FINAL SAFETY EVALUATION REPORT

TRANSNUCLEAR, INC.

STANDARDIZED NUHOMS® HORIZONTAL MODULAR STORAGE

SYSTEM FOR IRRADIATED NUCLEAR FUEL

DOCKET No. 72-1004

AMENDMENT NO. 10

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SAFETY EVALUATION REPORT

Docket No. 72-1004
Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel
Certificate of Compliance No. 1004
Amendment No. 10

SUMMARY

By application dated January 12, 2007, as supplemented on February 21, 2007; March 15, 2007; July 3, 2007; November 7, 2007; January 18, 2008; May 23, 2008; June 25, 2008; July 28, 2008; and October 8, 2008, Transnuclear, Inc. (TN) requested approval of an amendment, under the provisions of 10 CFR Part 72, Subpart K and L, to Certificate of Compliance (CoC) No. 1004 for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel.

TN requested a change to the CoC, including its attachments, and revision of the Final Safety Analysis Report (FSAR). TN requested the following changes:

- Addition of a dry shielded canister (DSC) designated the NUHOMS® 61BTH DSC and accompanying changes to accommodate this DSC.

- Addition of a DSC designated the NUHOMS® 32PTH1 DSC and accompanying changes to accommodate this DSC. TN also added an alternate high-seismic option of the horizontal storage module (HSM) for storing the 32PTH1 DSC.

- Allow storage of Westinghouse 15x15 Partial Length Shield Assemblies in the NUHOMS®-24PTH DSC.

- Allow storage of Control Components in the NUHOMS® 32PT DSC.

The NUHOMS® 61BTH system is designed to store up to 61 intact (or up to 16 damaged and the balance intact) boiling water reactor fuel assemblies with a maximum assembly average initial enrichment of 5.0 wt.%, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 3.0 years. The NUHOMS® 61 BTH system is designed to accommodate a maximum heat load of up to 31.2 kW per canister.

The NUHOMS® 32PTH1 system is designed to store up to 32 intact (or up to 16 damaged and the balance intact) pressurized water reactor fuel assemblies with a maximum assembly average initial enrichment of 5.0 wt.%, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 3.0 years. The NUHOMS® 32PTH1 system is designed to accommodate a maximum heat load of up to 40.8 kW per canister.

The Nuclear Regulatory Commission (NRC) staff has reviewed the application using the guidance provided in NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems,” January 1997. Based on the statements and representations in the application, as supplemented, the staff concludes that the TN Standardized NUHOMS® System, as amended, meets the requirements of 10 CFR Part 72.

1 GENERAL DESCRIPTION

The objective of the review of the general description of the Amendment 10 to the Standardized NUHOMS® System is to ensure that TN has provided a non-proprietary description that is adequate to familiarize reviewers and other interested parties with the pertinent features of changes to the system.

1.1 General Description and Operations Features

The Standardized NUHOMS® System is described in the Updated Final Safety Analysis Report (UFSAR) (Ref. 1) for Certificate of Compliance (CoC) 1004. The scope of Amendment 10 to CoC 1004 includes four separate changes. These changes are:

- Addition of a dry shielded canister (DSC) designated the NUHOMS® 61BTH DSC and accompanying changes to accommodate this DSC. The two digits after the NUHOMS® designation refer to the number of fuel assemblies stored in the DSC, the character B or P is used to designate the type of fuel (either boiling water reactor, or pressurized water reactor, respectively), T is used to designate that the DSC is intended for transportation in a 10 CFR Part 71 approved package, and H is used to designate that the design is qualified for fuel with burnup greater than 45 GWd/Mtu. The NUHOMS® 61BTH system is described in Appendix T of the Standardized NUHOMS® Updated Final Safety Analysis Report (UFSAR).

- Addition of a DSC designated the NUHOMS® 32PTH1 DSC and accompanying changes to accommodate this DSC. TN also added an alternate high-seismic option to the horizontal storage module for storing the 32PTH1 DSC. The NUHOMS® 32PTH1 system is described in Appendix U of the Standardized NUHOMS® UFSAR.

