cladding model by using equivalent densities. The weights of the top and bottom end fittings are distributed to the top and bottom spans of the fuel rod cladding models (Span L_T and Span L_B in Table 3-12). The typical details of finite element model and boundary conditions of fuel types WE 15x15 and WES 15x15 are shown on Figure 3-2.

The maximum bending stress corresponding to the maximum bending moment in the cladding tubes is calculated. The fuel gas internal pressure is also considered in the calculation. The cladding axial tensile stress due to the gas pressure is added to the bending stress due to the 75g drop load. In this elastic analysis, the 75g side drop load is applied as an acceleration. The maximum bending stresses for the fuel cladding from the ANSYS analyses are shown on Figures 3-3 to 3-7 and also summarized in Table 3-13.

3.5.3.2 End Drop

The structural integrity of the fuel cladding due to the end drop loading condition will be evaluated by the user under the 10CFR50 site license.

3.5.3.3 Results

Side Drop

Table 3-13 summarizes the maximum bending stresses in various specified fuel cladding during the 75g side drop of their transfer cask. All of the combined stresses are less than the yield strength of the irradiated cladding material (93,950 psi) with ample margin of safety. The maximum combined stress was calculated to be 76,931 psi in the cladding of the WE 15x15 fuel. It is less than the cladding yield strength of 93,950 psi at 725 °F.

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canister is presented in Appendix 3.9.1, Section 3.9.1.3.2 (page 3.9.1-36). The DSC canister shell buckling evaluation is presented in Appendix 3.9.1, Section 3.9.1.3.3 (page 3.9.1-61).

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

The ANSYS calculated stresses are the total stresses of the combined membrane, bending, and peak stresses. These total stresses are conservatively taken to be membrane stresses (P_m) as well as membrane plus bending stresses ($P_L + P_b$) and are evaluated against their corresponding ASME code stress limits. In the case where the total stresses, evaluated in this manner, exceed the ASME allowable stresses, a detailed stress linearization is performed to separate the membrane, bending, and peak stresses. The linearized stresses are then compared to their proper Code allowable stresses. ASME B&PV Code Subsection NB [12] is used for evaluation of loads under normal conditions. The thermal stress intensities are classified as secondary stress intensities, Q, for code evaluations.

Material properties obtained from Reference 10 for the 32PTH DSC canister materials, taken at the highest metal temperature of 500° F (from thermal evaluation presented in Chapter 4). The ANSYS Multilinear Kinematic Harding material option of inelastic analysis is employed in the analyses of all canister accident side drops. A multi-linear stress-strain curve for type 304 stainless steel at 500° F is constructed using the yield and tensile stress values taken from Reference 10.

Elastic and elastic-plastic analyses are performed to calculate the stresses in the 32PTH DSC canister under the transfer and storage loads. These detail load cases are summarized in Appendix 3.9.1, Tables 3.9.1-9, 3.9.1-10 and 3.9.1-19.

The calculated stresses in the canister shell due to normal transfer loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-11, 12, 15, and 16. The stresses due to normal storage loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-20, and 21.

An alternate 32PTH DSC canister design with a composite top and/or bottom is also evaluated for their structural adequacy.

Details of the structural evaluation of the alternate canister composite bottom design under loads of normal conditions are provided in Appendix 3.9.1, Section 3.9.1.3.4 (page 3.9.1-64). For the alternate canister composite bottom design, the stresses in the canister under the normal transfer loading conditions are summarized in Appendix 3.9.1, Tables 3.9.1-24, 25, 26, and 27. The loads under the normal storage conditions are bounded by the loads under the normal transfer conditions.

Under the loads of both the normal transfer and storage conditions, the stresses generated in the canister will not be significantly different between the canister designs with an one-piece top and with a composite top. SAR Drawing 10494–72–4, Rev. 0 shows the alternate composite top.

As described in Chapter 8, Section 8.1.1.3, operation steps 7 and 13, a maximum of 15 psig pressure may be applied at the canister vent port to assist draining of the water. Conservatively, the canister is structurally evaluated for a 60 psig internal pressure using the 2-D ANSYS finite element model described in Appendix 3.9.1, Section 3.9.1.3.2. The outer cover plate of the canister is removed from the 2-D model, since it is not yet installed during the application of this nitrogen or helium pressure. The maximum primary stress intensity and the maximum primary plus secondary stress intensity in the canister due to the 60 psig pressure load (conservatively used for stress calculation) are calculated to be 8,247 psi and 26,070 psi, respectively. Their corresponding stress limits as per ASME B&PV Code Subsection NB [12] are 16,400 psig and 49,200 psi, respectively. Based on this analysis, it concluded that the application of 15 psig pressure to the canister is conservative and acceptable.

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

The following table summarizes the results of the analysis described in detail in Appendix 3.9.7.

Drop Orientation	Peak Deceleration (gs)	Target Penetration Depth (in.)
End Drop	49	3.10
Side Drop	44	2.5
Corner Drop	16	6.5

The ranges of drop scenarios conservatively selected for design are:

1. A horizontal side drop from a height of 80 inches (75g horizontal drop).

2. Vertical end drops for the NUHOMS® HD system are non-mechanistic and thus, no end drops are postulated for the 32PTH DSC. However, 75g vertical end drop analyses are performed as a means of enveloping the 16g corner drop (in conjunction with the 75g horizontal side drop).

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

3.8 References

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2. NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems - Final Report," U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, January 1997.

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

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3.9 Appendices

The detailed structural analyses of the NUHOMS® HD system are included in the following appendices:

Appendix 3.9.1	32PTH DSC (Canister and Basket) Structural Analysis
Appendix 3.9.2	OS187H Transfer Cask Body Structural Analysis
Appendix 3.9.3	OS187H Transfer Cask Top Cover and RAM Access Cover Bolt Analyses
Appendix 3.9.4	OS187H Transfer Cask Lead Slump and Inner Shell Buckling Analysis
Appendix 3.9.5	OS187H Transfer Cask Trunnion Analysis
Appendix 3.9.6	OS187H Transfer Cask Shield Panel Structural Analysis
Appendix 3.9.7	OS187H Transfer Cask Impact Analysis
Appendix 3.9.8	Damaged Fuel Cladding Structural Evaluation
Appendix 3.9.9	HSM-H Structural Analysis
Appendix 3.9.10	OS187H Transfer Cask Dynamic Impact Analysis
Appendix 3.9.11	32PTH DSC Dynamic Impact Analysis

3.10 ASME Code Alternatives

The confinement boundary of the 32PTH DSC canister shell, the inner top cover/shield plug, the inner bottom cover, the siphon vent block, and the siphon/vent port cover plate are designed, fabricated and inspected in accordance with the ASME Code Subsections NB to the maximum practical extent. The basket is designed, fabricated and inspected in accordance with ASME Code Subsection NG to the maximum practical extent. Other canister components (such as outer bottom cover and shield plugs) are not governed by the ASME Code.

ASME Code Alternatives for the 32PTH DSC

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NCA	All	Not compliant with NCA
NB-1100	Requirements for Code Stamping of Components	The canister shell, the inner top cover/shield plug, The shell bottom, the inner bottom cover (alternate bottom design), and the siphon/vent port cover are designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, 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-2130 NB-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	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 & certification are maintained in accordance with TN's NRC approved QA program.
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 shell to the outer top cover weld, the shell to the inner top cover/shield plug weld (including option 2 or option 3 inner top cover as described in the SAR), and the siphon/vent cover welds, are all partial penetration welds. As an alternative to the NDE requirements of NB-5230, for Category C welds, all of these closure welds will be multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in ISG-15 for NDE. The multi-level PT examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. All of these welds will be designed to meet the guidance provided in ISG-15 for stress reduction factor.

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NB-2531	Vent & siphon Port Cover; straight beam UT per SA-578 for all plates for vessel	SA-578 applies to 3/8" and thicker plate only; allow alternate UT techniques to achieve meaningful UT results.
NB- 6000	All completed pressure retaining systems shall be pressure tested	The 32PTH is not a complete or "installed" pressure vessel until the top closure is welded following placement of Fuel Assemblies within the DSC. Due to the inaccessibility of the shell and lower end closure welds following fuel loading and top closure welding, as an alternative, the pressure testing of the DSC is performed in two parts. The DSC shell, shell bottom, including all longitudinal and circumferential welds, is pneumatically tested and examined at the fabrication facility. The shell to the inner top cover/shield plug closure weld (including option 2 or option 3 inner top cover as described in the SAR) are pressure tested and examined for leakage in accordance with NB-6300 in the field. The siphon/vent cover welds will not be pressure tested; these welds and the shell to the inner top cover/shield plug closure weld (including option 2 or option 3 inner top cover as described in the SAR) are helium leak tested after the pressure test. Per NB-6324 the examination for leakage shall be done at a pressure equal to the greater of the Design pressure or three-fourths of the test pressure. As an alternative, if the examination for leakage of these field welds, following the pressure test, is performed using helium leak detection techniques, the examination pressure may be reduced to 1.5 psig. This is acceptable given the significantly greater sensitivity of the helium leak detection method.
NB-7000	Overpressure Protection	No overpressure protection is provided for the 32PTH DSC. The function of the 32PTH DSC is to contain radioactive materials under normal, off-normal, and hypothetical accident conditions postulated to occur during transportation. The 32PTH DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The 32PTH DSC is pressure tested in accordance with the requirements of 10CFR71 and TN's approved QA program.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program.
NB-1132	Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component.	Outer bottom cover, bottom plate, bottom casing plate, side casing plate, top shield plug casing plate, lifting posts, grapple ring and grapple ring support are outside code jurisdiction; these components together are much larger than required to provide stiffening for the confinement boundary cover. These component welds are subject to root and final PT examinations.

ASME Code Alternatives for the 32PTH DSC Fuel Basket

Reference ASME Code Section/Article	Code Requirement	Alternatives, Justification & Compensatory Measures
NG/NF-1100	Requirement for Code Stamping of Components	The 32PTH DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but 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 be ASME Certified.
NG/NF-2130 NG/NF-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	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 & certification are maintained in accordance with TN's NRC approved QA program. The poison material and aluminum plates are not used for structural analysis, but to provide criticality control and heat transfer. They are not ASME Code Class I materials. See note 1.
NG/NF-8000	Requirements for nameplates, stamping & reports per NCA-8000	The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program.
NCA	All	Not compliant with NCA as no code stamp is used.

Note:

1. Because Subsection NCA does not apply, the NCA-3820 requirements for accreditation or qualification of material organizations do not apply. CMTR's shall be provided using NCA-3862 for guidance.

Table 3-1
Codes and Standards for the Fabrication and Construction of Principal Components

Component, Equipment, Structure	Code of Construction
32PTH DSC Shell Assembly	ASME Code, Section III, Subsection NB (1998 Edition through 2000 Addenda, including alternatives to the ASME code specified in SAR Section 3.10)
32PTH DSC Basket	ASME Code, Section III, Subsection NG (1998 Edition through 2000 Addenda)
Transfer Cask	ASME Code, Section III, Subsection NC (1998 Edition through 2000 Addenda)
HSM-H	- ACI 349-97 (Concrete) - AISC Ninth Edition (Structural Steel) - AWS D1.1-98 (Structural Welds) - ASCE 7-95 (Loads) - ANSI 57.9-84 (Loads & Load Combinations)

Table 3-12
Input Data for Fuel Rod Cladding Side Drop ANSYS Runs

Item	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Number of Supports(1)	7	8	8	8	8	8
Number Of Spans(1)	6	7	7	7	7	7
Total Length, L (in) (1)	152.152	151.635	151.635	151.635	151.635	147.174
Span L_1 (in) (1)	22.657	22.93	22.93	22.93	22.93	17.36
Span L_2 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_3 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_4 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_5 (in) (1)	24.69	19.05	19.05	19.05	19.05	17.36
Span L_6 (in) (1)	17.46	18.95	18.95	18.95	18.95	17.36
Span L_7 (in) (1)	-	19.19	19.19	19.19	19.19	17.36
Span L_B (in) (1)	1.775	1.204	1.204	1.204	1.204	8.495
Span L_T (in) (1)	1.00	1.161	1.161	1.161	1.161	5.159
Cladding Tube, D_O (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Cladding Tube, $t_{(Corroded)}$ (in)(8)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Cladding Tube, D_I (in)	0.3761	0.3317	0.3287	0.3317	0.3177	0.3867
Cladding Tube Volume, V_t (in^3/in)(2)	0.026987	0.02186	0.02342	0.02186	0.020994	0.032747
Tube Weight, w_1 (lb/in)(3)	0.006315	0.005116	0.00548	0.005116	0.004913	0.007663
Fuel Pellet, D (in)	0.3659	0.3225	0.3195	0.3225	0.3088	0.3765
Pellet Weight, w_2 (lb/in)(4)	0.040378	0.031368	0.030787	0.031368	0.028759	0.042751
(Tube+Pellet) w_s (lb/in)	0.046693	0.036484	0.036267	0.036484	0.033672	0.050414
Tube Eqv. Density, ρ_e (lb/in^3)(5)	1.730	1.669	1.549	1.669	1.604	1.540
Weight Bottom Fitting, W_B (lb)	12.566	12.566	12.566	12.566	12.566	12.566
Weight Top Fitting, W_T (lb)	17.416	18.012	18.012	18.012	18.012	18.012
$Tube_{Bot}$ Eqv. Density, ρ_B (lb/in^3)(6)	3.02	3.48	3.24	3.48	3.49	1.80
$Tube_{Top}$ Eqv. Density, ρ_T (lb/in^3)(7)	4.89	4.36	4.06	4.36	4.41	2.13

Notes:
(1) Number of supports and span lengths are taken from [11]. Support grids are 1.5 in. wide.
(2) $V_t = \pi/4[D_o^2 - D_i^2] \times 1.0$
(3) $W_1 w_1 = V_t \times \rho_{tube} = V_t \times 0.234$ lb/in
(4) $W_2 w_2 = \pi/4[D^2] \times 1.0 \times \rho_{Pellet} = \pi/4[D^2] \times 0.384$ lb/in
(5) $\rho_e = w_s / V_t$
(6) $\rho_B = [w_s + W_B/(\text{No. of tubes} \times L_B)] / V_t$
(7) $\rho_T = [w_s + W_T/(\text{No. of tubes} \times L_T)] / V_t$
(8) *Clad thickness reduced by 0.0027 in to account for an assumed oxide layer of 120 microns*

Table 3-13
Maximum Fuel Rod Cladding Axial Stresses During 75g Side Drop

Fuel Assembly Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Fuel Cladding OD, D (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Clad Thick. (Corr.), t (in) (1)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Average Radius, R (in) (2)	0.1989	0.1758	0.1725	0.1758	0.1688	0.2060
Fuel Pallet OD, D_P (in) (1)	0.3659	0.3225	0.3195	0.3225	0.3088	0.3765
Number of Spans, N(8)	6	7	7	7	7	7
Max. Span Length (in)(8)	24.69	22.93	22.93	22.93	22.93	17.36
No. of Rods, N (1)	204	264	264	264	264	176
Cladding Tube Weight (lb/in)(3)	0.006315	0.005116	0.00548	0.005116	0.004913	0.007663
Fuel Pellet Weight (lb/in)(4)	0.040378	0.031368	0.030787	0.031368	0.028759	0.042751
W_S, [Tube + Pellet] (lb/in)	0.046693	0.036484	0.036267	0.036484	0.033672	0.050414
30 Foot Side Drop - Equivalent g load	75	75	75	75	75	75
Max. Bending Stress, S_b (psi) (5)	66,642	63,230	59,160	63,230	63,442	47,725
Internal Pressure, P (psi)	2,235	2,235	2,235	2,235	2,235	2,235
Pressure Axial Stress, $S_{press.}$(psi) (6)	10,289	9,921	9,183	9,921	9,525	9,100
$S_{Max} = S_b + S_{press.}$ (psi)	76,931	73,151	68,343	73,151	72,967	56,825
Allowable Stress, $S_{all} = S_y$ (psi)(7)	93,950	93,950	93,950	93,950	93,950	93,950
Factor of Safety, (S_y / S_{Max})	1.22	1.28	1.37	1.28	1.29	1.65

Notes:
(1) Reduction of wall thickness by 0.0027 inch
(2) R = (D-t)/2
(3) Cladding Tube Weight = $[\pi / 4 \times (D^2 - (D - 2t)^2)] \times \rho_t = [\pi / 4 \times (D^2 - (D - 2t)^2)] \times 0.234$ lb/in.
(4) Fuel Pellet Weight = $[(\pi / 4) \times D_p^2] \times \rho_p = [(\pi / 4) \times D_p^2] \times 0.384$ lb/in.
(5) See Figures 3-3 to 3-7.
(6) $S_{pressure} = (P \times R) / (2 \times t)$
(7) Yield strength of high burn up Zircaloy cladding tube at 725 °F based on reference [38] with a strain rate at 0.5 s^{-1}.
(8) From Table 3-12

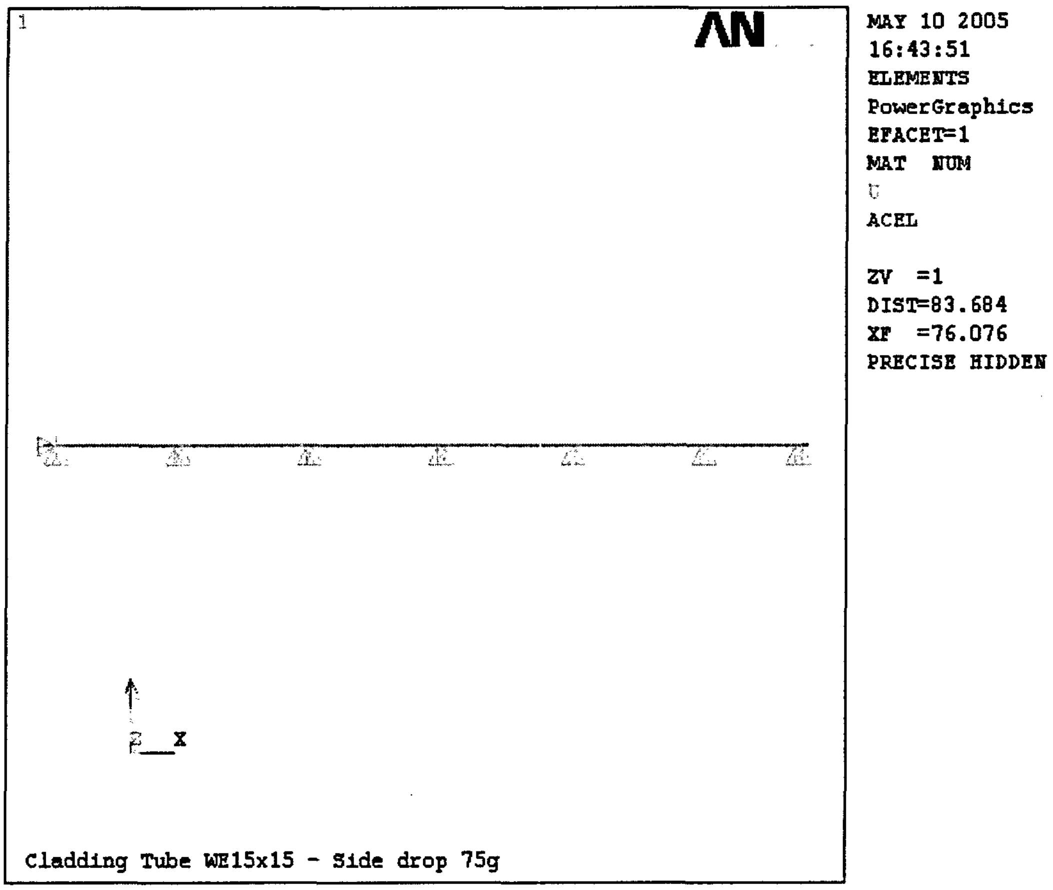

Figure 3-2
Finite Element Model and Boundary Conditions WE 15x15 and WES 15x15

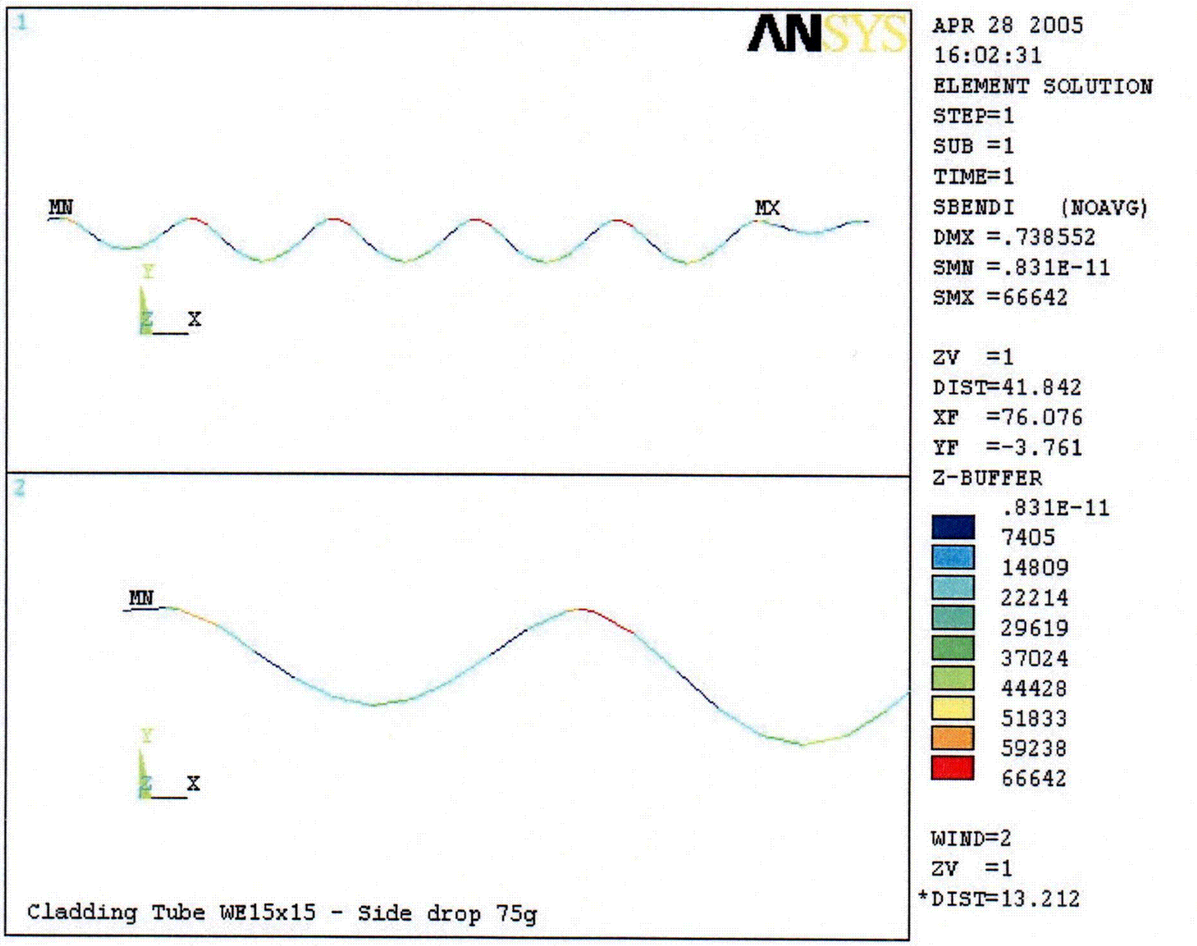

Figure 3-3
Bending stress – WE 15x15 and WES 15x15
(The bottom figure is enlarged view of span)

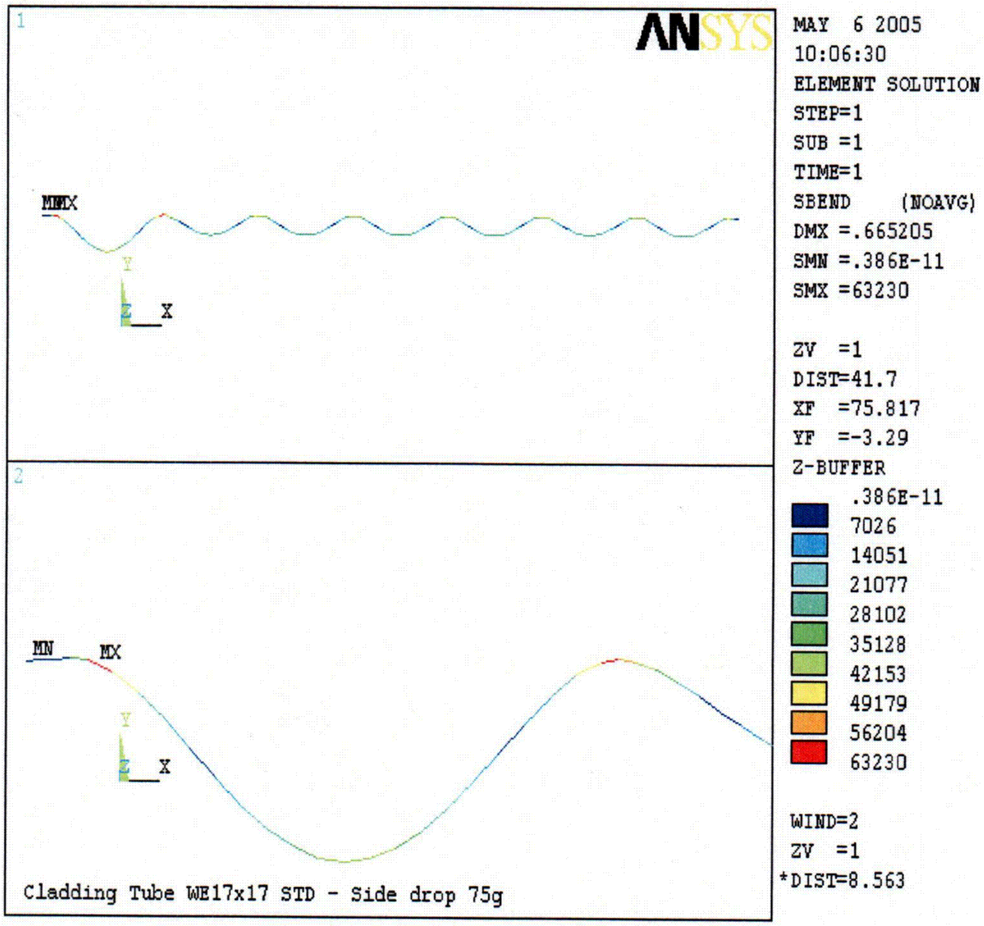

Figure 3-4
Bending stress – WE 17x17 and WEV 17x17
(The bottom figure is an enlarged view of the span)

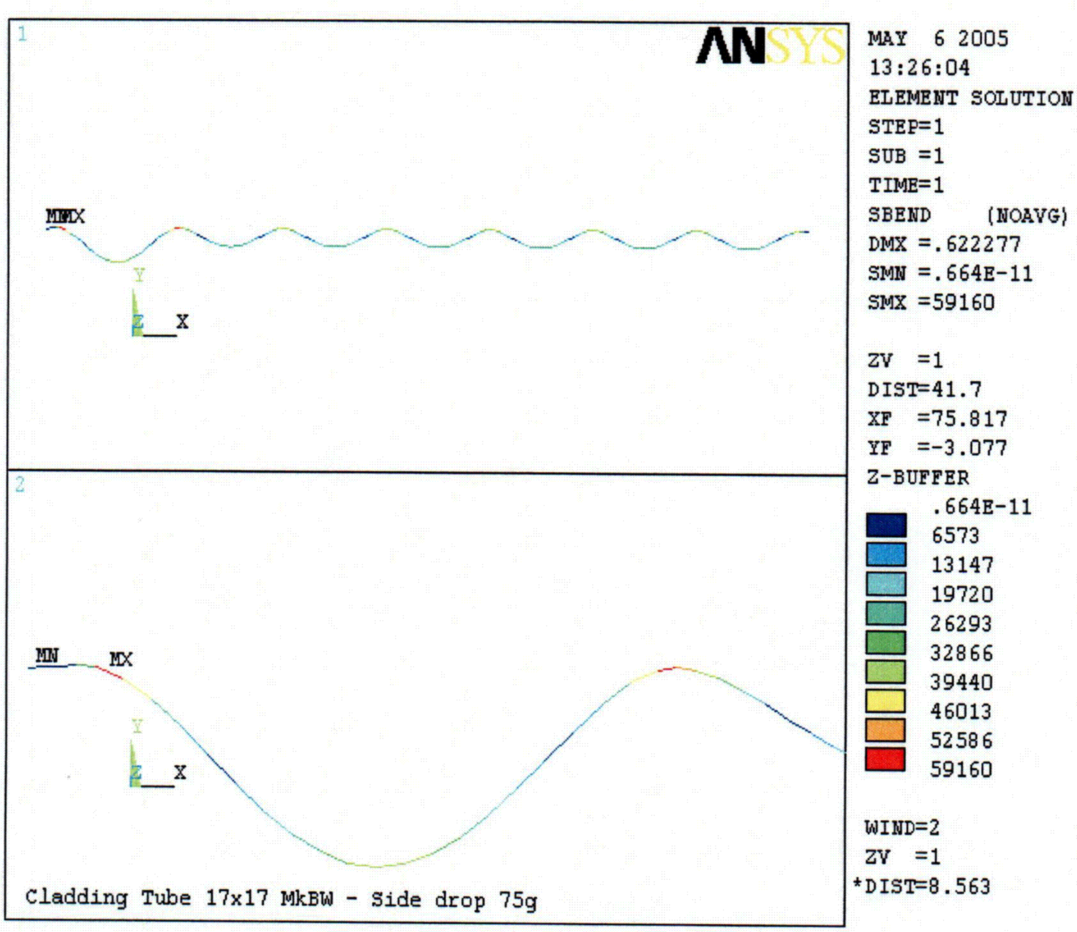

Figure 3-5
Bending stress – MK BW 17x17
(The bottom figure is an enlarged view of the span)

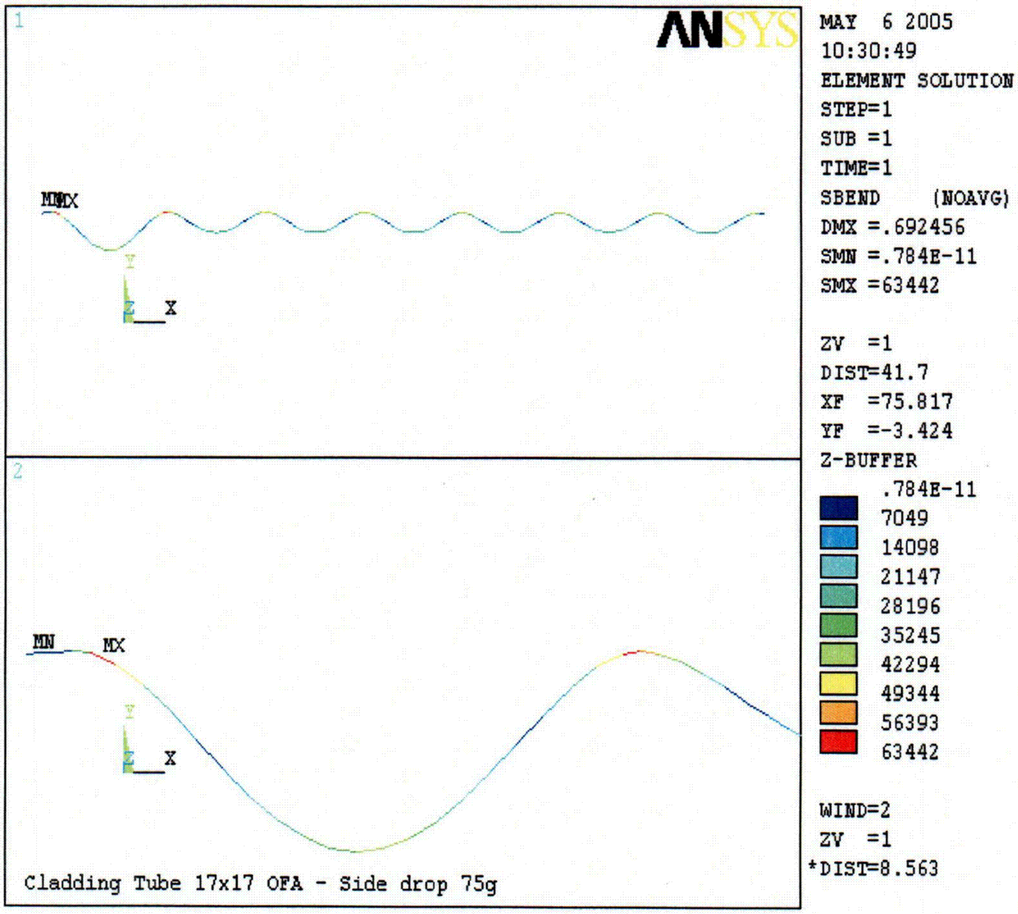

Figure 3-6
Bending stress – WEO 17x17
(The bottom figure is an enlarged view of the span)

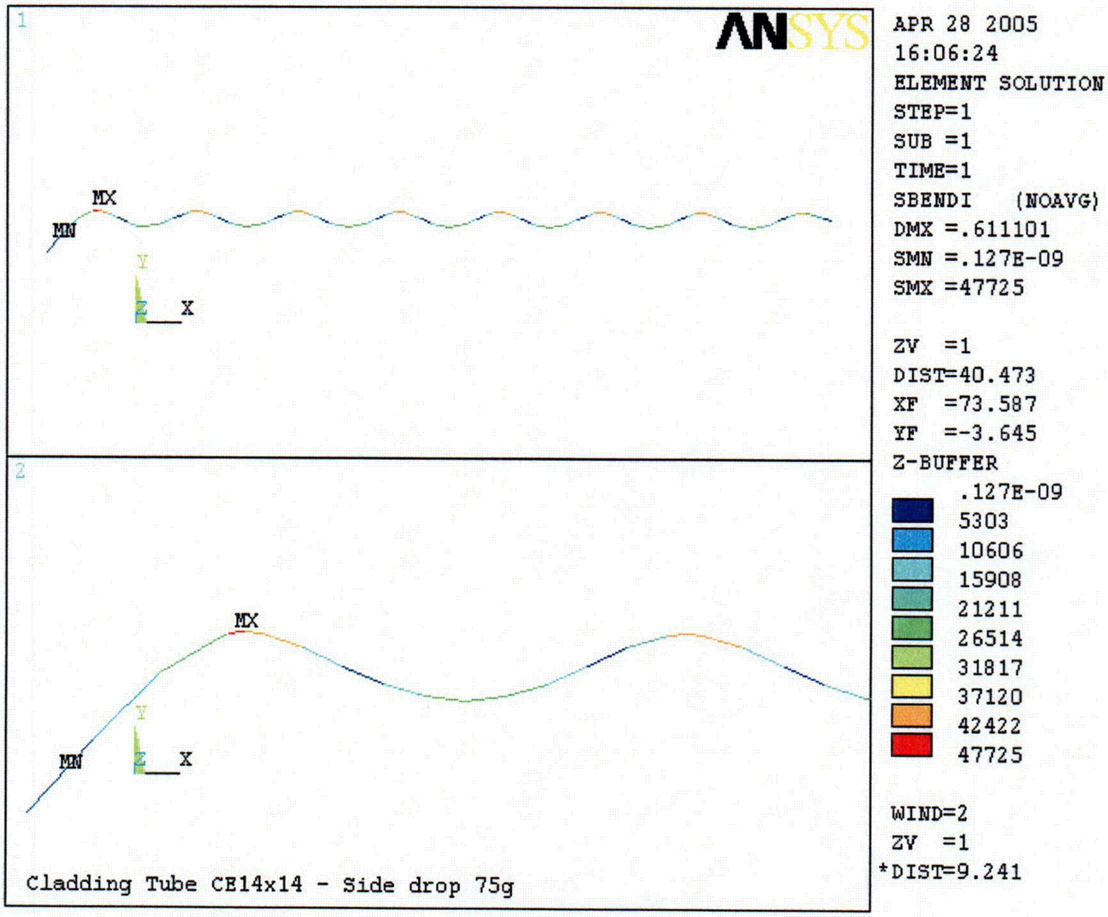

Figure 3-7
Bending stress – CE 14x14
(The bottom figure is an enlarged view of the span)

Lifting Block Weld Stresses

It is conservatively assumed that the full lift load acts on the throat area of the 5/16 in. all-around weld of each 2.5 in. × 2.5 in. square lifting block. There are four lifting blocks welded to the inside surface of canister bottom. The total throat area of the welds in all four blocks is,

$$\text{Weld throat area} = (5/16 \text{ in} \times \cos 45°) \times 2.5 \text{ in} \times 4 \times 4 = 8.84 \text{ in}^2$$

Therefore, the maximum shear stress in the weld, τ_w, is,

$$\tau_w = 169{,}146 \text{ lb} / 8.84 \text{ in}^2 = 19{,}134 \text{ psi} < S_y$$

Lifting Block thread stresses

Each lifting block has internal threads of 1-1/4-7UNC-2B and a minimum thread length of 2 inches.

For each block, the thread stripping shear area = 2.9441 in^2 / in of engagement [12].
For an engaging length of 2 inches, the total stripping shear area for 4 blocks is,

$$A = 2.9441 \text{ in}^2 \times 2 \text{ in.} \times 4 = 23.55 \text{ in}^2$$

Since the thread stripping shear area is greater than area of the weld shear area in above, the design thread shear area is acceptable.

Max. Tensile stress in Lift Block

For each block, the cross-section area, A_b, is,

$$A_b = 2.5 \text{ in} \times 2.5 \text{ in} = 6.25 \text{ in}^2$$

The major diameter of a 1-1/4-7UNC-2B thread is 1.25 in. [13]

The minimum cross-section area, A_{min}, is,

$$A_{min} = 6.25 \text{ in}^2 - \pi/4 \times (1.25 \text{ in})^2 = 5.02 \text{ in}^2$$

Therefore, the maximum membrane tensile stress, P_m, is,

$$P_m = 169{,}146 \text{ lb} / (5.02 \text{ in}^2 \times 4) = 8{,}424 \text{ psi} < S_y$$

Where, S_y = 30,000 psi for SA-240 Gr.304 at 70° F.

Therefore, it is concluded that the design lift blocks for the canister is structurally adequate.

Shear stress at the canister end closure welds

There are two closure welds in the canister design. One weld joins the canister shell and the inner top cover/shield plug (including option 2 or option 3 inner top cover as described in the Chapter 1 drawings). Another weld joins the canister shell and its outer cover. Since the radiographic examination of these two closure welds is not feasible, ISG-15 [14] requires a design stress reduction factor be used in the design calculation. For multi pass inspection, a stress reduction factor of 0.8 is recommended by ISG-15. However, for conservatism, a stress reduction factor of 0.7 is used in the evaluation of the stresses at these two welds in this section.

The allowable shear stresses at the closure welds based on Subsection NB [8] and Appendix F [3] are listed in the following table and are used to compare with the calculated maximum shear stresses.

ASME Code Allowable for Weld Stresses (304 SS 500°F)

Loading Condition	Stress Type	Stress Limits	Allowable Stress (ksi)
Normal	Shear	$(0.6\ S_m)^{(1)} \times 0.7^{(3)}$	(0.6 x 17.5) x 0.7 = 7.35
Accident	Shear	$(0.42S_u)^{(2)} \times 0.7^{(3)}$	(0.42 x 63.4) x 0.7= 18.64(4) (0.42 x 59.2) x 0.7= 17.4(5)

Notes:
1. Shear allowable from Subsection NB, NB-3227.2.
2. Shear allowable from Appendix F, F-1341.2.
3. The allowables were reduced (x 0.7) to include the quality factor from ISG-15 based on PT or MT of root and final layers.
4. For SA-240, Type 304
5. For SA-182, F304

Loading Conditions

The canister end closure welds are included in the ANSYS [3-1] finite element models and described in Appendix 3.9.1, Section 3.9.1.3.2 (pages 3.9.1-39 and 40). A total of 24 transfer load cases (Appendix 3.9.1, Section D.3, page 3.9.1-43) are analyzed by using these two models.

The most critical shear stress at the end closure welds for these analyzed load cases occurs for the 75g side drop + 30 psi internal pressure and the 75g side drop + 15 psi external pressure cases. The ANSYS result files for these two load cases are postprocessed to get the maximum shear stresses at the canister end closure weld locations. These shear stresses are compared with the above ASME code shear stress criteria.

3.9.1.5 References

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

2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, 1998 with 2000 Addenda.

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

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

5. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF, 1998, including 2000 Addendum.