- Allow storage of Westinghouse 15x15 Partial Length Shield Assemblies in the NUHOMS® 24PTH DSC. Appendix P of the Standardized NUHOMS® UFSAR describes the NUHOMS® 24PTH System. Amendment 10 to CoC 1004 describes the changes to Appendix P to support storage of the Westinghouse 15x15 Partial Length Shield Assemblies in the NUHOMS® 24PTH DSC.

- Allow storage of control components in the NUHOMS® 32PT DSC. Appendix M of the Standardized NUHOMS® UFSAR describes the NUHOMS® 32PT System. Amendment 10 to CoC 1004 describes the changes to Appendix M to support storage of control components in the NUHOMS® 32PT DSC.

1.1.1 61BTH System

The NUHOMS® 61BTH system is designed to store up to 61 intact (or up to 16 damaged and the balance intact) boiling water reactor (BWR) fuel assemblies with a maximum assembly average initial enrichment of 5.0 wt.%, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 3.0 years. The NUHOMS® 61BTH system is designed to accommodate a maximum heat load of up to 31.2 kW per canister. The 61BTH DSC is stored in either the previously approved Standardized horizontal storage module (HSM) described in the updated final safety analysis report (UFSAR) or in a slightly modified version of the previously approved HSM-H module described in Appendix P of the UFSAR. The 61BTH DSC is transferred to the HSM in either the previously approved OS197/OS197H Transfer Cask (TC) described in the UFSAR or in a slightly modified version of the previously approved OS197FC TC described in Appendix P of the UFSAR. This modified version of the TC is designated as OS197FC-B TC.

1.1.2 32PTH1 System

The NUHOMS® 32PTH1 system is designed to store up to 32 intact (or up to 16 damaged and the balance intact) pressurized water reactor (PWR) fuel assemblies with a maximum assembly average initial enrichment of 5.0 wt.%, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 3.0 years. The NUHOMS® 32PTH1 system is designed to accommodate a maximum heat load of up to 40.8 kW per canister. The 32PTH1 DSC is stored in a modified version of the previously approved HSM-H module described in Appendix P of the UFSAR. The diameter of the HSM-H access door is increased to accommodate the larger diameter of the 32PTH1 DSC, with spacers provided to accommodate the various DSC lengths of the 32PTH1 DSC. In addition, an alternate "high-seismic" option of the HSM-H, designated as HSM-HS, is added to the UFSAR for storing 32PTH1 DSC. The HSM-HS module is qualified for 1.0g horizontal and 1.0g vertical acceleration levels.

1.1.3 Changes to the 24PTH DSC

Amendment 10 to CoC 1004 adds Westinghouse 15x15 Partial Length Shield Assemblies (PLSAs) to the authorized content of the NUHOMS® 24PTH DSC described in Appendix P of the UFSAR. It also includes additional low enrichment burnups and cooling time options in the fuel qualification table for the 24PTH DSC.

1.1.4 Changes to the 32PT DSC

Amendment 10 to CoC 1004 expands the authorized content of the NUHOMS® 32PT DSC described in Appendix M of the UFSAR to include pressurized water reactor (PWR) fuel assemblies with Control Components (CCs) such as Burnable Poison Rod Assemblies (BPRAs), Thimble Rod Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Vibration Suppressor Inserts (VSIs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Neutron Source Assemblies (NSAs) and Neutron Sources. All PWR fuel assemblies currently authorized for storage in a 32PT DSC may store Control Components except Combustion Engineering (CE) 15x15 fuel assemblies.

An additional change is included that seeks to withdraw the analysis that determines the maximum allowable assembly average initial enrichment as a function of soluble boron concentration and Poison Rod Assembly (PRA) loading for the Westinghouse 14, Combustion Engineering (CE) 14 and CE 15 assembly classes with the 20-poison plate basket in the NUHOMS® 32PT DSC. This basket design has been determined to be uneconomical and therefore this detailed evaluation is removed for simplicity.

1.1.5 Changes to Standardized NUHOMS® Technical Specifications

A brief description for each of the changes to the Technical Specifications is provided in the following paragraphs.

- Add a clarification to paragraph 1.0, "Introduction", to clarify that the generic term "HSM" as used in the document includes both the Standardized HSM and HSM-H, unless specifically called out otherwise. Add a similar clarification to clarify that the generic term "TC" as used in the document includes both the Standardized transfer cask and the OS197 type transfer cask, unless specifically called out otherwise. This is a clarification of the terminology used in the Technical Specifications.

- Revise paragraph 1.1.1, item 1, to clarify that the 100°F maximum daily average temperature is applicable to all DSCs except the 32PTH1 DSC. The 32PTH1 DSC is designed for a 106°F maximum daily average temperature. In addition, clarify that the maximum yearly average temperature of 70°F is applicable to the 24P, 52B and 61BT DSCs as documented in the FSAR.

- Revise paragraph 1.1.1, item 2, to include the applicability of the specified off-normal ambient temperature limits to the NUHOMS® 61BTH and NUHOMS® 32PTH1 DSCs being added.

- Revise paragraph 1.1.1, item 3, to specify the different seismic levels applicable to the systems using the Standardized HSM and HSM-H. The increased seismic levels for systems using the HSM-H and HSM-HS modules are consistent with the structural analysis provided in this submittal.

- Add a new condition which specifies a minimum copper content requirement for any load bearing carbon steel component of the DSC support structure of a HSM-H. This restriction applies if the Independent Spent Fuel Storage Installation (ISFSI) is located in a coastal salt water marine atmosphere.

- Revise paragraphs 1.1.2 and 1.1.7 to reflect the addition of 61BTH and 32PTH1 systems.

- Revise paragraph 1.1.10 to be consistent with the structural analysis presented in Appendix U of the FSAR that at least three HSM-HS modules must be connected with each other.

- Revise "Limit/Specification" "Action," and "Bases" sections of Specification 1.2.1, "Fuel Specification", to add reference to Tables 1-1t, 1-1u, 1-1aa, and 1-1bb. Table 1-1t and Table 1-1 u specify the applicable parameters for each type of BWR fuel allowed to be stored in the NUHOMS® 61BTH system. Table 1-1aa and Table 1-1bb specify the applicable parameters for each type of Pressurized Water Reactor (PWR) fuel allowed to be stored in the NUHOMS® 32PTH1 system.

- Revise the "Bases" section of Specification 1.2.1, "Fuel Specification", to provide the supporting bases for the storage of authorized BWR and PWR fuel in the NUHOMS® 61BTH and 32PTH1 DSCs respectively. Add a cross reference to FSAR Appendices T and U which provide the safety analyses for the 61BTH and the 32PTH1 systems. In addition, add the supporting bases for the addition of Control Components to the content of the NUHOMS® 32PT DSC.

- Revise the "Bases" section of Specification 1.2.1 "Fuel Specification", to include specific subsections of FSAR Chapters T.9 and U.9 related to the qualification and testing requirements of the neutron absorber materials used in 61BTH and 32PTH1 DSCs respectively. This cross-reference makes the listed FSAR sections an integral part of the Technical Specifications.

- Revise Table 1-le and Table 1-1f to reflect the various parameters applicable to Control Components allowed for storage in the NUHOMS® 32PT DSC.

- Revise Table 1-1g to reflect the modifications to the soluble boron loading specification for storage of Control Components with the various fuel assemblies authorized for storage in the NUHOMS® 32PT DSC. In addition, revise Table 1-1g to explicitly show the applicable criticality requirements for fuel assemblies with or without Control Components.

- Revise Table 1-1l and Table 1-1m to specify the parameters related to the addition of WE 15x15 PLSAs for storage in the NUHOMS® 24PTH DSC. Revise the description of Reconstituted Assemblies to be consistent with the shielding analysis provided in UFSAR Chapter P.5.

- Revise Table 1-1n to reflect the generic definition of Control Components.

- Revise Table 1-1r to correct a spelling error for the term "areal density".

- Add Table 1-1t to specify the acceptable parameters for each type of intact or damaged BWR fuel assembly class allowed to be stored in the NUHOMS® 61BTH DSC.

- Add Table 1-1u to specify the acceptable BWR fuel assembly design characteristics of fuel authorized for storage into the NUHOMS® 61BTH DSC.