6. Manual of Steel Construction, Eighth Edition, American Institute of Steel Construction, Inc., 1980.

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

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

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

10. ANSYS User's Manual, Rev 6.0.

11. American National Standard ANSI N14.6 – 1993, "American National Standard for Radioactive Materials – Special Lifting Devices for Shipping Containers Weighing 10000 pounds (4500 kg) or More"

12. Table speeds calculation of Strength of Threads", R. C. Boucher, Product Engineering, November 27, 1961.

13. Machinery's Handbook, 24th Edition.

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

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

Table 3.9.1-9
32PTH DSC Canister Load Combinations during Transfer

Loading	Canister w/Transfer Cask Orientation	Service Level	Load for Analysis	Load Combinations	Analyzed Load Case No.	ANSYS Model
Dead Weight	Vertical(1)	A	1g Down (Axial)	1g Down + 15 psig Ext. Press. + Thermal (Vacuum Dry)	1	2-D
External Pressure	Vertical(1)	A	15 psig			
Thermal	Vertical(1)	A	Vacuum Dry			
Dead Weight	Horizontal(2)	A	2g Axial + 2g Trans. + 2g Vertical	A = 2g Axial + 2g Trans. + 2g Vertical A+ 30 psig Int. Pressure + Thermal (115° F)	2	2-D
Handling load in Transfer Cask	Horizontal(2)	A		A+ 15 psig Ext. Pressure + Thermal (-20° F)	3	2-D
Internal Pressure	Horizontal(2)	A	30 psig(6)	Pressure Stress	[2] (5)	2-D
Ext. Press.	Horizontal(2)	A	15 psig	Pressure Stress	[3] (5)	2-D
Thermal	Horizontal(2)	A	Thermal Stress (-20° F Ambient)	Thermal Stress	[3] (5)	2-D
Thermal	Horizontal(2)	A	Thermal Stress (115° F Ambient)	Thermal Stress	[2] (5)	2-D
Internal Pressure	Horizontal	D	120 psig(3)	Pressure Stress	4	2-D
External Pressure	Horizontal	D	25 psig(4)	Pressure Stress	5	2-D
Side Drop	Horizontal	D	75g Multiple Orientations (0°, 30°, 45°, impact on two rails, impact on one rails) Drop angles are enveloped by 0° (no rail) and 180° (two rails)	75g side drop at 0° (no rail) + 30 psig Int. Press. of Top / Bottom ends	6 / 7	3-D
				75g side drop at 180° (two rails) + 30 psig Int. Press. of Top / Bottom ends	8 / 9	3-D
				75g side drop at 0° (no rail) + 15 psig Ext. Press. of Top / Bottom ends	10 / 11	3-D
				75g side drop at 180° (two rails) + 15 psig Ext. Press. of Top / Bottom ends	12 / 13	3-D
Corner Drop	Horizontal	D	Enveloped by 75g Side Drop and 75g End Drop			
End Drop	Vertical	D	75g End Drop	75g Top/Bottom + 30 psig Int. Pressure	14 / 15	2-D
				75g Top/Bottom + 15 psig Ext. Pressure	16 / 17	2-D

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

APPENDIX 3.9.8
DAMAGED FUEL CLADDING STRUCTURAL EVALUATION

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3.9.8 DAMAGED FUEL CLADDING STRUCTURAL EVALUATION

3.9.8.1 Introduction

The purpose of this appendix is to demonstrate structural integrity of the damaged fuel cladding in the NUHOMS® 32PTH DSC following normal and off-normal loading conditions of storage and onsite transfer (required for Part 72 License) and normal condition of offsite transport (required for Part 71 License).

In this appendix, the damaged fuel is defined as: "damaged PWR fuel assemblies are fuel 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 pellet is not able to pass through the damaged cladding during handling and retrievability is assured following Normal/Off-Normal conditions".

This appendix evaluates stresses in the fuel cladding associated with normal and off-normal conditions of on-site transfer/storage and off-site transport. It also presents a fracture mechanics assessment of the cladding using conservative assumptions regarding defect size geometry and amount of oxidation in the cladding material. These evaluations demonstrate the structural integrity of the damaged fuel cladding under normal and off-normal conditions.

The NUHOMS® 32PTH DSC is designed to store 32 intact fuel assemblies, or no more than 16 damaged and the remainder intact, for a total of 32 standard PWR fuel assemblies per canister. All the fuel assemblies, intact or damaged, consist of PWR fuel assemblies with Zircaloy cladding. Damaged fuel assemblies may only be stored in the center compartments of the NUHOMS® 32PTH DSC, as shown in Chapter 2, Figure 2-2.

3.9.8.2 Design Input / Data

The design inputs, taken from References [2] and [12], are modified to include the reduction in cladding thickness due to oxidation. They are documented in the following table.

Fuel Assembly Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14	Notes
Fuel Assembly Weight (lb)	1,555	1,575	1,575	1,575	1,575	1,450	(1,2)
No. of Rods	204	264	264	264	264	176	(1)
Active Fuel Length (in)	144.0	144.0	144.0	144.0	144.0	137.0	(1)
No. of Internal Spacers	6	6	6	6	6	7	(3)
Max. Fuel Rod Span (in)	27.0	25.0	25.0	25.0	25.0	17.0	(5)
Fuel Rod OD (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373	(1,4)
Clad Thickness (in)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253	(1,4)
Fuel Pellet OD (in)	0.3659	0.3225	0.3195	0.3225	0.3088	0.3765	(1)
Fuel Tube Area (in^2)	0.0270	0.0219	0.0234	0.0219	0.0210	0.0327	
Fuel Tube M.I. (in^4)	5.35E-04	3.39E-04	3.60E-04	3.39E-04	3.00E-04	6.97E-04	
Fuel Rod Weight (lb)	7.62	5.97	5.97	5.97	5.97	8.24	(6)
Irradiated Yield Stress (psi)	69,500	69,500	69,500	69,500	69,500	69,500	(7)
Young's Modulus (psi)	10.6E6	10.6E6	10.6E6	10.6E6	10.6E6	10.6E6	(8)

Notes:

1. Data are obtained from Chapter 2, Table 2-1.
2. The fuel assembly weight includes BPRA weight.
3. The number of internal spacers is obtained from (Ref 12).
4. Include 0.00270 in thickness reduction to account for maximum oxide thickness.
5. Maximum fuel rod span is obtained from (Ref 12) and have been rounded up to whole number.
6. Fuel rod weight = Fuel Assembly Weight / No. of Rods.
7. Data are obtained from Figure 3.9.8-5 at 725 °F temperature.
8. Data is obtained from (Ref 3).

For **235** (tire width mm)/**75** (height to width ratio in %) **R 17.5** (rim diameter inch) **SLR184** tires:

Tire width = (235 mm)/(25.4mm/in) = 9.25 in

Height of the tire = 75% of 9.25 in = 6.94 in

Diameter of the tire = (17.5 in) + 2*6.94 in = 31.4 in

Total loaded trailer weight = weight of (loaded cask +trailer + skid +ram)

Loaded Cask Weight (with impact limiters) = 250,000 lbs. (conservative, see Chapter 3, Section 3.2.3)

Weight (trailer + skid + ram) = 39,700(trailer)+ 26,500(skid)+ 6,400(ram) [1]
= 72,600 lb

Total Load = 250,000 + 72,600 = 322,600 lb

Load per tire = (322,600 lb)/(32 tires) = 10,081 lb

Area of contact of the tire = (10,081 lbs/135 psi) = 74.7 in^2

Length of compression of the tire = 74.7 in^2 / 9.25 in = 8.08 in

Therefore, deflection of the tire = $(31.4/2) - \{(31.4/2)^2 - (8.08/2)^2\}^{1/2}$ = 0.5287 in

Tire stiffness/tire = (10,081 lb)/(0.5287 in) = 19,068 lb/in

Total tire stiffness for 32 tires = (19,068)(32) = 6.1×10^5 lb/in

As per Table 3.9.8-9, the measured tire stiffness = 1500 x 32 = 4.8×10^4 lb/in

Conservatively, use tire stiffness of 6.1×10^5 lb/in

The force in the fuel assemblies is $F = (K*M)^{1/2} * (v)$

Therefore, load per assembly = F / 32 lb

Equivalent g load in the fuel rods = F / 32 / W

The axial stress in the rod is = F / Fuel Tube Area

Using the methodology described above, the fuel tube axial stresses for the prescribed condition are computed and presented in the following table.

Fuel Assembly Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Total Fuel Weight (lb)	1,555	1,575	1,575	1,575	1,575	1,450
Fuel Tube Area (in^2)	0.0270	0.0219	0.0234	0.0219	0.0210	0.0327
gap (in) (1)	6.0	6.0	6.0	6.0	6.0	6.0
t (s)	0.211	0.211	0.211	0.211	0.211	0.211
v (in/s)	56.97	56.97	56.97	56.97	56.97	56.97
M (lb-s^2/in)	128.8	130.4	130.4	130.4	130.4	120.1
W (lb)	48.6	49.2	49.2	49.2	49.2	45.3
No. of Fuel Assemblies	32	32	32	32	32	32
K, lb/in	610,000	610,000	610,000	610,000	610,000	610,000
F (lb)	504,946	508,183	508,183	508,183	508,183	487,600
Force / Assembly (lb)	15,780	15,881	15,881	15,881	15,881	15,237
No of Rod / Assembly	204	264	264	264	264	176
Force / Rod (lb)	77.4	60.2	60.2	60.2	60.2	86.6
Equivalent g load	10.1	10.1	10.1	10.1	10.1	10.5
Axial Stress (lb)	2,865	2,747	2,571	2,747	2,864	2,648

Note:

(1) The gap between the fuel assembly and the DSC end component is conservatively assumed to be 6" (the actual length is around 2 in.).

The axial stresses in the fuel rods are compressive stresses, and they are significantly less than the irradiated yield stress of the cladding material = 69,500 psi (Figure 3.9.8-5). Therefore, the fuel rods will maintain their structural integrity when subjected to the trailer acceleration during transfer.

3.9.8.7 Trailer Deceleration from 5 mph to 0 mph during Transfer

During onsite transfer of the cask from the fuel building to the ISFSI the loaded trailer travels at a maximum constant velocity of 5 mph (88 in/s). Any sudden loads, which may occur during an emergency stop, are transferred from the road bed through the rubber tires, the trailer, the support skid, and the cask to the fuel assemblies. The fuel assemblies inside the canister are subjected to maximum postulated 1g (386.4 in/s ^{2}) equivalent axial transfer load [7]. Therefore, the maximum transfer acceleration is +/- 1g.

The initial velocity is v_i = 88 in/s, the deceleration, g = 386.4 in/s ^{2}

The maximum velocity at impact of the fuel assemblies on the inner bottom cover plate is

v = 88 in/sec - v_f (due to friction) - v_d (due to deceleration)

Where, v_f is a function of work done by the force due to friction (F_f).

Therefore, $(M^* v_f^2)/2 = F_f {}^*d$

Where:

M = mass of the fuel assemblies

F_f = M*g*0.3 (where the coefficient of friction between grid straps and canister is 0.3 [9])

d = gap between fuel assembly and the DSC plug

$v_f = \{(2^*F_f^*d)/M)\}^{1/2}$

Conservatively assume that cask is tied to the trailer so that it does not move.

v_d is calculated as follows:

Substituting in the kinematics equation $s = s_o + ut + a^*t^2/2$ (Section 3.9.8.5)

$s_o = 0$, u = 88 in/sec, Acceleration, a = 386.4 in/s ^{2} and solving for 't'

$v_d = u + a^*t$

Conservatively, ignoring v_d (change in velocity due to deceleration), at contact with the inner bottom cover plate of the DSC the velocity of the fuel assembly is

$v = 88 - v_f$

The contact force on the fuel assembly = $F = (K^*M)^{1/2} * (v)$

Where:

M = total mass of the fuel assemblies = (W*n)/g

W = maximum weight of each fuel assembly

n = number of fuel assemblies/canister = 32

K= conservatively use tire stiffness of 6.1 x 10^5 lb/in (Section 3.9.8.6)

$F = (M * K)^{1/2} * v$

Therefore, load per assembly = F / 32

Equivalent g load in the fuel rods = F / 32 / W.

The axial stress in the rod is = F / Fuel Tube Area.

Using the methodology described above, the fuel tube axial stresses for the prescribed condition are computed and presented in the following table.

Fuel Assembly Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Total Fuel Weight (lb)	1,555	1,575	1,575	1,575	1,575	1,450
Fuel Tube Area (in^2)	0.0270	0.0219	0.0234	0.0219	0.0210	0.0327
gap (in) (1)	6.0	6.0	6.0	6.0	6.0	6.0
M ($lb\text{-}s^2/in$)	128.8	130.4	130.4	130.4	130.4	120.1
W (lb)	48.6	49.2	49.2	49.2	49.2	45.3
F_f (lb)	14,928	15,120	15,120	15,120	15,120	13,920
v_f, (in/s)	37.3	37.3	37.3	37.3	37.3	37.3
v, (in/s)	50.7	50.7	50.7	50.7	50.7	50.7
K, lb/in	610,000	610,000	610,000	610,000	610,000	610,000
F (lb)	449,390	452,271	452,271	452,271	452,271	433,952
Force / Assembly (lb)	14,043	14,133	14,133	14,133	14,133	13,561
No of Rod / Assembly	204	264	264	264	264	176
Force / Rod (lb)	68.8	53.5	53.5	53.5	53.5	77.1
Equivalent g load	9.0	9.0	9.0	9.0	9.0	9.4
Axial Stress (lb)	2,550	2,445	2,288	2,445	2,549	2,356

Note:

(1) The gap between the fuel assembly and the DSC end component is conservatively assumed to be 6".

The axial stresses in the fuel rods are compressive stresses, and they are significantly less than the irradiated yield strength of the cladding material = 69,500 psi (Figure 3.9.8-5). Therefore, the fuel rods will maintain their structural integrity when subjected to the trailer deceleration during transfer.

3.9.8.10 One Foot End Drop Damaged Fuel Evaluation

The structural integrity of the fuel cladding due to the one-foot end drop loading condition will be analyzed in the 10CFR71 application.

3.9.8.11 One Foot Side Drop Damaged Fuel Evaluation

During off site transport (Part 71) the damaged fuel assemblies need to be evaluated for 1 foot side drop. The transport operation is carried out using the MP 187H Cask, with the DSC and the impact limiters in the horizontal position.

The maximum g load acting on the damaged fuel rods under 1 foot side drop load = 30g. The damaged fuel rod structural integrity under 1 foot side drop load is assessed by computing the bending stress in the rod and comparing it with the yield stress of the cladding material. The fracture assessment of the damaged fuel rod structural integrity is made by using two fracture geometries (ruptured sections) as described below.

It is assumed that the damaged fuel tube is burst at the spacers (supports) location, which is the location of maximum bending moment. The loading assumed is on the opposite side of the rod at the burst location. The following two geometries, used for the fracture evaluation of the damaged fuel rods, are based on these assumptions.

Fracture Geometry #1: The first geometry is shown in Figure 3.9.8-1. In this damage mode the fuel tube is assumed to bulge from diameter D to diameter W ($W \geq D$) and rupture to a hole of diameter (2a) at the bulge location. It is assumed that $(2a/w) = 0.5$ for this geometry.

Fracture Geometry #2: The second geometry is shown in Figure 3.9.8-2. The stress intensities factors for this geometry are determined using the solution for a tube with a crack subjected to pure bending moment given in Reference 13. This evaluation is based on a crack length to diameter ratio of 0.47 (or $2a/D_m$=0.47).

The basis for the 0.5 (ruptured hole to tube diameter ratio) for fracture geometry #1 and 0.47 (crack length to tube diameter ratio) for fracture geometry #2 are the experimental tests on "as received" Zircalloy fuel tubes with measured burst temperatures of up to 909°C, which showed flaw opening to diameter ratios of 0.4 to 0.5 [16].

3.9.8.11.1 Structural Integrity Evaluation with Fracture Geometry #1

The fracture geometry #1 (Ruptured Section) is shown in Figure 3.9.8-1. With reference to Figure 3.9.8-1, the methodology for computing the stress intensity factor K_I is as follows:

Fuel Rod OD = D

Oxidized Clad Thickness = t

Average radius, R = (D-t)/2

I = net tube MI.

Span Length = S

Assume (2a/W) = 0.5, where 2a = ruptured hole diameter,

W = bulged fuel tube diameter ≥ D.

Stress Intensity Factor, $K_I = (Y)(P*a^{1/2})/(t*W)$, [Reference 14, Fig. 8.7(c)]

Where:

Y = 2.11 {established using (2a/W) = 0.5 (for Forman et al. case) in Figure 3.9.8-3 }

P = average tensile force at the crack which is expressed as a function of moment on the cross section as:

$= (2MR^2t)/I$ (See Table 3.9.8-8)

$W = \pi R$

$M = 0.1058(W_s*S^2)$ (See Appendix 2 of Reference 3)

W_s = 30g Fuel Rod Weight / Length

Bending Stress = MD / 2I

Using the methodology described above, the stress intensity factors, K_I for the prescribed condition are computed and presented in the following table.

Fuel Assembly Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Fuel Rod OD, D (in)	0.4193	0.3713	0.3713	0.3713	0.3573	0.4373
Clad Thickness, t (in)	0.0216	0.0198	0.0213	0.0198	0.0198	0.0253
Average Radius, R (in)	0.1989	0.1758	0.1750	0.1758	0.1688	0.2060
Fuel Tube M.I. (in^4)	5.35E-04	3.39E-04	3.60E-04	3.39E-04	3.00E-04	6.97E-04
Span Length, S (in)	27.0	25.0	25.0	25.0	25.0	17.0
(2a/W)	0.5	0.5	0.5	0.5	0.5	0.5
Y	2.11	2.11	2.11	2.11	2.11	2.11
W (in)	0.62	0.55	0.55	0.55	0.53	0.65
Fuel Assembly Weight (lb)	1,555	1,575	1,575	1,575	1,575	1,450
No. of Rods	204	264	264	264	264	176
Active Fuel Length (in)	144.0	144.0	144.0	144.0	144.0	137.0
1-Foot Side Drop Equivalent g load	30	30	30	30	30	30
W_s (lb/in)	1.59	1.24	1.24	1.24	1.24	1.80
Moment, M (kip. in)	0.12	0.08	0.08	0.08	0.08	0.06
Bending Stress (psi)	47,990	45,040	42,390	45,040	48,950	17,300
P (kip)	0.391	0.297	0.298	0.297	0.309	0.170
K_I (ksi $in^{1/2}$)	24.2	21.3	19.9	21.3	22.6	8.8

The computed stress intensity factor is compared with experimentally obtained plane strain fracture toughness, K_{IC} of irradiated Zircaloy cladding material as reported in [15].

Reference15 reports a K_{IC} = 35 ksi in$^{1/2}$ at approximately 300°F which is greater than highest computed stress intensity factor, K_I of 24.2 ksi in$^{1/2}$ presented in the above table.

Therefore, the structural integrity of the damaged fuel rods, which are conservatively assumed to rupture as shown in Figure 3.9.8-1, will be maintained.

3.9.8.11.2 Structural Integrity Evaluation with Fracture Geometry #2

This geometry is shown in Figure 3.9.8-2. Stress intensity factors are computed for a crack in a fuel tube subjected to a uniform bending moment (M) using formulae given in Reference 13. As per Reference 13, page 472:

$$K_I = \sigma (\pi * R_m * \theta)^{1/2} F(\theta)$$

where,

$$F(\theta) = 1 + 6.8*(\theta/\pi)^{3/2} - 13.6*(\theta/\pi)^{5/2} + 20.0*(\theta/\pi)^{7/2}$$

σ = Bending Stress due to Uniform Moment 'M'

R_m = Average radius of the fuel tube

2θ = Angle which the crack makes at the center of the tube

K_I = Stress Intensity Factor at the crack

The K_I is computed for all the different fuel assemblies, and the results for all the fuel assemblies are presented in Table 3.9.8-1, 3.9.8-2, 3.9.8-3, 3.9.8- 4 and 3.9.8-5.

Based on the computed K_I using Fracture Geometries #1 & #2, a summary of the comparisons is presented as follows:

	Fracture Geometry #1 K_I	Fracture Geometry #2 K_I
WE & WES 15x15	24.2	33.8
WE 17x17	21.3	29.9
MK BW 17x17	19.9	28.0
WEV 17x17	21.3	29.9
WEO 17x17	22.6	31.8
CE 14x14	8.8	12.4

3.9.8.12 Conclusions

The maximum computed stresses in the fuel rods and their ratios to the irradiated yield stress of the cladding material are summarized in Table 3.9.8-6. From Table 3.9.8-6, it can be concluded that stresses for all load cases considered are significantly less than the yield stress of the Zircaloy cladding material (computed stresses are 4% to 49% of the yield stress).

It is important to note that, the stresses in the fuel rods for all analyzed normal and off normal load cases are compressive stresses (less than the critical buckling stress), except for the 1-foot transport condition side drop load.

For the 1-foot side drop it is demonstrated by using fracture mechanics procedures (by comparing computed stress intensity factors to critical crack initiation fracture toughness in Table 3.9.8-7), that the damaged fuel rods will maintain their structural integrity.

This calculation demonstrates that the fuel cladding in the NUHOMS® 32PTH DSC will retain its structural integrity when subjected to normal condition of storage and on site transfer loads. The fuel cladding will also maintain its integrity when subjected to a one-foot side drop during offsite transport. The fuel cladding integrity during the one-foot end drop and transport vibratory loads will be demonstrated in the 10CFR71 application. Therefore, the retrievability of the fuel assembly is assured when subjected to storage and transfer normal and off normal loads.

Table 3.9.8-1

WE & WES 15x15 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.4193
t (in) =	0.0216
R / t =	9.71
Rm (in) =	0.1989
M (kip-in) =	0.12
Theta (radian) =	0.47
I (in^4) =	5.34E-04
Bending Stress (ksi) =	47.99
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0099	1.0132	8.6
0.10	0.0318	0.0199	1.0363	12.4
0.15	0.0477	0.0298	1.0646	15.6
0.20	0.0637	0.0398	1.0966	18.6
0.25	0.0796	0.0497	1.1312	21.5
0.30	0.0955	0.0597	1.1677	24.3
0.35	0.1114	0.0696	1.2058	27.1
0.40	0.1273	0.0795	1.2450	29.9
0.45	0.1432	0.0895	1.2853	32.7
0.47	0.1496	0.0935	1.3017	33.8
0.51	0.1623	0.1014	1.3348	36.2
0.52	0.1655	0.1034	1.3432	36.7
0.55	0.1751	0.1094	1.3686	38.5
0.60	0.1910	0.1193	1.4117	41.5
0.65	0.2069	0.1293	1.4557	44.5
0.70	0.2228	0.1392	1.5009	47.6

Table 3.9.8-2

WE 17x17 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.3713
t (in) =	0.0198
R / t =	9.38
Rm (in) =	0.1758
M (kip-in) =	0.08
Theta (radian) =	0.47
I (in^4) =	3.39E-04
Bending Stress (ksi) =	45.04
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0088	1.0132	7.6
0.10	0.0318	0.0176	1.0363	11.0
0.15	0.0477	0.0264	1.0646	13.8
0.20	0.0637	0.0352	1.0966	16.4
0.25	0.0796	0.0439	1.1312	18.9
0.30	0.0955	0.0527	1.1677	21.4
0.35	0.1114	0.0615	1.2058	23.9
0.40	0.1273	0.0703	1.2450	26.4
0.45	0.1432	0.0791	1.2853	28.9
0.47	0.1496	0.0826	1.3017	29.9
0.51	0.1623	0.0896	1.3348	31.9
0.52	0.1655	0.0914	1.3432	32.4
0.55	0.1751	0.0967	1.3686	34.0
0.60	0.1910	0.1055	1.4117	36.6
0.65	0.2069	0.1142	1.4557	39.3
0.70	0.2228	0.1230	1.5009	42.0

Table 3.9.8-3

MK BW 17x17 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.3713
t (in) =	0.0213
R / t =	8.72
Rm (in) =	0.1750
M (kip-in) =	0.08
Theta (radian) =	0.47
I (in^4) =	3.60E-04
Bending Stress (ksi) =	42.39
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0088	1.0132	7.1
0.10	0.0318	0.0175	1.0363	10.3
0.15	0.0477	0.0263	1.0646	13.0
0.20	0.0637	0.0350	1.0966	15.4
0.25	0.0796	0.0438	1.1312	17.8
0.30	0.0955	0.0525	1.1677	20.1
0.35	0.1114	0.0613	1.2058	22.4
0.40	0.1273	0.0700	1.2450	24.7
0.45	0.1432	0.0788	1.2853	27.1
0.47	0.1496	0.0823	1.3017	28.0
0.51	0.1623	0.0893	1.3348	30.0
0.52	0.1655	0.0910	1.3432	30.4
0.55	0.1751	0.0963	1.3686	31.9
0.60	0.1910	0.1050	1.4117	34.4
0.65	0.2069	0.1138	1.4557	36.9
0.70	0.2228	0.1225	1.5009	39.5

Table 3.9.8-4

WEV 17x17 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.3713
t (in) =	0.0198
R / t =	9.38
Rm (in) =	0.1758
M (kip-in) =	0.08
Theta (radian) =	0.47
I (in^4) =	3.39E-04
Bending Stress (ksi) =	45.04
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0088	1.0132	7.6
0.10	0.0318	0.0176	1.0363	11.0
0.15	0.0477	0.0264	1.0646	13.8
0.20	0.0637	0.0352	1.0966	16.4
0.25	0.0796	0.0439	1.1312	18.9
0.30	0.0955	0.0527	1.1677	21.4
0.35	0.1114	0.0615	1.2058	23.9
0.40	0.1273	0.0703	1.2450	26.4
0.45	0.1432	0.0791	1.2853	28.9
0.47	0.1496	0.0826	1.3017	29.9
0.51	0.1623	0.0896	1.3348	31.9
0.52	0.1655	0.0914	1.3432	32.4
0.55	0.1751	0.0967	1.3686	34.0
0.60	0.1910	0.1055	1.4117	36.6
0.65	0.2069	0.1142	1.4557	39.3
0.70	0.2228	0.1230	1.5009	42.0

Table 3.9.8-5

WEO 17x17 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.3573
t (in) =	0.0198
R / t =	9.02
Rm (in) =	0.1688
M (kip-in) =	0.08
Theta (radian) =	0.47
I (in^4) =	3.00E-04
Bending Stress (ksi) =	48.95
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0084	1.0132	8.1
0.10	0.0318	0.0169	1.0363	11.7
0.15	0.0477	0.0253	1.0646	14.7
0.20	0.0637	0.0338	1.0966	17.5
0.25	0.0796	0.0422	1.1312	20.2
0.30	0.0955	0.0506	1.1677	22.8
0.35	0.1114	0.0591	1.2058	25.4
0.40	0.1273	0.0675	1.2450	28.1
0.45	0.1432	0.0759	1.2853	30.7
0.47	0.1496	0.0793	1.3017	31.8
0.51	0.1623	0.0861	1.3348	34.0
0.52	0.1655	0.0878	1.3432	34.5
0.55	0.1751	0.0928	1.3686	36.2
0.60	0.1910	0.1013	1.4117	39.0
0.65	0.2069	0.1097	1.4557	41.8
0.70	0.2228	0.1181	1.5009	44.8

Table 3.9.8-6

CE 14x14 - K_I Calculation using Fracture Geometry #2

OD (in) =	0.4373
t (in) =	0.0253
R / t =	8.64
Rm (in) =	0.2060
M (kip-in) =	0.06
Theta (radian) =	0.47
I (in^4) =	6.97E-04
Bending Stress (ksi) =	17.30
E (ksi) =	10,600

Theta (rad)	Theta/pi	Half Length (in)	F(Theta)	K_I (ksi $in^{1/2}$)
0.05	0.0159	0.0103	1.0132	3.2
0.10	0.0318	0.0206	1.0363	4.6
0.15	0.0477	0.0309	1.0646	5.7
0.20	0.0637	0.0412	1.0966	6.8
0.25	0.0796	0.0515	1.1312	7.9
0.30	0.0955	0.0618	1.1677	8.9
0.35	0.1114	0.0721	1.2058	9.9
0.40	0.1273	0.0824	1.2450	11.0
0.45	0.1432	0.0927	1.2853	12.0
0.47	0.1496	0.0968	1.3017	12.4
0.51	0.1623	0.1051	1.3348	13.3
0.52	0.1655	0.1071	1.3432	13.5
0.55	0.1751	0.1133	1.3686	14.1
0.60	0.1910	0.1236	1.4117	15.2
0.65	0.2069	0.1339	1.4557	16.3
0.70	0.2228	0.1442	1.5009	17.5

Table 3.9.8-7

Summary - Maximum Fuel Rod Stresses and Stress Ratios

Normal and Off Normal Load Case	Maximum [1] Stress (psi)	Stress [2] Ratio
On site Transport and Transfer Operations	2,865	0.04
One-foot Side Drop (Part 71)	48,950	0.70

Notes:
(1) Maximum stress for all fuel assemblies.
(2) Stress ratio = maximum stress / 69,500 (yield stress for Zircaloy cladding).

Table 3.9.8-8

Summary - Computed Fuel Tube Stress Intensity Factors and Ratios

Fracture Geometry	Max K_I (1) (ksi in$^{1/2}$)	K_{IC} (2) (ksi in$^{1/2}$)	Ratio Max K_I / K_{IC}
Geometry #1	24.2	35.0	0.69
Geometry #2	33.8	35.0	0.97

Notes:
1. Maximum K_I for all fuel assemblies.
2. K_{IC} = Crack initiation fracture toughness (plane strain fracture toughness).

Comparably, the maximum effective stress (Von Mises stress) in the cask structure shell is calculated to be 29.12 ksi (see Figure 3.9.10-21 of this Appendix) from the LS-DYNA dynamic analysis. This indicates that the static stress analysis using drop load of 75g is a very conservative approach, which produces about twice stress value of that produced by the dynamic LS-DYNA analysis.

5. Figure 3.9.10-23 shows the maximum effective stress (Von Mises stress) in transfer cask due to CG over corner drop from LS-DYNA analysis. The maximum effective stress at cask top cover plate is about 34.49 ksi, which is less than its allowable stress of 94.2 ksi (SA-240, Type XM 19 at 300°F). The maximum effective stress in the structural shell is about 24.0 ksi, which is less than its allowable stress of 66.2 ksi (SA-240, Type 304 at 300°F).

For g loads (including dynamic load factor) to be used for canister and basket structural analyses are described in Appendix 3.9.11.

3.9.10.6 References

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CHAPTER 4
THERMAL EVALUATION

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THERMAL EVALUATION

4.1 Discussion

The NUHOMS®-32PTH DSC is designed to passively reject decay heat during storage and transfer for normal, off-normal, and accident conditions while maintaining temperatures and pressures within specified limits. Objectives of the thermal analyses performed for this evaluation include:

- Determination of maximum and minimum temperatures with respect to material limits to ensure components perform their intended safety functions,
- Determination of temperature distributions to support the calculation of thermal stresses,
- Determination of maximum DSC internal pressures for normal, off-normal, and accident conditions, and
- Determination of the maximum fuel cladding temperature, and to confirm that this temperature will remain sufficiently low to prevent unacceptable degradation of the fuel during storage.

To establish the heat removal capability, several thermal design criteria are established for the System. These are:

- Maximum temperatures of the containment structural components must not adversely affect the containment function.
- To maintain the stability of the neutron shield resin in the transfer cask (TC) during normal transfer conditions, a maximum allowable temperature of 300°F is set for the neutron shield material [1].
- A maximum fuel cladding temperature limit of 400°C (752°F) has been established for normal conditions of storage and for short-term storage operations such as transfer and vacuum drying [2]. During off-normal storage and accident conditions, the fuel cladding temperature limit is 570°C (1058°F) [2].
- A maximum temperature limit of 327°C (620°F) is considered for the lead in the transfer cask, corresponding to the melting point [3].

- The ambient temperature range for normal operation is 0 to 100°F (-18 to 38°C). The minimum and maximum off-normal ambient temperatures are -20°F (-29 °C) and 115°F (46°C) respectively. In general, all the thermal criteria are associated with maximum temperature limits and not minimum temperatures. All materials can be subjected to a minimum environment temperature of -20°F (-29 °C) without adverse effects.

- The maximum DSC internal pressure during normal and off-normal conditions must be below the design pressures of 15 psig and 20 psig respectively. For accident cases, the maximum DSC internal pressure must be lower than 70 psig during storage and lower than 120 psig during transfer operation.

The NUHOMS®-32PTH DSC is analyzed based on a maximum heat load of 34.8 kW from 32 fuel assemblies with a maximum heat load of 1.5 kW per assembly. For CE 14x14 fuel assembly the maximum total heat load is limited to 33.8 kW. The loading requirements described in Section 4.3.1.3 are used to develop the bounding load configurations.

A description of the detailed analyses performed for normal/off-normal conditions is provided in Section 4.3, and accident conditions in Section 4.4. The thermal analyses performed for the loading and unloading conditions are described in Section 4.5. DSC internal pressures are discussed in Section 4.6.

The analyses consider the effect of the decay heat flux varying axially along a fuel assembly. The axial decay heat profile for a PWR fuel assembly is based on [4]. Section 4.7 describes the calculated peaking factors and the methodology to apply the axial heat profile in the model.

Fuel assemblies are considered as homogenized materials in the fuel compartments. The effective thermal conductivity of the fuel assemblies used in the thermal analysis is based on the conservative assumption that heat transfer within the fuel region occurs only by conduction and radiation where any convection heat transfer is neglected. The lowest effective properties among the applicable fuel assemblies are selected to perform the thermal analysis. Section 4.8 presents the calculation that determines the bounding effective thermal properties of the applicable fuel assemblies.

The thermal evaluation concludes that with a design basis heat load of 34.8 kW and the loading requirements described in Section 4.3.1.3, all design criteria are satisfied.

4.3 Thermal Evaluation for Normal and Off-Normal Conditions

4.3.1 Thermal Models for Normal and Off-Normal Conditions

The finite element models are developed using the ANSYS computer code [16]. ANSYS is a comprehensive thermal, structural, and fluid flow analysis package. It is a finite element analysis code capable of solving steady-state and transient thermal analysis problems in one, two, and three dimensions. Heat transfer via a combination of conduction, radiation, and convection can be modeled by ANSYS.

Three finite element models are used for evaluation of the normal and off-normal storage and transfer conditions:

- A transfer cask model (OS-187H) to determine temperature distributions within the cask body and neutron shielding. This model also includes the DSC shell and the helium gap between the DSC and the cask inner surface.
- A DSC model including the basket and the homogenized fuel assemblies to determine temperature distributions within the DSC and its contents.
- A HSM-H model including the DSC shell and shield plugs to determine temperature distribution in the HSM-H concrete structure, the supporting rails, and the DSC shell.

The analysis starts first with evaluating the transfer cask or the HSM-H model. The resultant temperatures of the DSC shell are then applied as boundary conditions to the exterior nodes of the DSC model. This approach allows modeling of sufficient detail within the DSC while keeping the overall size of the individual models reasonable.

Ambient temperatures between 0 and 100°F are considered as normal, long-term transfer and storage conditions. Minimum and maximum off-normal ambient temperatures are -20°F and 115°F. Should these extreme temperatures ever occur, they would be expected to last for a short period of time. Nevertheless, these ambient temperatures are conservatively assumed to occur for a significant duration to result in a steady-state temperature distribution in the NUHOMS®-32PTH system components.

Since the normal conditions are bounded by the off-normal conditions, the finite element models are evaluated only for off-normal conditions. The thermal stresses and the DSC internal pressures for the normal conditions are therefore conservatively calculated based on the resultant temperatures for the off-normal conditions.

4.3.1.1 Steady State Transfer Cask Model (OS187H)

OS187H transfer cask is designed to provide structural and radiological protection for the DSC during transfer operation while providing passive heat removal for the canisterized spent fuel. The three-dimensional finite element model of the OS187H transfer cask represents a 180° symmetric section of the TC and includes the geometry and material properties of the DSC shell and shield plugs, inner shell, gamma shell (lead), and structural shell of the transfer cask, as well as the shielding panel, cask lid, cask bottom plate, and the solid neutron shields. Properties of pure water are assumed for the liquid neutron shield contained in the shielding panel.

The neutron shield panel consists of a cylindrical shell welded to the cask structural shell and supported by 17 rings. Each of the 15 inner supporting rings has four holes to allow filling and draining of water in or out of the panel. The water in the neutron shield panel is modeled as 16 individual, cylindrical segments using SOLID70 elements. Effective conductivities are calculated for individual segments in Section 4.9 to model the combination of the conduction and convection heat transfer through the water contained in the shielding panel.

Radiation between the DSC outer shell and the cask inner shell is modeled using radiation LINK31 elements. The LINK elements connect the outermost nodes of the DSC shell to the inner most nodes of the transfer cask in the radial and axial directions. A macro[4] is written to retrieve the average surface area of the elements attached to each LINK31 element and apply it as a real constant to the corresponding LINK31 element.

Since the outer diameter of DSC is very close to the inner diameter of the cask, the radiating surfaces of the DSC and cask can be considered as parallel planes. The effective emissivity for the radiation exchange between the parallel planes is calculated as follows and applied as real constant to radiation LINK31 elements.

$$\varepsilon_{eff} = \frac{1}{\left(\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1\right)} = 0.2987$$

A surface emissivity of 0.46 for stainless steel (see Section 4.2) is used for ε_1, ε_2 in the above equation to calculate the real constant of ε_{eff}. The value of ε_{eff} remains unchanged for all the radiation LINK elements.

Following assumptions are considered in developing the model:

a) DSC in centered axially in the transfer cask. This assumption reduces the axial heat transfer and hence maximizes the DSC shell temperature, which in turn results in higher fuel cladding temperature in the DSC model.

b) The total decay heat load (34.8 kW) is considered evenly distributed over the radial inner surface of the DSC cavity. The applied heat flux is:

$$\text{Decay heat flux} = \frac{Q}{\pi D_i L} = 3.34 \text{ Btu/hr-in}^2 \quad \text{or} \quad 3.25 \text{ Btu/hr-in}^2 \text{ for CE 14x14 only}$$

where,

Q = total decay heat load = 34.8 kW = (118,748 Btu/hr) or 33.8 kW (115,336 Btu/hr) for CE 14x14 only

[4] See Appendix 4.16.1 for macros

The circumference of the DSC model is divided into three regions for convection boundary conditions as shown in Figure 4-9. The surface of the DSC shell from -64.2° to -60° is located above the upper edge of the slots in the slotted plate. The free convection is therefore restricted over this area. For conservatism, this area is considered as a dead zone with no free convection. Calculation of free convection coefficients for the DSC regions is discussed in Section 4.11.

Similar to the DSC circumference, the cross section of the HSM-H cavity is divided into different regions to apply the convection boundary conditions. Energy and hydraulic equations are combined to calculate the exit and the average bulk air temperatures for various ambient temperatures. Section 4.13 shows the regions and describes briefly the methodology to calculate the exit and the average bulk air temperatures in the HSM-H cavity.

Convection on HSM-H end walls is calculated using free convection correlations for vertical surfaces at HSM-H average bulk air temperature (T_c). Convection on the lower part of the side wall, below the side heat shield, is determined using free convection correlation for vertical surfaces at ambient temperature (T_c). For the space between the side wall and the side heat shield, free convection correlation for a narrow channel is used to determine the free convection coefficient. For the HSM-H ceiling and the HSM-H basemat, correlations for flat horizontal surfaces are used to determine free convection coefficients. Air temperatures for the convection on the basemat and ceiling are ambient temperature (T_c) and exit air temperature (T_{exit}) respectively. The calculation methods of free convection coefficients are discussed in detail in Section 4.11. Figure 4-10 shows the convection boundary conditions applied in the HSM-H model.

The thermal test reported in reference [25] shows that the HSM-H thermal analysis methodology conservatively predicts the DSC and the HSM-H component temperatures.

Insolance is applied as a constant heat flux on the roof and front wall of the HSM-H, which are exposed to the ambient. The value of the solar heat flux is taken from [17] averaged over a 24 hour period. The insolance is applied as a constant heat flux over the SURF152 elements superimposed on the SOLID70 elements on the HSM-H roof and front wall. A solar absorptivity of 1.0 is assumed for the concrete surface. The values of the applied heat fluxes are listed below:

Shape	Insolance [17] (gcal/cm^2)	Averaged over 24 hr (Btu/hr-in^2)
HSM roof	800	0.8537
HSM front wall	200	0.2134

Insolance is not considered for the minimum ambient temperature of -20°F.

Convection and radiation from the roof and the front wall are combined together as a total convection coefficient. The calculation of the total convection coefficient is discussed in Section 4.11.

The decay heat load is considered to be distributed evenly on the radial inner surface of the DSC for the steady state runs in this analysis. The applied decay heat flux is:

$$Decay\ heat\ flux = \frac{Q}{\pi D_i L} = 3.34 \quad \text{Btu/hr-in}^2 \text{ or } \quad 3.25 \text{ Btu/hr-in}^2 \text{ for CE 14x14 only}$$

where,

Q = total decay heat load = 34.8 kW = (118,748 Btu/hr) or 33.8 kW (115,336 Btu/hr) for CE 14x14 only
Di = inner DSC diameter = 68.75"
L = DSC cavity length = 164.5"

In the event that the side heat shields are not equipped with fins, applying the maximum decay heat load of 34.8 kW increases the maximum component temperatures within the HSM-H. In order to limit the maximum concrete temperature below the values considered for the structural analyses in Chapter 3, the maximum decay heat load is decreased for the HSM-H modules without fins on the side heat shields. The maximum decay heat load for the HSM-H modules with un-finned aluminum side heat shields is 32.0 kW, which gives a uniform heat flux of 3.07 Btu/hr-in^2.

$$Decay\ heat\ flux = \frac{Q}{\pi D_i L} = 3.07 \quad \text{Btu/hr-in}^2 \quad \text{for HSM-H with un-finned aluminum side heat shields}$$

$Q_1 = 32.0$ kW = 109,194 Btu/hr

For the HSM-H modules with galvanized side heat shields, the maximum decay heat load is limited to 26.1 kW.

$$Decay\ heat\ flux = \frac{Q}{\pi D_i L} = 2.51 \quad \text{Btu/hr-in}^2 \quad \text{for HSM-H with galvanized steel side heat shields}$$

$Q_2 = 26.1$ kW = 89,061 Btu/hr

It is assumed that soil has a temperature of 70°F at 10' below the HSM-H basemat for hot conditions. The soil temperature for cold condition (-20°F) is assumed to be 45°F. These assumptions are consistent with the assumptions in the thermal analysis of the standardized HSM design [19]. The HSM-H basemat is considered to be a 4' thick concrete slab. Due to low conductivity of concrete and soil, the model is insensitive to the thickness of the basemat / soil and the soil temperature. The heat flux and fixed temperature boundary conditions applied in the model are shown in Figure 4-11.