- Add Table 1-1v to specify the maximum lattice average enrichment of intact fuel allowed for storage in the NUHOMS® 61BTH DSC as a function of the DSC/basket type and minimum B10 loading in the poison plates.

- Add Table 1-1w to specify the maximum lattice average enrichment of damaged fuel allowed for storage in the NUHOMS® 61BTH DSC as a function of the DSC/basket type and minimum B10 loading in the poison plates.

- Add Table 1-1aa to specify the acceptable parameters for each type of intact PWR fuel assembly class allowed to be stored in the NUHOMS® 32PTH1 DSC.

- Add Table 1-1bb to specify the acceptable PWR fuel assembly design characteristics of fuel authorized for storage into the NUHOMS® 32PTH1 DSC.

- Add Table 1-1cc to specify the maximum assembly average initial enrichment for which each intact fuel assembly class (with or without CCs) is qualified as a function of soluble boron concentration and basket type (fixed boron) for storage in the NUHOMS® 32PTH1 DSC.

- Add Table 1-1dd to specify the maximum assembly average initial enrichment for which each damaged fuel assembly class (with or without CCs) is qualified as a function of soluble boron concentration and basket type (fixed boron) in the NUHOMS® 32PTH1 DSC.

- Add Table 1-1ee to specify the thermal and radiological characteristics for Control Components authorized for storage in the NUHOMS® 32PT and NUHOMS® 32PTH1 DSC.

- Add Table 1-1ff to specify the minimum B10 content of the poison plates as a function of the various NUHOMS® 32PTH1 basket types.

- Revise Tables 1-3a through 1-3h to include additional initial enrichments, to meet client needs.

- Add Fuel Qualification Tables 1-4a, 1-4b, 1-4c, 1-4d, 1-4e and 1-4f for the NUHOMS® 61BTH DSC.

- Add Fuel Qualification Tables 1-5a, 1-5b, 1-5c, 1-5d, 1-5e and 1-5f for the NUHOMS® 32PTH1 DSC.

- Add Figures 1-17, 1-18, 1-19, 1-20, 1-21, 1-22, 1-23 and 1-24 to specify the eight heat load zoning configurations analyzed for the NUHOMS® 61BTH DSC.

- Add Figure 1-25 to specify the locations inside the NUHOMS® 61BTH DSC where up to 16 damaged fuel assemblies may be stored.

- Add Figures 1-26, 1-27, and 1-28 to specify the three heat load zoning configurations analyzed for the NUHOMS® 32PTH1 DSC.

- Revise the Title and "Applicability" subsections of Specification 1.2.3a to extend the applicability of this specification to the NUHOMS® 61BTH and NUHOMS® 32PTH1 DSC.

- Revise the Title, "Applicability" and the "Bases" sections of Specification 1.2.4a to extend the applicability of this specification to the NUHOMS® 61BTH and NUHOMS® 32PTH1 DSC.

- Add a new Specification 1.2.7e, entitled "HSM-H Dose Rates with a Loaded Type 2 61BTH DSC Only", to specify the limiting doses rates due to the storage of a loaded Type 2 61BTH DSC inside the HSM-H.

- Add a new Specification 1.2.7f, entitled "HSM or HSM-H Dose Rates with a Loaded Type 1 61BTH DSC Only", to specify the limiting doses rates due to the storage of a loaded Type 1 61BTH inside the HSM or HSM-H.

- Add a new Specification 1.2.7g, entitled "HSM-H Dose Rates with a Loaded 32PTH1 DSC Only", to specify the limiting doses rates due to the storage of a loaded 32PTH1 DSC inside the HSM-H.

- Revise the Title of Specification 1.2.8 to include Type 1 61BTH DSC, since this DSC is qualified for storage in the Standardized HSM based on the shielding analysis provided Appendix T of the FSAR.

- Add a new specification 1.2.8b, entitled "HSM-H Maximum Air Exit Temperature with a Loaded 61BTH DSC", to specify the limiting air exit temperature due to the storage of a either a Type 1 or Type 2 NUHOMS® 61BTH DSC inside the HSM-H.

- Add a new specification 1.2.8c, entitled "HSM-H Maximum Air Exit Temperature with a Loaded 32PTH1 DSC", to specify the limiting air exit temperature due to the storage of a NUHOMS® 32PTH1 DSC inside the HSM-H.

- Add a new Specification 1.2.11d, entitled "Transfer Cask Dose Rates with a Loaded 61BTH DSC", to specify the limiting doses rates due to the transfer of a loaded 61BTH DSC inside the Transfer Cask.

- Add a new Specification 1.2.11e, entitled "Transfer Cask Dose Rates with a Loaded 32PTH1 DSC", to specify the limiting doses rates due to the transfer of a loaded 32PTH1 DSC inside the Transfer Cask.

- Revise the Title, Limit No. 1, and Bases of Specification 1.2.14, entitled "TC/DSC Transfer Operations at High Ambient Temperatures" to clarify that this Specification applies to all currently licensed systems (24P, 52B, 61BT, 32PT, 24PHB, and 24PTH DSCs) and the NUHOMS® 61BTH DSC. This clarification is needed since the new 32PTH1 system is designed for a maximum ambient temperature of 106°F as discussed in the next bullet item.

- Add a new Specification 1.2.14a, entitled "TC/DSC Transfer at High Ambient Temperatures (32PTH1 DSC Only)" to specify the maximum ambient temperature limit of 106°F for the NUHOMS® 32PTH1 system.

- Add a new Specification 1.2.15d, entitled "Boron Concentration in the DSC Cavity Water for the 32PTH1 Design Only", to specify the minimum boron concentration required during loading of the NUHOMS® 32PTH1 system.

- Revise the Limit No.2 of Specification 1.2.17b to correct a spelling error in the term "vacuum drying".

- Add a new Specification 1.2.18a, entitled "Time Limit for Completion of Type 2 61BTH DSC Transfer Operation" to specify the limits for the completion of transfer of a loaded NUHOMS® 61BTH DSC.

- Add a new Specification 1.2.18b, entitled "Time Limit for Completion of 32PTH1 DSC Transfer Operation" to specify the limits for the completion of transfer of a loaded NUHOMS® 32PTH1 DSC.

- Revise the bases section of Specification 1.3.1 to add FSAR Appendices T and U which provide the analysis for the storage of NUHOMS® 61BTH and NUHOMS® 32PTH1 DSCs inside a HSM-H. In addition, replace the term "40 hours limit" with "analyzed time limit" to describe the time limit in a generic manner.

- Update Table 1.3.1 to reflect the changes as described above.

1.1.6 Changes to Standardized NUHOMS® Certificate of Compliance

In the CoC for Amendment 9, Condition 6 stated in part that all Standardized NUHOMS® Systems must be fabricated and used in accordance with CoC No. 1004 Amendment 9. This Condition has been deleted. General licensees may use either the current issue of the certificate or previously approved amendments of the certificate for storage under the provisions of 10 CFR 72.10.

1.2 Drawings

1.2.1 Equivalent Materials - 61BTH and 32PTH1 System Drawings

The TN canister designs which are the subject of this amendment are all of conventional construction methods and materials for a spent fuel storage canister. In order to provide manufacturing flexibility, the applicant has specified that “equivalent” or alternate materials may be used for fabrication of certain specified canister components. The allowable equivalent materials or material standards vary depending upon which specification governs the normally specified material(s).

For non-ASME Code materials, TN specifies ASTM as the governing standard for materials used to fabricate components which are not important to safety. For this class of materials, equivalent materials shall have yield and ultimate strength equal to or greater than the specified ASTM material, allowing for metric conversion round-off, and essentially the same chemistry as the specified ASTM material. Equivalent materials for ASTM materials may be produced to foreign standards in lieu of ASTM standards. TN approval is required for equivalent material selections.

For specified ASME Code materials, which are used for ITS components, only other ASME materials may used. Specific alternate ASME Code materials have been added to the drawings where needed.

The staff finds the applicant's specification of alternate materials to be acceptable.