4.3.1.3 Steady State 32PTH DSC Model

The 32PTH DSC is a high integrity stainless steel welded pressure vessel that provides confinement of radioactive material, encapsulates the fuel in a helium atmosphere, and when placed in the transfer cask, provides radiological shielding.

A three dimensional finite element model of the 32PTH DSC is developed using ANSYS [16] to determine the maximum fuel cladding temperature. The DSC model includes the DSC shell, shield plugs, basket rails, basket, and fuel assemblies. The fuel assemblies are modeled as homogenized regions within the fuel compartments. The effective thermal properties for the homogenized fuel are calculated in Section 4.8.

The following conservative assumptions are considered in developing the finite element model to maximize the fuel cladding temperature:

- No convection occurs within the DSC cavity,
- The basket containing the fuel assemblies is centered axially in the DSC cavity,
- Heat transfer across the contact gaps within the basket occurs only by gasous conduction.

The following gaps are considered between components in the model at thermal equilibrium:

- 0.010" gap between each two adjacent basket plates except for the following cases:
  - between the aluminum inserts and the stainless steel rails – this gap is considered to be at least 0.020"
  - between the aluminum and the poison plates, when applicable. The aluminum plate and the poison plate are sandwiched between fuel compartments. For ease of modeling the 0.010" gaps are placed on both sides of the paired plates. These gaps account for the total contact resistance between the four plates shown in Figure 4-13, Detail B.
- 0.010" gap between the basket plates and aluminum rails
- 0.100" radial gap between rails and inner shell (see Section 4.11 for justification)

The axial cold gap of 0.07" between the stainless steel support plates and the aluminum plates is *divided into a 0.01" axial gap at the bottom and a 0.060" axial gap at the top of the stainless steel* plate. All dimensions of the canister are at nominal values. Details of the finite element model are shown in Figures 4-12 to 4-14.

Five basket types in two categories are designed for NUHOMS-32PTH DSC. Relevant characteristics of these basket types are listed below.

Basket type	I	II
A	Boron Aluminum, or Metal Matrix Composites (MMC) Maximum thickness 0.187"	Boral® Maximum thickness 0.075"
B		
C		
D		Not applicable
E		Not applicable

Aluminum plates are to be paired with the poison plates to make a nominal thickness of 0.5". The conductivity of the borated aluminum/MMC plate depends on the boron content and the fabrication procedure. To bound the maximum component temperature, the maximum thickness of the boron containing plate (0.1875") is considered in the model for basket type I.

Paired Boral®/ aluminum plates are used in basket type II. An effective conductivity is calculated for the paired Boral® / aluminum plates, as discussed in Section 4.2. Other combination of aluminum and poison plates that satisfies the conductivity requirements in Chapter 9 can be used in the basket.

Heat transfer from the fuel regions occurs only by conduction through the basket plates and the rails. Conduction and radiation heat transfer are considered between the rails and the DSC shell. Conduction through components is modeled using SOLID70 elements.

Radiation between the rails and the DSC shell is modeled using radiation LINK31 elements using the same methodology as described in Section 4.3.1.1. Axial radiation is also considered between the top and bottom surfaces of the fuel assemblies to the shield plugs. The emissivity of the heavily oxidized top and bottom surfaces of the fuel assemblies are considered to be 0.9.

Steady State Boundary conditions for the DSC Model

The nodal temperatures of the DSC shell are retrieved from the transfer cask or HSM-H models described in Sections 4.3.1.1 and 4.3.1.2, and applied to the corresponding nodes in the DSC model via a macro described in Appendix 4.16.1.

The SOLID70 elements representing the homogenized fuel are given heat generating boundary conditions in the region of the active fuel length. Active fuel length is considered to be 144" [20] beginning at approximately 4.0" above the bottom of the fuel assembly [20]. Fuel assembly has a total length of 162" in the model. Peaking factors to apply the axial decay heat profile for the homogenized fuel region are calculated in Section 4.7.

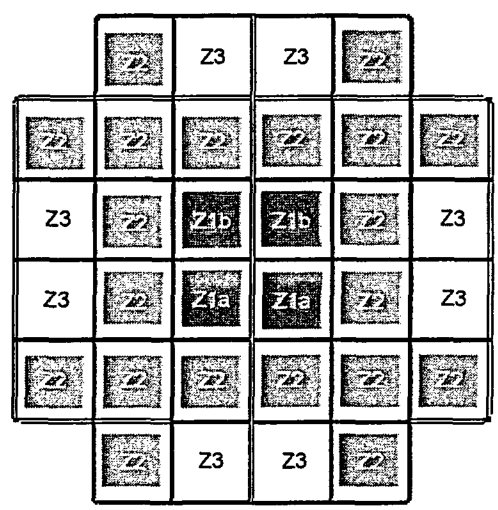
The maximum heat load per canister is 33.8 kW for CE 14x14 fuel assemblies and 34.8 kW for other fuel assemblies. Since CE 14x14 fuel assembly has a shorter active fuel length than the other assemblies, a lower total heat load is considered for CE 14x14 assembly to avoid a high heat generating rate. The maximum decay heat per assembly is 1.5 kW. Heat load zoning, as illustrated below, is used to maximize the number of higher heat load assemblies per DSC. The loading requirements are as follows.

For CE 14x14 Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat $\leq$ 33.8 kW
- 4 fuel assemblies in zone 1 with $Q_{z1} \leq 0.775$ kW
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.068$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW

For other fuel Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat $\leq$ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat $\leq$ 3.2 kW
  - $Q_{z1a} \leq 1.05$ kW in the lower compartments
  - $Q_{z1b} \leq 0.8$ kW in the upper compartments
- 20 fuel assemblies in zone 2 with $Q_{z2} \leq 1.1$ kW
- 8 fuel assemblies in zone 3 with $Q_{z3} \leq 1.5$ kW



Heat generation rates as a function of spent fuel parameters are calculated in Appendix 4.16.2. Five extreme loading configurations are considered to bound the maximum component temperatures. The loading configurations are shown in Figure 4-15. In the first configuration, the heat load in the core compartments is maximized, so that zone 1 has a uniform heat load of 0.8

kW per assembly and zone 2 has a heat load of 1.1 kW per assembly. Since the total heat load is limited to 34.8 kW, the heat load of zone 3 is 1.2 kW per assembly.

The heat load in the peripheral compartments is maximized in loading configuration 2, so that zone 3 has a heat load of 1.5 kW per assembly and zone 2 has a heat load of 1.1 kW per assembly. Since the total heat load is limited to 34.8 kW, the heat load of zone 1 is 0.2 kW per assembly. A heat load of 0.2 kW per assembly for a fuel assembly in zone 1 is rather unrealistic. To have a more realistic estimation of maximum component temperatures loading configuration 3 is considered, in which zone 1 has a heat load of 0.55 kW per assembly and zone 3 has a heat load of 1.5 kW per assembly. Zone 2 is divided into two subdivisions. The first subdivision includes the fuel assemblies around the central assemblies with a heat load of 0.925 kW per assembly and the second subdivision located at the periphery has a heat load of 1.1 kW per assembly.

In loading configuration 4, the heal load in zone 1 and zone 3 are maximized, so that the central and peripheral compartments have maximum heat load. The heat load is 1.5 kW per assembly in zone 3 and 0.8 kW per assembly in zone 1. The remaining heat load is divided uniformly over assemblies in zone 2, which gives a heat load of 0.98 kW per assembly.

To investigate the effect of non-uniform loading in zone 1, loading configuration 5 is considered, in which the two lower compartments in zone 1 have a heat load of 1.05 kW per assembly. It gives a heat load of 0.55 kW per assembly for the two upper compartments in zone 1 based on the loading restrictions.

Similar to load configuration 1, the heat load in the core compartments is maximized for CE 14x14 assemblies in load configuration 6. The heat load of zone 3 is 1.17 kW per assembly.

Load configuration 7 is similar to configuration 4, the heat load in zones 1 and 3 are maximized to investigate the effect of the maximum heat load in zone 3 on the cladding temperature.

The sevenfive loading configurations discussed above are considered only for the maximum ambient temperature of 115°F during transfer operation. For the other conditions loading configuration 1 is evaluated, which gives the maximum DSC component temperatures for high enriched fuel assemblies in basket type I.

Heat generating rate for each segment of the active fuel region is calculated as follows:

$$\dot{q}''' = \frac{\left(\dfrac{Q}{4a^2 L_a}\right)}{0.984}$$

where

Q = Heat load per assembly defined for each loading zone
a = half width of fuel compartment =Width of the modeled fuel assembly = 8.7"/2 = 4.35"
L_a =Active fuel length = 137 for CE 14x14 / 144" for other assemblies
PF = Peaking Factor from Section 4.7

The area beneath the peaking factor curve shown in Section 4.7 is 0.984. The heat generating value is divided by this factor to avoid any reduction of the total heat load in the model. The total

heat load applied in the model is verified by retrieving the reaction solution from the solved model and comparing it to the maximum heat load value. Typical applied boundary conditions are shown in Figure 4-16

4.3.2 Maximum Temperatures for Normal and Off-Normal Conditions

Steady state thermal analyses are performed using the maximum decay heat load of 34.8 kW (33.8 kW for CE 14x14) per canister, 115°F ambient temperature, and the maximum insolation per reference [17]. Insolation is averaged over a 12 hour period for transfer conditions and over a 24 hour period for storage conditions.

The temperature distributions within the TC, the HSM-H, and the DSC models are shown in Figures 4-17 to 4-23. Summaries of the maximum component temperatures are listed in Tables 4-1 and 4-2. The maximum component temperatures for 34.8 kW heat load bounds the temperatures calculated for 33.8 kW heat load as shown in Table 4-1.

The maximum temperatures calculated for off-normal conditions bound the values for the normal conditions. Therefore, thermal stress and DSC internal pressures for both normal and off-normal conditions are calculated based on the temperatures resulted from the maximum off-normal conditions (115°F ambient) for conservatism.

4.3.3 Minimum Temperatures for Normal and Off-Normal Conditions

Temperature distributions under the minimum ambient temperatures of –20°F with no insolation and the maximum design heat load are determined under steady state conditions to maximize the temperature gradients in the TC, the HSM-H and the DSC. Figures 4-24 and 4-25. show the temperature distributions for transfer operations and storage conditions at -20°F respectively. Tables 4-3 and 4-4 summarize the results of these analyses.

The resultant DSC and transfer cask temperatures for the -20°F ambient during transfer and storage are used to calculate the thermal stresses for the normal conditions at 0°F ambient.

4.3.4 Maximum Internal Pressures for Normal and Off-Normal Conditions

Maximum internal pressure within the NUHOMS®-32PTH DSC is calculated in Section 4.6

4.3.5 Maximum Thermal Stresses for Normal and Off-Normal Conditions

Maximum thermal stresses during normal and off-normal conditions of storage and transfer are calculated in Chapter 3.

4.3.6 Evaluation of Thermal Performance for Normal and Off-Normal Conditions

The thermal analysis for normal and off-normal conditions of transfer and storage concludes that the NUHOMS®-32PTH System design meets all applicable requirements.

4.5 Thermal Evaluation for Loading and Unloading Conditions

Fuel loading and unloading operations occur in the fuel handling building. During loading operation fuel assemblies are submerged in pool water permitting heat dissipation. After fuel loading is complete, the TC and 32PTH DSC are removed from the pool and the DSC is drained (nitrogen or helium is used to assist removal of water), backfilled with nitrogen or helium, dried, backfilled with helium and sealed. The TC will be sealed and backfilled with helium after sealing the DSC.

4.5.1 Vacuum Drying

The loading condition evaluated is the heatup of the DSC before transfer to the storage site. The 32PTH DSC heatup occurs during draining, vacuum drying, backfilling, and sealing of the DSC, when the DSC is contained in the TC in the vertical position inside the fuel handling building. At the design basis heat load, the water in the annulus between the DSC and the transfer cask could boil between the time the canister is drained, and the time it is backfilled with helium. There are two methods that may be utilized to prevent this; one is to monitor the temperature of the annulus water and if required, circulate or introduce fresh water to maintain the temperature below 180°F, the other is to simply drain the annulus water when it exceeds this temperature limit. In any of these methods, the DSC may be backfilled with helium after complete drainage of the water.

It is assumed in this evaluation that the complete drainage of water from the 32PTH DSC cavity may occur either before or after welding the DSC top shield plug. Partial drainage of water from the DSC cavity and from the annulus between the DSC and the TC is required to perform the welding. After drainage of cavity water (nitrogen or helium is used to assist removal of water), backfilling with nitrogen or helium is required.

Fuel cladding temperature must be maintained below 752°F as required in [2]. The following procedures are considered for limitation of fuel temperature between the time of complete drain and helium backfill of the 32PTH DSC.

A. Annulus water temperature remains below 180°F by water flow or circulation in the annulus between the DSC and the TC, as required, for the entire vacuum drying process. A time limit is calculated for this procedure which includes all the activities after complete DSC drainage until DSC backfilling starts.

B. Water neither flows nor circulates in the annulus between the DSC and the TC. The water in the annulus will be drained as soon as its temperature exceeds 180°F. Two time limits are calculated for this procedure. Similar to procedure A, the first time limit starts after complete DSC drainage. The second time limit includes the activities after drainage of the annulus water to the point that DSC backfilling starts

C. This procedure is the same as procedure B except that the DSC will be backfilled with helium after drainage of the DSC water. To consider the worst case, it is assumed that backfilling of the DSC starts not immediately after drainage of the DSC water, but occurs after drainage of the annulus water. The two time limits described above for procedure B are also calculated for procedure C.

If one chooses to follow procedure C and backfill the DSC with helium after drainage of water, there is no time limit for completion of the vacuum drying process. The reason is the DSC shell temperature is maintained at temperatures lower than the values calculated for the storage conditions. With helium in the DSC cavity, the fuel cladding temperature is well below the values calculated for the off-normal storage conditions in Section 4.3.6, and would never approach the allowable limit of 752°F.

After completion of the vacuum drying, the DSC must be sealed, the annulus between the DSC and the transfer cask must be drained (if not already drained), the cask must be sealed and backfilled with helium. To ensure the integrity of the fuel cladding, a time limit is considered for performing the activities after vacuum drying until backfilling of the transfer cask starts. This time limit is calculated for procedure B, which has the shortest time limits of all three procedures. For the other procedures, specifically procedure A, the time limit to seal and backfill the transfer cask is significantly longer.

Parts of the above procedures might be combined together to build a new procedure. The time limit for the new procedure can be calculated from appropriate combination of the resultant transient curves discussed in Section 4.5.1.4.

Transient thermal analyses are performed to determine the component temperatures at the end of each procedure separately. A bounding initial average temperature is considered to start the transient analysis.

The three-dimensional model of the 32PTH DSC within the TC described in Section 4.4.1.1 is slightly modified to analyze the vacuum drying procedures. The model contains a half slice of the 32PTH DSC within the TC. The modifications are:

- The DSC is centered in the transfer cask cavity
- The effective conductivity of fuel assemblies are changed to the values reported for vacuum conditions in Section 4.2
- Air conductivity is given to the elements representing the gas and gaps within the basket
- It is considered that the annulus between the DSC and the TC is initially filled with water
- Radiation is not considered between the basket rails and the DSC shell

All the other material properties remain unchanged.

Free convection and radiation are combined together to calculate the total heat transfer coefficient from the TC outer surface to the ambient. Due to the large outer diameter of the TC, the free convection coefficient approaches that for a vertical flat plate. The correlations to calculate the free convection coefficient on vertical plates are discussed in Section 4.11. Following inputs are considered to calculate the total heat transfer coefficient on the outer surface of the transfer cask in this evaluation.

- Ambient temperature in the fuel handling building is 100°F.

- Height of the cylinder is 173", which is approximately the length of the neutron shield panel.
- Surface emissivity of the transfer cask is 0.9 (see Section 4.2 for painted surfaces)

A decay heat load of 34.8 kW is considered for all the transient runs. The decay heat is applied as heat generating boundary conditions on the elements representing the homogenized fuel assemblies with a peaking factor of 1.1. Loading configuration 1 is considered for this purpose. Adiabatic boundary conditions are applied on the top and bottom faces of the slice model for conservatism. The other boundary conditions are discussed separately for each procedure in Sections 4.5.1.1 to 4.5.1.3.

An average, initial temperature at the beginning of the transient runs is calculated for the 32PTH DSC and transfer cask as follows.

Initial Temperature 1 = initial pool temperature +
average heat up rate with water in DSC × duration of lifting +
average heat up rate without water in DSC × duration of drainage
when water from the DSC cavity is drained completely before the welding process

and

Initial Temperature 2 = initial pool temperature +
average heat up rate with water in DSC × duration of lifting +
average heat up rate with water in DSC × duration of welding
when water from the DSC cavity is drained completely after the welding process

Following assumptions are considered to calculate the initial temperature:

- Initial pool temperature is 115°F
- No heat dissipation occurs from the transfer cask outer surface
- All the decay heat is used to heat up the transfer cask and its content
- Lifting the transfer cask from the pool to the fuel handling building and performing the required inspections take 2 hours
- Drainage (pumping) of water from the DSC takes 4 hours
-

The average heat up rate is defined as:

$$heat\ up\ rate = \frac{Q}{M\,\overline{C}_p}$$

Q = total decay heat load = 34.8 kW (118748 Btu/hr)
M = total weight (lbm)
$\overline{C}_p$ = average specific heat (Btu/lbm-°F)

The average specific heat is the mass average specific heat of all of the components.

$$\overline{C}_p = \frac{\sum m_i\, C_{p,i}}{M}$$

The components volumes and weights are taken from Chapter 3. Specific heat values increase generally at higher temperatures. Specific heats of the components are taken at about 100°F, which results in higher initial temperature and increases the conservatism in the model. A

summary of the heat up rate calculation is shown in Table 4-7. The initial average temperature of the transfer cask and its content is then:

Initial average temp 1 = 115 + 3.2 × 2 + 4.5 × 4 = 139.4°F
with initial pool temperature =115°F
average heat up rate during lifting = 3.2°F /hr (see Table 1)
duration of lifting = 2 hrs
average heat up rate after drainage of DSC = 4.5 °F /hr (see Table 1)
duration of draining water from DSC = 4 hrs

Initial average temp 2 = 115 + 3.2 × 2 + 3.2 × 10 = 153.4°F
with initial pool temperature =115°F
average heat up rate during lifting = 3.2°F /hr (see Table 1)
duration of lifting = 2 hrs
average heat up rate before drainage of DSC = 3.2°F /hr (see Table 1)
duration of welding the DSC shield plug = 10 hrs

For conservatism, an initial temperature of 160°F is considered for the TC and its content at the start of the transient runs.

4.5.1.1 Boundary Conditions for Procedure A

Adequate water should flow or circulated in the 32PTH DSC/TC annulus to prevent water from boiling. In this case the maximum surface temperature of the DSC shell does not exceed the boiling point of water. To simulate procedure A, it is assumed conservatively that the DSC shell temperature remains at 215°F during the entire vacuum drying process. The start time of simulation is after complete drainage of the DSC water.

Temperature gradient through the TC is determined by applying constant temperature of 215°F at the inner shell of the TC. Free convection and radiation boundary conditions are applied on the outer surface of the TC using the total heat transfer coefficient described in Section 4.11.

4.5.1.2 Boundary Conditions for Procedure B

Conduction and free convection heat transfer are combined together to calculate an effective conductivity for the water in the annulus. The calculation of the effective conductivity for the water in the annulus is discussed in detail in Section 4.9.

After draining the water from the annulus, thermal properties of air (conduction only) are considered for the elements in the annulus between the 32PTH DSC and the TC. Free convection and radiation boundary conditions are applied on the outer surface of the TC using the total heat transfer coefficient described in Section 4.11.

Procedure B is also considered to calculate the time limit to backfill the transfer cask with helium after completion of the vacuum drying. For this purpose, the properties of the DSC backfill gas is changed to that of helium, and the fuel effective conductivities are changed to those calculated for helium atmosphere. Time of this change is 28 hours after complete drainage of DSC water or 14 hours after drainage of the annulus water. Other boundary conditions remain unchanged.

4.5.1.3 Boundary Conditions for Procedure C

The same boundary conditions as those described for procedure B are considered for Procedure C except that the 32PTH DSC is backfilled with helium after drainage of the annulus water. It is considered that it takes three hours until the helium replaces the nitrogen and water vapor within the DSC cavity completely. Before helium backfill, the model considers air conductivity for the DSC back fill gas which is conservative for helium. For nitrogen, the thermal conductivity value is within 6% of the value for air at expected temperatures and is acceptable due to conservatisms listed in Section 4.3.1.3. After the three hour period, the conductivity of back fill gas is changed to that of helium, and the fuel effective conductivities are changed to those calculated for helium atmosphere.

4.5.1.4 Evaluation of Vacuum Drying Procedure

Transient simulation of vacuum drying procedures gives the time-temperature history of the fuel assemblies with the maximum decay heat load of 34.8 kW. Duration of the vacuum process is limited to the time at which the maximum temperature of the fuel assemblies is close to the allowable limit of 752°F (400°C) [2]. A margin of about 20°F is considered for conservatism in determining the time limit for procedure A. The maximum fuel cladding temperatures are summarized in Table 4-8.Typical temperature distributions at the end of vacuum drying process are shown in Figure 4-34. Histories of the maximum component temperatures are shown in Figures 4-35 to 4-37.

As Table 4-8 shows, the vacuum drying can proceed up to 36 hours, if procedure A is followed. For procedure B, the time limit to complete the vacuum drying is 14 hours after drainage of the annulus water or 28 hours after complete drainage of DSC water, whichever is the limiting time. For these evaluations it is assumed that nitrogen is used to assist removal of water and the DSC cavity is backfilled with nitrogen after draining of the bulk water in the cavity.

Backfilling the transfer cask must start within12 hours after completion of the vacuum drying, if one chooses to follow procedure B. The time limit to start backfilling the transfer cask with helium is significantly longer, if procedure A is followed. For procedure C, backfilling of the transfer cask with helium must start within 42 hours after complete DSC drainage or 28 hours after drainage of the annulus water based on the time-temperature history curve shown in Figure 4-37.

Should the decay heat load be lower than 34.8 kW, the time frame will increase for completion of the vacuum drying process. At some decay heat load, the maximum fuel cladding temperature remains always below the allowable limit regardless of the vacuum drying duration. To determine the decay heat load at which the time limitation is not required, models of procedure A to C are investigated separately assuming steady state conditions. Uniform heat generating boundary conditions are applied on the fuel assemblies in the steady state analysis. The results summarized in Table 4-9 show that the fuel cladding temperature remains always below the allowable limit for 23.2 kW decay heat load using procedure A. Similarly, there is no time limit for vacuum drying with 16.0 kW and 22.4 kW using procedures B and C respectively.

Vacuum drying procedures A to C preclude any thermal cycling of fuel cladding. Backfilling the DSC with helium gas causes a one time temperature drop, which is not considered as a repeated thermal cycling. Re-evacuation of the DSC under helium atmosphere does not reduce the pressure sufficiently to decrease the thermal conductivity of helium. Therefore, evacuation and re-pressurizing the DSC under helium atmosphere proceed on a descending curve to the minimum steady state temperatures, and does not include any thermal cycling. It concludes that the limit of 65°C (118°F) considered for thermal cycling is not applicable for NUHOMS®-32PTH system.

4.5.2 Reflooding

For unloading operations, the DSC will be filled with the spend fuel pool water through the siphon port. During this filling, the DSC vent port is maintained open with effluents routed to the plant's off-gas monitoring system.

When the pool water is added to a DSC cavity containing hot fuel and basket components, some of the water will flash to steam causing internal cavity pressure to rise. The steam pressure is released through the vent port. The initial flow rate of the reflood water must be controlled such that the internal pressure in the DSC cavity does not exceed 20 psig. This is assured by monitoring the maximum internal pressure in the DSC cavity during reflood event. The reflood of the DSC is considered as a "Service Level D" event and the design pressure of the DSC is 120 psig. Therefore, there is sufficient margin in the DSC internal pressure during the reflooding event to ensure that the DSC will not be over pressurized.

The maximum fuel cladding temperature during reflooding process is significantly less than the vacuum drying condition owing to the presence of water/steam in the DSC cavity. Hence, the peak cladding temperature during the reflooding operation will be less than 734°F calculated for procedure A in Section 4.5.1 when water circulates in the annulus between the DSC and transfer cask.

To evaluate the effects of the thermal loads on the fuel cladding during reflooding operations, a conservative high fuel rod temperature of 750°F and a conservative low quench water temperature of 50°F are used.

The following material properties, corresponding to 750°F, are used in the evaluation.

Modulus of elasticity, $E = 10.4\text{x}10^6$ psi $= 7.17\text{x}10^{10}$	(Pa)	[26]
Modulus of rigidity, $G = 2.47\text{x}10^{10}$	(PaPa)	[31]
Thermal expansion coefficient, $\alpha = 6.72\text{x}10^{-6}$	(1/K)	[31]
Yield stress, Sy = 80,500 psi $= 5.55\text{x}10^8$	(Pa)	[26]
Poisson's ratio, $\upsilon = \dfrac{E}{2G} - 1$		[27]

The fuel cladding stress is evaluated as a hollow cylinder with an outer surface temperature of T (50°F), and the inner surface temperature of T+ΔT (750°F) using the following equations from [27].

Maximum circumferential stresses are:

$$\text{(outer surface)} \quad \sigma_{to} = \frac{\Delta T \cdot \alpha \cdot E}{2(1-\upsilon)\ln(r_o/r_i)}\left(1 - \frac{2\,r_i^2}{(r_o^2 - r_i^2)}\ln(\frac{r_o}{r_i})\right) \qquad \text{tension}$$

$$\text{(inner surface)} \quad \sigma_{ti} = \frac{\Delta T \cdot \alpha \cdot E}{2(1-\upsilon)\ln(r_o/r_i)}\left(1 - \frac{2\,r_o^2}{(r_o^2 - r_i^2)}\ln(\frac{r_o}{r_i})\right) \qquad \text{compression}$$

The longitudinal stresses are equal to the tangential stresses [27]. The maximum stresses calculated for the fuel assembly types to be stored in the NUHOMS-32PTH are summarized in the following table.

	WE & WES 15x15	WE 17x17	MK BW 17x17	WEO 17x17	CE 14x14
OD fuel rod (in)	0.422	0.374	0.374	0.360	0.440
Clad thickness (in)	0.0243	0.0225	0.0240	0.0225	0.028
ID Clad (in)	0.3734	0.3290	0.3260	0.3150	0.3840
σ_{to} max (Pa)	1.64E+08	1.64E+08	1.63E+08	1.63E+08	1.63E+08
σ_{to} max (psi)	23,768	23,719	23,644	23,676	23,654
σ_{ti} max (Pa)	1.78E+08	1.78E+08	1.79E+08	1.78E+08	1.79E+08
σ_{ti} max (psi)	25,787	25,835	25,910	25,879	25,900

σ_max (psi) = 25,910

The maximum stress is 25,910 psi. The calculated maximum stress is much less than the yield stress of 80,500 psi. Therefore, cladding integrity is maintained during reflooding operation.

4.6 Maximum Internal Pressure

The following methodology is used to determine the maximum pressures within the 32PTH DSC during storage and transfer conditions:

- Average cavity gas temperatures are derived from component temperatures.
- The amount of helium present within the canister after the initial backfilling is determined via the ideal gas law.
- The total amount of free gas within the fuel assemblies, including both fill and fission gases, is calculated based on data reported in [28].
- The amount of released gas from the fuel rods into the DSC cavity is determined based on the maximum fraction of the ruptured fuel rods considered in NUREG 1536 [22].
- The amount of helium gas is added to the amount of released gases to make the total amount of gases in the 32PTH DSC cavity.
- Finally, the maximum cavity pressures are determined via the ideal gas law.

The design pressures for the NUHOMS®-32PTH DSC are summarized in the following table.

Condition	Maximum Allowable Pressure For Storage (psig)	Maximum Allowable Pressure for Transfer (psig)
Normal	15	15
Off-Normal	20	20
Accident	70	120

Based on the ideal gas law, the internal pressure of the DSC increases as the average gas temperature increases. Since the DSC normal operating temperatures are bounded by the off-normal temperatures, the maximum internal pressure of the DSC is conservatively calculated based on the off-normal temperatures for both the normal and the off-normal conditions. The average cavity gas temperatures are calculated for loading configuration 1 and HSM-H with unfinned side heat shields at 34.8 kW, which give the maximum component temperatures.

The maximum fractions of the fuel rods that can rupture and release their free gases to DSC cavity for normal, off-normal, and accident cases are 1, 10, and 100% respectively as considered in NUREG 1536 [22].

4.6.1 Average Gas Temperature

To determine the average gas temperature, volume average temperatures of the elements representing the helium gaps (T_{void}) and the homogenized fuel assemblies (T_{fuel}) are calculated discretely from the thermal models. Although the average temperature of the homogenized fuel elements includes the fuel rods and the helium gas between them, this average temperature is considered as the average gas temperature within fuel compartments. The following volumes are considered to calculate the gas average temperature:

Gas volume in the fuel compartments = Volume of the fuel compartments – Volume of the fuel rods
Volume of the fuel compartment = 8.7 x 8.7 x 162 x 32 = 392,377 in^3
Volume of the fuel rods = 148,488 in^3 [Chapter 3]
Gas volume in the fuel compartments ($V_{He,comp}$) = 243,889 in^3

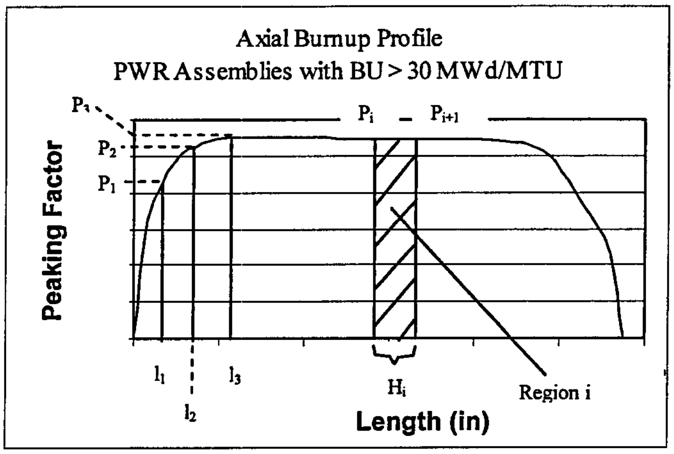
Average peaking factor is:

$$P_j = \frac{A_j}{H_j}$$

P_j = Average peaking factors of fuel region j
H_j= Height of fuel region i

The following Figure depicts this methodology. The resultant average peaking factors for active fuel length of 144" are listed in Table 4-11.

Calculation of the Average Peaking Factor



The height of each region is converted to the corresponding local coordination in the finite element model to apply the peaking factors in the model. The peaking factors applied in the model are listed below.

For WE and MK BW Fuel Assemblies (Active Fuel Length =144")

Region No.	Height from bottom of active fuel		Z-axis in FEM		Peaking Factor
	from	To	from	to	
1	0	1.32	4	5.32	0.107
2	1.32	7.0675	5.32	11.0675	0.582
3	7.0675	14.5	11.0675	18.5	0.908
4	14.5	22.0675	18.5	26.0675	1.048
5	22.0675	37.0675	26.0675	41.0675	1.100
6	37.0675	57.69	41.0675	61.69	1.104
7	57.69	66.9425	61.69	70.9425	1.096
8	66.9425	82.0675	70.9425	86.0675	1.094
9	82.0675	97.0675	86.0675	101.0675	1.095
10	97.0675	111.9425	101.0675	115.9425	1.088
11	111.9425	121.26	115.9425	125.26	1.046
12	121.26	127.0675	125.26	131.0675	0.955
13	127.0675	136.26	131.0675	140.26	0.743
14	136.26	144	140.26	148	0.374

For CE 14x14 Fuel Assembly (Active Fuel Length =137")

Region No.	Height from bottom of active fuel from	To	Z-axis in FEM from	to	Peaking Factor
1	0	5.5	5.5	11.0675	0.441
2	5.5	11.0675	11.0675	18.5	0.874
3	11.0675	18.5	18.5	26.0675	1.041
4	18.5	26.0675	26.0675	41.0675	1.100
5	26.0675	41.0675	41.0675	61.69	1.103
6	41.0675	61.69	61.69	65.32	1.097
7	61.69	65.32	65.32	78.51	1.094
8	65.32	78.51	78.51	95.32	1.095
9	78.51	95.32	95.32	110.32	1.091
10	95.32	110.32	110.32	120	1.054
11	110.32	120	120	125.32	0.974
12	120	125.32	125.32	136.75	0.732
13	125.32	137	136.75	142.5	0.321

A comparison between the axial burnup profile from Reference [4] and the axial burnup profile used in the finite element model is shown in the Figure 4-39.
Figure 4-39 shows that the calculated axial profile perfectly matches the data from reference [4] except for the very ends of the active fuel. The small discrepancy at the very ends is due to the size of the regions and has a minimum effect on the thermal evaluation.

4.8 Effective Fuel Properties

4.8.1 Discussion

The NUHOMS®-32PTH DSC finite element models simulate the effective thermal properties of the fuel with a homogenized material occupying the volume within the basket where the fuel assemblies are stored. Effective values for density, specific heat, and conductivity are determined for this homogenized material for use in the finite element models.

The 32PTH DSC is capable of handling a variety of spent PWR fuel assemblies. In order to determine conservative thermal properties of the homogenized fuel assembly, all of the PWR fuel assemblyies types to be stored in the 32PTH DSC are studied. WE and MK BW fuel assemblies are considered in one category with active fuel length of 144". The lowest effective thermal conductivity, density, and specific heat of thise studied fuel assembly groupies are selected to apply in the finite element model. Use of these properties would conservatively predict bounding maximum temperatures for the components of the NUHOMS®-32PTH DSC. The effective fuel properties for CE 14x14 assembly are considered separately since CE 14x14 assembly has a shorter active fuel length.

The characteristics of the fuel assemblies to be stored in the 32PTH DSC are listed in Table 4-12.

4.8.2 Summary of Material Properties

1. UO_2, Fuel Pellets
Conductivity and specific heat for fuel pellets are taken from [30] and listed below.

Temperature (°C)	k (cal/s-cm-°C) [30]	Temperature (°F)	k (Btu/hr-in-°F)
25	0.025	77	0.503
100	0.021	212	0.423
200	0.018	392	0.362
300	0.015	572	0.302
500	0.0132	932	0.266
700	0.0123	1292	0.248
800	0.0124	1472	0.250

Temperature (°C)	C_p (cal/g-°C) [30]	Temperature (°F)	C_p (Btu/lbm-°F)
0	0.056	32	0.056
100	0.063	212	0.063
200	0.0675	392	0.068
400	0.0722	752	0.072
1200	0.079	2192	0.079

The density of fuel pellets (UO_2) is 10.96 g/cc = 0.396 lbm/in^3 [30].

2. Zircaloy-4, Cladding

Table B-2.I of Reference [31] lists measured and calculated values of thermal conductivity for zircaloy-4 at various temperatures. The measured values used in this calculation are listed below.

Temperature (K)	k (W/m-K) [31]	Temperature (°F)	k (Btu/hr-in-°F)
373.2	13.6	212	0.655
473.2	14.3	392	0.689
573.2	15.2	572	0.732
673.2	16.4	752	0.790
773.2	18.0	932	0.867
873.2	20.1	1112	0.968

Table B-1.1 of [31] lists specific heat values for Zircaloy as a function of temperature.

Temperature (K)	C_p (J/kg-K) [31]	Temperature (°F)	C_p (Btu/lbm-°F)
300	281	80	0.067
400	302	260	0.072
640	331	692	0.079
1090	375	1502	0.090

The density of Zircaloy is 6.56 g/cm3 = 0.237 lbm/in3, as defined in [30].

Table B-3.11 of [31] lists the measured emissivity values for fuel cladding. For ease of calculation a temperature independent emissivity of 0.8 is set for zircaloy4 in this calculation.

εzirc = 0.80

3. Helium

Temperature (K)	Conductivity [5] (W/m-k)	Temperature (°F)	Conductivity (Btu/hr-in-°F)
200	0.1151	-100	0.0055
250	0.1338	-10	0.0064
300	0.150	80	0.0072
400	0.180	260	0.0087
500	0.211	440	0.0102
600	0.247	620	0.0119
800	0.307	980	0.0148
1000	0.363	1340	0.0175

4. Air at low pressure (0.1 bar)

Temperature (K)	Conductivity [5] (W/m-k)	Temperature (°F)	Conductivity (Btu/hr-in-°F)
200	0.0180	-100	0.0009
300	0.0263	80	0.0013
400	0.0336	260	0.0016
500	0.0403	440	0.0019
600	0.0466	620	0.0022
800	0.0577	980	0.0028
1000	0.0681	1340	0.0033

The air conductivity at low pressure is used to calculate the effective transverse conductivity for vacuum drying conditions. Air is not allowed for blowdown operations. Only nitrogen or helium are used. If nitrogen is used for blowdown, use of air conductivity values for nitrogen is acceptable because there is only 6% difference between air and nitrogen conductivities at expected temperatures and also due to the conservatisms listed in Section 4.3.1.3.

5. Stainless Steel SA-240, Type 304

A stainless steel emissivity of 0.3, a value lower than the measured values from Reference [14] is used in the analysis for conservatism.

4.8.3 Effective Fuel Conductivity

4.8.3.1 Transverse Effective Conductivity

The purpose of the effective conductivity in the transverse direction of a fuel assembly is to relate the temperature drop of a homogeneous heat generating square to the temperature drop across an actual assembly cross section for a given heat load. This relationship is established by the following equation obtained from Reference [32]:

$$k_{eff} = \frac{Q}{4L_a(T_c - T_o)}(0.29468)$$

where:

k_{eff} = Effective thermal conductivity (Btu/hr-in.-°F)
Q = Assembly head generation (Btu/hr)
Q_{react} = Reaction solution retrieved from quarter model (Btu/hr)

$Q = 4 \times Q_{react} \times L_a$ for WE and MK BW assemblies with quarter symmetric models

$Q = Q_{react} \times L_a$ for CE 14x14 assembly with full-scale model

Q_{react} = Reaction solution retrieved from the ANSYS model (Btu/hr-in)
L_a = Assembly active length (in.)
T_o = Maximum temperature (°F)
T_s = Surface temperature (°F)

Discrete finite element models of the fuel assemblies to be stored in the NUHOMS®-32PTH DSC are developed using the ANSYS computer code [16]. These two-dimensional models simulate heat transfer by radiation and conduction and include the geometry of the fuel rods and

fuel pellets. Helium or air properties are used as the fill gas in the fuel assembly. A fuel assembly decay heat load of 0.8 kW [9] is used for heat generation. An active length of 144" is assumed for WE and MK BW assemblies. The active fuel length of CE 14x14 assembly is considered to be 137".

The finite element models are used to calculate the maximum radial temperature difference with isothermal boundary conditions. All components are modeled using 2-D PLANE55 thermal solid elements. LINK32 elements are placed on the exteriors of the fuel assembly components to set up the creation of the radiation super-element. The compartment wall is modeled using LINK32 elements and used only to set up the surrounding surface for the creation of the radiation matrix super-element using the /AUX12 processor in ANSYS. All LINK32 elements are unselected prior to solution of the thermal problem. The thermal properties used in the model are described in Section 4.8.2, and the fuel assembly geometries are shown in Table 4-12. A typical ANSYS finite element model of fuel assemblies is shown in Figure 4-40 for fuel assemblies WE 17x17 and CE 14x14.

Several computational runs were made for each model using isothermal boundary temperatures ranging from 100 to 1000°F. In determining the temperature dependent effective conductivities of the fuel assemblies an average temperature, equal to $(T_o + T_s)/2$, is used for the fuel temperature. The transverse effective conductivity is calculated in helium for storage and transfer conditions. For vacuum drying conditions, the conductivity of helium is replaced by air conductivity at low pressure. The vacuum drying of the DSC generally does not reduce the pressure sufficiently to reduce the thermal conductivity of the water vapor and air in the DSC cavity [33]. Therefore, air conductivity at low pressures is assumed for the backfill gas for vacuum drying conditions and the effect of water vapor conductivity is neglected.

4.8.3.2 Axial Effective Conductivity

The backfill gas, fuel pellets, and zircaloy behave like resistors in parallel. However, due to the small conductivity of the fill gas and the axial gaps between fuel pellets, credit is only taken for the zircaloy in the determination of the axial effective conductivities.

$$kaxial = \frac{cladding\ area}{4a^2} \times cladding\ conductivity$$

with a = half of compartment width = 8.7"/2 = 4.35"

4.8.4 Effective Fuel Density and Specific Heat

Volume average density and weight average specific heat are calculated to determine the effective density and specific heat for each fuel assembly type separately. The equations to determine the effective density and specific heat are shown below.

$$\rho_{eff} = \frac{\sum \rho_i V_i}{V_{assembly}} = \frac{\rho_{UO2}\ V_{UO2} + \rho_{Zr4}\ V_{Zr4}}{4a^2 L_a}$$

[9] 0.8 kW is the maximum decay heat load for the fuel assemblies in the center of the basket.

$$C_{p,eff} = \frac{\sum \rho_i V_i C_{Pi}}{\sum \rho_i V_i} = \frac{\rho_{UO2}\ V_{UO2}\ C_{P,UO2} + \rho_{Zr4}\ V_{Zr4}\ C_{P,Zr4}}{\rho_{UO2}\ V_{UO2} + \rho_{Zr4}\ V_{Zr4}}$$

4.8.5 Conclusion

The effective transverse conductivity values are plotted in Figure 4-41. Among WE and MK BW assemblies, fuel type WEO 17x17 has the lowest conductivity for the range of 100 to 700°F under helium atmosphere. For temperatures higher than 700°F, fuel assembly MK BW 17x17 has the lowest transverse conductivity. To bound the transverse effective conductivity, the lowest effective conductivity value in each temperature range is selected to apply in the thermal analysis. The effective transverse conductivity of CE 14x14 is used separately in a DSC model with 137" active fuel length.