1.2.2 61BTH and 32PTH1 System Drawings

Appendix T, Chapter 1 of the UFSAR contains the drawings for the NUHOMS® 61BTH System, including drawings of the structures, systems and components (SSC) important to safety. The staff determined that the drawings contain sufficient detail on dimensions, materials, and specifications to allow for a thorough evaluation of the NUHOMS® 61BTH System. Specific SSC are evaluated in Sections 3 through 12 of this SER.

Appendix U, Chapter 1 of the UFSAR contains the drawings for the NUHOMS® 32PTH1 System, including drawings of the structures, systems, and components (SSC) important to safety. The staff determined that the drawings contain sufficient detail on dimensions, materials, and specifications to allow for a thorough evaluation of the NUHOMS® 32PTH1 System. Specific SSC are evaluated in Sections 3 through 12 of this SER.

1.3 DSC Contents

The revisions and changes to the DSC contents are described below.

1.3.1 61BTH DSC Contents

The NUHOMS® 61BTH system is designed to store up to 61 intact (including reconstituted) or up to 16 damaged and balance intact, 7x7, 8x8, 9x9, or 10x10 BWR fuel assemblies manufactured by General Electric, Exxon/ANF, or Framatome ANP, or equivalent reload fuel. The fuel to be stored is limited to a maximum lattice average initial enrichment of 5.0 wt.%, a maximum assembly average burnup of 62 GWd/MTU, and a minimum cooling time of 3.0 years.

1.3.2 32PTH1 DSC Contents

The NUHOMS® 32PTH1 system is designed to store up to 32 intact (including reconstituted) Babcock and Wilcox (B&W) 15x15, Westinghouse (WE) 17x17, Combustion Engineering (CE) 15x15, WE 15x15, CE 14x14, and WE 14x14 class PWR fuel assemblies. The fuel to be stored is limited to a maximum assembly average initial enrichment of 5.0 wt. % U-235, a maximum assembly average bumup of 62 GWd/MTU, and a minimum cooling time of 3.0 years. The 32PTH1 DSC is designed to store up to 32 Control Components (CCs) which include Burnable Poison Rod Assemblies (BPRAs), Thimble Plug Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), and Neutron Source Assemblies (NSAs).

1.3.3 Change of Contents to the 24PTH and 32PT DSCs

The changes to the contents for the 24PTH and 32PT DSCs authorized by Amendment 10 to the Standardized NUHOMS® are described in Section 1.1.3 and 1.1.4 of this report.

1.4 Technical Qualifications of Applicant

Appendix T, Section 1.3, and Appendix U, Section 1.3, of the UFSAR contain identification of agents and contractors. TN provides the design, analysis, licensing and quality assurance for the NUHOMS® 61BTH and NUHOMS® 32PTH1 systems. Fabrication of the casks is performed by one or more fabricators qualified under TN's quality assurance (QA) program. The TN QA program is evaluated in Section 13 of this SER.

1.5 Evaluation Findings

Based on the review of the submitted material, the staff makes the following findings:

F1.1 A general description of the NUHOMS® 61BTH DSC and NUHOMS® 32PTH1 DSC Systems are presented in Sections 1 of Appendix T and Appendix U of the UFSAR, respectively, with special attention to design and operating characteristics, unusual or novel design features and principal safety considerations. The changes to the NUHOMS® 24PTH and NUHOMS® 32PT DSC contents are adequately described in the Amendment.

F1.2 Drawings for NUHOMS® 61BTH DSC and NUHOMS® 32PTH1 DSC System SSC important to safety are presented in Sections 1 of Appendix T, and U of the UFSAR, respectively. Specific SSC are evaluated in Sections 3 through 12 of this Safety Evaluation Report (SER).

F1.3 Specifications for the spent fuel to be stored in the NUHOMS® 61BTH DSC and NUHOMS® 32PTH1 DSC systems are stated in Appendix T and Appendix U UFSAR Sections 1, 2, and 6, respectively. Changes to the contents for the 24PTH and 32PT canisters are stated in Appendix P and Appendix M UFSAR Sections 1, 2, and 6, respectively.

F1.4 The technical qualifications of the applicant to engage in the proposed activities are identified in Appendix U and Appendix T Section 1.3 of the UFSAR.