The calculated transverse effective conductivties for vacuum drying conditions are plotted in Figure 4-42. As Figure 4-42 shows, fuel assembly MK BW 17x17 has the lowest conductivity for vacuum drying conditions, which are used in thermal analysis for vacuum conditions.

The axial effective conductivity for each fuel type is calculated using the equation from Section 4.8.3.2. The resultant values are listed in Table 4-13 and plotted in Figure 4-43. The lowest axial effective conductivity belongs to fuel type WE 15x15 among WE and MK BW assemblies. This value is used in all DSC models except for the DSC model containing CE 14x14 fuel assemblies. analysis. The latest model uses the CE 14x14 axial conductivity shown separately in Figure 4-43.

Effective density of each fuel type is calculated using the corresponding equation from Section 4.8.4. Since using the lowest density results in the highest cladding temperature for accident conditions, the density of fuel assembly WEO 17x17 is the bounding density. The calculated effective density values are listed in Table 4-13.

Effective specific heat values are calculated as a function of temperature using the corresponding equation from Section 4.8.4. Properties of fuel pellets and fuel cladding from Section 4.8.2 are linearly interpolated for this purpose. The lowest specific heat belongs to the fuel type WE 15x15 (and WES 15x15). Since the lowest specific heat results in the highest cladding temperature for transient calculations, specific heat of fuel type WE 15x15 (and WES 15x15) is selected for thermal analysis as the bounding property. The calculated effective specific heat values are listed in Table 4-13.

Since CE 14x14 fuel assembly is analyzed only for steady state transfer conditions, the effective density and the effective specific heat are not calculated for this fuel type.

The bounding effective fuel properties used in the finite element models for WE and MK BW assemblies are listed in Section 4.2.

4.9 Effective Conductivity of Fluids in the Transfer Cask

4.9.1 Effective Conductivity in the Shielding Panel

Heat transfer in the shielding panel occurs by conduction and convection through the fluid (water) contained in the shielding. The shielding panel consists of 16 cylindrical segments. Each segment can be considered as two concentric, horizontal cylinders. The following correlation from [5] is used to calculate the free convection coefficient for water within each of the panel segments.

$$k_{con} = Nu \; k_w$$

k_{con} = effective conductivity for conduction and convection from inner to outer cylinder
k_w = conductivity of water

$$Nu = \left[Nu_{COND}, Nu_l\right]_{max}$$

$$Nu_{COND} = \frac{\ln(D_o / D_i)}{\cosh^{-1}\left[\left(D_o^2 + D_i^2 - 4E^2\right)/2D_oD_i\right]} \qquad \text{conduction}$$

$$Nu_l = 0.603\,\overline{C}_l \frac{\ln(D_o / D_i)\, Ra^{1/4}}{\left[(L/D_i)^{3/5} + (L/D_o)^{3/5}\right]^{5/4}} \qquad \text{laminar flow}$$

where,

$$Ra = \frac{g\beta(T_i - T_o)L^3}{\nu^2} \times \Pr \qquad \text{with} \qquad L = (D_o - D_i)/2 \qquad \text{and}$$

$$\overline{C}_l = \tfrac{4}{3}\frac{0.503}{\left[1 + (0.492/\Pr)^{9/16}\right]^{4/9}}$$

All water properties are evaluated at average temperature:

$$T_{avg} = (T_o + T_i)/2$$

T_o = average temperature of the outer cylinder
T_i = average temperature of the inner cylinder

Diameter of the inner cylinder is 81.7", and diameter of outer cylinder is 91.825". The average inner and outer temperatures are initially unknown. Iterative solution of the ANSYS [16] model combined with the above correlations determines the inner and outer temperatures, and the effective conductivity. The iteration continues until the difference between the applied coefficient in the ANSYS model and the calculated coefficient is less than 5% for the off-normal conditions at 115°F ambient. To ease the analysis, this criterion is increased to 10% for the off-normal conditions at -20°F ambient, which is less sensitive for thermal evaluations.

Water properties are reported in Section 4.2. The calculated effective conductivity values and their verifications are shown in the Table 4-14 and 4-15 for normal and off-normal transfer conditions.

The same methodology as described above is used to calculate the effective conductivity of liquid neutron shield during the burning period of fire accident case

The concentration of the decay heat for the rubble fuels is maximized, when all the rubble are compressed to a minimum height at one end of the fuel compartment.

To bound the maximum cladding temperature of the intact fuel assemblies, it is assumed that all the 16 damaged fuel assemblies transform to rubble. The cladding is considered as powder but the pellets are assumed to keep their shape in the rubble. An approximate void volume between the pellets can be evaluated considering the area ratio of the pellet cross-section to the square area with a width equal to the pellet outer diameter. The increased volume due to the void spaces between pellets is then:

$$\{(OD_{pellet}^2 - \pi\, OD_{pellet}^2 / 4) / (\pi\, OD_{pellet}^2 / 4)\} \times 100 = (4/\pi - 1) \times 100 = 27.32\ \%$$

The minimum height of the fuel rubble is calculated as follows.

$$H_{\min} = \frac{V_{UO2} \times 1.2732 + V_{Zr4}}{A}$$

where

A = cross-sectional area of the fuel compartment = 8.7 × 8.7 = 75.69 in^2
V_{UO2} = volume of fuel pellets from Section 4.8
V_{Zr4} = volume of fuel cladding from Section 4.8

Table 4-24 summarizes the calculation of H_{min} for all the fuel types. The shortest height of 61" is considered for the fuel rubble.

Thermal model of the transfer cask described in Section 4.3 is modified for the purpose of the evaluation. It is assumed that the seals of transfer cask and the shielding shell will be damaged in the consequence of the hypothetical drop accident. In this event, the helium in the annulus and the water in the shielding shell will be released to the ambient. To evaluate the thermal effects of this accident, the transfer cask model developed in Section 4.3 is used to determine the DSC shell temperature when the DSC contains fuel rubble. Helium conductivity in the annulus is replaced with air conductivity. The effective conductivity in the shielding panel is also recalculated based on air properties.

To stabilize the ANSYS run and shorten the run time, the LINK31 elements simulating the radiation between the DSC and transfer cask are replaced with equivalent effective conductivity. Calculations of the effective conductivities for air in annulus and in the shielding shell are based on the methodologies described in Section 4.9. The equivalency of the applied effective conductivities to the radiation elements (LINK31) is verified on hand comparison of the maximum temperatures resulted from separate runs of the transfer cask slice model using LINK31 elements and equivalent effective conductivities.

Steady state boundary conditions are considered to run the transfer cask model. Total heat load of 34.8 kW is applied uniformly on the DSC inner radial surface. The resultant DSC shell temperatures are transferred then to the DSC model to determine the maximum fuel temperature for this accident case.

The 32PTH DSC model described in Section 4.3 is also slightly modified to include the fuel rubble. The height of the elements in the core compartments are adjusted, so that a region with the height of 61" (H_{min}) is created. This region is assigned as fuel rubble region. All the elements beyond the fuel rubble region, which previously represented homogenized fuel within the core compartments, are deleted. The decay heat load of the damaged fuel assemblies are applied as a uniform heat generation rate without peaking factor to the elements in the fuel rubble region. Thermal properties of helium are considered for the elements representing the fuel rubble to eliminate the uncertainties regarding the fuel rubble conductivity. The decay heat profile from Section 4.7 is considered for the intact fuels in the peripheral compartments for this analysis. The DSC model is run steady state to determine the maximum component temperatures.

Except for those mentioned above, the geometry and material properties of all the other elements in the DSC and the transfer cask models remain unchanged.

In the drop accident case considered above, it was assumed that the liquid neutron shield and the helium in the transfer cask were lost. Since the 15 min fire has only a short term effect on the neutron shield panel as shown in Figure 4-29, and the transfer cask and the DSC models are run steady state, the drop accident case bounds the fire accident case temperatures.

4.14.3 Effective Properties of Damaged Fuel

Defected spacer or grids might change the fuel rod pitch and hence change the effective fuel conductivity. It is assumed that the fuel rods in the assembly with defected grids can move in axial and in transverse directions. The axial moving of the fuel rods has no impact on the thermal conductivity in either direction. To determine the impact of the transverse moving on the fuel effective conductivity, the fuel assemblies WEO 17x17 and Framatome MK BW 17x17 are investigated. The reason to investigate these assemblies is that the intact assembly WEO 17x17 has the lowest transverse conductivity in temperature range from 100 to 700°F and the intact assembly MK BW 17x17 has the lowest transverse conductivity for temperatures higher than 700°F as shown in Section 4.8.

For the investigation, the effective transverse fuel conductivity is determined using the same methodology described in Section 4.8.

The effect of the transverse moving of the fuel rods is investigated by changing the pitch size of the fuel rods. The pitch size is changed from the minimum closest packed pitch to the maximum most spread out pitch. A 0.01" gap has been added to the minimum and maximum pitch to account for contact resistance. Typical finite element models of reconfigured fuel assemblies are shown in Figure 4-47.

Each pitch is evaluated for two different compartment wall temperatures and then the average conductivity is determined. Compartment wall temperatures of 200°F and 300°F are considered for various pitch sizes of WEO 17x17 assembly. For MK BW 17x17 assembly, compartment wall temperatures of 700°F and 800°F are considered. The effective transverse conductivities are interpolated to average temperatures of 300°F for WEO 17x17 and 800°F for MK BW 17x17.

The results of the investigation are summarized in Table 4-25 and plotted in Figure 4-48. As Figure 4-48 shows, the minimum transverse conductivities occur at a pitch sizes of 0.387" for WEO 17x17 and 0.402" for MK BW 17x17.

Finite element models of WEO 17x17 and MK BW 17x17 with minimum conductivity pitch sizes are created to determine the minimum effective transverse conductivity of reconfigured fuel for the temperature range of 100 to 1000°F. The results are listed in Table 4-26 and plotted in Figure 4-49. WEO 17x17 assembly provides lower transverse conductivities for the entire temperature range. Following values calculated for reconfigured WEO 17x17 are used in the model for the effective transverse conductivity of damaged fuel.

Temperature (°F)	Transverse Effective Conductivity (Btu/hr-in-°F)
150	0.0138
243	0.0161
337	0.0187
432	0.0217
527	0.0252
624	0.0290
721	0.0331
818	0.0376
916	0.0426
1014	0.0481

Reconfiguration of the fuel rods as a consequence of damaged grids does not have any impact on the other effective fuel properties such as density, specific heat, and axial conductivity.

4.14.4 Evaluation of DSC Thermal Performance with Damaged Fuel

To establish the heat removal capability and the integrity of the intact fuel cladding, maximum fuel cladding temperature limit of 752°F is considered for normal / off-normal transfer conditions [2]. For the accident conditions, a maximum fuel cladding temperature limit of 1058°F is considered [2].

Temperature distributions for the normal / off-normal, and accident cases are shown in Figures 4-50 and 4-51. A comparison between the maximum component temperatures resulted for a DSC with 32 intact fuel assemblies and a DSC with 16 damaged fuel assemblies are shown in Table 4-27.

As Table 4-27 shows, the maximum fuel cladding temperature remains below the allowable limit for the DSC containing 16 damaged fuel assemblies. The basket temperature increases only by 3°F for this case. Regarding the margin to the allowable limit this temperature increase is not significant. Similar behavior is expected for storage conditions.

The maximum temperature of intact fuels, when the damaged fuel is transformed to rubble in consequence of an accident is lower than the maximum fuel temperature resulted from fire accident case with 32 intact fuel assemblies.

Due to the increased fuel and basket temperatures during transfer of damaged fuel, the inner DSC pressure increases in comparison to transfer of 32 intact fuel assemblies. Using the same methodology as described in section 4.6, the internal pressure of DSC containing damaged fuels is calculated. The results of pressure calculation are shown in Table 4-28. As Table 4-28 shows, the DSC pressure increase due to transfer of damaged fuels is minimal (about 0.1 psi). Similar behavior is expected to occur for the normal / off-normal storage conditions.

Table 4-27 shows that the maximum fuel and basket temperatures drop when the damaged fuel is transformed to rubble in consequence of an accident. Therefore, the 32PTH DSC inner pressure in this case is bounded by the pressure calculated for the fire accident case in Section 4.6.

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Table 4-1
Maximum Component Temperatures during Transfer Operations at 115°F ambient

Component	Maximum Temperature 34.8 kW (°F)	Allowable Maximum Temperature (°F)
DSC shell	475	
Cask inner shell	340	
Lead gamma shielding	337	621 [3]
Cask structural shell	280	
Neutron shield panel	263	
Cask lid inner plate *	275	
Cask lid outer plate	217	
Solid neutron shield	265	300 [1]
Cask lid seal †	240	400 [24]
Bottom plate seal ‡	255	400 [24]
Liquid neutron shield (Bulk temperature) §	265	286.9 **
Liquid neutron shield (Maximum temperature)	275	

	Maximum Temperature (°F) 34.8 kW					Allowable Max. Temp. (°F)
Basket Type	Type I				Type II	
Component	**Conf. # 1**	**Conf. # 2**	**Conf. # 3**	**Conf. # 4**	**Conf. # 1**	
Fuel cladding	719	705	700	715	723	752 [2]
Fuel compartment	693	667	673	689	697	
Basket Al plates	692	666	672	688	696	
Basket rails	561	559	559	558	561	

	Maximum Temperature (°F) 33.8 kW for CE 14x14 Fuel Assembly		Allowable Max. Temp. (°F)
Basket Type	Type I		
Component	**Configuration # 6**	**Configuration # 7**	
Fuel cladding	717	712	752 [2]
Fuel compartment	689	685	
Basket Al plates	689	684	
Basket rails	555	552	
DSC Shell	467	467	

* Temperatures of cask lid, solid neutron absorber, and seals are from the transfer cask sub-models.
† Maximum temperature of cask body at seal location
‡ Maximum temperature of ram access ring at seal location
§ Bulk temperature is the volumetric average temperature of the elements in shielding segments 8 and 9, see Figure 4-2.
** 286.9°F is the saturated water temperature at 40 psig.

Table 4-12
Characteristics of Fuel Assemblies

Fuel Type	WE & WES 15x15	WE & WEV 17x17	MK BW 17x17	WEO 17x17	CE 14x14
Active fuel length	142-144	144	144	144	137
Pellet OD	0.3649-0.3669	0.3225	0.3195	0.3088	0.3765
Rod OD	0.422	0.374	0.374	0.360	0.440
Clad wall thickness	0.0243	0.0225	0.0240	0.0225	0.028
Rod pitch	0.563	0.496	0.496	0.496	0.580
No. of fuel rods	204	264	264	264	176
No. of Guide/Instrument tubes	21	25	25	25	5
Guide tube OD	0.484-0.545	0.429-0.482	0.482	0.429-0.482	1.115
Guide tube wall thickness	0.015	0.016	0.016	0.016	0.04
Instrument tube OD	0.545	0.474-0.545	0.482	0.474-0.545	---
Instrument tube wall thickness	0.015	0.015-.016	0.016	0.015-.016	---

All Dimensions are in inches

Table 4-13
Effective Fuel Properties

Transverse Effective Fuel Conductivity in Helium

Fuel Type	WE & WES 15x15			WE 17x17		
T_o (°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)
100	172	136	0.0194	171	136	0.0194
200	261	231	0.0230	261	231	0.0226
300	352	326	0.0269	352	326	0.0266
400	445	423	0.0311	445	423	0.0307
500	538	519	0.0368	539	520	0.0354
600	633	617	0.0424	633	617	0.0418
700	729	714	0.0490	729	715	0.0476
800	825	813	0.0560	825	813	0.0552
1000	1019	1010	0.0737	1019	1010	0.0727
Q_{react} (Btu/hr-in)	4.751			4.685		
Q (Btu/hr) / kW	2699 / 0.8			2699 / 0.8		

Fuel Type	MK BW 17x17			WEO 17x17		
T_o (°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)
100	170	135	0.0197	173	137	0.0189
200	260	230	0.0230	262	231	0.0223
300	352	326	0.0266	353	327	0.0260
400	445	423	0.0307	445	423	0.0307
500	539	520	0.0354	539	520	0.0354
600	633	617	0.0418	633	617	0.0418
700	729	715	0.0476	729	715	0.0476
800	825	813	0.0552	825	813	0.0552
1000	1020	1010	0.0690	1019	1010	0.0727
Q_{react} (Btu/hr-in)	4.685			4.685		
Q (Btu/hr) / kW	2699 / 0.8			2699 / 0.8		

Transverse Effective Fuel Conductivity for Vacuum Conditions

Fuel Type	WE & WES 15x15			WE 17x17		
T_o (°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)
100	272	186	0.0081	275	188	0.0079
200	336	268	0.0103	340	270	0.0099
300	408	354	0.0130	411	356	0.0124
400	486	443	0.0163	489	445	0.0155
500	569	535	0.0203	572	536	0.0192
600	656	628	0.0250	658	629	0.0238
700	746	723	0.0304	748	724	0.0288
800	838	819	0.0368	839	820	0.0354
Q_{react} (Btu/hr-in)	4.685			4.685		
Q (Btu/hr) / kW	2699 / 0.8			2699 / 0.8		

Fuel Type	MK BW 17x17			WEO 17x17		
T_o (°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)	T_c (°F)	T_{avg} (°F)	k (Btu/hr-in-°F)
100	276	188	0.0078	275	188	0.0079
200	340	270	0.0099	339	270	0.0099
300	412	356	0.0123	410	355	0.0126
400	490	445	0.0153	488	444	0.0157
500	572	536	0.0192	570	535	0.0197
600	659	630	0.0234	657	629	0.0242
700	748	724	0.0288	746	723	0.0300
800	840	820	0.0345	838	819	0.0363
Q_{react} (Btu/hr-in)	4.685			4.685		
Q (Btu/hr) / kW	2699 / 0.8			2699 / 0.8		

Table 4-13 – Continued
Effective Fuel Properties

Axial Effective Fuel Conductivity in Helium or Vacuum

Fuel type	WE & WES 15x15	WE & WEV 17x17	MK BW 17x17	WEO 17x17
No of fuel rods	204	264	264	264
OD fuel rod (in)	0.422	0.374	0.374	0.360
Clad thickness (in)	0.0243	0.0225	0.0240	0.0225
No of guides tubes	20	24	24	24
OD guide tubes (in)	0.484	0.429	0.482	0.429
Wall thickness (in)	0.015	0.016	0.016	0.016
No of Instrument tubes	1	1	1	1
OD Instrument tube (in)	0.545	0.474	0.482	0.474
Wall thickness (in)	0.015	0.015	0.016	0.015

Fuel type	WE & WES 15x15	WE & WEV 17x17	MK BW 17x17	WEO 17x17
Cladding area (in^2)	6.66	7.08	7.55	6.82
Compartment area (in^2)	75.69	75.69	75.69	75.69
Temperature	k-axial	k-axial	k-axial	k-axial
(°F)	(Btu/hr-in-°F)	(Btu/hr-in-°F)	(Btu/hr-in-°F)	(Btu/hr-in-°F)
212	0.0576	0.0612	0.0653	0.0590
392	0.0606	0.0644	0.0687	0.0620
572	0.0644	0.0685	0.0730	0.0659
752	0.0695	0.0739	0.0788	0.0711
932	0.0763	0.0811	0.0865	0.0781
1112	0.0852	0.0905	0.0966	0.0872

Table 4-13 – Continued
Effective Fuel Properties

Effective Fuel Density

Fuel Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEO 17x17
No of fuel rods	204	264	264	264
OD fuel rod (in)	0.422	0.374	0.374	0.360
Clad thickness (in)	0.0243	0.0225	0.0240	0.0225
No of guides tubes	20	24	24	24
OD guide tubes (in)	0.484	0.429	0.482	0.429
Wall thickness (in)	0.015	0.016	0.016	0.016
No of Instrument tubes	1	1	1	1
OD Instrument tube (in)	0.545	0.474	0.482	0.474
Wall thickness (in)	0.015	0.015	0.016	0.015
Active fuel length (in)	142	144	144	144
Pellet OD (in)	0.3649	0.3225	0.3195	0.3088
Fuel Type	**WE & WES 15x15**	**WE 17x17**	**MK BW 17x17**	**WEO 17x17**
Cladding area (in^2)	6.66	7.08	7.55	6.82
Cladding volume (in^3)	946	1019	1088	982
Pellet area (in^2)	21.33	21.57	21.17	19.77
UO_2 volume (in^3)	3029	3105	3048	2847
ρ eff (lbm/in^3)	0.1325	0.1350	0.1344	0.1248

Effective Specific Heat of Fuel

Fuel Type	WE & WES 15x15	WE 17x17	MK BW 17x17	WEO 17x17
No of fuel rods	204	264	264	264
OD fuel rod (in)	0.422	0.374	0.374	0.360
Clad thickness (in)	0.0243	0.0225	0.0240	0.0225
No of guides tubes	20	24	24	24
OD guide tubes (in)	0.484	0.429	0.482	0.429
Wall thickness (in)	0.015	0.016	0.016	0.016
No of Instrument tubes	1	1	1	1
OD Instrument tube (in)	0.545	0.474	0.482	0.474
Wall thickness (in)	0.015	0.015	0.016	0.015
Active fuel length (in)	142	144	144	144
Pellet OD (in)	0.3649	0.3225	0.3195	0.3088
	WE & WES 15x15	**WE 17x17**	**MK BW 17x17**	**WEO 17x17**
Cladding area (in^2)	6.66	7.08	7.55	6.82
Cladding volume (in^3)	946	1019	1088	982
Pellet area (in^2)	21.33	21.57	21.17	19.77
UO_2 volume (in^3)	3029	3105	3048	2847
Temperature	Cp eff	Cp eff	Cp eff	Cp eff
(°F)	(Btu/lbm-°F)	(Btu/lbm-°F)	(Btu/lbm-°F)	(Btu/lbm-°F)
80	0.0593	0.0594	0.0595	0.0594
260	0.0654	0.0655	0.0656	0.0656
692	0.0726	0.0727	0.0728	0.0727
1502	0.0779	0.0780	0.0782	0.0781

Table 4-13 – Continued
Effective Fuel Properties for CE 14x14

Transverse Effective Fuel Conductivity in Helium

Fuel Type			**CE 14x14**	
T_o (°F)	T_c (°F)	T_{avg} (°F)	Q_{react} (Btu/hr-in)	k (Btu/hr-in-°F)
100	181	140	19.968	0.0182
225	291	258	19.969	0.0222
350	404	377	19.969	0.0271
475	519	497	19.970	0.0331
600	637	618	19.970	0.0402
725	755	740	19.970	0.0483
850	875	863	19.970	0.0577

Axial Effective Conductivity

Fuel type	**CE 14x14**
No of fuel rods	176
OD fuel rod (in)	0.440
Clad thickness (in)	0.028
No of guides tubes	5
OD guide tubes (in)	1.115
Wall thickness (in)	0.04
No of Instrument tubes	---
OD Instrument tube (in)	---
Wall thickness (in)	---
Fuel type	**CE 14x14**
Cladding area (in^2)	7.05
Compartment area (in^2)	75.69
Temperature	k-axial
(°F)	(Btu/hr-in-°F)
212	0.0610
392	0.0642
572	0.0682
752	0.0736
932	0.0808

Table 4-24
Minimum Height of the Fuel Rubble

ρ_{UO2}	= 0.396	lb/in3
ρ_{Zr4}	= 0.237	lb/in3
Fuel Comp width	= 8.70	In

Fuel Type	**WE & WES 15x15**	**WE & WEV 17x17**	**MK BW 17x17**	**WEO 17x17**
No of fuel rods	204	264	264	264
OD fuel rod (in)	0.422	0.374	0.374	0.360
Clad thickness (in)	0.0243	0.0225	0.0240	0.0225
No of guides tubes	20	24	24	24
OD guide tubes (in)	0.484	0.429	0.482	0.429
Wall thickness (in)	0.015	0.016	0.016	0.016
No of Instrument tubes	1	1	1	1
OD Instrument tube (in)	0.545	0.474	0.482	0.474
Wall thickness (in)	0.015	0.015	0.016	0.015
Active fuel length (in)	142	144	144	144
Pellet OD (in)	0.3649	0.3225	0.3195	0.3088
Cladding area (in^2)	6.66	7.08	7.55	6.82
Cladding volume (in^3)	946	1019	1088	982
Pellet area (in^2)	21.33	21.57	21.17	19.77
UO_2 volume (in^3)	3029	3105	3048	2847
H_{min} (in)	63	66	66	61

Table 4-25
Transverse Effective Fuel Conductivity at Various Fuel Rod Pitches

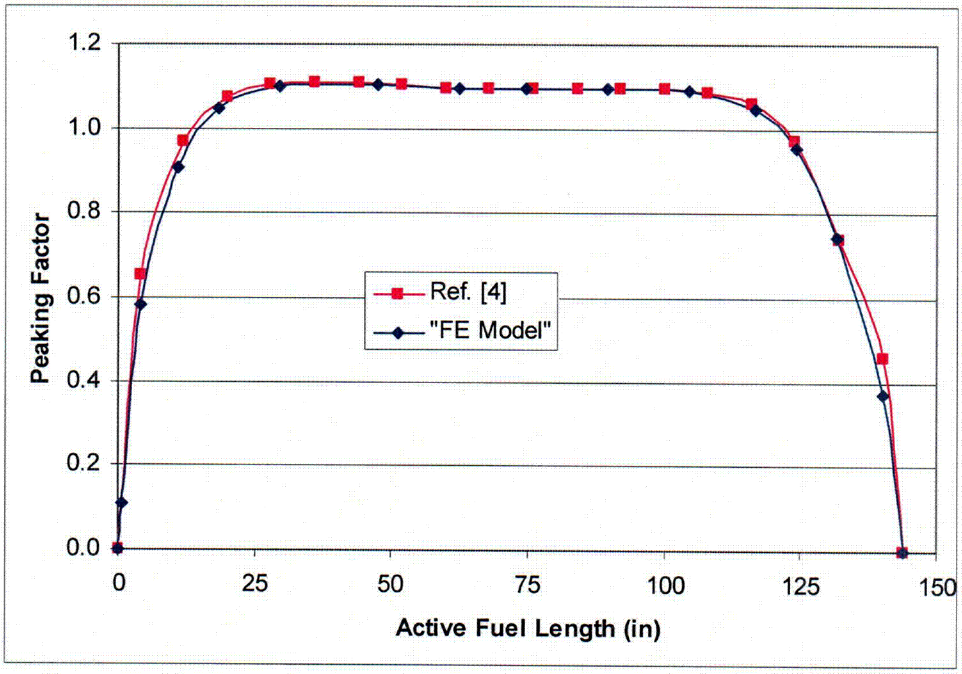
	Assembly Type MK BW 17x17					
Pitch (in)	T_o (°F)	T_c (°F)	T_{avg} (°F)	Q_{react} (Btu/hr-in)	k (Btu/hr-in-°F)	k @ 800°F (Btu/hr-in-°F)
0.384	700	739	719	4.6770	0.0357	0.0396
	800	834	817	4.6770	0.0405	
0.4	700	740	720	4.6770	0.0347	0.0385
	800	835	818	4.6770	0.0393	
0.438	700	738	719	4.6770	0.0362	0.0405
	800	833	817	4.6770	0.0413	
0.446225	700	737	719	4.6770	0.0371	0.0415
	800	833	816	4.6770	0.0424	
0.46445	700	735	717	4.6770	0.0398	0.0446
	800	830	815	4.6770	0.0455	
0.482675	700	732	716	4.6780	0.0434	0.0488
	800	828	814	4.6787	0.0496	
0.5009	700	728	714	4.6783	0.0493	0.0556
	800	824	812	4.6788	0.0565	
0.519125	700	722	711	4.6786	0.0637	0.0728
	800	819	809	4.6791	0.0738	

	Assembly Type WEO 17x17					
Pitch (in)	T_o (°F)	T_c (°F)	T_{avg} (°F)	Q_{react} (Btu/hr-in)	k (Btu/hr-in-°F)	k @ 300°F (Btu/hr-in-°F)
0.37	200	286	243	4.6761	0.0159	0.0176
	300	374	337	4.6769	0.0187	
0.4	200	287	244	4.6761	0.0158	0.0174
	300	375	337	4.6769	0.0184	
0.427	200	283	242	4.6762	0.0166	0.0182
	300	372	336	4.6768	0.0193	
0.4501	200	278	239	4.6763	0.0177	0.0195
	300	367	334	4.6768	0.0205	
0.4732	200	271	236	4.6764	0.0194	0.0215
	300	361	331	4.6768	0.0226	
0.4963	200	263	231	4.6767	0.0219	0.0246
	300	354	327	4.6769	0.0256	
0.5194	200	252	226	4.6770	0.0266	0.0305
	300	344	322	4.6769	0.0316	

Table 4-26
Transverse Effective Conductivity of Damaged Fuel

	T_o (°F)	T_c (°F)	T_{avg} (°F)	Q_{react} (Btu/hr-in)	k (Btu/hr-in-°F)
WEO 17x17	100	200	150	4.6770	1.38E-02
	200	285	243	4.6769	1.61E-02
	300	374	337	4.6769	1.87E-02
	400	463	432	4.6769	2.17E-02
	500	555	527	4.6769	2.52E-02
	600	648	624	4.6769	2.90E-02
	700	742	721	4.6769	3.31E-02
	800	837	818	4.6769	3.76E-02
	900	932	916	4.6769	4.26E-02
	1000	1029	1014	4.6769	4.81E-02
MK BW 17x17	100	194	147	4.6762	1.47E-02
	200	281	240	4.6762	1.70E-02
	300	370	335	4.6762	1.98E-02
	400	460	430	4.6762	2.28E-02
	500	552	526	4.6769	2.64E-02
	600	645	623	4.6769	3.04E-02
	700	740	720	4.6770	3.46E-02
	800	835	818	4.6770	3.93E-02
	900	931	916	4.6770	4.44E-02
	1000	1028	1014	4.6770	5.01E-02

For Total Decay Heat Load of 34.8 kW



For Total Decay Heat of 33.8 kW, CE 14x14 Fuel Assemblies

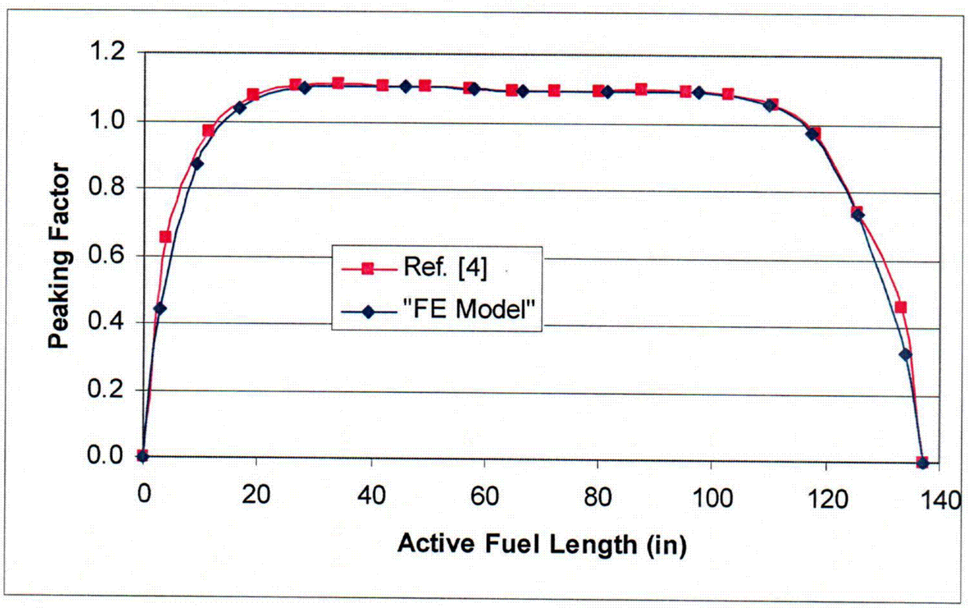


Figure 4-39
Comparison of the Axial Heat Profiles in the FE Model and in Ref. [4]

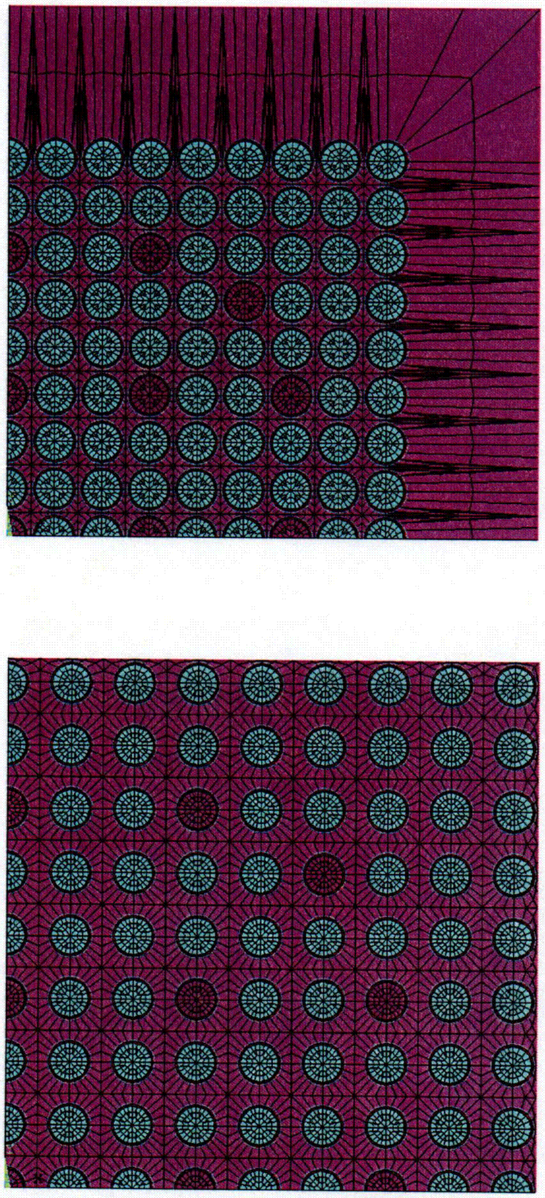


Figure 4-47
Typical FE Models of Damaged (Reconfigured) Fuel WEO 17x17

CHAPTER 5
SHIELDING EVALUATION

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5. SHIELDING EVALUATION

The shielding evaluation presented for the NUHOMS® 32PTH System demonstrates adequacy of the shielding design for the payload described in Chapter 2. The geometry of the NUHOMS® System is described in Chapter 1. The heavy concrete walls and roof of the Horizontal Storage Module (HSM-H) provide the bulk of the shielding for the payload in the storage condition. During fuel loading and transfer operations, the combination of thick steel shield plugs at the ends of the 32PTH-DSC and heavy steel/lead/neutron shield material of the OS187H transfer cask provide shielding for personnel loading and transferring the 32PTH-DSC to the HSM-H. Figure 5-1 through Figure 5-4 and Table 5-1provide the general configuration and material thicknesses of the important components of the NUHOMS® 32PTH System.

For this shielding evaluation, source terms are calculated for the bounding Framatome ANP Advanced MK BW 17x17 (MK BW 17x17) fuel assembly. This fuel assembly is bounding because it contains the greatest mass of fuel.

Also included in the source term is the bounding Non-Fuel Assembly Hardware (NFAH) which is the BPRA.

Several burnup/enrichment combinations with minimum 5 year cooling times are addressed for the fuel to provide more flexibility in qualifying fuel for storage. These combinations form the basis for the NUHOMS® 32PTH System fuel specifications in Chapter 12. Bounding operating histories are assumed for the NFAH with a minimum cooling time of 4 days. The methodology, assumptions, and criteria used in this evaluation are summarized in the following subsections.

Section 5.4 provides a three dimensional (3-D) shielding analysis for the NUHOMS® 32PTH System using MCNP [2,6]

5.1 Discussion and Results

The maximum and average dose rates due to 32 design basis PWR fuel assemblies stored with 32 design basis NFAH (BPRAs) in the NUHOMS® 32PTH System are summarized in Table 5-2 through Table 5-5. Table 5-2 provides the dose rates on the surface of the HSM-H while Table 5-3 through Table 5-5 provide the dose rates on and around the Transfer Cask (top, bottom and sides) during fuel loading, and transfer operations.

As previously stated, the NUHOMS® HD System is capable of storing PWR spent fuel, and non-fuel assembly hardware (NFAH) such as the Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), and Vibration Suppresser Inserts (VSIs). Based on the source term calculations presented in Section 5.2, the design basis fuel source term is the Framatome MK BW 17x17 fuel assembly with 60 GWd/MTU burnup, a minimum initial enrichment of 4.0 weight % U-235 and a cooling time of 7 years. The design basis NFAH source term is a BPRA assembly irradiated to 30 GWD/MTU and a cooled for 4 days.

A discussion of the method used to determine the design basis fuel and NFAH source terms is included in Section 5.2. The model specification and shielding material densities are given in Section 5.3. The method used to determine the dose rates due to 32 design basis fuel assemblies with 32 design basis NFAH in the NUHOMS® 32PTH System is provided in Section 5.4.

Normal and off-normal conditions are modeled with the NUHOMS® 32PTH System intact, including the filled neutron shield in the transfer cask. The shielding calculations are performed using the MCNP Monte Carlo transport code [2]. Average and peak dose rates on the front, side, top and back of the HSM-H and the OS187H Transfer Cask System are calculated. Occupational doses during loading, transfer to the ISFSI, and maintenance and surveillance operations are provided in Chapter 10. Locations where streaming could occur are discussed in Chapter 10.

For accident conditions (e.g., cask drop, fire), the transfer cask neutron shield water (shown in Figure 5-4 is assumed to be removed and a 1 inch void in the lead due to "lead slump' is also assumed at the top and/or bottom. Site dose and occupational dose analyses are addressed in Chapter 10 (including requirements for site specific 72.104 and 72.106 analyses).

5.2 Source Specification

Source terms are calculated with the SAS2H (ORIGEN-S) module of SCALE 4.4 [1]. The following sub-sections provide a discussion of the fuel assembly and Non-Fuel Assembly Hardware (NFAH) material weights and composition, gamma and neutron source terms and energy spectrum. The SAS2H results are used to develop source terms suitable for use in the shielding calculations.

There are five principal sources of radiation associated with the NUHOMS® 32PTH System that are of concern for radiation protection. These are:

1. Primary gamma radiation from the spent fuel
2. Primary gamma radiation from activation products in the structural materials found in the spent fuel assembly and the NFAH
3. Primary neutron radiation from the spent fuel
4. Neutrons produced from sub-critical multiplication in the fuel
5. Capture gammas from (n,γ) reactions in the NUHOMS® 32PTH System materials

The first three sources of radiation are evaluated using SAS2H. The capture gamma radiation and sub-critical multiplication are handled as part of the shielding analysis which is performed with MCNP.

The neutron flux during reactor operation is peaked in the active fuel (in-core) region of the fuel assembly and drops off rapidly outside the in-core region. Much of the fuel assembly hardware is outside of the in-core region of the fuel assembly. To account for this reduction in neutron flux, each fuel assembly type is divided into four exposure zones. A neutron flux (fluence) correction is applied to each region to account for this reduction in neutron flux outside the in-core region. The correction factors are given in Table 5-6. The four exposure zones, or regions are [4]:

Bottom—location of fuel assembly bottom nozzle and fuel rod end plugs
In-core—location of active fuel
Plenum—location of fuel rod plenum spring and top plug
Top—location of top nozzle

The Framatome MK BW 17x17 assembly is the bounding fuel assembly design for shielding purposes because it has the highest initial heavy metal loading as compared to the 14x14, 15x15, and other 17x17 fuel assemblies which are also authorized contents of the NUHOMS®-32PTH DSC and described in Chapter 2. The SAS2H/ORIGEN-S modules of the SCALE code with the 44 group ENDF/B-V library are used to generate the gamma and neutron source terms. For the bounding MK BW 17x17 fuel assembly, an initial enrichment of 4.0 wt% U-235 is assumed. The fuel assembly is irradiated with a constant specific power of 25 MW/assy to a total burnup of 60 GWD/MTU. A conservative three-cycle operating history is utilized with a 20 day down time between each cycle. The fuel assembly masses for each irradiation region are listed in Table 5-7.

Data for the WE 17x17 assembly is from Reference [7]. Some values for the WE 15x15 were assumed to be the same as the WE 17x17. The design-basis heavy metal weight is 0.476 MTU. These masses are irradiated in the appropriate fuel assembly region in the SAS2H/ORIGEN-S models. The mass of hardware for the MK BW 17x17 assembly is the greatest; however, the source term from the irradiated hardware for the WE 17x17 is bounding.

If reconstituted fuel assemblies (considered as intact fuel in the criticality analyses) with stainless steel rods undergo further irradiation, their gamma source term on a per DSC basis shall be bounded by the total design basis gamma source terms shown (on an assembly basis) in Table 5-10 for the design basis fuel assembly.

TPA

The TPA materials and masses for each irradiation zone are listed in Table 5-8. These materials are irradiated in the appropriate zone for fourteen cycles of operation. The TPA is irradiated to an equivalent assembly life burnup of 210 GWd/MTU over 14 cycles. The model assumes that the TPA is irradiated in an assembly each with an initial enrichment of 3.50 weight % U-235.The fuel assembly, containing the TPA, is burned for three cycles with a burnup of 15 GWd/MTU per cycle. This is equivalent to an assembly life burnup of 45 GWd/MTU over the three cycles. The results for a cooling time of 20 years are increased by the ratio of 14/3 to achieve the equivalent 210 GWD/MTU source.

BPRA

The BPRA materials and masses for each irradiation zone are also listed in Table 5-8. These materials are irradiated in the appropriate zone for three cycles of operation. The model assumes that the BPRA is irradiated in an assembly each with an initial enrichment of 3.50 weight % U-235. The fuel assembly containing the BPRA is burned for three cycles with a burnup of 10 GWd/MTU per cycle. This is equivalent to an assembly life burnup of 30 GWd/MTU over the three cycles. The source term for the BPRA is taken at 4 days cooling time.

VSI

VSIs are very similar in design to burnable poison rod assemblies: the stainless steel baseplate and hold-down spring assembly designs are identical to those used on older Westinghouse BPRAs. Each VSI contains 24 solid Zircalloy-4 damper rods that are attached to the hold-down assembly using a crimp nut top connector. The damper rods are the same diameter and length as BPRA rodlets. The VSIs are assumed to be equivalent in source strength to BPRAs.

Elemental Compositions of Structural Materials

To account for the source terms due to the elemental composition of the fuel assembly and NFAH structural materials the following methodology is used:

1) The material composition for each irradiation region is determined for the assembly and NFAH type.

2) The elemental compositions for each of the structural materials present in each region is determined by multiplying the total weight of each material in a specific irradiation zone (Table 5-7) by the elemental compositions. The fuel assembly and NFAH elemental composition, including impurities, for each material are taken from Reference [7].

3) The results of each material are summed to determine the total elemental composition for each irradiation zone.

4) The elemental composition is multiplied by the appropriate flux factor given in Table 5-6.

5) Finally, the elemental composition is entered in the light element card of the SAS2H input. The elemental composition for the fuel assembly is shown in Table 5-9.

The SAS2H calculation applies the total flux to the light elements; therefore, the total composition must be adjusted by the appropriate flux factor in the input. A SAS2H input is created for each irradiation zone of each fuel assembly and NFAH type. An example input file for the active fuel zone is shown in Section 5.5.2.

5.2.1 Gamma Sources

Source terms for the fuel bounding Framatome MK BW 17x17 fuel assembly and associated burnup/initial enrichment/cooling times and NFAH components are calculated with SAS2H module and the 44 group ENDF/B-V library. The SAS2H calculated contributions from actinides, fission products, and activation products, as applicable, are included for each irradiation region. The 7-year post irradiation cooling time results for the MK BW 17x17 fuel with 60 GWD/MTU burnup, and 4.0 wt % U-235 initial enrichment are shown in Table 5-10. The post irradiation cooling time results for the TPA, and BPRA are shown in Table 5-11, and Table 5-12, respectively.

Based on the results presented in Table 5-11 and Table 5-12 (maximum gamma source term) the design basis NFAH is the BPRA. The spectrum is dominated by Co-60 for all NFAH. These design basis fuel assembly sources with the BPRA source are used in the MCNP calculations to determine the bounding dose rates on and around the NUHOMS® 32PTH System, including the Transfer Cask.

5.2.2 Neutron Source

The total neutron source for the NUHOMS® 32PTH System is also calculated with SAS2H. The total neutron sources for the MK BW 17x17 assembly is summarized in Table 5-13. Again, the design basis source term is for 60 GWd/MTU burnup, 4.00 weight % U-235 initial enrichment and 7-year cooling time. The neutron source term consists primarily of spontaneous fission neutrons (largely from Cm-244) with (α,O-18) sources of lesser importance, both causing secondary fission neutrons. The overall spectrum is well represented by the Cm-244 fission spectrum.

5.3 Model Specification

The neutron and gamma dose rates on the surface of the HSM-H, and on the surface, and at 1.5 and 3 feet from the surface of the OS187H Transfer Cask are evaluated with the Monte Carlo transport code MCNP [2, 6]. The flux-to-dose conversion factors specified by the ANSI/ANS 6.1.1-1977 5, are used and provided in Table 5-14.

5.3.1 Description of the Radial and Axial Shielding Configurations

Figure 5-1 is a sketch of an HSM-H cut away at the mid-vertical plane. Figure 5-3 is also a cut through the vertical mid-plane, the 32PTH-DSC is shown in phantom lines, and the front door is at the left hand side. The rear wall of the HSM-H module has a minimum thickness of 1 foot. A 3-foot shield wall is placed along the rear and sides of the HSM-H, as shown in Figure 5-1.

The MCNP computer models are built to evaluate the dose rate along the front wall surface, the rear shield wall surface, the vent openings, the roof surface, and on the side shield walls.

Figure 5-4 shows the shielding configuration of the OS187H transfer cask.

5.3.1.1 Storage Configuration

A three-dimensional MCNP model was developed for the HSM-H Model. The HSM length was designated as the x axis (North-South direction), the width as the y axis (East-West direction), and the HSM height as the z axis. The HSM door is designated as the S side and the –x direction, with the E wall as the –y direction. The roof is the +z direction. The E wall is designated as a reflective boundary and an end shield wall (3 ft thick) is attached to the W wall. The geometry of nearly all components of the HSM is Cartesian, except for the 32PTH-DSC, which is cylindrical. The MCNP model is a full 3-D representation of a single DSC inside the HSM-H with the reflective boundary, end and side shield walls. A three foot thick concrete shield wall is placed at the rear of the HSM. A NUHOMS®-32PTH-DSC MCNP model was developed for the transfer cask analysis, discussed below. This model was revised slightly and located within the HSM model. The DSC support rails are not included in the model. The heat shields are modeled as flat plates without fins or louvers and horizontal vent "liner" plates (2cm thk) are modeled in the top side vents.

Two liners are used for gamma dose attenuation at the bottom vents. The "top" liner is a 1-inch steel plate, positioned at the roof of the bottom vent. The "front" liner is a 1-inch steel plate, at the side of the inlet vent (near the HSM front). Due to modeling constraints the "front" liner is modeled as part of the vent. This simplification does not impact the overall gamma dose rates.

5.3.1.2 Loading/Unloading Configurations

The dose rates on the surface, and at 1.5 and 3 feet from the surface of the 32PTH-DSC/ Transfer Cask are evaluated with MCNP. Three different key configurations in the loading/unloading of the spent fuel are analyzed. The three different stages modeled are, (1) Decontamination, (2) Dry Welding and (3) Transfer. Calculations are performed assuming no temporary shielding is utilized for in the configurations, which is normally done at the sites.

Table 5-6
Flux Factor By Fuel Assembly Region

Fuel Assembly Region	Flux Factor
Bottom	0.20
In-Core	1.00
Plenum	0.20
Top	0.10

Table 5-7
Westinghouse Fuel Assembly Materials and Masses

Region	Material	Mass (kg/assembly) WE 15x15	WE 17x17	MK BW 17x17
Top Fitting				
Upper Tie Plate	SS 304	6.8	6.8	7.0
Hold Down Springs	Inconel 718	1.1	1.37	1.1
Plenum				
Cladding & Guide Tubes	Zr-4	6.1	5.5	6.3
Plenum Spring	SS 302	1.5	1.9	4.7
Fuel Zone				
Cladding & Guide Tubes	Zr-4	99.2	102.9	109.9*
Grids	Zr-4			8.2
	Inconel-718	5.9	5.9	0.8
Grid Brazing Material				
	Nicrobraze 50	1.2	1.2	-
Miscellaneous				
	SS 304	4.6	4.6	0.1*
Bottom Fitting				
Bottom Tie Plate	SS 304	5.7	5.7	4.3
Total		132.1	135.6	142.4

* Clad is M5™ which is treated as Zr-4

Table 5-9
Fuel Assembly Material Masses (kg/assembly)

Scaling Factors	0.1	0.2	1	0.2	
	Top Fitting	**Plenum**	**Active Fuel**	**Bottom Fitting**	**Total**
15x15					
Chromium	0.1501	0.0555	2.2972	0.2166	2.7194
Manganese	0.0138	0.0060	0.1059	0.0228	0.1485
Iron	0.4879	0.2121	4.4512	0.7848	5.9360
Cobalt	0.0011	0.0003	0.0328	0.0009	0.0350
Nickel	0.1178	0.0268	4.3714	0.1017	4.6177
Zirconium	0.0000	1.1945	97.128	0.0000	98.322
Aluminum	0.0007	0.0000	0.0380	0.0000	0.0387
Silicon	0.0070	0.0030	0.0124	0.0000	0.0224
Titanium	0.0009	0.0000	0.0473	0.0000	0.0481
Niobium	0.0061	0.0000	0.3272	0.0000	0.3333
Molybdenum	0.0033	0.0000	0.1768	0.0000	0.1801
Tin	0.0000	0.0195	1.6608	0.0182	1.6986
17x17					
Chromium	0.1551	0.0698	2.3018	0.2166	2.7433
Manganese	0.0139	0.0076	0.1060	0.0228	0.1503
Iron	0.4927	0.2676	4.4595	0.7848	6.0047
Cobalt	0.0012	0.0003	0.0329	0.0009	0.0353
Nickel	0.1317	0.0339	4.3715	0.1017	4.6388
Zirconium	0.0000	1.0770	100.75	0.0000	101.83
Aluminum	0.0008	0.0000	0.0381	0.0000	0.0389
Silicon	0.0071	0.0038	0.0124	0.0182	0.0415
Titanium	0.0011	0.0000	0.0473	0.0000	0.0484
Niobium	0.0076	0.0000	0.3272	0.0000	0.3348
Molybdenum	0.0041	0.0000	0.1768	0.0000	0.1809
Tin	0.0000	0.0176	1.7200	0.0182	1.7558

Table 5-10
SAS2H Gamma Sources for 60 GWd/MTU, 7-Year Cooled
MK BW 17x17 Fuel Assembly

(γ/s/assembly)

Energy Interval (meV)			Fuel	Bottom	Plenum	Top
1.000E-02	to	5.000E-02	1.532E+15	1.298E+11	1.499E+11	1.096E+11
5.000E-02	to	1.000E-01	4.151E+14	1.643E+10	2.080E+10	2.136E+10
1.000E-01	to	2.000E-01	3.240E+14	8.873E+09	9.762E+09	5.155E+09
2.000E-01	to	3.000E-01	9.290E+13	4.910E+08	5.335E+08	2.563E+08
3.000E-01	to	4.000E-01	6.066E+13	1.432E+09	1.462E+09	3.356E+08
4.000E-01	to	6.000E-01	7.102E+14	2.627E+10	2.539E+10	2.121E+07
6.000E-01	to	8.000E-01	3.087E+15	1.360E+10	1.314E+10	9.567E+08
8.000E-01	to	1.000E+00	3.374E+14	1.819E+10	6.393E+09	1.248E+10
1.000E+00	to	1.330E+00	2.748E+14	4.704E+12	5.982E+12	6.234E+12
1.330E+00	to	1.660E+00	7.314E+13	1.328E+12	1.689E+12	1.760E+12
1.660E+00	to	2.000E+00	5.506E+11	3.493E-01	4.747E+01	4.592E-01
2.000E+00	to	2.500E+00	7.537E+11	3.152E+07	4.009E+07	4.178E+07
2.500E+00	to	3.000E+00	3.712E+10	4.888E+04	6.217E+04	6.478E+04
3.000E+00	to	4.000E+00	4.718E+09	1.175E-14	3.835E-15	1.289E-09
4.000E+00	to	5.000E+00	3.768E+07			
5.000E+00	to	6.500E+00	1.512E+07			
6.500E+00	to	8.000E+00	2.966E+06			
8.000E+00	to	1.000E+01	6.298E+05			
		Total:	6.908E+15	6.247E+12	7.899E+12	8.144E+12

Table 5-13
SAS2H Neutron Sources for 60 GWD/MTU, 7-10 yr Cooled Fuel
MK BW 17x17 Fuel Assembly

(n/sec/assembly)

Grp	Energy Interval (meV)			7 yr	8 yr	9 yr	10 yr
1	6.43	-	20.0	2.036E+07	1.957E+07	1.882E+07	1.810E+07
2	3.00	-	6.43	2.297E+08	2.209E+08	2.124E+08	2.044E+08
3	1.85	-	3.00	2.519E+08	2.423E+08	2.331E+08	2.244E+08
4	1.40	-	1.85	1.433E+08	1.377E+08	1.325E+08	1.275E+08
5	0.90	-	1.40	1.948E+08	1.872E+08	1.800E+08	1.732E+08
6	0.40	-	0.90	2.129E+08	2.047E+08	1.968E+08	1.893E+08
7	0.10	-	0.40	4.168E+07	4.007E+07	3.853E+07	3.706E+07
			Total:	1.095E+09	1.052E+09	1.012E+09	9.740E+08

CHAPTER 6
CRITICALITY EVALUATION

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Table 6-1
Maximum Assembly Average Initial Enrichment for Each Fuel Design for both Intact and Damaged Fuel Assemblies

Assembly Class and Type[(1),(2)]	Maximum Assembly Average Initial enrichment of U-235 as a Function of Soluble Boron Concentration and Fixed Poison Loading (Basket Type)				
	Basket Type	Minimum Soluble Boron Concentration			
		2000 ppm	2300 ppm	2400 ppm	2500 ppm
CE 14x14 Intact Fuel Assembly (without BPRA)	A	4.05	4.40	4.45	4.55
	B	4.55	4.90	5.00	-
	C	4.70	5.00	-	-
	D	5.00	-	-	-
	E	-	-	-	-
WE 15x15, WES 15x15 Intact Fuel Assembly (with and without BPRAs)	A	3.50	3.70	3.80	3.90
	B	3.80	4.10	4.20	4.30
	C	3.95	4.25	4.35	4.45
	D	4.20	4.50	4.70	4.80
	E	4.50	4.80	4.90	5.00
WE 17x17, WEV 17x17 WEO 17x17 MK BW 17x17 Intact Fuel Assembly (with and without BPRAs)	A	3.50	3.70	3.80	3.90
	B	3.80	4.10	4.20	4.30
	C	3.95	4.25	4.35	4.45
	D	4.20	4.50	4.60	4.70
	E	4.45	4.70	4.90	5.00
CE 14x14 Damaged Fuel Assembly (without BPRAs)	A	3.90	4.20	4.25	4.35
	B	4.35	4.70	4.80	4.90
	C	4.50	4.85	4.95	5.00
	D	4.85	5.00	-	-
	E	5.00	-	-	-
WE 15x15, WES 15x15 Damaged Fuel Assembly (with and without BPRAs)	A	3.40	3.60	3.70	3.80
	B	3.75	4.00	4.10	4.20
	C	3.85	4.15	4.25	4.35
	D	4.10	4.40	4.50	4.60
	E	4.35	4.70	4.80	4.90
WE 17x17, WEV 17x17 WEO 17x17 MK BW 17x17 Damaged Fuel Assembly (with and without BPRAs)	A	3.40	3.60	3.70	3.80
	B	3.75	4.00	4.10	4.20
	C	3.85	4.15	4.25	4.35
	D	4.10	4.40	4.50	4.60
	E	4.30	4.65	4.80	4.90

(1) WE 15x15 bounds all 15x15
(2) WE 17x17 bounds all 17x17

Table 6-3
Authorized Contents for NUHOMS®-32PTH DSC

Assembly Type(1)	Array
Westinghouse 17x17 Standard (WE 17x17) Westinghouse 17x17 Vantage 5H (WEV 17x17)	17x17
Westinghouse 17x17 OFA (WEO 17x17)	17x17
Framatome ANP Advanced MK BW 17x17 (MK BW 17x17)	17x17
Westinghouse 15x15 Standard (WE 15x15) Westinghouse 15x15 Surry Improved (WES 15x15)	15x15
CE 14x14 Standard (CE 14x14)	14x14

(1) Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed above are also acceptable.

Table 6-4
Fuel Assembly Design Parameters(2) for Criticality Analysis

Manufacturer(1)	Array	Version	Active Fuel Length (inches)	# Fuel Rods per Assembly	Pitch (inches)	Fuel Pellet OD (inches)
Westinghouse	17x17	Standard Vantage	144	264	0.4960	0.3225
Westinghouse	17x17	OFA	144	264	0.4960	0.3088
Framatome	17x17	MK BW	144	264	0.4960	0.3195
Westinghouse	15x15	Std / Surry	144	204	0.5630	0.3669
CE	14x14	Std	137	176	0.5800	0.3765
CE	14x14	Ft. Calhoun	128	176	0.5800	0.3815
Manufacturer(1)	**Array**	**Version**	**Clad Thickness (inches)**	**Clad OD (inches)**	**Guide Tube OD Inst. Tube OD (inches)**	**Guide Tube ID Inst. Tube ID (inches)**
Westinghouse	17x17	Standard Vantage	0.0225	0.374	24 @ 0.4820 1 @ 0.4740	24 @ 0.4500 1 @ 0.4440
Westinghouse	17x17	OFA	0.0225	0.360	24 @ 0.4820 1 @ 0.4740	24 @ 0.4500 1 @ 0.4440
Framatome	17x17	MK BW	0.0225	0.374	24 @ 0.4820 1 @ 0.4820	24 @ 0.4500 1 @ 0.4500
Westinghouse	15x15	Std / Surry	0.0243	0.422	20 @ 0.5450 1 @ 0.5450	20 @ 0.5100 1 @ 0.5100
CE	14x14	Std	0.0280	0.440	5 @ 1.115	5 @ 1.035
CE	14x14	Ft. Calhoun	0.0280	0.440	5 @ 1.115	5 @ 1.035

(1) Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed above are also acceptable.
(2) All Dimensions shown are nominal

Table 6-7
NUHOMS®-32PTH - Fixed Poison Loading Requirements

Basket Type	Borated Aluminum Loading	Boral® Loading
A	7.0 mg B-10/cm^2 Thickness = 0.050"	9.0 mg B-10/cm^2 Thickness = 0.075"
B	15.0 mg B-10/cm^2 Thickness = 0.075"	19.0 mg B-10/cm^2 Thickness = 0.075"
C	20.0 mg B-10/cm^2 Thickness = 0.075"	25.0 mg B-10/cm^2 Thickness = 0.075"
D	32.0 mg B-10/cm^2 Thickness = 0.125"	Not Applicable
E	50.0 mg B-10/cm^2 Thickness = 0.187"	Not Applicable

Note: New neutron absorbers or changes to existing absorbers will be qualified as per information provided in Chapter 9.

CHAPTER 7
CONFINEMENT

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7. CONFINEMENT

7.1 Confinement Boundary

The 32PTH DSC is a high integrity stainless steel welded vessel that provides confinement of radioactive materials encapsulates the fuel in a helium atmosphere and provides biological shielding during 32PTH DSC closure and transfer and storage operations. The 32PTH DSC is designed to maintain confinement of radioactive material within the limits of 10CFR 72.104(a), 10CFR 72.106(b) and 10CFR 20 under normal, off-normal, and credible accident conditions. Chapter 3 concludes that the design including the helium atmosphere within the 32PTH DSC will adequately protect the spent fuel cladding against degradation that might otherwise lead to gross ruptures during storage. The design ensures that fuel degradation during storage will not pose operational safety problems with respect to removal of the fuel from storage.

The DSC cylindrical shell, the inner top cover/shield plug[1], and shell bottom form the confinement boundary for the spent fuel. The vent and siphon covers and welds are also included in the confinement boundary. The outer top cover plate is a structural attachment to the confinement boundary. The dimensions and material descriptions for the confinement boundary assemblies and the redundantly welded barriers are discussed in Chapter 1. The components important to safety are identified in Chapter 2.

7.1.1 Confinement Vessel

The cylindrical shell and inner shell to bottom cover plate welds are made during fabrication of the 32PTH DSC and are fully compliant to ASME Section III, Subsection NB. The welds between the shell and inner top cover/shield plug[1] (including siphon and vent cover welds and option 2 or option 3 design welds shown in Figure 7-1) are made after fuel loading. These welds are designed, fabricated, inspected and tested using alternatives to the ASME code specified in SAR Section 3.10.

Stringent design and fabrication requirements ensure that the confinement function of the 32PTH DSC is maintained. The cylindrical shell and shell bottom are pressure tested in accordance with the ASME Code, Section III, Subarticle NB-6300. This pressure test is performed after installation of the shell bottom at the fabricator's facility and may be performed concurrently with the leak test, provided the requirements of NB-6300 are met.

Following the pressure test, a leak test of the shell assembly, including the shell bottom, is performed in accordance with ANSI N14.5 [2] and the ASME Code, Section V, Article 10. These tests are typically performed at the fabricator's facility. The acceptance criteria for the test are "leaktight" as defined in [2].

The process involved in leak testing the 32PTH DSC involves temporarily sealing the shell from the top end. The gas filled envelope and evacuated envelope testing methodologies have the

[1] For option 2 design (described in Chapter 1 drawings): Top casing plate, siphon/vent block, alignment pin block and lifting post are included in the confinement boundary
For option 3 design (described in Chapter 1 drawings): Top shield plug outer plate is included in the confinement boundary

required nominal test sensitivity for leaktight construction and are used for leak testing. A helium mass spectrometer is used to detect any leakage as defined in [2].

During final drying and sealing operations of the 32PTH DSC, the top closure confinement welds are applied to confine radioactive materials within the cavity.

The inner top cover/shield plug weld (including option 2 or option 3 inner top cover welds discussed in Figure 7-1) is welded to the DSC shell using automated welding equipment. Once the 32PTH DSC has been vacuum dried, a pressure test is performed by backfilling the DSC cavity with helium. Following a satisfactory completion of the pressure test, the siphon/vent covers are welded and a leak test is performed to verify that the weld between the DSC shell and the inner top cover/shield plug (including option 2 or option 3 design welds shown in Figure 7-1) and the siphon/vent cover welds meet the leak-tight criteria of [2]. The outer top cover plate is also welded in place using automated welding equipment. The outer top cover plate is a structural attachment to the confinement boundary.

7.1.2 Confinement Penetrations

All penetrations in the 32PTH DSC confinement boundary are welded closed. The 32PTH DSC is designed to have no credible leakage as described above.

7.1.3 Seals and Welds

The welds made during fabrication of the 32PTH DSC that affect the confinement boundary include the weld applied to the shell bottom and the circumferential and longitudinal seam welds applied to the cylindrical shell. These welds are inspected (radiographic or ultrasonic inspection, and liquid penetrant inspection) according to the requirements of Subsection NB of the ASME Code.

The welds applied to the vent and siphon port covers and the inner top cover/shield plug (including option 2 or option 3 inner cover) during closure operations, define the confinement boundary at the top end of the 32PTH DSC. These welds are applied using a multiple-layer technique with multi-level PT in accordance with alternatives to the ASME code as specified in SAR Section 3.10. This effectively eliminates any pinhole leak which might occur in a single-pass weld, since the chance of pinholes being in alignment on successive weld passes is negligibly small. Figure 7-1 provides a graphic representation of the confinement boundaries and welds.

7.1.4 Closure

The 32PTH DSC is closed entirely by welding and thus, no closure devices are utilized for confinement.

7.4 Supplemental Data

7.4.1 Confinement Monitoring Capability

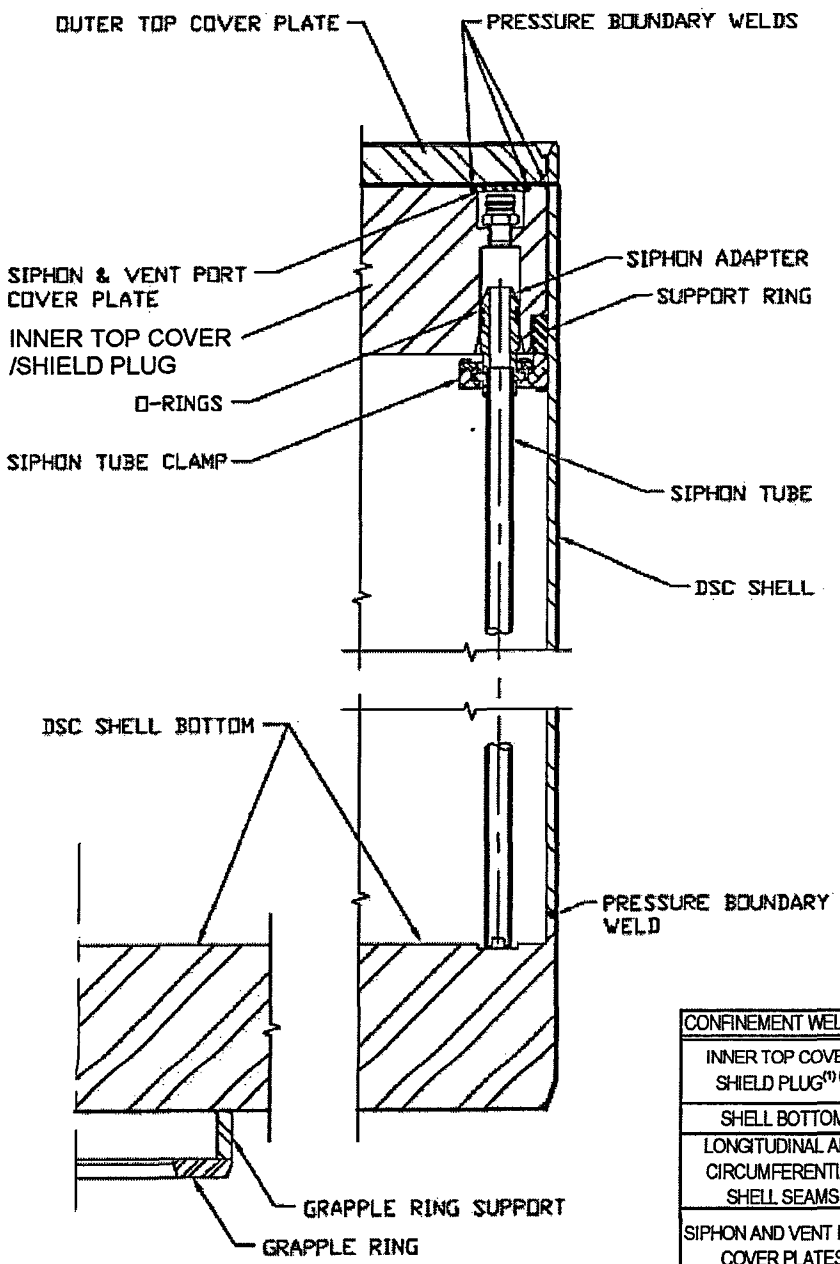
The NUHOMS® HD System is a self-contained passive system that does not produce routine, solid, liquid or gaseous effluents. Effluent processing systems, or monitoring for airborne or liquid radioactivity, are not required to protect personnel or the environment during storage conditions. Since the 32PTH DSC is closed entirely by welding, a closure monitoring system is not utilized in accordance with NRC ISG-5 [3].

7.4.2 References

1. American Society of Mechanical Engineers, Boiler & Pressure Vessel Code, Section III, 1998 Edition with Addenda through 2000.

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

3. NRC Spent Fuel Project Office, Interim Staff Guidance, ISG-5, Revision 1, Confinement Evaluation.



NDE REQUIREMENTS FOR
CONFINEMENT BOUNDARY WELDS

CONFINEMENT WELD	NDE REQUIREMENTS	WELD TYPE
INNER TOP COVER/ SHIELD PLUG(1) (2)	MULTI-LEVEL PT	PARTIAL PENETRATION
SHELL BOTTOM	RT OR UT AND PT	FULL PENETRATION
LONGITUDINAL AND CIRCUMFERENTIAL SHELL SEAMS	RT AND PT	FULL PENETRATION
SIPHON AND VENT PORT COVER PLATES	MULTI-LEVEL PT	PARTIAL PENETRATION

(1) Includes shell to the top casing plate weld, shell to the siphon/vent block weld, and shell to the alignment pin block weld for option 2 design described in Chapter 1 drawings
(2) Includes shell to the top shield plug outer plate weld for option 3 design described in Chapter 1 drawings

Figure 7-1
32PTH DSC Confinement Boundaries and Welds

CHAPTER 8
OPERATION PROCEDURES

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8 OPERATING PROCEDURES

This chapter outlines a sequence of operations to be incorporated into procedures for preparation of the NUHOMS® HD System DSC, loading of fuel, closure of the DSC, transport to the ISFSI, transfer into the HSM-H, monitoring operations, and retrieval and unloading. Operations are presented in their anticipated approximate performance sequence. Alternate sequencing that achieves the same purpose is acceptable. Temporary shielding may be used throughout as appropriate to maintain doses as low as reasonably achievable (ALARA). Use nitrogen or helium to assist in removal of water. After water is drained from the DSC, (sections 8.1.1.2 & 8.1.1.3), the DSC shall be backfilled with nitrogen or helium.

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

8.1.1 Narrative Description

The following steps describe the recommended generic operating procedures for the NUHOMS® System. A list of major equipment used during loading and unloading operations is provided in Table 8-1. A pictorial representation of key phases of this process is provided in Figure 8-1.

8.1.1.1 Transfer Cask and DSC Preparation

1. Verify by plant records or other means that candidate fuel assemblies meet the physical, thermal and radiological criteria specified in the Technical Specifications.
2. Clean or decontaminate the transfer cask as necessary to meet licensee pool and ALARA requirements, and to minimize transfer of contamination from the cask cavity to the DSC exterior.
3. Examine the transfer cask cavity for any physical damage.
4. Verify specified lubrication of the transfer cask rails.
5. Examine the DSC for any physical damage and for cleanliness. Verify that bottom fuel spacers or damaged fuel bottom end caps, if required, are present in all fuel compartments. Remove damaged fuel top end caps if they are in place. Record the DSC serial number which is located on the grappling ring. Verify the basket type by identifying the last character in the serial number.
6. Install lifting rods and eyes into the four threaded sockets in the bottom of the DSC cavity. Verify specified thread engagement.
7. Lift the DSC into the cask cavity and rotate the DSC to match the transfer cask alignment marks.
8. Remove the lifting rods and eyes.
9. Fill the transfer cask/DSC annulus with clean water.
10. Seal the top of the annulus, using for example an inflatable seal.
11. A tank filled with clean water, and kept above the pool surface may be connected to the top vent port of the transfer cask via a hose to provide a

positive pressure in the annulus. This is an optional arrangement, which provides additional assurance that contaminated water from the fuel pool will not enter the annulus. Do not pressurize this tank, nor raise it sufficiently high to float the DSC. For the 32PTH DSC with a 69.75 inch OD, and an empty weight of 49,000 lb, a differential pressure of 12.8 psi, equivalent to 29.6 ft of pure water, would be sufficient to lift the DSC.

12. If the DSC top covers were trial fitted, they must be removed prior to filling the DSC with water. The vent port quick connect fitting in the inner top cover may be removed to facilitate hydrogen monitoring later. The drain port fitting may be either left in place or removed – water may be pumped from the DSC either with or without the fitting.

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

14a. Optionally, secure a sheet of suitable material to the bottom of the cask to minimize the potential for ground-in contamination. This step may be done at any convenient time prior to immersion.

14b. Drain or fill the transfer cask liquid neutron shield, as required by licensee ALARA requirements and crane weight limits. This step may be done at any convenient time prior to immersion.

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

8.1.1.2 DSC Fuel Loading

1. Verify proper engagement of the lifting yoke with the transfer cask lifting trunnions.

2. Lift the transfer cask / DSC and position them over the cask loading area of the spent fuel pool.

3. Lower the cask into the fuel pool until the bottom of the cask is at the height of the fuel pool surface. As the cask is lowered into the pool, spray the exterior surface of the cask with clean water to minimize surface adhesion of contamination.

4. Place the cask in the location of the fuel pool designated as the cask loading area.

5. Disengage the lifting yoke from the transfer cask lifting trunnions and move the yoke clear of the cask. Spray the lifting yoke with clean water if it is raised out of the fuel pool.

6. Load pre-selected spent fuel assemblies into the DSC basket compartments. The licensee shall develop procedures to verify that the boron content of the water conforms to the Technical Specifications, and that fuel identifications are verified and documented. Damaged fuel must be loaded only in designated compartments fitted with a damaged fuel bottom end cap.

7. After all the fuel assemblies have been placed into the DSC and their identities verified, install damaged fuel top end caps into designated compartments containing damaged fuel.

8. Lower the inner top cover/shield plug[1] in the DSC, aligning it with the guide on the DSC wall, and engaging the drain tube, until it seats on its support ring.

9. Visually verify that the inner top cover/shield plug is properly seated in the DSC. Reseat if necessary.

10. Position the lifting yoke and verify that it is properly engaged with the transfer cask trunnions.

11. Lift the transfer cask to the pool surface and spray the exposed portion of the cask with clean water.

12. Drain any water from above the inner top cover/shield plug back to the spent fuel pool. Up to 1300 gallons of water may be removed from the DSC prior to lifting the transfer cask clear of the pool surface. Up to 15 psig of nitrogen or helium may be used to assist the removal of water. The DSC shall be backfilled with nitrogen or helium after drainage of bulk water.

13. Lift the cask from the fuel pool, continuing to spray the cask with clean water.

14. Move the cask with loaded DSC to the area designated for DSC draining and closure operations. The set-down area should be level or slightly sloped toward the DSC drain tube.

8.1.1.3 DSC Closing, Drying, and Backfilling

1. Fill the transfer cask liquid neutron shield if it was drained for weight reduction during preceding operations.

2. Decontaminate the transfer cask exterior.

3. Disengage the rigging from the inner top cover/shield plug, and remove the eyebolts. Disengage the lifting yoke from the trunnions.

[1] Including option 2 or option 3 inner top cover as described in Chapter 1 drawings.

4. Disconnect the annulus overpressure tank if one was used, decontaminate the exposed surfaces of the DSC shell perimeter, remove any remaining water from the top of the annulus seal, and remove the seal.

5. Open the cask cavity drain port and allow water from the annulus to drain out until the water level is approximately twelve inches below the top of the DSC shell. Take swipes around the outer surface of the DSC shell to verify conformance with Technical Specification limits.

6. Cover the transfer cask / DSC annulus to prevent debris and weld splatter from entering the annulus.

7. If water was not drained from the DSC earlier, connect a pump to the DSC drain port and remove up to 1300 gallons of water. Use nitrogen or helium to assist the removal of water. This lowers the water sufficiently to allow welding of the inner top cover/shield plug, while keeping about half of the water in the DSC to cool the spent fuel (Pay special attention to step 14 below). Up to 15 psig of nitrogen, or helium gas may be applied at the vent port to assist the water pump down.

8. Install the automated welding machine onto the inner top cover/shield plug.

9. Continuous hydrogen monitoring during the welding of the inner top cover/shield plug is required [1]. Insert a hydrogen monitor intake line through the vent port such that it terminates just below the inner top cover/shield plug. Temperature monitoring of the TC cavity/annulus water is also required, see step 14.

10. Verify that the hydrogen concentration does not exceed 2.4% [1]. If this limit is exceeded, stop all welding operations and purge the DSC cavity with helium (or other inert gas) via the vent port to reduce hydrogen concentration safely below the 2.4% limit.

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

12. Remove the automated welding machine.

13. Pump remaining water from the DSC. Remove as much free standing water as possible to shorten vacuum drying time. Up to 15 psig of nitrogen, or helium gas may be applied at the vent port to assist the water pump down.

14. There are three methods described in Chapter 4 to assure that the fuel temperature limit is not exceeded during vacuum drying. Each method is associated with a time limit for vacuum drying, starting from the time that pumping of liquid water from the DSC is complete as required by the Technical Specifications for vacuum drying. As required by the technique chosen, either

a) install annulus water circulation equipment, or

b) drain annulus water if temperature exceeds 180°F

c) for either a or b, the DSC may be evacuated to 100 mbar or lower, and backfilled with helium to atmospheric pressure prior to start of vacuum drying.

All helium used in backfilling operations shall be at least 99.99% pure (this may be done as part of step 15).

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

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

16. Evacuate the DSC to the pressure required by the Technical Specification for vacuum drying, and isolate the vacuum pump. The isolation valve should be as near to the DSC as possible, with a pressure gauge on the DSC side of the valve.

17. Maintain the water condition in the transfer cask / DSC annulus as required by the technique chosen (step 14).

18. If the Technical Specification is satisfied, i.e., if the pressure remains below the specified limit for the required duration with the pump isolated, continue to the next step. If not, repeat steps 16 and 17.

19a. Purge air from the backfill manifold, open the isolation valve, and backfill the DSC cavity with helium to 16.5 to 18 psig and hold for 10 minutes.

19b. Reduce the DSC cavity pressure to atmospheric pressure, or slightly over.

20. If the quick connect fittings were removed for vacuum drying, remove the vacuum line adapters from the ports, and re-install the quick connect fittings using suitable pipe thread sealant.

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

22. Backfill the DSC with helium to the pressure specified in the Technical Specifications, and disconnect the vacuum / backfill manifold from the DSC.

23. Repeat steps 21 and 22 if the DSC interior is exposed to nitrogen during any succeeding operations.

24a. Weld the covers over the vent and drain ports, performing non-destructive examination as required by the Technical Specifications. The welds shall have at least two layers.

24b. Install a temporary test head fixture (or any other alternative means). Perform a leak test of the inner top cover/shield plug to the DSC shell welds and siphon/vent cover welds in accordance with the Technical Specification limits. Verify that the personnel performing the leak test are qualified in accordance with SNT-TC-1A.

25. Install the automated welding machine onto the outer top cover plate and place the outer top cover plate with the welding system onto the DSC. Verify correct rotational alignment of the cover and the DSC shell.

26. Complete the outer top cover welding and perform the non-destructive examinations as required by the Technical Specifications. The weld must be made in at least two layers.

27. Remove everything except the DSC from the transfer cask cavity: welding machine, protective covering from the transfer cask / DSC annulus, annulus temperature monitoring or water circulation equipment, temporary shielding, etc.

28. Install the transfer cask lid and bolt it.

29. Evacuate the transfer cask cavity to below 100 mbar, and backfill the transfer cask annulus with helium in accordance with the Technical Specifications pressure tolerance and time limit.

8.1.1.4 Transfer Cask Downending and Transport to ISFSI

1. Drain or fill the transfer cask liquid neutron shield, as required by licensee ALARA requirements and crane weight limits.

2. The transfer trailer should be positioned so that the cask support skid is accessible to the crane with the trailer supported on its vertical jacks. If required due to space limitations, the crane may remain in a stationary position while the cask support skid and trailer translate underneath the cask as it is downended, (the trailer cannot be supported on the vertical jacks.)

3. Engage the lifting yoke and lift the transfer cask over the cask support skid onto the transfer trailer.

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

5. Move the crane while simultaneously lowering the cask until the cask upper trunnions are just above the support skid upper trunnion pillow blocks. Alternatively, if the crane is to remain stationary as identified above, slowly move the trailer and support skid as the cask is lowered until the upper trunnions are just above the support skid upper trunnion pillow blocks.

6. Verify that the cask and trunnion pillow blocks are properly aligned.

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

8. Verify the trunnions are properly seated onto the skid and install the trunnion tower closure plates. Refill the cask liquid neutron shield, if it was drained in step 1 above.

8.1.1.5 DSC Transfer to the HSM-H

1. The maximum lifting height and ambient temperature requirements of the Technical Specifications must be met during transfer from the fuel building to the HSM-H.

2. Prior to loading the DSC into the HSM-H, verify that there is no debris in the HSM-H, the air inlet and outlets are not blocked, the air inlet and outlet screens are not damaged, and the rails are lubricated as specified.

3. Tow the transfer trailer with the loaded cask to the ISFSI.

4. Position the transfer trailer to within a few feet of the HSM-H to maintain doses ALARA when the cask lid is removed.

5. Verify that the centerline of the HSM-H and cask approximately coincide. Reposition the trailer as necessary following appropriate ALARA practices.

6. Using a portable crane, unbolt and remove the cask lid.

7. Back the trailer to within a few inches of the HSM-H, set the trailer brakes and disengage the tractor. Drive the tractor clear of the trailer and extend the transfer trailer vertical jacks.

8. Remove the skid tie-down bracket fasteners and use the hydraulic skid positioning system to bring the cask into approximate vertical and horizontal alignment with the HSM-H. Using optical survey equipment and the alignment marks on the cask and the HSM-H, adjust the position of the cask until it is aligned with the HSM-H.

9. Using the skid positioning system, fully insert the cask into the HSM-H access opening docking collar.

10. Secure the cask to the front wall embedments of the HSM-H using the cask restraints.

11. Verify the alignment of the transfer cask is within specified tolerance using the optical survey equipment.

12. Remove the bottom ram access cover plate from the transfer cask. Extend the ram through the bottom cask opening into the DSC grapple ring.

13. Activate the hydraulic cylinder on the ram grapple and engage the grapple arms with the grapple ring.

14. Activate the hydraulic ram to initiate insertion of the DSC into the HSM-H. Stop the ram when the DSC reaches the support rail stops at the back of the module.

15. Disengage the ram grapple mechanism so that the grapple is retracted away from the grapple ring.

16. Retract and disengage the hydraulic ram system from the cask and move it clear of the cask. Remove the cask restraints from the HSM-H. Replace the bottom ram access cover plate.

17. Using the skid positioning system, disengage the cask from the HSM-H access opening.

18. Install the DSC seismic restraint.

19. Install the HSM-H door and secure it in place.

20. Replace the transfer cask lid. Secure the skid to the trailer, retract the vertical jacks.

21. Tow the trailer and cask from the ISFSI

22. Adjust the seismic restraint on the DSC one week following initial placement.

8.1.1.6 Monitoring Operations

1. Perform routine security surveillance in accordance with the licensee's ISFSI security plan.

2. Perform a daily visual surveillance of the HSM-H air inlets and outlets (bird screens) to verify that no debris is obstructing the HSM-H vents in accordance with Technical Specification requirements.