F1.5 The quality assurance program, and implementing procedures are described in Appendix U and Appendix T Section 13 of the UFSAR.

F1.6 The staff concludes that the information presented in Section 1 of UFSAR Appendix M, P, U, and T satisfies the requirements for the general description under 10 CFR Part 72 (Ref. 2). This finding is reached on the basis of a review that considered the regulation itself, Regulatory Guide 3.61, "Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask," (Ref. 3) and accepted practices.

1.6 References

1. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.

2. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

3. 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

2 PRINCIPAL DESIGN CRITERIA

The objective of evaluating the principal design criteria related to the system, structures, and components (SSC) important to safety is to ensure that they comply with the relevant general criteria established in 10 CFR Part 72 (Ref. 1).

2.1 Structures, Systems, and Components Important to Safety

The SSCs important to safety for the NUHOMS® 61BTH System and the NUHOMS® 32PTH1 System are discussed in Safety Analysis Report (SAR) Sections T.2.3.1, and U.2.3.1, respectively (Ref. 2). These sections note that the quality category of components that are important to safety and those that are deemed not important to safety are shown in the drawings listed in SAR Section T.1.5 and U.1.5 for the NUHOMS® 61BTH System and the NUHOMS® 32PTH1 System, respectively. The staff agrees with the determinations stated in the drawings in SAR Section T.1.5, and U.1.5, for the NUHOMS® 61BTH dry shielded canister (DSC) and the NUHOMS® 32PTH1 DSC, respectively.

2.2 Design Basis for Structures, Systems, and Components Important to Safety

2.2.1 Spent Fuel Specifications

2.2.1.1 61BTH System

The allowable contents of the 61BTH DSC include 61 intact (including reconstituted) and/or damaged boiling water reactor (BWR) fuel assemblies meeting the parameters specified in Tables 1-1t and 1-1u of Technical Specification 1.2.1, “Fuel Specifications.” There are two alternate design configurations for the NUHOMS® 61BTH DSC designated as the Type 1 and Type 2 configuration. The maximum decay heat per assembly for the Type 1 61BTH DSC is 0.54 kilowatts (kW) per assembly with a maximum canister heat load of 22 kW. The maximum decay heat per assembly for the Type 2 61BTH DSC is 0.70 kW with a maximum heat load of 31.2 kW per canister. The fuel to be stored in the 61BTH DSC is limited to a maximum lattice average initial enrichment of 5.0 wt.% U235. The maximum allowable fuel assembly average burnup is 62 gigawatt days per metric ton (GWd/MTU) and the minimum cooling time is 3 years. A detailed description of the allowable fuel and storage configurations is provided in Tables T.2-1 through T.2-10 in the SAR.

2.2.1.2 32PTH1 System

The allowable contents of the 32PTH1 DSC include 32 intact (including reconstituted) and /or damaged pressurized water reactor (PWR) fuel assemblies meeting the parameters specified in Tables 1-1aa and 1-1bb of Technical Specification 1.2.1, “Fuel Specifications.” There are three alternate design configurations for the 32PTH1 DSC depending on the canister length: a short DSC designated as the 32PTH1-S DSC, a medium length DSC designated as the 32PTH1-M DSC and a long DSC designated as the 32PTH1-L DSC. The 32PTH1 DSC basket is designed with two alternate options: a Type 1 basket with solid aluminum transition rails and a Type 2 basket with steel transition rails including aluminum inserts. The Type 1 basket is the preferred option for canisters with high decay heat loads, since the solid aluminum rails allow a more direct heat conduction path from the basket edge to the DSC shell.

The NUHOMS® 32PTH1 DSCs may store fuel assemblies in any of three alternate heat load zoning configurations. The maximum decay heat per fuel assembly and the maximum canister heat load allowed is specified in SAR Figures U.2-1 through U.2-3. The maximum DSC heat load of 40.8 kW is for heat load zoning configuration 1 shown in SAR Figure U.2-1 and is applicable to the Type 1 32PTH1 DSC only.