3. Perform a temperature measurement for each HSM-H in accordance with Technical Specification requirements.

8.2 Procedures for Unloading the DSC

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

8.2.1 DSC Retrieval from the HSM-H

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

14a. Install the transfer cask top cover plate and ready the trailer for transfer/transport.

14b. Evacuate the transfer cask cavity to below 100 mbar, and backfill with helium in accordance with the Technical Specifications pressure tolerance and time limit, if using a transfer cask. If using a transportation cask, follow applicable requirements for the transportation cask.

15. Replace the door and seismic restraint on the HSM-H.

8.2.2 Removal of Fuel from the DSC

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

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

1. Tow the trailer with the loaded cask to the cask handling area inside the plant's fuel handling building. Drain the transfer cask liquid neutron shield as required by licensee ALARA requirements and crane weight limits.

2. Position and ready the trailer for access by the crane.

3. Engage the lifting yoke with the trunnions of the transfer cask.

4. Verify that the yoke lifting hooks are properly aligned and engaged onto the transfer cask trunnions.

5. Lift the transfer cask approximately one inch off the trunnion supports. Verify that the yoke lifting hooks are properly positioned on the trunnions.

6. Move the crane in a horizontal motion while simultaneously raising the crane hook vertically and lift the transfer cask off the trailer. Move the transfer cask to the cask decontamination area.

7. Lower the transfer cask into the cask staging area in the vertical position.

8. Unbolt the transfer cask lid and remove it.

9. Install temporary shielding to reduce personnel exposure as required. Fill the transfer cask/DSC annulus with clean water and seal the top of the annulus, using, for example, an inflatable seal.

10. Locate the drain and vent port using the indications on the outer top cover plate. Place a portable drill press on the top of the DSC. Align the drill over the drain port.

11. Cut or drill a hole through the top cover plate to expose the drain port on the inner top cover. Remove the drain port cover plate with an annular hole cutter. Repeat for the vent port.

12. Obtain a sample of the DSC atmosphere. Confirm acceptable hydrogen concentration and check for presence of fission gas indicative of degraded fuel cladding.

13. If degraded fuel is suspected, additional measures appropriate for the specific conditions are to be planned, reviewed, and implemented to minimize exposures to workers and radiological releases to the environment.

14. Verify that the boron content of the fill water conforms to the Technical Specifications. Fill the DSC with water from the fuel pool or equivalent source through the drain port with the vent port open. The vented cavity gas may include steam, water, and radioactive material, and should be routed accordingly. Monitor the vent pressure and regulate the water fill rate to ensure that the pressure does not exceed 15 psig.

15. Provide for continuous hydrogen monitoring of the DSC cavity atmosphere during all subsequent cutting operations to ensure that hydrogen concentration does not exceed 2.4%. Purge with helium (or any other inert gas) as necessary to maintain the hydrogen concentration below this limit.

16. Provide suitable protection for the transfer cask during cutting operations. To prevent damage to the transfer cask during cutting, up to 8 inches at the top of the canister may be raised clear of the cask by removing the ram access port from the cask, and setting the cask down over a pedestal which fits inside the DSC grapple ring, lifting the DSC.

17. Using plasma arc-gouging, a mechanical cutting system, or other suitable means, remove the weld of the outer top cover plate to the DSC shell.

18. Remove the outer top cover plate.

19. Remove the weld of the inner top cover/shield plug to the shell in the same manner as the outer cover plate. Do not remove the inner top cover/shield plug at this time unless the removal is being done remotely in a dry transfer system.

20. Remove any remaining excess material on the inside shell surface by grinding.

21. Clean the transfer cask surface of dirt and any debris which may be on the transfer cask surface as a result of the weld removal operation.

22. Engage the yoke onto the trunnions, install eyebolts or other lifting attachment(s) into the inner top cover/shield plug, and connect the rigging cables to the eyebolts/lifting attachment(s).

23. Verify that the lifting hooks of the yoke are properly positioned on the trunnions.

24. Lift the transfer cask just far enough to allow the weight of the transfer cask to be distributed onto the yoke lifting hooks. Verify that the lifting hooks are properly positioned on the trunnions.

25. Optionally install suitable protective material onto the bottom of the transfer cask to minimize cask contamination. Move the transfer cask to the spent fuel pool.

26. Prior to lowering the transfer cask into the pool, adjust the pool water level, if necessary, to accommodate the volume of water which will be displaced by the transfer cask during the operation.

27. Position the transfer cask over the cask loading area in the spent fuel pool.

28. Lower the transfer cask into the pool. As the transfer cask is being lowered, the exterior surface of the transfer cask should be sprayed with clean water.

29. Disengage the lifting yoke from the transfer cask and lift the inner top cover/shield plug from the DSC.

30. Remove any failed fuel top end caps.

31. Remove the fuel from the DSC.

8.3 Supplemental Information

8.3.1 Other Operating Systems

The NUHOMS® System is a passive storage system and requires no operating systems other than those systems used in transferring the DSC to and from the HSM-H.

8.3.2 Operation Support System

The NUHOMS® System is a self contained passive system and requires no effluent processing systems during storage conditions.

8.3.3 Surveillance and Maintenance

Surveillance and maintenance requirements are discussed in Chapters 9 and 12. The only required surveillances during storage are monitoring of the HSM-H air exhaust temperature, and visual verification that the inlet and outlet vents are not blocked. There is no normally required maintenance of the HSM-H or DSC.

8.4 References

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

2. NUREG-0612, "Control of Heavy Loads at Nuclear Power Plants," USNRC, July 1980

Table 8-1
Major Equipment Used During NUHOMS® HD System Loading and Unloading Operations

NUHOMS® HD System	Function
Dry Shielded Canister (DSC)	Fuel confinement.
Horizontal Storage Module (HSM-H)	Shielding, physical protection
Transfer Cask	Handling and transport of loaded DSC
Transfer trailer with support frame, ram, alignment system, and hydraulic power pack, pressure gauges and pressure relief	Transport of loaded transfer cask, and transfer of DSC into or retrieval from HSM-H; monitor and limit force applied to DSC by ram

Other Equipment and Instruments	Function
Lift yoke	Lifting transfer cask empty or loaded, in conformance to NUREG-0612 [2]
Lifting eyes, slings, rigging, etc.	Lifting the empty DSC, DSC covers, and the transfer cask lid in conformance to NUREG-0612 [2]
Water pump, hoses, connectors, fittings	Draining the DSC
Transfer cask / DSC annulus seal	Contamination control of the DSC exterior by pool water
Small water tank and hose	Maintaining positive pressure in annulus
Vacuum pump / helium backfill manifold, valves, hoses, fittings, adapters, pressure and vacuum gauges, etc.	Pressure test, vacuum drying and backfill of DSC; helium backfill of transfer cask cavity
Helium leak test equipment, including test head	Leak test closure welds
Gas bottles (nitrogen and/or helium)	Pressurize canister cavity for blowdown pressure test, helium backfill, etc.
Tractor	Towing the transfer trailer
Mobile crane and rigging	Removal of HSM-H door and transfer cask lid at ISFSI
Scaffolding, manlifts, etc	As required for easy access during operations
Temporary shielding	*As required to maintain doses ALARA*
Automatic welder	Remote welding of inner and outer top covers
Manual or automatic welder	Welding of vent and drain cover plates
Radiation detectors	Surveys to maintain doses ALARA
Transit with platform	Align transfer cask and ram with HSM-H
Hydrogen detector	Monitoring DSC cavity hydrogen during welding (loading) or cutting (unloading) of inner top cover
Temperature sensor and/or water circulation system	Optional, monitoring or circulation of water in transfer cask / DSC annulus

DSC Opening Equipment and Instruments	Function
Plasma torch or other cutting machine	Removal of lids for unloading of fuel
Portable drill press and annular cutters	Removal of vent and siphon covers
Gas sampling cylinder with quick connect adapter	Sampling of cavity gas prior to opening of DSC
Pressure gauge and water flow control valve	Limiting DSC pressure during reflooding

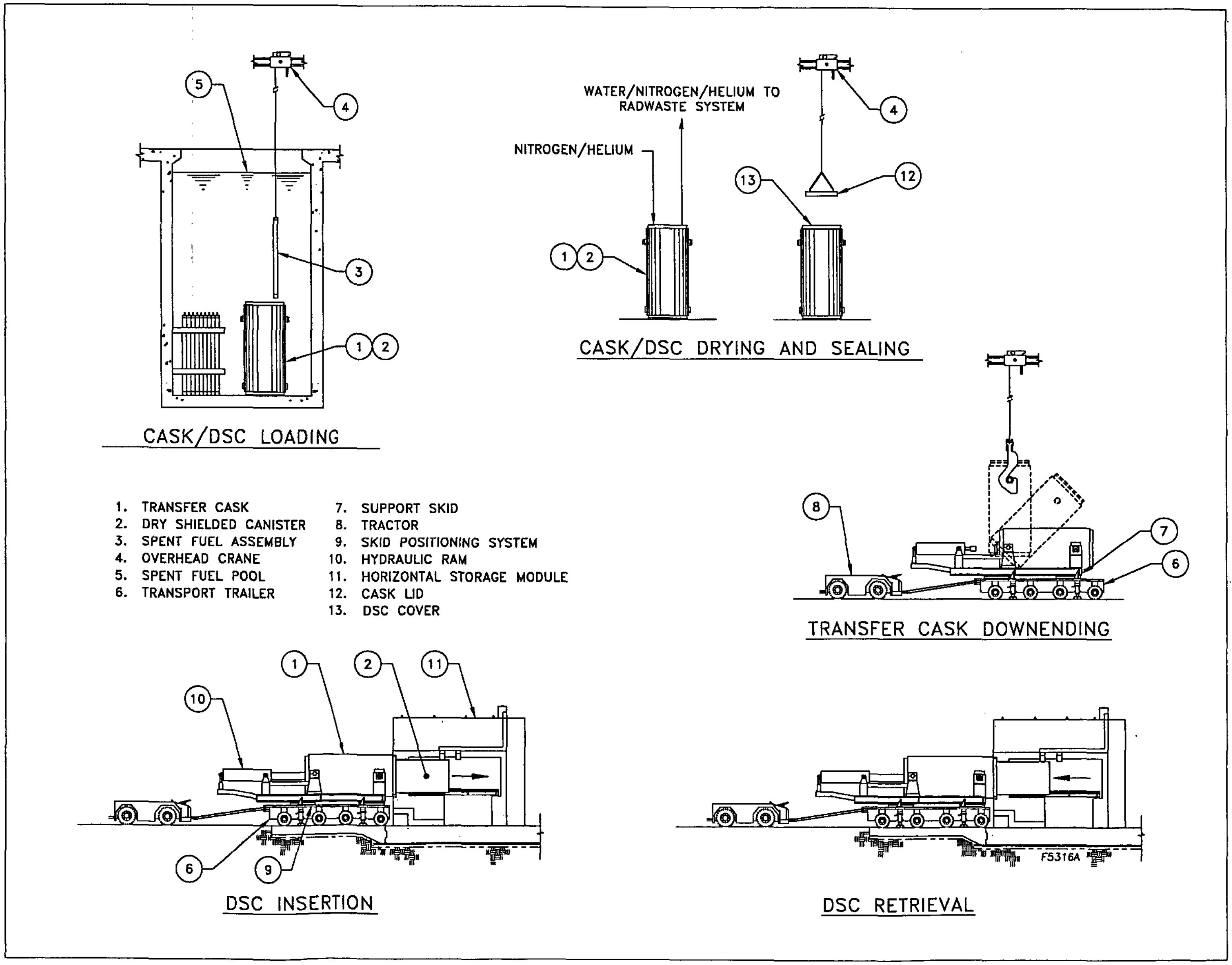

Figure 8-1
NUHOMS® HD System Loading Operations

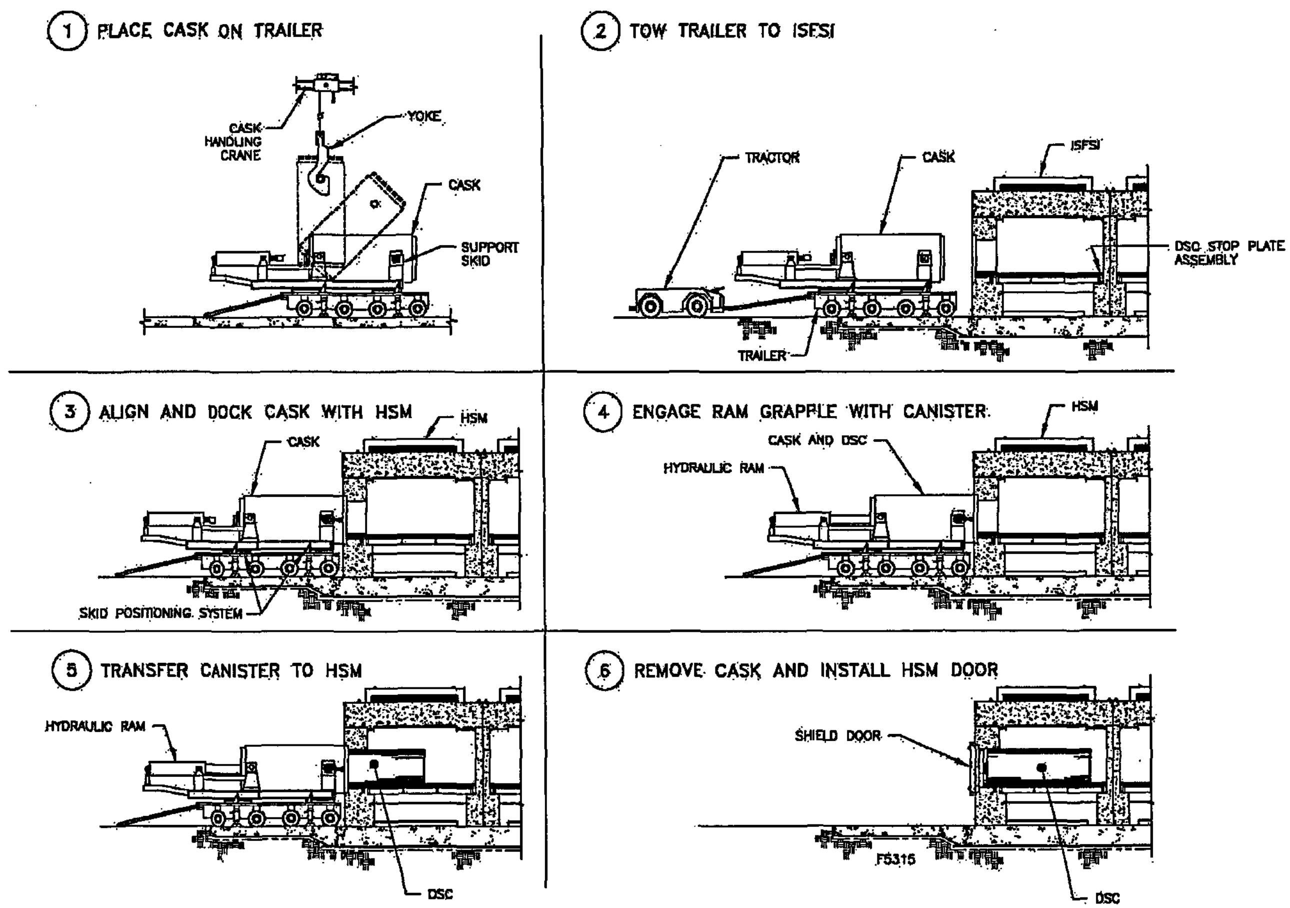

Figure 8-1
NUHOMS® HD System Loading Operations
(concluded)

CHAPTER 9
ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

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9. ACCEPTANCE TESTS AND MAINTENANCE PROGRAM

9.1 Acceptance Criteria

9.1.1 Visual Inspection and Non-Destructive Examination (NDE)

Visual inspections are performed at the fabricator's facility to ensure that the 32PTH DSC, the OS187H Transfer Cask and the HSM-H 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 1; acceptance criteria are as specified by the governing code. NDE personnel are qualified in accordance with SNT-TC-1A [2].

The confinement welds on the DSC are inspected in accordance with ASME B&PV Code Subsection NB [1] including alternatives to ASME Code specified in SAR Section 3.10.

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.

The Transfer Cask welds are inspected in accordance with ASME B&PV Code Subsection NC for class 2 components, as modified by code alternates identified in Section 3.10 of Chapter 3.

9.1.2 Structural and Pressure Tests

The DSC confinement boundary except inner top cover/shield plug (including option 2 or option 3 inner top cover as described in the SAR) 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 to18 psig which bounds 1.1 x DSC design pressure of 15 psig.

The inner top cover/shield plug (including option 2 or option 3 inner top cover) to the DSC shell weld is also pressure tested between 16.5 to 18 psig at the field after the fuel assemblies are loaded in the canister. This test is in accordance with the alternatives to the ASME code specified in SAR Section 3.10.

HSM-H reinforcement and concrete are tested as described in Section 2.5.2 and footnotes to Tables 4.1-5 and 4.4-3.

The Transfer Cask lifting (top) trunnions will be load tested in accordance with ANSI N14.6 [3] for a single failure proof design, i.e., three times the design load. The design load is conservatively set at 250,000 lbs (Section 3.2.2); therefore, the test load is 750,000 lbs (375,000 lbs/trunnion).

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 1×10^{-7} ref cm^3/s, i.e., "leaktight" as defined in ANSI N14.5 [4]. Personnel performing the leak test are qualified in accordance with SNT-TC-1A [2].

The weld between the DSC shell and inner top cover/shield plug (including option 2 or option 3 inner top cover) and siphon/vent cover welds are also leak tested to an acceptance criteria of 1 x 10^{-7} ref cm^3/s at the field after the fuel assemblies are loaded in the canister.

The Transfer Cask lid, ram access, vent, and drain cover o-rings, vent and drain quick connect fittings, neutron shield welds, and neutron shield fittings are leak tested prior to first use.

If bubble leak testing is used, no leak indication is allowed. If pressure drop or helium leak testing is used, the maximum allowable leak for each of the components listed is 10^{-3} ref cm^3/s.

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.

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.

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 of each HSM-H.

The heat transfer analysis for the basket includes credit for the thermal conductivity of neutron-absorbing materials, as specified in Section 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 9.5.1.

9.1.7 Neutron Absorber Tests

CAUTION
Sections 9.1.7.1 through 9.1.7.3 below are incorporated by reference into the NUHOMS® CoC 1030 Technical Specifications (paragraph 4.3.1) and shall not be deleted or altered in any way without a CoC amendment 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) Boron-aluminum alloy (borated aluminum)

(b) Boron carbide-aluminum metal matrix composite

(c) Boral®

The 32PTH 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 materials is given in Table 9-1.

9.1.7.1 Boron Aluminum Alloy (Borated Aluminum)

See the Caution in Section 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 as a uniform fine dispersion of discrete AlB_2 or TiB_2 particles in the matrix of aluminum or aluminum alloy. 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, with sufficient margin to minimize rejection, typically 10 % excess. 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 9.5.2. 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.

Visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products and Castings"[5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions,

abrasion, isolated pores, or discoloration are acceptable. Widespread blisters, rough surface, or cracking shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.

9.1.7.2 Boron Carbide / Aluminum Metal Matrix Composites (MMC)

See the Caution in Section 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. It is a low-porosity product, with a metallurgically bonded matrix. The boron carbide content shall not exceed 40% by volume.

Prior to use in the 32PTH DSC, MMCs shall pass the qualification testing specified in Section 9.5.3, and shall subsequently be subject to the process controls specified in Section 9.5.4.

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 9.5.2. 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.

Visual inspections shall follow the recommendations in Aluminum Standards and Data, Chapter 4 "Quality Control, Visual Inspection of Aluminum Mill Products and Castings" [5]. Local or cosmetic conditions such as scratches, nicks, die lines, inclusions, abrasion, isolated pores, or discoloration are acceptable. Widespread blisters, rough surfaces, or cracking shall be evaluated for acceptance in accordance with the Certificate Holder's QA procedures.

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

9.1.7.3 Boral®

See the Caution in Section 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. The average size of the boron carbide particles in the finished product is approximately 50 microns after rolling. 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 an approximately 1 cm^2 area of a coupon taken near

one of the corners of 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.

Visual inspections shall verify that the Boral® core is not exposed through the face of the sheet at any location.

9.2 Maintenance Program

The NUHOMS® HD System is designed to be totally passive with minimal maintenance requirements. The 32PTH DSC does not require any maintenance once it is loaded into the HSM-H. The HSM-H does not require any maintenance other than that indicated in off-normal operations, Chapter 11, such as clearing of blocked air inlets. Periodic inspection is therefore limited to the Transfer Cask.

9.2.1 Inspection

The following inspections of the transfer cask should be performed prior to each fuel loading or unloading campaign:

A. Visual inspection of the transfer cask trunnions for damaged bearing surfaces

B. Visual or functional inspection of all taps, threaded inserts, and bolts

C. Functional inspection of all quick-connect fittings

D. Visual inspection of the interior surface of the cask for any indications of excessive wear.

E. Visual inspection of the neutron shield jacket for indications of damage

F. Visual inspection of all Transfer Cask o-rings for indications of damage

Within the year prior to any loading or unloading campaign, the top trunnion bearing surfaces and accessible welds shall be examined by dye penetrant. No linear indications shall be acceptable other than surface scratches and wear.

9.2.2 Tests

The Transfer Cask lid, ram access, vent, and drain cover o-rings, vent and drain quick connect fittings, and neutron shield fittings shall be leak tested within the year before the start of any fuel loading or unloading campaign. If bubble leak testing is used, no leak indication is allowed. If pressure drop or helium leak testing is used, the maximum allowable leak for each of the components listed is 10^{-3} ref cm^3/s. If any of the listed components is replaced, that component shall be leak tested before use in fuel loading or unloading operations.

No periodic testing of the 32PTH DSC, HSM-H or routine support equipment is required.

Temperature and radiation monitoring is provided in accordance with the Technical Specifications. Periodic calibration of the monitoring equipment shall be as required by the licensee's quality program.

9.2.3 Repair, Replacement, and Maintenance

Any parts which fail inspections listed in 9.1.2 shall be repaired or replaced. Such parts may be also be accepted as-is if determined appropriate by engineering and licensing review.

9.3 Marking

The HSM-H and 32PTH DSC are marked with the model number, unique identification number, and empty weight in accordance with 10 CFR 72.236(k) as shown in drawing 10494-72-7.

9.4 Pre-Operational Testing and Training Exercise

A dry run training exercise of the loading, closure, handling, unloading, and transfer of the NUHOMS® HD System shall be performed by each licensee prior to their first use of the system to load spent fuel assemblies. The dry run shall be conducted with simulated fuel to match the weight of the actual fuel. The dry run need not be performed in the sequence of operations in Chapter 8. The dry run shall include:

(a) Loading of mock-up fuel

(b) DSC draining, vacuum drying, welding, and backfilling

(c) Loading of the Transfer Cask onto the Transfer Trailer, and transfer to the ISFSI

(d) DSC transfer to the HSM-H

(e) DSC retrieval from the HSM-H

(f) Re-flooding of a sealed 32PTH DSC

(g) Removal of the covers from a sealed 32PTH DSC

The dry run will simulate, as nearly as possible, the detailed written procedures developed by the licensee for NUHOMS® HD System operations. Guidelines for the dry run follow.

A. An actual or a mock-up 32PTH DSC loaded with mock-up fuel is typically utilized. The 32PTH DSC is loaded into the transfer cask; the transfer cask/DSC annulus seal is installed.

B. Functional testing is performed with the transfer cask and lifting equipment. These tests are to ensure that the transfer cask can be safely lifted from the plant's cask receiving area to the cask washdown area. The cask is partially lowered into the spent fuel pool and positioned in the cask loading area to verify clearances and travel path. The inner top cover is installed to verify handling and alignment operations.

C. The transfer cask is placed on the transfer trailer, which is moved to the ISFSI aligned with an HSM-H. Compatibility of the transfer trailer with the transfer cask, verification of the transfer route to the ISFSI, and maneuverability within the confines of the ISFSI are verified.

D. The transfer trailer is aligned and docked with the HSM-H. The hydraulic ram is used to insert the 32PTH DSC loaded with mock-up fuel assemblies into the HSM-H and then to retrieve it. Transfer of the 32PTH DSC to the HSM-H will verify that the support skid positioning system and the hydraulic ram system operate safely for both insertion and retrieval.

E. A weld mockup, typically a shortened 32PTH DSC mockup modeling the top end, covers, and drain tube, is used to demonstrate closure welding, draining, drying, backfill, re-flooding, and canister opening operations.

F. The dry run is deemed successful if the expected results are achieved safely and without damage to any of the components or associated equipment.

G. Should any equipment or components require modification in order to achieve the expected results, it will be retested, as necessary, to confirm that the modification is adequate. Should the dry run indicate that procedures require change in order to achieve the expected results, the changes will be incorporated into the appropriate operating procedures prior to use for fuel transfer.

9.5 Specification for Neutron Absorbers

9.5.1 Specification for Thermal Conductivity Testing of Neutron Absorbers

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, Table 9-2, 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, additional tests may be performed on the material from that lot. If the mean value of those tests 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 boron appearing in the same 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 thermal analysis in Chapter 4 assumes a 3/16 inch thick neutron absorber paired with a 5/16 inch aluminum 1100 plate. The specified thickness of the neutron absorber may vary, and 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"

thermal conductivity acceptance criterion for the neutron absorber will be based on the nominal thickness specified. The minimum thermal conductivity shall be such that the total thermal conductance (sum of conductivity * thickness) of the neutron absorber and the aluminum 1100 plate shall equal the conductance assumed in the analysis, as shown in Table 9-3, where the acceptance criterion is highlighted.

The aluminum 1100 plate does not need to be tested for thermal conductivity; the material may be credited with the values published in the ASME Code Section II part D. The neutron absorber material need not be tested for thermal conductivity if the nominal thickness of the aluminum 1100 plate is 0.425 inch or greater. This case is examined explicitly in chapter 4, where no credit is taken for the thermal conductivity of Boral®.

9.5.2 Specification for Acceptance Testing of Neutron Absorbers by Neutron Transmission

CAUTION

Section 9.5.2 is incorporated by reference into the NUHOMS® CoC 1030 Technical Specifications (paragraph 4.3.1) and shall not be deleted or altered in any way without a CoC amendment approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.

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. 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 of up to 1.2 centimeter diameter. A beam size greater than 1.2 centimeter diameter but no larger than 1.7 centimeter diameter may be used if computations are performed to demonstrate that the calculated $k_{effective}$ of the system is still below the calculated Upper Subcritical Limit (USL) of the system assuming defect areas the same area as the beam. Alternatively, the confidence and probability levels can be increased such that it will result in equivalent acceptance rates for the material as the 1.2 centimeter diameter beam size.

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.

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 up to 1.1 cm^2.

The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level or better. The following illustrates one acceptable method.

The acceptance criterion for individual plates is determined from a statistical analysis of the test results for their lot. The minimum B10 areal densities determined by neutron transmission are converted to volume density, i.e., the minimum 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 [7].

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 this minimum 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.

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

9.5.3 Specification for Qualification Testing of Metal Matrix Composites

9.5.3.1 Applicability and Scope

Metal matrix composites (MMCs) shall consist of fine boron carbide particles in an aluminum or aluminum alloy matrix. The ingot shall be produced by either powder metallurgy (PM), thermal spray techniques, or by direct chill (DC) or permanent mold casting. In any case, the final MMC product shall have density greater than 98% of theoretical, a metallurgically bonded matrix, and boron carbide content no greater than 40% by volume. Boron carbide particles for the products considered here typically have an average size in the range 10-40 microns, although the actual specification may be by mesh size, rather than by average particle size. No more than 10% of the

particles shall be over 60 microns. The material shall have negligible interconnected porosity exposed at the surface or edges.

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 9.5.4 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.

9.5.3.2 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 9.5.3.4. It must have a uniform distribution of boron carbide. This is demonstrated by the tests in Section 9.5.3.5.

9.5.3.3 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.

The need for thermal damage and corrosion (hydrogen generation) testing shall be evaluated case-by-case based on comparison of the material composition and environmental conditions with previous thermal or corrosion testing of MMCs.

Thermal damage testing is not required for 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 full density MMCs consisting only of boron carbide in an aluminum 1100 matrix, because testing on one such material has already been performed by Transnuclear[4].

9.5.3.4 Required Qualification Tests and Examinations to Demonstrate Mechanical Integrity

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

[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

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%
     (Alternatively show that the material fails in a ductile manner, e.g., by scanning electron microscopy of the fracture surface or by bend testing.)

and

b) testing (ASTM-B311[6]) to verify more than 98% of theoretical density. Testing or examination for exposed interconnected porosity shall be performed by a means to be approved by the Certificate Holder.

9.5.3.5 Required Tests and Examinations to Demonstrate B10 Uniformity

CAUTION

Section 9.5.3.5 is incorporated by reference into the NUHOMS® CoC 1030 Technical Specifications (paragraph 4.3.1) and shall not be deleted or altered in any way without a CoC amendment approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.

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 9.5.2, or by chemical analysis for boron carbide content in the composite.

9.5.3.6 Approval of Procedures

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

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

6 ASTM B311, Test Method for Density Determination for Powder Metallurgy (P/M) Materials Containing Less Than Two Percent Porosity

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

9.5.4 Specification for Process Controls for Metal Matrix Composites

9.5.4.1 Applicability and Scope

The applicability of this section is the same as that of Section 9.5.3. It addresses the process controls to ensure that the material delivered for use is equivalent to the qualification test material.

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 9.5.4 is required, depending on the characteristics of the material that could be affected by the process change.

9.5.4.2 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, or reduce the mechanical strength or ductility of the MMC.

9.5.4.3 Identification and Control of Key Process Changes

CAUTION
Section 9.5.4.3 is incorporated by reference into the NUHOMS® CoC 1030 Technical Specifications (paragraph 4.3.1) and shall not be deleted or altered in any way without a CoC amendment approval from the NRC. The text of this section is shown in bold type to distinguish it from other sections.

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 9.5.4.2.

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 may be 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 6000 series 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, and

(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.

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.

9.6 References

1. ASME Boiler and Pressure Vessel Code, Section III, 1998 Edition with 2000 Addenda.
2. SNT-TC-1A, "American Society for Nondestructive Testing, Personnel Qualification and Certification in Nondestructive Testing," 1992.
3. ANSI N14.6, "American National Standard for Special Lifting Devices for Shipping Containers Weighing 10,000 Pounds or More for Nuclear Materials," New York, 1996.
4. ANSI N14.5-1997, "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials", February 1998.
5. "Aluminum Standards and Data, 2003" The Aluminum Association.
6. Topical report: Credit for 90% of the 10B in Boral®", AAR Report 1829, AAR Manufacturing, Oct 2004
7. Natrella, "Experimental Statistics," Dover, 2005

10. RADIATION PROTECTION

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

10.1.1 Policy Considerations

The licensee's radiation safety and ALARA policies should be applied to the ISFSI. The ALARA program should follow the general guidelines of Regulatory Guides 1.8 4, 8.8 1, 8.10 3 and 10 CFR 20 6. ISFSI personnel should be trained in the proper operation, inspection, repair and maintenance of the NUHOMS® HD System and updated on ALARA practices and dose reduction techniques. Implementation of ISFSI procedures should be reviewed by the licensee to ensure ALARA exposure.

10.1.2 Design Considerations

The thick inner cover of the DSC is designed to minimize exposure during draining, drying, and closure operations. The vent and drain ports are designed for maximum water flow rate and vacuum conductance to minimize the time (and thereby the exposure) associated with draining and vacuum drying. The design of the cover welds minimizes exposure during closure operations. The welds are designed to be easily performed by remote welding equipment. Because the cover welds are not used to lift the canister, they are relatively small, reducing the time needed to complete them. Because they are austenitic welds, no pre-heating is required. These welds are tested to be leak-tight as described in Chapter 7. Therefore, exposure associated with a leaking DSC is eliminated.

Lead, steel, water, and borated plastic in the transfer cask provide required gamma and neutron shielding during transfer activities. The exterior of the transfer cask is decontaminated prior to transfer to the ISFSI, thereby minimizing exposure of personnel to surface contamination.

The NUHOMS® HSM-H storage modules include no active components which require periodic maintenance thereby minimizing potential personnel dose due to maintenance activities.

The shielding design features of the storage modules storage minimize occupational exposure for any activities on or near the ISFSI. These features are:

- The DSCs are loaded and sealed prior to transfer to the ISFSI. Seals are austenitic stainless welds with at least two layers.
- The fuel will not be unloaded nor will the DSCs be opened at the ISFSI unless the ISFSI is specifically licensed for these purposes.
- The fuel is stored in a dry inert environment inside the DSCs so that no radioactive liquid is available for leakage.

- The DSCs are sealed with a helium atmosphere to prevent oxidation of the fuel. The leaktight design features are described in Chapter 7.
- The DSCs are heavily shielded on both ends to reduce external dose rates. The shielding design features are discussed in Chapter 5.
- No radioactive material will be discharged during storage since the DSC is designed, fabricated, and tested to be leaktight.
- The DSC outside surface is contamination free due to the use of clean water sealed in the annulus between the cask and DSC during loading operations.
- HSM's provide thick concrete shielding, while placement of modules immediately adjacent to one another enhances the effectiveness of this shielding.

Regulatory Position 2 of Regulatory Guide 8.8 1, is incorporated into the design considerations, as described below:

- Regulatory Position 2a on access control is met by use of a fence with a locked gate that surrounds the ISFSI and prevents unauthorized access.
- Regulatory Position 2b on radiation shielding is met by the heavy shielding of the NUHOMS® System which minimizes personnel exposures.
- Regulatory Position 2c on process instrumentation and controls is met by designing the instrumentation for a long service life and locating readouts in a low dose rate location. The use of thermocouples for temperature measurements located in embedded thermowells provides reliable, easily maintainable instrumentation for this monitoring function.
- Regulatory Position 2d on control of airborne contaminants may be applicable for vacuum drying operations of DSCs containing damaged fuel. Diversion of the vacuum pump exhaust to an appropriate filtration system is recommended in the Chapter 8 operations. The regulatory position does not apply during transfer or storage because neither gaseous releases nor significant surface contamination are expected.
- Regulatory Position 2e on crud control is not applicable to the ISFSI because there are no systems at the ISFSI that could transport crud. The leaktight DSC design ensures that spent fuel crud will not be released or transferred from the DSC. Draining back to the spent fuel pool provides control over any crud that could be entrained in the outflow from the DSC draining operations.
- Regulatory Position 2f on decontamination is met because the transfer cask is decontaminated prior to transfer to the ISFSI. The transfer cask accessible surfaces are designed to facilitate decontamination.

Regulatory Position 2g on radiation monitoring does not apply. There is no need for airborne radioactivity monitoring because the DSCs are sealed by leaktight welds. Airborne radioactivity due to damaged fuel is discussed under Regulatory Position 2d

the type and number of storage units, layout, characteristics of the irradiated fuel to be stored, site characteristics (e.g., berms, distance to the controlled area boundary, etc.), and reactor operations at the site in order to demonstrate compliance with 10CFR72.104.

10.3 Estimated Onsite Collective Dose Assessment

This section provides estimates of occupational for typical ISFSI operations. Offsite dose rates for normal and anticipated conditions controlled by 10 CFR 72.104 are addressed in Section 10.2. Dose rates from accident conditions controlled by 10 CFR 72.106 are addressed in Chapters 5 and 11.

Assumed annual occupancy times, including the anticipated maximum total hours per year for any individual and total person-hours per year for all personnel for each radiation area during normal operation and anticipated operational occurrences will be evaluated by the licensee in a 10 CFR 72.212 evaluation to address the site specific ISFSI layout, inspection, and maintenance requirements. In addition, the estimated annual collective doses associated with loading operations will be addressed by the licensee in a 10 CFR 72.212 evaluation.

10.3.1 DSC Loading, Transfer and Storage Operations

The estimated occupational exposures to ISFSI personnel during loading, transfer, and storage of the DSC (time and manpower may vary depending on individual ISFSI practices) is shown in Table 10-1. The task times, number of personnel required and total doses are listed in this table. The total dose is estimated to be 2.2 rem per loaded canister. This is a bounding estimate; measured doses from Standardized NUHOMS® System loading campaigns have been 600 mrem or lower per canister for normal operations.

The average distance for a given operation takes into account that the operator may be in contact with the transfer cask, but this duration will be limited. For draining activities and vacuum drying the attachment of fittings will take place closer to the cask than the operation of the pumps. For decontamination activities, although operators could be near the cask for some activities, other parts of the operation could be performed from farther away. For this reason, 1 foot or 3 feet is an appropriate average distance for these operations.

The operator's hands may be in a high dose rate location momentarily, for example when connecting fittings at the ports. This does not translate into a whole-body dose, and therefore, these localized streaming effects are not considered here.

For operations near the top end of the 32PTH DSC, most of the work will take place around the perimeter and a smaller portion will take place directly over the shielded inner top cover.

Regulatory Guide 8.34 [7] is to be employed in defining the on-site occupational dose and monitoring requirements.

10.3.2 DSC Retrieval Operations

Occupational exposures to ISFSI personnel during 32PTH DSC retrieval are similar to those exposures calculated for 32PTH DSC insertion. Dose rates for retrieval operations will be lower than those for insertion operations due to radioactive decay of the spent fuel inside the HSM. Therefore, the dose rates for 32PTH DSC retrieval are bounded by the dose rates calculated for insertion.

Components	SAR Sections
Basket	Appendix 3.9.1, Section 3.9.1.2.3 (pages 3.9.1-15 to 19)
Canister	Appendix 3.9.1, Load Cases 6 through 17, (pages 3.9.1-46 to 50)
Transfer Cask	Appendix 3.9.2, Load Cases 7 through 9 (pages 3.9.2-24 to 25)
Fuel Cladding	Section 3.5.3, Appendix 3.9.8

Accident Dose Calculation

Based on analysis results presented in Appendix 3.9.1 and Appendix 3.9.2, the accidental transfer cask drop scenarios do not breach the transfer cask/32PTH DSC confinement boundaries. The function of transfer cask lead shielding is not compromised by these drops. The transfer cask neutron shield, however, may be damaged in an accidental drop.

The transfer cask surface dose rate, with the neutron shield intact for the 32PTH DSC in the transfer cask is calculated in Chapter 5 of this SAR as 384 mrem/hr gamma and 125 mrem/hr neutron.

The dose rate at the transfer cask surface due to the loss of the neutron shield is also calculated; at 1 meter from the cask, the peak dose is 186 mrem/hr gamma and 2200 mrem/hr neutron. The dose at the site boundary would be significantly below 2.4 rem/hr and thus meet the acceptance criteria of 5 rem.

Corrective Actions

The DSC will be inspected for damage, and the DSC opened and the fuel removed for inspection, as necessary. Removal of the transfer cask top cover plate may require cutting of the bolts in the event of a corner drop onto the top end. These operations will take place in the plant fuel building decontamination area and spent fuel pool after recovery of the transfer cask. Following recovery of the transfer cask and unloading of the DSC, the transfer cask will be inspected, repaired and tested as appropriate prior to reuse.

For recovery of the cask and contents, it may be necessary to develop a special sling/lifting apparatus to move the transfer cask from the drop site to the fuel pool. This may require several weeks of planning to ensure all steps are correctly organized. During this time, lead blankets may be added to the transfer cask to minimize on-site exposure to site operations personnel. The transfer cask would be roped off to ensure the safety of the site personnel.

11.3.2 Earthquake

Cause of Accident

The seismic design criteria for the NUHOMS® HD System is consistent with the criteria set forth in Chapter 2, Section 2.2.3, with the exception that the NRC Regulatory Guide 1.60 (R.G. 1.60) [3] response spectra is anchored to a maximum ground acceleration of 0.30g (instead of 0.25g) for the horizontal components and 0.20g (instead of 0.17g) for the vertical component. The results of the frequency analysis of the HSM-H structure (which includes a simplified model of the DSC) yield a lowest frequency of 23.2 Hz in the transverse direction and 28.4 Hz in the longitudinal direction. The lowest vertical frequency exceeds 33 Hz. Thus, based on the R.G. 1.60 response spectra amplifications, the corresponding seismic accelerations used for the design of the HSM-H are 0.37g and 0.33g in the transverse and longitudinal directions respectively and 0.20g in the vertical direction. The corresponding accelerations applicable to the DSC are 0.41g and 0.36g in the transverse and longitudinal directions, respectively, and 0.20g in the vertical direction.

Accident Analysis

The seismic analyses of the components which are important to safety are analyzed as follows:

Components	SAR Sections
Basket	Appendix 3.9.1, Section 3.9.1.2.3 (page 3.9.1-21)
Canister	Appendix 3.9.1, Section 3.9.1.3.2 (page 3.9.1-58)
Transfer Cask	Appendix 3.9.2, Load Case 6 (page 3.9.2-22)
HSM-H	Appendix 3.9.9, Section 3.9.9.2 (page 3.9.9-23)

The results of these analyses show that seismic stresses are well below ASME code allowables.

Accident Dose Calculations

All the components which are important to safety are designed and analyzed to withstand the design basis earthquake accident. Hence, no radiation is released and there is no associated dose increase due to this event.

Corrective Actions

After a seismic event, all components would be inspected for damage. Any debris would be removed. An evaluation would be performed to determine if the system components were still within the licensed design basis.

evaluation of this event, which is presented in Appendix 3.9.9, Section 3.9.9.10.4. The structural evaluation of the 32PTH DSC based on the thermal evaluation presented in Chapter 4 of this SAR is presented in Appendix 3.9.1, storage load case 6 (page 3.9.1-59).

Accident Dose Calculation

There are no off-site dose consequences as a result of this accident. The only significant dose increase is that related to the recovery operation where it is conservatively estimated that the on-site workers will receive an additional dose of no more than one man-rem during the eight hour period it is estimated may be required for removal of debris from the air inlet and outlet openings in the HSM-H.

Corrective Actions

Debris removal is all that is required to recover from a postulated blockage of the HSM ventilation air inlets and outlets. Cooling will begin immediately following removal of the debris from the inlets and outlets. The amount and nature of debris can vary, but even in the most extreme case, manual means or readily available equipment can be used to remove debris.

The debris is conservatively assumed to remain in place for 34 hours. The last seven hours of this period are assumed to be the time required to completely remove all the debris before the natural circulation air flow can be restored.

11.3.7 Lightning

Cause of Accident

The likelihood of lightning striking the HSM-H and causing an off-normal condition is not considered to be a credible event. Lightning protection system requirements are site specific and depend upon the frequency of occurrences of lightning storms in the proposed ISFSI location and the degree of protection offered by other grounded structures in the proximity of the HSM-Hs. The addition of simple lightning protection equipment, required by plant criteria, to HSM-H structures (i.e., grounded handrails, ladders, etc.) is considered a miscellaneous attachment.

Accident Analysis

Should lightning strike in the vicinity of the HSM-H the normal storage operations of the HSM-H will not be affected. The current discharged by the lightning will follow the low impedance path offered by the surrounding structures. Therefore, the HSM-H will not be damaged by the heat or mechanical forces generated by current passing through the higher impedance concrete. Since the HSM-H requires no equipment for its continued operation, the resulting current surge from the lightning will not affect the normal operation of the HSM-H.

11.3.5 Flood

Cause of Accident

Flooding conditions simulating a range of flood types, such as tsunami and seiches as specified in 10CFR72.122 (b) are considered. In addition, floods resulting from other sources, such as high water from a river or a broken dam, are postulated as the cause of the accident.

Accident Analysis

The HSM-H is evaluated for flooding in Appendix 3.9.9, Section 3.9.9.10.3. Based on the evaluation presented in that section, the HSM-H will withstand the design basis flood.

Accident Dose Calculation

The radiation dose due to flooding of the HSM-H is negligible. Flooding does not breach the confinement boundary. Therefore radioactive material inside the DSC will remain sealed in the DSC and, therefore, will not contaminate the encroaching flood water.

Corrective Actions

Because of the location and geometry of the HSM-H vents, it is unlikely that any significant amount of silt would enter an HSM-H should flooding occur. Any silt deposits would be removed using a pump suction hose or fire hose inserted through the inlet vent to suck the silt out, or produce a high velocity water flow to flush the silt through the HSM-H inlet vents.

11.3.6 Blockage of HSM-H Air Inlet and Outlet Openings

This accident conservatively postulates the complete blockage of the ventilation air inlet and outlet openings of the HSM-H.

Cause of Accident

Since the NUHOMS® HSM-Hs are located outdoors; there is a remote probability that the ventilation air inlet and outlet openings could become blocked by debris from such unlikely events as floods and tornados. The NUHOMS® design features such as the perimeter security fence and the redundant protected location of the air inlet and outlet openings reduce the probability of occurrence of such an accident. Nevertheless, for this conservative generic analysis, such an accident is postulated to occur and is analyzed.

Accident Analysis

The thermal evaluation of this event is presented in Chapter 4, Section 4 for 32PTH DSC (34.8 kw) and Amendment #8, Section P.4 for 24PTH DSC (40.8 kw). The analysis performed for HSM-H with 24PTH DSC bounding the values for HSM-H with 32PTH DSC. Therefore, the temperatures determined in Amendment #8, Section P.4 are used in the HSM-H structural

CHAPTER 12
TECHNICAL SPECIFICATIONS FOR THE NUHOMS® HD SYSTEM

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12 OPERATING CONTROLS AND LIMITS

12.1 Use and Application

12.1.1 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-H)	The HSM-H is a reinforced concrete structure for storage of a loaded 32PTH DSC at a spent fuel storage installation.
DAMAGED FUEL ASSEMBLY	A DAMAGED FUEL ASSEMBLY is a fuel assembly with known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means.
DRY SHIELDED CANISTER (32PTH DSC)	A 32PTH DSC is a welded pressure vessel that provides confinement of INTACT or DAMAGED FUEL ASSEMBLIES in an inert atmosphere.
INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI)	The facility within a perimeter fence licensed for storage of spent fuel within HSM-Hs.
INTACT FUEL ASSEMBLY	Spent Nuclear Fuel Assemblies without known or suspected cladding defects greater than pinhole leaks or hairline cracks and which can be handled by normal means.
LOADING OPERATIONS	LOADING OPERATIONS include all licensed activities on a 32PTH DSC while it is being loaded with INTACT or DAMAGED FUEL ASSEMBLIES, and in a TRANSFER CASK while it is being loaded with a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES. LOADING OPERATIONS begin when the first INTACT or DAMAGED FUEL ASSEMBLY is placed in the 32PTH DSC and end when the TRANSFER CASK is ready for TRANSFER OPERATIONS.
STORAGE OPERATIONS	STORAGE OPERATIONS include all licensed activities that are performed at the ISFSI while a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES is located in an HSM-H on the storage pad within the ISFSI perimeter.

12.1.1 Definitions (continued)

TRANSFER CASK (TC)	The TRANSFER CASK consists of a licensed NUHOMS® OS187H onsite transfer cask. The TRANSFER CASK will be placed on a transfer trailer for movement of a 32PTH DSC to the HSM-H.
TRANSFER OPERATIONS	TRANSFER OPERATIONS include all licensed activities involving the movement of a TRANSFER CASK loaded with a 32PTH DSC containing INTACT or DAMAGED FUEL ASSEMBLIES. TRANSFER OPERATIONS begin when the TRANSFER CASK is placed on the transfer trailer following LOADING OPERATIONS and end when the 32PTH DSC is located in an HSM-H on the storage pad within the ISFSI perimeter.
UNLOADING OPERATIONS	UNLOADING OPERATIONS include all licensed activities on a 32PTH DSC to unload INTACT or DAMAGED FUEL ASSEMBLIES. UNLOADING OPERATIONS begin when the 32PTH DSC is removed from the HSM-H and end when the last INTACT or DAMAGED FUEL ASSEMBLY has been removed from the 32PTH DSC.

12.1.2 Logical Connectors

PURPOSE

The purpose of this section is to explain the meaning of logical connectors.

Logical connectors are used in Technical Specifications (TS) to discriminate between, and yet connect, Discrete Conditions, Required Actions, Completion Times, Surveillances, and Frequencies. The only logical connectors that appear in TS are AND and OR. The physical arrangement of these connectors constitutes logical conventions with specific meanings.

BACKGROUND

Several levels of logic may be used to state Required Actions. These levels are identified by the placement (or nesting) of the logical connectors and by the number assigned to each Required Action. The first level of logic is identified by the first digit of the number assigned to a Required Action and the placement of the logical connector in the first level of nesting (i.e., left justified with the number of the Required Action). The successive levels of logic are identified by additional digits of the Required Action number and by successive indentions of the logical connectors.

When logical connectors are used to state a Condition, Completion Time, Surveillance, or Frequency, only the first level of logic is used, and the logical connector is left justified with the statement of the Condition, Completion Time, Surveillance, or Frequency.

EXAMPLES

The following examples illustrate the use of logical connectors:

EXAMPLE 12.1.2-1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO (Limiting Condition for Operation) not met.	A.1 Verify... AND A.2 Restore...	

In this example the logical connector AND is used to indicate that when in Condition A, both Required Actions A.1 and A.2 must be completed.

(continued)

12.1.2 Logical Connectors (continued)

EXAMPLES (continued)

EXAMPLE 12.1.2-2

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met.	A.1 Stop... OR A.2 A.2.1 Verify... AND A.2.2 A.2.2.1 Reduce... OR A.2.2.2 Perform... OR A.3 Remove...	

This example represents a more complicated use of logical connectors. Required Actions A.1, A.2, and A.3 are alternative choices, only one of which must be performed as indicated by the use of the logical connector OR and the left justified placement. Any one of these three Actions may be chosen. If A.2 is chosen, then both A.2.1 and A.2.2 must be performed as indicated by the logical connector AND. Required Action A.2.2 is met by performing A.2.2.1 or A.2.2.2. The indented position of the logical connector OR indicates that A.2.2.1 and A.2.2.2 are alternative choices, only one of which must be performed.

12.1.3 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 Times(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 facility 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 facility is not within the LCO Applicability. Once a Condition has been entered, subsequent subsystems, components, or variables expressed in the Condition, discovered to be not within limits, will not 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)

12.1.3 Completion Times (continued)

EXAMPLES

The following examples illustrate the use of Completion Times with different types of Conditions and Changing Conditions.

EXAMPLE 12.1.3-1

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1 AND B.2 Perform Action B.2	12 hours 36 hours

Condition B has two Required Actions. Each Required Action has its own separate Completion Time. Each Completion Time is referenced to the time that Condition B is entered.

The Required Actions of Condition B are to complete action B.1 within 12 hours AND complete action B.2 within 36 hours. A total of 12 hours is allowed for completing action B.1 and a total of 36 hours (not 48 hours) is allowed for completing action B.2 from the time that Condition B was entered. If action B.1 is completed within 6 hours, the time allowed for completing action B.2 is the next 30 hours because the total time allowed for completing action B.2 is 36 hours.

EXAMPLES

EXAMPLE 12.1.3-2

ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. One system not within limit.	A.1 Restore system to within limit.	7 days
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1. AND B.2 Perform Action B.2.	12 hours 36 hours

When a system is determined to not meet the LCO, Condition A is entered. If the system is not restored within 7 days, Condition B is also entered and the Completion Time clocks for Required Actions B.1 and B.2 start. If the system is restored after Condition B is entered, Condition A and B are exited, and therefore, the Required Actions of Condition B may be terminated.

(continued)

12.1.3 Completion Times (continued)

EXAMPLES (continued)

EXAMPLE 12.1.3-3

ACTIONS

-- NOTE --

Separate Condition entry is allowed for each component.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. LCO not met.	A.1 Restore compliance with LCO.	4 hours
B. Required Action and associated Completion Time not met.	B.1 Perform Action B.1. AND B.2 Perform Action B.2.	6 hours 12 hours

The Note above the ACTIONS Table is a method of modifying how the Completion Time is tracked. If this method of modifying how the Completion Time is tracked was applicable only to a specific Condition, the Note would appear in that Condition rather than at the top of the ACTIONS Table.

The Note allows Condition A to be entered separately for each component, and Completion Times tracked on a per component basis. When a component is determined to not meet the LCO, Condition A is entered and its Completion Time starts. If subsequent components are determined to not meet the LCO, Condition A is entered for each component and separate Completion Times start and are tracked for each component.

IMMEDIATE COMPLETION TIME

When "Immediately" is used as a Completion Time, the Required Action should be pursued without delay and in a controlled manner.

12.1.4 Frequency

PURPOSE	The purpose of this section is to define the proper use and application of Frequency requirements
DESCRIPTION	Each Surveillance Requirement (SR) has a specified Frequency in which the Surveillance must be met in order to meet the associated Limiting Condition for Operation (LCO). An understanding of the correct application of the specified Frequency is necessary for compliance with the SR. The "Specified Frequency" is referred to throughout this section and each of the Specifications of Section 12.3.0, Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability. The "Specified Frequency" consists of the requirements of the Frequency column of each SR, as well as certain Notes in the Surveillance column that modify performance requirements. Situations where a Surveillance could be required (i.e., its Frequency could expire), but where it is not possible or not desired that it be performed until sometime after the associated LCO is within its Applicability, represent potential SR 12.3.0.4 conflicts. To avoid these conflicts, the SR (i.e., the Surveillance or the Frequency) is stated such that it is only "required" when it can be and should be performed. With a SR satisfied, SR 12.3.0.4 imposes no restriction. (continued)

12.1.4 Frequency (continued)

EXAMPLES (continued)

The following examples illustrate the various ways that Frequencies are specified:

EXAMPLE 12.1.4-1

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify pressure within limit.	12 hours

Example 12.1.4-1 contains the type of SR most often encountered in the Technical Specifications (TS). The Frequency specifies an interval (12 hours) during which the associated Surveillance must be performed at least one time. Performance of the Surveillance initiates the subsequent interval. Although the Frequency is stated as 12 hours, an extension of the time interval to 1.25 times the stated Frequency is allowed by SR 12.3.0.2 for operational flexibility. The measurement of this interval continues at all times, even when the SR is not required to be met per SR 12.3.0.1 (such as when the equipment is determined to not meet the LCO, a variable is outside specified limits, or the unit is outside the Applicability of the LCO). If the interval specified by SR 12.3.0.2 is exceeded while the facility is in a condition specified in the Applicability of the LCO, the LCO is not met in accordance with SR 12.3.0.1.

If the interval as specified by SR 12.3.0.2 is exceeded while the facility is not in a condition specified in the Applicability of the LCO for which performance of the SR is required, the Surveillance must be performed within the Frequency requirements of SR 12.3.0.2 prior to entry into the specified condition. Failure to do so would result in a violation of SR 12.3.0.4.

(continued)

12.1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 12.1.4-2

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
Verify flow is within limits.	Once within 12 hours prior to starting activity AND 24 hours thereafter

Example 12.1.4-2 has two Frequencies. The first is a one-time performance Frequency, and the second is of the type shown in Example 12.1.4-1. The logical connector "AND" indicates that both Frequency requirements must be met. Each time the example activity is to be performed, the Surveillance must be performed prior to starting the activity.

The use of "once" indicates a single performance will satisfy the specified Frequency (assuming no other Frequencies are connected by "AND"). This type of Frequency does not qualify for the 25% extension allowed by SR 12.3.0.2.

"Thereafter" indicates future performances must be established per SR 12.3.0.2, but only after a specified condition is first met (i.e., the "once" performance in this example). If the specified activity is canceled or not performed, the measurement of both intervals stops. New intervals start upon preparing to restart the specified activity.

(continued)

12.1.4 Frequency (continued)

EXAMPLES (continued)

EXAMPLE 12.1.4-3

SURVEILLANCE REQUIREMENTS

SURVEILLANCE	FREQUENCY
--------------------NOTE-------------------- *Not required to be met until 96 hours after verifying the helium leak rate is within limit.*	Once after verifying the helium leak rate is within limit.
Verify 32PTH DSC vacuum drying pressure is within limit.	

As the Note modifies the required performance of the Surveillance, it is construed to be part of the "specified Frequency." Should the vacuum drying pressure not be met immediately following verification of the helium leak rate while in LOADING OPERATIONS, this Note allows 96 hours to perform the Surveillance. The Surveillance is still considered to be performed within the "specified Frequency."

Once the helium leak rate has been verified to be acceptable, 96 hours, plus the extension allowed by SR 12.3.0.2, would be allowed for completing the Surveillance for the vacuum drying pressure. If the Surveillance was not performed within this 96 hour interval, there would then be a failure to perform the Surveillance within the specified Frequency, and the provisions of SR 12.3.0.3 would apply.

12.2 Functional and Operating Limits

12.2.1 Fuel to be Stored in the 32PTH DSC

The spent nuclear fuel to be stored in each 32PTH DSC/HSM-H at the ISFSI shall meet the following requirements:

a. Fuel shall be INTACT FUEL ASSEMBLIES or DAMAGED FUEL ASSEMBLIES. DAMAGED FUEL ASSEMBLIES shall be placed in basket fuel compartments which contain top and bottom end caps. Damaged fuel assemblies shall be stored in the 16 inner-most basket fuel compartments, as shown in Figure 12-1.

b. Fuel types shall be limited to the following:

   Westinghouse 15x15 Standard (WE 15x15) Assemblies
   Westinghouse Surry Improved 15x15 (WES 15x15) Assemblies
   Westinghouse 17x17 Standard (WE 17x17) Assemblies
   Westinghouse 17x17 Vantage 5H (WEV 17x17) Assemblies
   Westinghouse 17x17 OFA (WEO 17x17) Assemblies
   Framatome ANP Advanced MK BW 17x17 (MK BW 17x17) Assemblies
   Combustion Engineering 14x14 (CE 14x14) Assemblies

   The fuel assemblies are specified in Table 12-1. Equivalent reload fuel assemblies that are enveloped by the fuel assembly design characteristics listed in Table 12-2 for a given assembly class are also acceptable for storage.

   Fuel burnup and cooling time is to be consistent with the limitations specified in Table 12-4.

   Non-Fuel Assembly Hardware (NFAH) stored integral to the assemblies in a 32PTH DSC, shall be limited to Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), and Vibration Suppressor Inserts (VSIs). The NFAH stored shall have acceptable combinations of burnup and cooling time described in Table 12-5. CE 14x14 fuel assemblies are to be stored without NFAH.

(continued)

12.2.1 Fuel to be Stored in the 32PTH DSC (continued)

c. The maximum heat load for a single fuel assembly, including insert components, is 1.5 kW. The maximum heat load per 32PTH DSC, including any integral insert components, shall not exceed 34.8 kW for WE 15x15, WES 15x15, WE 17x17, WEV 17x17, WEO 17x17, and MK BW 17x17 assemblies and 33.8 kW for CE 14x14 assemblies. The total 32PTH DSC shielding source term is given in Table 12-3. Any fuel assembly that is thermally qualified from Table 12-4 is acceptable from a shielding perspective, since the maximum decay heat load is 1.5 kW and only 8 are allowed in the 32PTH DSC. The shielding analysis assumes 32, 1.5 kW assemblies are in the 32PTH DSC. Fuel assemblies may be qualified for four (4) heat load zones designated as Zones 1a, 1b, 2 and 3. Figure 12-2 shows the heat load zone locations. Table 12-4 identifies the acceptable combinations of enrichment, burnup and cooling times.

d. Fuel can be stored in the 32PTH DSC in any of the following configurations:

   1) A maximum of 32 INTACT fuel assemblies; or

   2) Up to 16 DAMAGED FUEL ASSEMBLIES, with the balance INTACT FUEL ASSEMBLIES.

e. Fuel dimensions and weights are provided in Table 12-2.

f. The maximum neutron and gamma source terms are provided in Table 12-3.

12.2.2 Functional and Operating Limits Violations

If any Functional and Operating Limit of 12.2.1 is violated, the following actions shall be completed:

12.2.2.1 The affected fuel assemblies shall be placed in a safe condition.

12.2.2.2 Within 24 hours, notify the NRC Operations Center.

12.2.2.3 Within 30 days, submit a special report which describes the cause of the violation and the actions taken to restore compliance and prevent recurrence.

12.3 Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability

LCO 12.3.0.1	LCOs shall be met during specified conditions in the Applicability, except as provided in LCO 12.3.0.2.
LCO 12.3.0.2	Upon discovery of a failure to meet an LCO, the Required Actions of the associated Conditions shall be met, except as provided in LCO 12.3.0.5. If the LCO is met or is no longer applicable prior to expiration of the specified Completion Time(s), completion of the Required Action(s) is not required, unless otherwise stated.
LCO 12.3.0.3	Not applicable to a spent fuel storage cask.
LCO 12.3.0.4	When an LCO is not met, entry into a specified condition in the Applicability shall not be made except when the associated ACTIONS to be entered permit continued operation in the specified condition in the Applicability for an unlimited period of time. This Specification shall not prevent changes in specified conditions in the Applicability that are required to comply with ACTIONS, or that are related to the unloading of a 32PTH DSC. Exceptions to this Specification are stated in the individual Specifications. These exceptions allow entry into specified conditions in the Applicability when the associated ACTIONS to be entered allow operation in the specified condition in the Applicability only for a limited period of time.
LCO 12.3.0.5	Equipment removed from service or not in service in compliance with ACTIONS may be returned to service under administrative control solely to perform testing required to demonstrate it meets the LCO or that other equipment meets the LCO. This is an exception to LCO 12.3.0.2 for the system returned to service under administrative control to perform the testing required to demonstrate that the LCO is met.
LCO 12.3.0.6	Not applicable to a spent fuel storage cask.
LCO 12.3.0.7	Not applicable to a spent fuel storage cask.

(continued)

12.3 Limiting Condition for Operation (LCO) and Surveillance Requirement (SR) Applicability (continued)

SR 12.3.0.1	SRs shall be met during the specified conditions in the Applicability for individual LCOs, unless otherwise stated in the SR. Failure to meet a Surveillance, whether such failure is experienced during the performance of the Surveillance or between performances of the Surveillance, shall be failure to meet the LCO. Failure to perform a Surveillance within the specified Frequency shall be failure to meet the LCO except as provided in SR 12.3.0.3. Surveillances do not have to be performed on equipment or variables outside specified limits.
SR 12.3.0.2	The specified Frequency for each SR is met if the Surveillance is performed within 1.25 times the interval specified in the Frequency, as measured from the previous performance or as measured from the time a specified condition of the Frequency is met. For Frequencies specified as "once," the above interval extension does not apply. If a Completion Time requires periodic performance on a "once per . . ." basis, the above Frequency extension applies to each performance after the initial performance. Exceptions to this Specification are stated in the individual Specifications.
SR 12.3.0.3	If it is discovered that a Surveillance was not performed within its specified Frequency, then compliance with the requirement to declare the LCO not met may be delayed, from the time of discovery, up to 24 hours or up to the limit of the specified Frequency, whichever is less. This delay period is permitted to allow performance of the Surveillance. If the Surveillance is not performed within the delay period, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered. When the Surveillance is performed within the delay period and the Surveillance is not met, the LCO must immediately be declared not met, and the applicable Condition(s) must be entered.
SR 12.3.0.4	Entry into a specified condition in the Applicability of an LCO shall not be made unless the LCO's Surveillances have been met within their specified Frequency. This provision shall not prevent entry into specified conditions in the Applicability that are required to comply with ACTIONS or that are related to the unloading of a 32PTH DSC.

12.3.1 32PTH DSC Fuel Integrity

12.3.1.1 32PTH DSC Vacuum Drying Time (Duration) and Pressure

LCO 12.3.1.1

Duration: Vacuum Drying of the 32PTH DSC shall be achieved within the following time durations after drainage of bulk water (blowdown):

Notes:
1. The DSC shall be backfilled with nitrogen or helium after drainage of bulk water.
2. Nitrogen or helium will be used to assist the removal of water prior to welding the inner top cover/shield plug.

Procedure A – Water in the TC cavity/annulus remains below 180°F

Heat Load (kW)	Time Limit
kW ≤ 23.2	No limit
23.2< kW ≤ 34.8	36 hours after DSC water drainage
23.2< kW ≤ 34.8	No limit if helium backfill after DSC water drainage

Procedure B – Water in the TC cavity/annulus is drained when it exceeds 180°F

Heat Load (kW)	Time Limit
kW ≤ 16.0	No limit
16.0< kW ≤ 34.8	28 hours after DSC water drainage or 14 hours after drainage of TC cavity/annulus water, which ever is limiting

Procedure C – Water in the TC cavity/annulus is drained when it exceeds 180°F and after DSC water drainage the DSC is backfilled with helium.

Heat Load (kW)	Time Limit
kW ≤ 22.4	No limit
22.4< kW ≤ 34.8	42 hours after DSC water drainage or 28 hours after drainage of TC cavity/annulus water, which ever is limiting

Pressure: The 32PTH DSC vacuum drying pressure shall be sustained at or below 3 Torr (3 mm Hg) absolute for a period of at least 30 minutes following evacuation.

APPLICABILITY: During LOADING OPERATIONS.

12.3.1 32PTH DSC Fuel Integrity (continued)

ACTIONS

--------------------------------NOTE--------------------------------------

This specification is applicable to all 32PTH DSCs.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. 32PTH DSC vacuum drying pressure limit not met:		
Procedure A, within 30 hours for a DSC with heat load greater than 23.2 kW. Procedure B, within either 22 hours after DSC water drainage or 8 hours after annulus water drainage for a DSC with heat load greater than 16.0 kW. Procedure C, within either 36 hours after DSC water drainage or 22 hours after annulus water drainage for a DSC with heat load greater than 22.4 kW.	A.1 Establish helium pressure of at least 0.5 atm and no greater than 15 psig in the 32PTH DSC. OR A.2 Flood the DSC with spent fuel pool water submerging all fuel assemblies.	6 hours 6 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
S.R.12.3.1.1	Verify that the 32PTH DSC vacuum pressure is less than, or equal to, 3 Torr (3 mm Hg) absolute for at least 30 minutes, within the specified total time duration based on heat load.	Once per 32PTH DSC, after an acceptable NDE of the inner top cover/ shield plug weld.

12.3.1.2 32PTH DSC Helium Backfill Pressure

LCO 12.3.1.2 32PTH DSC helium backfill pressure shall be 2.5 ± 1 psig (stable for 30 minutes after filling) after completion of vacuum drying.

APPLICABILITY: During LOADING OPERATIONS.

ACTIONS

--- NOTE ---

This specification is applicable to all 32PTH DSCs.

CONDITION	REQUIRED ACTION	COMPLETION TIME
Note: Not applicable until SR 12.3.1.2 is performed.		
A. The required backfill pressure cannot be obtained or stabilized.	A.1 Establish the 32PTH DSC helium backfill pressure to within the limit.	24 hours
	<u>OR</u>	
	A.2 Flood the DSC with spent fuel pool water submerging all fuel assemblies.	24 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
S.R.12.3.1.2	Verify that the 32PTH DSC helium backfill pressure is 2.5 ± 1 psig.	Once per 32PTH DSC, after the completion of TS 12.3.1.1 actions.

12.3.1.3 Transfer Cask Cavity Helium Backfill Pressure

LCO 12.3.1.3 OS187H transfer cask cavity/annulus helium backfill shall be initiated within 9 hours after completion of 32PTH DSC helium backfill for loading OR for unloading within 9 hours of retracting the DSC into the TC and installation of the TC lid. The pressure shall be 2.0 ± 1 psig.

APPLICABILITY: During LOADING and UNLOADING OPERATIONS.

ACTIONS

NOTE

This specification is applicable to all 32PTH DSCs/OS187H TC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. The transfer cask cavity/ annulus helium backfill cannot be initiated within 8 hrs of 32PTH DSC helium backfill completion during loading OR within 8 hrs of retracting the DSC into the TC and installation of the TC lid during unloading. NOTE *Note: Not applicable until SR 12.3.1.3 is performed.*	A.1 Flood the TC cavity/annulus with water	1 hour
B. The required backfill pressure cannot be obtained or stabilized.	B.1 Establish the TC cavity/annulus helium backfill pressure to within the limit. OR B.2 Flood the TC cavity/annulus with water.	18 hours 18 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
S.R.12.3.1.3	Verify that the OS187H cavity/annulus helium backfill pressure is 2.0 ± 1 psig, stable for 30 minutes after filling. OR Monitor the OS187H cavity/annulus pressure during transfer operation to verify it does not drop below 1.0 psig.	Once per 32PTH DSC, after the completion of TS 12.3.1.2 actions or after the installation of the TC lid.

12.3.2 Cask Criticality Control

LCO 12.3.2 The dissolved boron concentration of the spent fuel pool water and the water added to the cavity of a loaded DSC shall be at least the boron concentration shown in Table 12-7 for the basket type and fuel enrichment selected.

APPLICABILITY: During LOADING and UNLOADING OPERATIONS.

ACTIONS

---------- NOTE ----------

This specification is applicable to all 32PTH DSCs/OS187H TC.

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. Dissolved boron concentration limit not meet.	A.1 Suspend loading of fuel assemblies into DSC AND A.2 Remove all fuel assemblies from DSC	Immediately 24 hours

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 12.3.2.1	Verify dissolved boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements.	Within 4 hours prior to commencing LOADING OPERATIONS AND 48 hours thereafter while the DSC is in the spent fuel pool or while water is in the DSC.
SR 12.3.2.2	Verify dissolved boron concentration limit in spent fuel pool water and water to be added to the DSC cavity is met using two independent measurements.	Once within 4 hours prior to flooding DSC during UNLOADING OPERATIONS AND 48 hours thereafter while the DSC is in the spent fuel pool or while water is in the DSC.

12.4 Design Features

The specifications in this section include the design characteristics of special importance to each of the physical barriers and to maintenance of safety margins in the NUHOMS® HD System design. The principal objective of this section is to describe the design envelope that may constrain any physical changes to essential equipment. Included in this section are the site environmental parameters that provide the bases for design, but are not inherently suited for description as LCOs.

12.4.1 Site

12.4.1.1 Site Location

Because this SAR is prepared for a general license, a discussion of a site-specific ISFSI location is not applicable.

12.4.2 Storage System Features

12.4.2.1 Storage Capacity

The total storage capacity of the ISFSI is governed by the plant-specific license conditions.

12.4.2.2 Storage Pad

For sites for which soil-structure interaction is considered important, the licensee is to perform site-specific analysis considering the effects of soil-structure interaction. Amplified seismic spectra at the location of the HSM-H center of gravity (CG) is to be developed based on the SSI responses. HSM-H seismic analysis information is provided in SAR Appendix 3.9.9.10.2.

The storage pad location shall have no potential for liquefaction at the site-specific SSE level earthquake.

Additional requirements for the pad configuration are provided in Section 12.4.6.2.

(continued)

12.4 Design Features (continued)

12.4.3 Canister Criticality Control

The NUHOMS®-32PTH is designed for unirradiated fuel with an assembly average initial enrichment of less than or equal to 5.0 wt. % U-235 taking credit for soluble boron in the DSC cavity water during loading operations and the boron content in the poison plates of the DSC basket. The 32PTH DSC has multiple basket configurations, based on the material type and boron content in the poison plates, as listed in Table 12-6. Table 12-7 defines the requirements for boron concentration in the DSC cavity water as a function of the DSC basket type for the various intact and damaged fuel classes (most reactive) authorized for storage in the 32PTH DSC.

A Type I basket contains poison plates that are either borated aluminum or MMC while a Type II basket contains Boral® poison plates. The basket types are further defined by the B-10 areal density in the plates, ranging from the lowest, Type A to the highest, Type E.

12.4.3.1 Neutron Absorber Tests

Borated Aluminum, MMCs, or Boral® shall be supplied in accordance with SAR Sections 9.1.7.1, 9.1.7.2, 9.1.7.3, 9.5.2, 9.5.3.5 and 9.5.4.3, with the minimum B10 areal density specified in Table 12-6. These sections of the SAR are hereby incorporated into the NUHOMS® HD CoC.

12.4.4 Codes and Standards

12.4.4.1 Horizontal Storage Module (HSM-H)

The reinforced concrete HSM-H is designed to meet the requirements of ACI 349-97. 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-H.

12.4.4.2 Dry Shielded Canister (32PTH DSC)

The 32PTH DSC is designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, Division 1, 1998 Edition with Addenda through 2000, Subsections NB, NF, and NG for Class 1 components and supports. Code alternatives are discussed in 12.4.4.4.

12.4.4.3 Transfer Cask (OS187H)

The OS187H Transfer Cask is designed, fabricated and inspected to the maximum practical extent in accordance with ASME Boiler and Pressure Vessel Code Section III, 1998 Edition with Addenda through 2000, Subsection NC for Class 2 vessels.

12.4.4.4 Alternatives to Codes and Standards

ASME Code alternatives for the 32PTH DSC are listed below:

DSC ASME Code Alternatives, Subsection NB

Reference ASME Code Section/Article	Code Requirement	Justification & Compensatory Measures
NCA	All	Not compliant with NCA
NB-1100	Requirements for Code Stamping of Components	The canister shell, the inner top cover/shield plug, the inner bottom cover, and the siphon/vent port cover are designed & fabricated in accordance with the ASME Code, Section III, Subsection NB to the maximum extent practical. However, 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-2130 NB-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	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 & certification are maintained in accordance with TN's NRC approved QA program.
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 shell to the outer top cover weld, the shell to the inner top cover/shield plug weld (including option 2 or option 3 inner top cover as described in the SAR), and the siphon/vent cover welds, are all partial penetration welds. As an alternative to the NDE requirements of NB-5230, for Category C welds, all of these closure welds will be multi-layer welds and receive a root and final PT examination, except for the shell to the outer top cover weld. The shell to the outer top cover weld will be a multi-layer weld and receive multi-level PT examination in accordance with the guidance provided in ISG-15 for NDE. The multi-level PT examination provides reasonable assurance that flaws of interest will be identified. The PT examination is done by qualified personnel, in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000. All of these welds will be designed to meet the guidance provided in ISG-15 for stress reduction factor.
NB-2531	Vent & siphon Port Cover; straight beam UT per SA-578 for all plates for vessel	SA-578 applies to 3/8" and thicker plate only; allow alternate UT techniques to achieve meaningful UT results.

DSC ASME Code Alternatives, Subsection NB (concluded)

Reference ASME Code Section/Article	Code Requirement	Justification & Compensatory Measures
NB-6000	All completed pressure retaining systems shall be pressure tested	The 32PTH is not a complete or "installed" pressure vessel until the top closure is welded following placement of Fuel Assemblies within the DSC. Due to the inaccessibility of the shell and lower end closure welds following fuel loading and top closure welding, as an alternative, the pressure testing of the DSC is performed in two parts. The DSC shell, shell bottom, including all longitudinal and circumferential welds, is pneumatically tested and examined at the fabrication facility. The shell to the inner top cover/shield plug closure weld (including option 2 or option 3 inner top cover as described in the SAR) are pressure tested and examined for leakage in accordance with NB-6300 in the field. The siphon/vent cover welds will not be pressure tested; these welds and the shell to the inner top cover/shield plug closure weld (including option 2 or option 3 inner top cover as described in the SAR) are helium leak tested after the pressure test. Per NB-6324 the examination for leakage shall be done at a pressure equal to the greater of the Design pressure or three-fourths of the test pressure. As an alternative, if the examination for leakage of these field welds, following the pressure test, is performed using helium leak detection techniques, the examination pressure may be reduced to 1.5 psig. This is acceptable given the significantly greater sensitivity of the helium leak detection method.
NB-7000	Overpressure Protection	No overpressure protection is provided for the 32PTH DSC. The function of the 32PTH DSC is to contain radioactive materials under normal, off-normal, and hypothetical accident conditions postulated to occur during transportation. The 32PTH DSC is designed to withstand the maximum internal pressure considering 100% fuel rod failure at maximum accident temperature. The 32PTH DSC is pressure tested in accordance with the requirements of 10CFR71 and TN's approved QA program.
NB-8000	Requirements for nameplates, stamping & reports per NCA-8000	The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program.
NB-1132	Attachments with a pressure retaining function, including stiffeners, shall be considered part of the component.	Outer bottom cover, bottom plate, bottom casing plate, side casing plate, top shield plug casing plate, lifting posts, grapple ring and grapple ring support are outside code jurisdiction; these components together are much larger than required to provide stiffening for the confinement boundary cover. These component welds are subject to root and final PT examinations.

Basket ASME Code Alternatives, Subsection NG/NF

Reference ASME Code Section/Article	Code Requirement	Justification & Compensatory Measures
NCA	All	Not compliant with NCA
NG/NF-1100	Requirements for Code Stamping of Components	The 32PTH DSC baskets are designed & fabricated in accordance with the ASME Code, Section III, Subsection NG to the maximum extent practical as described in the SAR, but 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 be ASME Certified.
NG/NF-2130 NG/NF-4121	Material must be supplied by ASME approved material suppliers Material Certification by Certificate Holder	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 & certification are maintained in accordance with TN's NRC approved QA program. The poison material and aluminum plates are not used for structural analysis, but to provide criticality control and heat transfer. They are not ASME Code Class I materials. See note 1.
NG/NF-8000	Requirements for nameplates, stamping & reports per NCA-8000	The 32PTH DSC nameplates provide the information required by 10CFR71, 49CFR173, and 10CFR72 as appropriate. Code stamping is not required for the 32PTH DSC. QA Data packages are prepared in accordance with the requirements of 10CFR71, 10CFR72, and TN's approved QA program.

Notes: 1. Because Subsection NCA does not apply, the NCA-3820 requirements for accreditation or qualification of material organizations do not apply. CMTR's shall be provided using NCA- 3862 for guidance.

Proposed alternatives to the ASME code, other than the aforementioned ASME Code alternatives may be used when authorized by the Director of the Office of Nuclear Material Safety and Safeguards, or designee. The applicant should demonstrate that:

1. The proposed alternatives would provide an acceptable level of quality and safety, or

2. Compliance with the specified requirements of ASME Code, Section III, 1998 Edition with Addenda through 2000 would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Requests for exceptions in accordance with this section should be submitted in accordance with 10CFR 72.4.

12.4.5 HSM-H Side Heat Shields

The HSM-H utilizes side heat shields to protect the HSM-H concrete surfaces and provide for enhanced heat transfer within the HSM-H. Three side heat shield configurations have been evaluated in the SAR: finned anodized aluminum, flat (unfinned) anodized aluminum, and flat (unfinned) galvanized steel. Heat load limits for these three heat shield configurations and material types are established at 34.8 kW, 32.0 kW, and 26.1 kW per DSC, respectively. Alternate heat shield material types and configurations may be evaluated using the HSM-H thermal performance methodology described in the SAR.

12.4.6 Storage Location Design Features

The following storage location design features and parameters shall be verified by the system user to assure technical agreement with this SAR.

12.4.6.1 Storage Configuration

HSM-Hs are placed together in single rows or back to back arrays. An end shield wall is placed on the outside end of any loaded outside HSM-H. A rear shield wall is placed on the rear of any single row loaded HSM-H.

12.4.6.2 Concrete Storage Pad Properties to Limit 32PTH DSC Gravitational Loadings Due to Postulated Drops

The TC/32PTH DSC has been evaluated for drops of up to 80 inches onto a reinforced concrete storage pad. The evaluations are based on the concrete parameters specified in EPRI Report NP-7551, "Structural Design of Concrete Storage Pads for Spent Fuel Casks," August 1991.

(continued)

12.4 Design Features (continued)

12.4.6.3 Site Specific Parameters and Analyses

The following parameters and analyses shall be verified by the system user for applicability at their specific site. Other natural phenomena events, such as lightning, tsunamis, hurricanes, and seiches, are site specific and their effects are generally bounded by other events, but they should be evaluated by the user.

1. Tornado maximum wind speeds: 290 mph rotational
   70 mph translational

2. Flood levels up to 50 ft. and water velocity of 15 fps.

3. One-hundred year roof snow load of 110 psf.

4. Normal ambient temperatures of 0°F to 100°F.

5. Off-normal ambient temperature range of –20°F without solar insolation to 115°F with full solar insolation.

6. The potential for fires and explosions shall be addressed, based on site-specific considerations.

7. Supplemental Shielding: In cases where engineered features (i.e., berms, shield walls) are used to ensure that the requirements of 10CFR 72.104(a) are met, such features are to be considered important to safety and must be evaluated to determine the applicable Quality Assurance Category.

8. Seismic loads of up to 0.30g horizontal and up to 0.20 g vertical.

12.5 Administrative Controls

12.5.1 Procedures

Each user of the NUHOMS® HD System will prepare, review, and approve written procedures for all normal operations, maintenance, and testing at the ISFSI prior to its operation. Written procedures shall be established, implemented, and maintained covering the following activities that are important to safety:

- Organization and management
- Routine ISFSI operations
- Alarms and annunciators
- Emergency operations
- Design control and facility change/modification
- Control of surveillances and tests
- Control of special processes
- Maintenance
- Health physics, including ALARA practices
- Special nuclear material accountability
- Quality assurance, inspection, and audits
- Physical security and safeguards
- Records management
- Reporting
- All programs specified in Section 12.5.2

12.5.2 Programs

Each user of the NUHOMS® HD System will implement the following programs to ensure the safe operation and maintenance of the ISFSI:

- Safety Review Program
- Training Program
- Radiological Environmental Monitoring Program
- Radiation Protection Program
- HSM-H Thermal Monitoring Program

12.5.2.1 Safety Review Program

Users shall conduct safety reviews in accordance with 10CFR 72.48 to determine whether proposed changes, tests, and experiments require NRC approval before implementation. Changes to the Technical Specification Bases and other licensing basis documents will be conducted in accordance with approved administrative procedures.

Changes may be made to Technical Specification Bases and other licensing basis documents without prior NRC approval, provided the changes meet the criteria of 10CFR 72.48.

The safety review process will contain provisions to ensure that the Technical Specification Bases and other licensing basis documents are maintained consistent with the SAR.

Proposed changes that do not meet the criteria above will be reviewed and approved by the NRC before implementation. Changes to the Technical Specification Bases implemented without prior NRC approval will be provided to the NRC in accordance with 10CFR 72.48.

(continued)

12.5.2 Programs (continued)

12.5.2.2 Training Program

Training modules shall be developed as required by 10CFR 72. Training modules shall require a comprehensive program for the operation and maintenance of the NUHOMS® HD System and the independent spent fuel storage installation (ISFSI). The training modules shall include the following elements, at a minimum:

- NUHOMS® HD System design (overview)
- ISFSI Facility design (overview)
- Systems, Structures, and Components Important to Safety (overview)
- NUHOMS® HD System Safety Analysis Report (overview)
- NRC Safety Evaluation Report (overview)
- Certificate of Compliance conditions
- NUHOMS® HD System Technical Specifications
- Applicable Regulatory Requirements (e.g.,10CFR 72, Subpart K, 10CFR 20, 10 CFR Part 73)
- Required Instrumentation and Use
- Operating Experience Reviews
- NUHOMS® HD System and Maintenance procedures, including:
  - Fuel qualification and loading,
  - Rigging and handling,
  - Loading Operations as described in Chapter 8 of the SAR,
  - Unloading Operations including reflooding,
  - Auxiliary equipment operations and maintenance (i.e., welding operations, vacuum drying, helium backfilling and leak testing, reflooding),
  - Transfer operations including loading and unloading of the Transfer Vehicle,
  - ISFSI Surveillance operations,
  - Radiation Protection,
  - Maintenance, as described in Section 9.2 of the SAR,
  - Security, and
  - Off-normal and accident conditions, responses and corrective actions.

12.5.2.3 Radiological Environmental Monitoring Program

a) A radiological environmental monitoring program will be implemented to ensure that the annual dose equivalent to an individual located outside the ISFSI controlled area does not exceed the annual dose limits specified in 10CFR 72.104(a).

b) Operation of the ISFSI will not create any radioactive materials or result in any credible liquid or gaseous effluent release.

(continued)

12.5.2 Programs (continued)

12.5.2.4 Radiation Protection Program

The Radiation Protection Program will establish administrative controls to limit personnel exposure to As Low As Reasonably Achievable (ALARA) levels in accordance with 10CFR Part 20 and Part 72.

a) As part of its evaluation pursuant to 10CFR 72.212, the licensee shall perform an analysis to confirm that the limits of 10CFR 20 and 10CFR 72.104 will be satisfied under the actual site conditions and configurations considering the planned number of 32PTH DSCs to be used and the planned fuel loading conditions.

b) A monitoring program to ensure the annual dose equivalent to any real individual located outside the ISFSI controlled area does not exceed regulatory limits is incorporated as part of the environmental monitoring program in the Radiological Environmental Monitoring Program of Section 12.5.2.3.

c) Following completion of the welding of 32PTH DSC inner top cover/shield plug, siphon and vent cover plates, these welds are leak tested to demonstrate that these welds meet the "leak-light" criterion ($\leq 1.0 \times 10^{-7}$ reference cm^3/sec) as defined in "American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials," ANSI N14.5-1997. If the leakage rate exceeds 1.0×10^{-7} reference cm^3/sec, check and repair these welds.

This specification ensures that an inert helium atmosphere will be maintained around the fuel and radiological consequences will be negligible.

d) Following placement of each loaded Transfer Cask into the cask decontamination area and prior to transfer to the ISFSI, the 32PTH DSC smearable surface contamination levels on the outer top 1 foot surface of the 32PTH DSC shall be less than 2,200 dpm/100 cm^2 from beta and gamma emitting sources, and less than 220 dpm/100 cm^2 from alpha emitting sources.

The contamination limits specified above are based on the allowed removable external radioactive contamination specified in 49 CFR 173.443 (as referenced in 10 CFR 71.87(i)) the system provides significant additional protection for the 32PTH DSC surface than the transportation configuration. The HSM-H will protect the 32PTH DSC from direct exposure to the elements and will therefore limit potential releases of removable contamination. The probability of any removable contamination being entrapped in the HSM-H air flow path released outside the HSM-H is considered extremely small.

(continued)

12.5.2 Programs (continued)

12.5.2.5 HSM-H Thermal Monitoring Program

This program provides guidance for temperature measurements that are used to monitor the thermal performance of each HSM-H. The intent of the program is to prevent conditions that could lead to exceeding the concrete and fuel clad temperature criteria.

a) HSM-H Air Temperature Difference

Following initial 32PTH DSC transfer to the HSM-H, the air temperature difference between ambient temperature and the roof vent temperature will be measured 24 hours after DSC insertion into the HSM and again 7 days after insertion into the HSM-H. If the air temperature differential is greater than 70°F, the air inlets and exits should be checked for blockage. If after removing any blockage found, the temperature difference is still ≥100°F, corrective actions and analysis of existing conditions will be performed in accordance with the site corrective action program to confirm that conditions adversely affecting the concrete or fuel cladding do not exist.

The specified air temperature rise ensures the fuel clad and concrete temperatures are maintained at or below acceptable long-term storage limits. If the temperature rise is ≤100°F, then the HSM-H and 32PTH DSC are performing as designed and no further temperature measurements are required.

b) HSM-H Inlets and Outlets (Front Wall and Roof Bird Screens)

Since the HSM-Hs are located outdoors, there is a possibility that the HSM-H air inlet and outlet openings could become blocked by debris. Although the ISFSI security fence and HSM-H bird screens reduce the probability of HSM-H air vent blockage, the ISFSI SAR postulates and analyzes the effects of air vent blockage.

The HSM-H design and accident analyses demonstrate the ability of the ISFSI to function safely if obstructions in the air inlets or outlets impair airflow through the HSM-H for extended periods. This specification ensures that blockage will not exist for periods longer than assumed in the analyses.

Site personnel will conduct a daily visual inspection of the air vents to ensure that HSM-H air vents are not blocked for more than 34 hours and that blockage will not exist for periods longer than assumed in the safety analysis.

(continued)

12.5.3 Lifting Controls

12.5.3.1 Transfer Cask Lifting Heights

The lifting height of a loaded transfer cask/32PTH DSC, is limited as a function of location, as follows:

a) The maximum lift height and handling height for all TRANSFER OPERATIONS where the TC/32PTH is in the horizontal position on the trailer shall be 80 inches.

b) The maximum lift height of the transfer cask/32PTH DSC shall be restricted by site (10CFR50) limits for all handling operations except those listed in 12.5.3.1a above. An evaluation of the fuel cladding structural integrity shall be performed for all credible drops under the user's 10CFR50 heavy loads program.

These restrictions ensure that any 32PTH DSC drop as a function of location is within the bounds of the accident analysis.

12.5.3.2 Cask Drop

Inspection Requirement

The 32PTH DSC will be inspected for damage after any transfer cask drop of fifteen inches or greater.

Background

TC/32PTH DSC handling and loading activities are controlled under the 10CFR 50 license until a loaded TC/32PTH DSC is placed on the transporter, at which time fuel handling activities are controlled under the 10CFR 72 license. Although the probability of dropping a loaded TC/32PTH DSC while en route from the Fuel Handling Building to the ISFSI is small, the potential exists to drop the cask 15 inches or more.

(continued)

12.5.3 Lifting Controls (continued)

12.5.3.2 Cask Drop (continued)

Safety Analysis

The analysis of bounding drop scenarios shows that the transfer cask will maintain the structural integrity of the 32PTH DSC confinement boundary from an analyzed side drop height of 80 inches. The 80-inch drop height envelopes the maximum height from the bottom of the transfer cask when secured to the transfer trailer while en route to the ISFSI.

Although analyses performed for cask drop accidents at various orientations indicate much greater resistance to damage, requiring the inspection of the DSC after a drop of 15 inches or greater ensures that:

1. The DSC will continue to provide confinement.

2. The transfer cask can continue to perform its design function regarding DSC transfer and shielding.

12.5.4 HSM-H Dose Rate Evaluation Program

This program provides a means to help ensure that the cask (DSC) is loaded properly and that the facility will meet the off-site dose requirements of 72.104(a).

1. As part of its evaluation pursuant to 10 CFR 72.212, the licensee shall perform an analysis to confirm that the limits of 10 CFR Part 20 and 10 CFR 72.104 will be satisfied under the actual site conditions and configurations considering the planned number of HSMs to be used and the planned fuel loading conditions.

2. On the basis of the analysis in TS 12.5.4.1, the licensee shall establish a set of HSM-H dose rate limits which are to be applied to 32PTH DSCs used at the site. Limits shall establish peak dose rates for:

   a. HSM-H front surface,
   b. HSM-H door centerline, and
   c. End shield wall exterior.

3. Notwithstanding the limits established in TS 12.5.4.2, the dose rate limits may not exceed the following values as calculated for a content of design basis fuel as follows:

   a. 800 mrem/hr at the front bird screen,
   b. 2 mrem/hr at the door centerline, and
   c. 2 mrem/hr at the end shield wall exterior.

4. If the measured dose rates do not meet the limits of TS 12.5.4.2 or TS 12.5.4.3, whichever are lower, the licensee shall take the following actions:

   a. Notify the U.S. Nuclear Regulatory Commission (Director of the Office of Nuclear Material Safety and Safeguards) within 30 days,
   b. Administratively verify that the correct fuel was loaded,
   c. Ensure proper installation of the HSM-H door,
   d. Ensure that the DSC is properly positioned on the support rails, and
   e. Perform an analysis to determine that placement of the as-loaded DSC at the ISFSI will not cause the ISFSI to exceed the radiation exposure limits of 10 CFR Part 20 and 72 and/or provide additional shielding to assure exposure limits are not exceeded.

12.5.5 Concrete Testing

HSM-H concrete shall be tested for elevated temperatures to verify that there are no significant signs of spalling or cracking and that the concrete compressive strength is greater than that assumed in the structural analysis. Tests shall be performed at or above the calculated peak temperature and for a period no less than the 40 hour duration of HSM-H blocked vent transient for components exceeding 350 degrees F.

Table 12-1
Fuel Specifications

Fuel Type	Maximum Assembly Average Initial Enrichment	Cladding Material	Minimum Cooling Time	Minimum Assembly Average Initial Enrichment	Maximum Burnup
WE 15x15 WES 15x15	5.0 weight % U-235	Zircalloy-4 Zirlo	5 years	See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits	60 GWD/MTU
WE 17x17 WEV 17x17 WEO 17x17	5.0 weight % U-235	Zircalloy-4 Zirlo	5 years	See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits	60 GWd/MTU
MK BW 17x17	5.0 weight % U-235	M5	5 years	See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits	60 GWd/MTU
CE 14x14	5.0 weight % U-235	Zircalloy-4 Zirlo	5 years	See Table 12-4 for Enrichment, Burnup, and Cooling Time Limits	60 GWd/MTU
NFAH	N/A	N/A	See Table 12-5		

Table 12-2
Fuel Dimension and Weights

Parameter	WE & WES 15x15	WE 17x17	MK BW 17x17	WEV 17x17	WEO 17x17	CE 14x14
Maximum Assembly Average Initial Enrichment, wt % U235	5.00	5.00	5.00	5.00	5.00	5.00
Clad Material	Zr-4/Zirlo	Zr-4/Zirlo	M5	Zr-4/Zirlo	Zr-4/Zirlo	Zr-4/Zirlo
No of fuel rods	204	264	264	264	264	176
No of guide/instrument tubes	21	25	25	25	25	5
Assembly Length(3)	162.2	162.4	162.4	162.4	162.4	159.5
Max Uranium Loading (MTU)	467	467	476	467	467	385
Assembly Cross Section	8.424 x 8.424	8.426 x 8.426	8.425 x 8.425	8.426 x 8.426	8.426 x 8.426	8.25 x 8.25
Max Assembly Weight with Insert components(4)	1528	1575	1554	1533	1533	1450(5)

(1) Nominal values shown unless stated otherwise
(2) All dimensions are inches
(3) Includes allowance for irradiation growth
(4) Weights of TPAs and VSIs are enveloped by BPRAs
(5) Without NFAH

Table 12-3
Maximum Neutron and Gamma Source Terms

Parameter	MK BW 17x17
Gamma Source (γ/sec/DSC)	2.22E+17
Neutron Source (n/sec/DSC)	3.52E+10

Parameter	BPRA
Gamma Source (γ/sec/assy)*	2.30E+14
Decay heat (Watts/assy)**	9

* - 30GWD/MTU cooled 4 days
** - 30GWD/MTU cooled 5 years

Table 12-4
Fuel Qualification Table(s)

The Decay Heat (DH) in watts is expressed as:

$$F1 = A + B*X1 + C*X2 + D*X1^2 + E*X1*X2 + F*X2^2$$
$$DH = F1*Exp(\{[1-(5/X3)]*G\}*[(X3/X1)^H]*[(X2/X1)^I])$$

where,

- F1 Intermediate Function, basically the Thermal source at 5 year cooling
- X1 Assembly Burnup in GWD/MTU
- X2 Maximum Assembly Average Initial Enrichment in wt. % U-235 (max 5%, min: Zone 1- 1.5%, Zone 2 -1.6%, Zone 3- 2.5%)
- X3 Cooling Time in Years (min 5 yrs)

A = 13.69479 B=25.79539 C=-3.547739 D= 0.307917 E=-3.809025
F = 14.00256 G=-0.831522 H= 0.078607 I =-0.095900

Examples for Zone 1a -1050 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.50	32.8	37.2	40.7	43.7	48.1	55.2
2.50	34.7	39.2	42.7	45.6	50.0	57.0
3.00	35.5	40.1	43.6	46.5	51.0	57.9
3.50	36.2	40.9	44.5	47.4	52.0	58.9
4.00	36.8	41.5	45.3	48.3	52.8	59.9
4.50	37.2	42.1	45.9	49.0	53.7	60.0

Examples for Zone 1b -800 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.50	26.3	30.0	32.9	35.4	39.2	45.2
2.00	27.1	30.8	33.8	36.2	40.0	46.0
2.50	27.7	31.5	34.5	37.0	40.8	46.7
3.00	28.2	32.1	35.2	37.7	41.5	47.5
3.50	28.5	32.5	35.7	38.3	42.2	48.3
4.00	28.5	32.9	36.2	38.8	42.8	49.0
4.50	28.5	33.0	36.4	39.2	43.3	49.7

Table 12-4
Fuel Qualification Table(s) (concluded)
Examples for Zone 2 -1100 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years	10 Years	15 Years
1.60	34.2	39.8	42.4	45.4	50.0	57.3
2.50	36.0	40.6	44.2	47.2	51.7	58.9
3.00	36.9	41.5	45.2	48.2	52.8	59.9
3.50	37.6	42.4	46.1	49.1	53.7	60.0
4.00	38.3	43.1	46.9	50.0	54.7	60.0
4.50	38.7	43.8	47.7	50.8	55.6	60.0

Examples for Zone 3 -1500 watts (Burnup GWD/MTU)

Maximum Assembly Average Initial Enrichment (wt. % U-235)	5 Years	6 Years	7 Years	8 Years
3.50	47.9	53.5	57.8	60.0
4.00	48.9	54.6	59.0	60.0
4.25	49.4	55.1	59.5	60.0
4.50	49.9	55.6	60.0	60.0

Table 12-5
NFAH Thermal Qualification

Minimum Cooling Time (years)

NFAH	30 GWD/MTU	40 GWD/MTU	50 GWD/MTU	210 GWD/MTU
BPRA/VSI	5	7	9	-
TPA				2
Criteria: Insert decay heat ≤ 9 watts				

Table 12-6
B10 Specification for the NUHOMS®-32PTH Poison Plates

NUHOMS®-32PTH DSC Basket Type	Minimum B10 Areal Density, gm/cm^2	
	Natural or Enriched Boron Aluminum Alloy / Metal Matrix Composite (MMC) (Type I)	Boral® (Type II)
A	0.007	0.009
B	0.015	0.019
C	0.020	0.025
D	0.032	N/A
E	0.050	N/A

Table 12-7
Maximum Assembly Average Initial Enrichment for Intact and Damaged Fuel Loading

Assembly Class and Type[(1), (2)]	Maximum Assembly Average Initial Enrichment of U-235 as a Function of Soluble Boron Concentration and Fixed Poison Loading (Basket Type)				
	Basket Type	Minimum Soluble Boron Concentration			
		2000 ppm	2300 ppm	2400 ppm	2500 ppm
CE 14x14 Intact Fuel Assembly (without BPRA)	A	4.05	4.40	4.45	4.55
	B	4.55	4.90	5.00	-
	C	4.70	5.00	-	-
	D	5.00	-	-	-
	E	-	-	-	-
WE 15x15 WES 15x15 Intact Fuel Assembly (with and without BPRAs)	A	3.50	3.70	3.80	3.90
	B	3.80	4.10	4.20	4.30
	C	3.95	4.25	4.35	4.45
	D	4.20	4.50	4.70	4.80
	E	4.50	4.80	4.90	5.00
WE 17x17 WEV 17x17 WEO 17x17 MK BW 17x17 Intact Fuel Assembly (with and without BPRAs)	A	3.50	3.70	3.80	3.90
	B	3.80	4.10	4.20	4.30
	C	3.95	4.25	4.35	4.45
	D	4.20	4.50	4.60	4.70
	E	4.45	4.70	4.90	5.00
CE 14x14 Damaged Fuel Assembly (without BPRA)	A	3.90	4.20	4.25	4.35
	B	4.35	4.70	4.80	4.90
	C	4.50	4.85	4.95	5.00
	D	4.85	5.00	-	-
	E	5.00	-	-	-
WE 15x15 WES 15x15 Damaged Fuel Assembly (with and without BPRAs)	A	3.40	3.60	3.70	3.80
	B	3.75	4.00	4.10	4.20
	C	3.85	4.15	4.25	4.35
	D	4.10	4.40	4.50	4.60
	E	4.35	4.70	4.80	4.90
WE 17x17 WEV 17x17 WEO 17x17 MK BW 17x17 Damaged Fuel Assembly (with and without BPRAs)	A	3.40	3.60	3.70	3.80
	B	3.75	4.00	4.10	4.20
	C	3.85	4.15	4.25	4.35
	D	4.10	4.40	4.50	4.60
	E	4.30	4.65	4.80	4.90

Note 1: WE 15x15 bounds all 15x15
Note 2: WE 17x17 bounds all 17x17

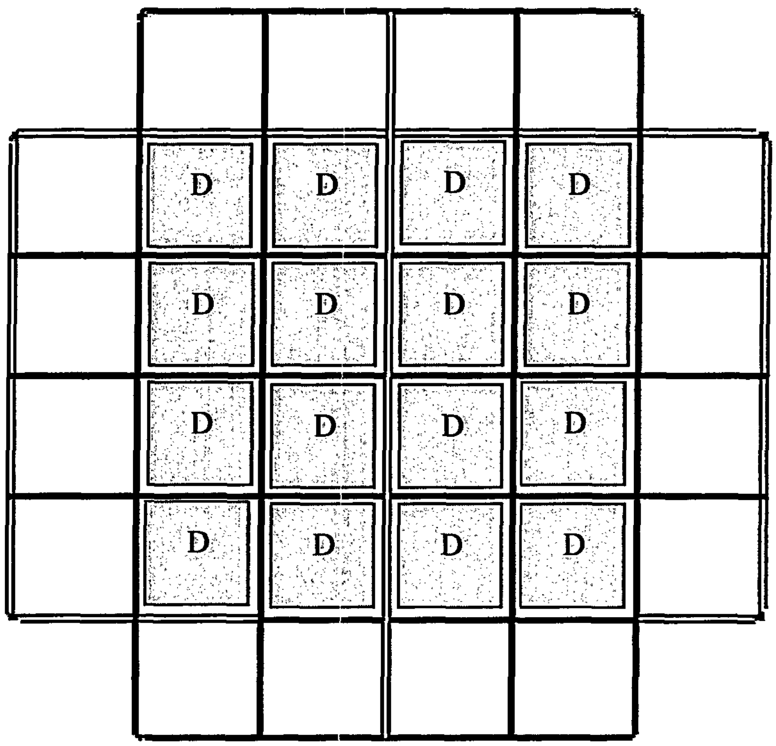
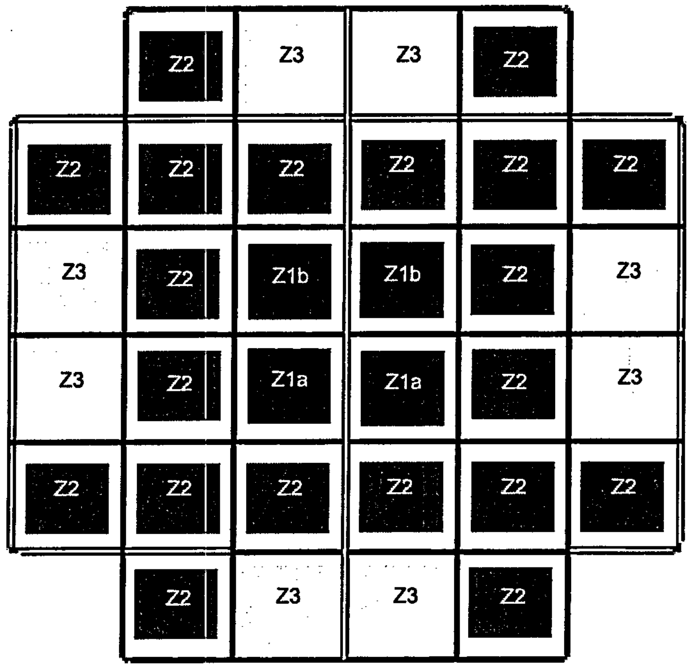


Figure 12-1
Damaged Fuel Assembly Locations



For CE 14x14 Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 33.8 kW
- 4 fuel assemblies in zone 1 with Q_{z1} ≤0.775 kW
- 20 fuel assemblies in zone 2 with Q_{z2} ≤ 1.068 kW
- 8 fuel assemblies in zone 3 with Q_{z3} ≤ 1.5 kW

For other Assemblies

- Q_{zi} is the maximum decay heat per assembly in zone i
- Total Decay Heat ≤ 34.8 kW
- 4 fuel assemblies in zone 1 with
  - total decay heat ≤ 3.2 kW
  - Q_{z1a} ≤ 1.05 kW in the lower compartments
  - Q_{z1b} ≤ 0.8 kW in the upper compartments
- 20 fuel assemblies in zone 2 with Q_{z2} ≤ 1.1 kW
- 8 fuel assemblies in zone 3 with Q_{z3} ≤ 1.5 kW

Figure 12-2
<u>Heat Load Zones</u>

B 12.3.1 32PTH DSC FUEL INTEGRITY

B 12.3.1.1 32PTH DSC Vacuum Drying Time (Duration) and Pressure

BASES

BACKGROUND

A 32PTH DSC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. A shield plug is then placed on the 32PTH DSC. Subsequent operations involve moving the 32PTH DSC to the decontamination area and removing water from the 32PTH DSC. After the 32PTH DSC shield plug is secured, vacuum drying of the 32PTH DSC is performed, and the 32PTH DSC is backfilled with helium. During normal storage conditions, the fuel assemblies are stored in the 32PTH DSC with an inert helium atmosphere, which is a better conductor than nitrogen or vacuum, which results in lower fuel clad temperatures and provides an inert atmosphere during storage conditions.

32PTH DSC vacuum drying is utilized to remove residual moisture from the cavity after the 32PTH DSC has been drained of water. Any water which was not drained from the 32PTH DSC evaporates from fuel or basket surfaces due to the vacuum. This vacuum drying operation is aided by the temperature increase due to the heat generation of the fuel.

APPLICABLE SAFETY ANALYSIS

The confinement of radioactivity during the storage of spent fuel in a 32PTH DSC is ensured by the use of multiple confinement barriers and systems. The barriers relied upon are the fuel pellet matrix, the fuel cladding tubes in which the fuel pellets are contained, and the 32PTH DSC in which the fuel assemblies are stored. Long-term integrity of the fuel cladding depends on storage in an inert atmosphere. This protective environment is accomplished by removing water from the 32PTH DSC and backfilling the 32PTH DSC with an inert gas. The removal of water is necessary to prevent phase change–related pressure increase upon heatup. Time limits on vacuum drying >23.2 kW per Procedure A, >16 kW per Procedure B, and > 22.4 kW heat loads are required for keeping the fuel cladding under the maximum temperature limits. This SAR evaluates and documents that the 32PTH DSC confinement boundary is not compromised due to any normal, off-normal or accident condition postulated (SAR Chapter 3 and 11 structural analyses) and the fuel clad temperature remains below allowable values (SAR Chapter 4).

LCO

A stable vacuum pressure of < 3 torr further ensures that all liquid water has evaporated in the 32PTH DSC cavity, and that the resulting inventory of oxidizing gases in the 32PTH DSC is below 0.25 volume %.

APPLICABILITY

This is applicable to all 32PTH DSCs.

ACTIONS

The actions specified require establishment of a helium pressure of at least 0.5 atmosphere within the time limits specified in the LCO. The timeframe specified applies to the vacuum drying operations and the helium backfill operations. If the required vacuum can not be established within the timeframe specified in the Condition column of the Actions table, a helium atmosphere (with a pressure of at least 0.5 atmosphere) is to be established within 6 hours or perform an assessment and implementation of corrective actions to return the 32PTH DSC to an analyzed condition or reflood the DSC submerging all fuel assemblies. The 15 psig limit in the action section is conservatively below the maximum analyzed blowdown pressure.

SURVEILLANCE REQUIREMENTS

Ensure a minimum oxidizing gas content.

REFERENCES

SAR Chapter 3 and 4

B12.3.1 32PTH DSC FUEL INTEGRITY

B 12.3.1.2 32PTH DSC Helium Backfill Pressure

BASES

BACKGROUND

A 32PTH DSC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. An inner top cover/shield plug is then placed on the 32PTH DSC. Subsequent operations involve moving the 32PTH DSC to the decontamination area and removing water from the 32PTH DSC. After the 32PTH DSC inner top cover/shield plug is welded, vacuum drying of the 32PTH DSC is performed, and the 32PTH DSC is backfilled with helium. During normal storage conditions, the 32PTH DSC is backfilled with helium, which is a better conductor than nitrogen or vacuum, which results in lower fuel clad temperatures. The inert helium environment protects the fuel from potential oxidizing environments.

APPLICABLE SAFETY ANALYSIS

Long-term integrity of the fuel cladding depends on storage in an inert atmosphere. SAR section 3.5 evaluates the effect of long term storage and short term temperature transients on fuel cladding integrity. Credit for the helium backfill pressure is taken to limit the potential for corrosion of the fuel cladding. SAR Chapter 4 evaluates the 32PTH DSC maximum pressure under normal, off-normal, and accident conditions.

LCO

32PTH DSC backpressure is maintained within a range of pressure that will ensure maintenance of the helium backfill pressure over time and will not result in excessive 32PTH DSC pressure in normal, off-normal and accident conditions.

APPLICABILITY

This specification is applicable to all 32PTH DSCs.

ACTIONS

The actions required and associated completion times are associated with the time limits established in specification 12.3.1.2. The total time for vacuum drying and helium backfill is specified in specification 12.3.1.2 as a function of 32PTH DSC heat load and operational procedure. These time limits are imposed to ensure that the 32PTH DSC fuel cladding will not exceed maximum allowable temperatures.

SURVEILLANCE REQUIREMENTS

To ensure that: (1) the atmosphere surrounding the irradiated fuel is a non-oxidizing inert gas; (2) the atmosphere is favorable for the transfer of decay heat.

REFERENCES

SAR Chapters 3 and 4

B12.3.1 32PTH DSC FUEL INTEGRITY

B 12.3.1.3 Transfer Cask Cavity Helium Backfill Pressure

BASES

BACKGROUND

A 32PTH DSC is placed in the spent fuel pool and loaded with fuel assemblies meeting the requirements of the Functional and Operating Limits. An inner top cover/shield plug is then placed on the 32PTH DSC. Subsequent operations involve moving the 32PTH DSC to the decontamination area and removing water from the 32PTH DSC. After the 32PTH DSC inner top cover/shield plug is welded, vacuum drying of the 32PTH DSC is performed, and the 32PTH DSC is backfilled with helium. The 32PTH DSC outer top cover plate is welded, and, if not previously done, the water drained from the transfer cask (TC) annulus. After installation of the TC lid, the TC cavity is backfilled with helium to assure adequate heat transfer which maintains the fuel cladding temperatures below the maximum allowable temperature.

APPLICABLE SAFETY ANALYSIS

Long-term integrity of the fuel cladding depends on storage in an inert atmosphere and maintaining fuel cladding temperature below an acceptable limit. SAR Chapter 4 evaluates the 32PTH DSC temperatures under normal, off-normal, and accident conditions.

LCO

The OS187H cavity is maintained within a range of pressure that will ensure maintenance of the helium backfill pressure over the transfer time and will not result in excessive pressure in normal, off-normal and accident conditions. The cavity helium backfill must commence within 12 hours after completion of DSC vacuum drying.

APPLICABILITY

This specification is applicable to OS187H transfer cask with loaded 32PTH DSC in transfer condition.

ACTIONS

Should the helium pressure not meet the requirements of this specification, the TC/32PTH DSC must be returned to an analyzed condition or unloaded.

SURVEILLANCE REQUIREMENTS

To ensure the transfer cask cavity is in a helium environment prior to transfer operations in the TC.

REFERENCES

SAR Chapter 4

CHAPTER 13
QUALITY ASSURANCE

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13. QUALITY ASSURANCE

TN's Quality Assurance (QA) program has been established in accordance with the requirements of 10CFR 72, Subpart G [1]. The QA program applies to the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of the NUHOMS® HD System and components identified as "important to safety" and "safety related." These components and systems are defined in Chapter 2 of the SAR.

13.1 Introduction

The complete description and specific commitments of the TN QA program are contained in the TN QA Program Description Manual [2]. This manual has been approved by the Nuclear Regulatory Commission (NRC) for performing 10CFR 72 related activities. Changes to the TN QA program shall be submitted to the NRC for approval within thirty (30) days of implementation. Changes to the TN QA program which decrease or delete previously approved QA commitments shall be submitted to the NRC for approval prior to implementation.

The matrix in Table 13-1 shows the 10CFR 72, Subpart G criteria and the respective sections of the TN QA Program Description Manual and TN Implementing Procedures Manual [3] that address the criteria.

Figure 13-1 shows the organization structure for the NUHOMS® HD System project.

13.2 "Important-to-Safety & "Safety Related" NUHOMS® HD System Components

TN will apply its QA program to the NUHOMS® HD System components within its scope of responsibility which are defined as "important to safety" and " safety related" as delineated in Section 2.5. QA procedures are used to establish the quality category of components, subassemblies, and piece parts according to each item's importance to safety.

In Section 2.5, each component is identified as "important to safety," "not important to safety," or "safety related". During the design process, items that are considered "important to safety" are further categorized using a graded quality approach. When the graded quality approach is used, a list shall be developed for each "important to safety" item which includes an assigned quality category consistent with the item's importance to safety. Quality categories are determined based on the following and the guidance provided in NUREG/CR-6407 [4]:

Category A items are critical to safe operation. These items include structures, components and systems whose failure or malfunction could directly result in a condition adversely affecting public health and safety. This would include conditions such as loss of primary containment with subsequent release of radioactive material, loss of shielding or an unsafe geometry compromising criticality control.

Category B items have a major impact on safety. These items include structures, components, and systems whose failure or malfunction could indirectly result in a condition adversely affecting public health and safety. An unsafe operation could result only if a primary event occurs in conjunction with a secondary event or other failure or environmental occurrence.

Category C items have a minor impact on safety. These items include structures, components, and systems whose failure or malfunction would not significantly reduce the packaging effectiveness and would be unlikely to create a condition adversely affecting public health and safety.

For "safety related" items the Quality Assurance program is applied as described for Category A items. The Quality Assurance program as described in Section 13.3 is applied to each "important to safety" graded category and is limited as follows.

Category A

A. The design is based on the most stringent industrial codes or standards. Design verification shall be accomplished by prototype testing or formal design review.

B. Vendors for items and services for this category may only be selected from the Approved Suppliers List.

C. TN suppliers and sub-tier suppliers must have a QA program based on applicable criteria in Subpart G to 10CFR 72, or equivalent.

D. Complete traceability of raw materials and the use of certified welders and processes is required.

E. All personnel performing Quality Assurance related inspections, tests, and examinations shall be qualified and certified in accordance with the requirements of the QA program.

F. Only qualified and certified auditors and lead auditors shall perform audits.

G. TN QA personnel shall be required to inspect and/or approve supplier fabricated components prior to authorizing shipment release.

H. Welding consumables shall be procured as a Category A item if the intended use is unknown. If purchased for a specific Category B or C application, the material must be identified and its use restricted to fabrication of the same level.

Category B

A. The design is based on the most stringent industrial codes and standards. But design verification may be accomplished by use of alternate calculations or computer codes.

B. The procurement of items may be from suppliers on the Approved Suppliers List or QA program requirements for the supplier may be based upon the inspection and test requirements of the procured item.

C. Traceability of materials is not required; however, specified welds require completion by qualified, certified welders.

D. Quality Assurance verification activities shall be performed by personnel qualified and certified in accordance with the requirements of the QA program.

E. Only lead auditor personnel require certification in accordance with the QA program.

Category C

A. Items may be purchased from a catalog or "off-the-shelf."

B. When received, the item shall be identified and checked for compliance with the purchase order and for damage.

Items not considered important-to-safety will be controlled in accordance with good industrial practices.

If a utility elects to perform construction, and has an NRC approved QA program (10CFR 50) [5]that is equivalent to or exceeds TN's program, then the utility QA program is considered an acceptable substitute for their scope of responsibility.

13.3 Description of TN 10CFR 72, Subpart G QA Program

13.3.1 Project Organization

The NUHOMS® HD System has been designed by a dedicated TN project organization.

QA duties are performed by the TN project organization, the QA Manager, and QA Specialists.

The organization structure for the NUHOMS® HD System project is presented in Table 13-1. A description of TN's organizational structure, functional responsibilities, levels of authority, and lines of internal and external (client and supplier) communication may be found in the TN QA Program Description Manual.

Project QA controls are determined by the Project Manager and approved by QA. All Project Plans, regardless of the indicated applicability of QA requirements, are reviewed by QA to assure that QA controls are commensurate with the specific activity, item complexity, importance to safety and client-imposed contractual requirements.

Project personnel are indoctrinated, trained, and qualified in accordance with the TN QA program.

13.3.2 QA Program

TN will apply the QA program to components defined in Section 2.5 as "important to safety" and "safety related" in accordance with the TN QA Program Description Manual.

TN has established and implemented a QA program for the control of quality in the design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of storage containers for nuclear products. Training and/or evaluation of personnel qualifications in accordance with written procedures are required for personnel performing activities affecting quality. The QA program assures that all quality requirements, engineering specifications and specific provisions of any package design approval are met. Those characteristics critical to safety are emphasized.

The TN QA Manager regularly evaluates the TN QA program for adherence to the 18 point criteria in scope, implementation and effectiveness. Further, the TN President requires that the QA program, including the QA Program Description Manual and Implementing Procedures Manual, be implemented and enforced on all applicable projects at TN.

13.3.3 Design Control

"Important to safety" and "safety related" NUHOMS® HD System design activities shall be implemented in accordance with the TN QA Manual. Design verification will be performed by a competent individual with the appropriate skill level. However, this individual's skill level may not be the same as the originator but must be equivalent.

Errors and deficiencies in the design, including the design process, are documented in the form of Corrective Action Reports.

Industry standards and specifications are used for the selection of suitable materials, parts, equipment and processes for "important to safety" and "safety related" structures, systems, or components as defined in the various chapters and sections of this SAR.

13.3.4 Procurement Document Control

Procurement documents are prepared in accordance with the TN QA program which delineates the actions to be accomplished in the preparation, review, approval, and control of procurement documents. Review and approval of procurement documents by QA are documented on the procurement documents prior to release to assure the adequacy of quality requirements stated therein. This review determines that quality requirements are correctly stated, inspectable, and controllable; that there are adequate acceptance and rejection criteria; and that the procurement document has been prepared, reviewed, and approved in accordance with QA program requirements. Refer to Section 13.2 for supplier selection requirements.

The procurement documents shall identify the documentation required to be submitted for information, review, or approval by TN or TN's client. The time of submittal shall also be established. When TN requires the supplier to maintain specific QA records, the retention times and disposition requirements shall be prescribed.

13.3.5 Procedures, Instructions, and Drawings

As required by the TN QA program, activities affecting quality are prescribed in approved, written procedures, instructions, or drawings and these procedures, instructions, and drawings shall be followed.

13.3.6 Document Control

The issuance, distribution, and receipt of documents which prescribe activities affecting quality are controlled in accordance with the TN QA program. Controlled documents include, but are not limited to, the TN design specifications and criteria documents, drawings, instructions, and test procedures.

The individuals or groups responsible for reviewing, approving, and issuing documents and revisions thereto are identified in the "Responsibilities" sections of the TN QA implementing procedures.

13.3.7 Control of Purchased Items and Services

The control of purchased items and services shall be implemented in accordance with the TN QA program.

Surveillance of subcontracted activities is planned and performed in accordance with written procedures to assure conformance to the purchase order. These procedures provide for instructions that specify the characteristics to be witnessed, inspected or verified, and accepted;

the method of surveillance and the extent of documentation required; and those responsible for implementing these instructions.

TN suppliers shall furnish documentation that identifies any procurement requirements which have not been met, together with a description of those nonconformances dispositioned as "use-as-is" or "repair."

Documentation from TN suppliers which demonstrates compliance with procurement requirements (such as material test reports, NDE results, performance test results, etc.) is periodically evaluated by audits, independent inspections, or tests as necessary to assure its validity.

13.3.8 Identification and Control of Materials, Parts, and Components

Materials, parts, and components shall be identified and controlled in accordance with the TN QA program. Hardware identification requirements are determined during generation of design drawings and specifications such that the location and method of identification do not affect the form, fit, function, or quality of the item being identified.

13.3.9 Control of Special Processes

The control of special processes, such as nondestructive examination, chemical cleaning, welding, and heat treating shall be performed in accordance with the TN QA program.

13.3.10 Inspection

Receipt inspections, and in-process and final inspections of TN-fabricated, constructed, or erected items, systems, components, or structures shall be performed in accordance with the TN QA program.

13.3.11 Test Control

Test control shall be accomplished in accordance with the TN QA program.

13.3.12 Control of Measuring and Test Equipment

The TN QA program defines the requirements for calibration of measuring and test equipment. Calibration is against certified measurement standards which have known relationships to national standards, where such standards exist. Where such standards do not exist, the basis for calibration shall be documented.

13.3.13 Handling, Storage and Shipping

Handling, storage, and shipping shall be conducted in accordance with the TN QA program. Special handling, preservation, storage, cleaning, packaging, and shipping requirements are established and accomplished by qualified individuals in accordance with predetermined work and inspection instructions.

13.3.14 Inspection and Test Status

The use of inspection and test status tags shall be implemented in accordance with the TN QA program.

13.3.15 Control of Nonconforming Items

The TN QA program defines the requirements and assigns the responsibilities for the control, identification, segregation, documentation, and close-out of nonconforming items to prevent their inadvertent installation or use in fabrication, construction, or erection.

Nonconformance reports identify the item description and quantity, the disposition of the nonconformance, the inspection requirements, and signature approval of the disposition. They are periodically analyzed to show quality trends and help identify root causes of nonconformances. Significant results are reported to responsible management for review and assessment.

Nonconforming items are segregated from acceptable items and tagged to prevent inadvertent use until properly dispositioned and closed out.

13.3.16 Corrective Action

Corrective action for conditions adverse to quality shall be taken in accordance with the TN QA program. For significant conditions adverse to quality the cause is determined and action to preclude recurrence is taken and reported to the appropriate levels of management.

13.3.17 Records

The TN QA program defines the scope of the records program such that sufficient records are maintained to provide documentary evidence of the quality of items and activities affecting quality.

13.3.18 Audits and Surveillances

A comprehensive system of planned and documented audits, including audits of suppliers and site construction activities, verifies compliance with all aspects of the TN QA program and determines the effectiveness of the program.

Audits are performed by certified lead auditors and are planned, performed, and documented in accordance with the TN QA program.

Unannounced QA surveillances may be performed on activities affecting quality by the TN QA Manager, or his designee, on an as-needed basis to further assure compliance with QA requirements.

13.4 Conditions of Approval Records

As required by 10CFR 72, Subpart L, TN will establish and maintain records for each storage component fabricated under a certificate of compliance as required by §72.234(d). The records will be available for inspection as required by §72.234(e). Written procedures and appropriate tests will be established prior to use of the storage components which will be provided to each NUHOMS® HD System user as required by §72.234(f).

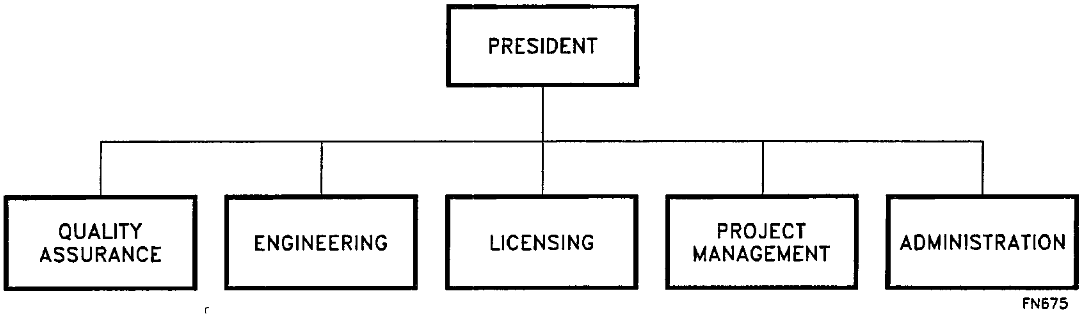
13.5 Supplemental Information

13.5.1 References

1. CFR Title 10, Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.
2. "Transnuclear Quality Assurance Program Description Manual," current revision.
3. "Transnuclear Quality Implementing Procedures Manual," current revision.
4. NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," February 1996.
5. CFR Title 10, Part 50, Domestic Licensing of Production and Utilization Facilities.

Table 13-1
TN QA Program Description Manual and Implementing Procedures Manual

10CFR 72, Subpart G	QA Program	
.142	1.0	Organization
.144	2.0	QA Program
.146	3.0	Design Control
.148	4.0	Procurement Document Control
.150	5.0	Procedures, Instructions, and Drawings
.152	6.0	Document Control
.154	7.0	Control of Purchased Items and Services
.156	8.0	Identification and Control of Materials, Parts, and Components
.158	9.0	Control of Special Processes
.160	10.0	Inspection
.162	11.0	Test Control
.164	12.0	Control of Measuring and Test Equipment
.166	13.0	Handling, Storage, and Shipping
.168	14.0	Inspection and Test Status
.170	15.0	Control of Nonconforming Items
.172	16.0	Corrective Action
.174	17.0	Records
.176	18.0	Audits



Notes:
1. Licensing may report to Engineering.
2. Administration activities may report to the various other organizations.

Figure 13-1
Project Organization Chart