The fuel to be stored is limited to a maximum assembly average initial enrichment of 5.0 wt.% U-235. The maximum allowable assembly average burnup is limited to 62 GWd/MTU and the minimum cooling time is 3 years. The characteristics of the control components are described in SAR Table U.2-2. A detailed description of the allowable fuel and storage configurations is provided in Tables U.2-1 through U.2-12 in the SAR.

2.2.1.3 24PTH Changes

Amendment 10 to CoC 1004 adds Westinghouse 15x15 Partial Length Shield Assemblies (PLSAs) to the authorized content of the NUHOMS® 24PTH DSC described in SAR Section P.2.1. In addition, Amendment 10 added Vibration Suppression Inserts, and Neutron Sources to the list of controlled components that can be stored in the 24PTH DSC. The amendment also includes additional low enrichment burnups and cooling time options in the fuel qualification table for the 24PTH DSC. The applicant has made changes to SAR Tables P.2-1, P.2-2, P.2-3, and P.2-6 through P.2-13 that are consistent with these changes. In addition, corresponding changes were made to Technical Specification Tables 1.1l, 1.1m, and 1.1n to be consistent with the changes made in SAR Section P.2 regarding controlled components.

2.2.1.4 32PT Changes

Amendment 10 to CoC 1004 expands the authorized contents of the NUHOMS® 32PT DSC described in Appendix M of the UFSAR to include pressurized water reactor (PWR) fuel assemblies with Control Components such as Burnable Poison Rod Assemblies (BPRAs), Thimble Rod Assemblies (TPAs), Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Vibration Suppressor Inserts (VSIs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Neutron Source Assemblies (NSAs) and Neutron Sources. All PWR fuel assemblies currently authorized for storage in a 32PT DSC may store Control Components except Combustion Engineering (CE) 15x15 fuel assemblies. The applicant has made changes to SAR Section M.2.1 and SAR Tables M.2-1 and M.2.2a describing the controlled components. In addition, corresponding changes were made to Technical Specification tables 1-1e, 1-1f, and 1-1ee to be consistent with the changes made in SAR Section M.2 regarding controlled components.

2.2.2 External Conditions

Section T.2.2 of the SAR identifies the bounding site environmental conditions and natural phenomena for which the 61BTH DSC, HSM-H, and OS-197FC-B are analyzed. Section U.2.2 of the SAR identifies the bounding site environmental conditions and natural phenomena for which the 32PTH1 DSC, HSM-H, high seismic HSM-HS, and OS-200FC are analyzed. In cases where these did not change, no descriptions were given. External conditions are further evaluated in Sections 3 through 12 of this Safety Evaluation Report (SER).

2.3 Design Criteria for Safety Protection Systems

A summary of the design criteria for the safety protection systems of the 61BTH DSC is presented in Section T.2.3 of the SAR. Details of the design are provided in Sections T.3 though T.11 of the SAR. A summary of the design criteria for the safety protection systems of the 32PTH1 DSC, HSM-H, and high seismic HSM-HS, are presented in Section U.2.3 of the SAR. Details of the design are provided in Sections U.3 though U.11 of the SAR.

The applicant has designed the 61BTH and 32PTH1 DSCs to provide storage of spent fuel for 40 years. The Standardized NUHOMS® System has been licensed by the NRC staff for 20 years of storage. The fuel cladding integrity is assured by the 61BTH and 32PTH1 DSCs and basket design which limits fuel cladding temperatures and maintains a non-oxidizing environment in the cask cavity. The 61BTH and 32PTH1 DSCs are designed to maintain a subcritical configuration during loading, handling, storage, and accident conditions. A combination of fixed neutron absorbers and favorable geometry are employed for the 61BTH DSC. A combination of soluble boron in the pool, fixed neutron absorbers, and favorable geometry are employed for the 32PTH1 DSC. The 61BTH and 32PTH1 DSC shells and basket structures are designed, fabricated and inspected in accordance with the ASME B&PV Code, Section III, Subsections NB and NG, respectively, with a few alternative provisions (Ref. 3). The complete list of alternative provisions to the ASME Code and the corresponding justification for the 61BTH DSC shell and the basket structure are provided in Table T.3.1-2 and Table T.3.1-3, respectively. The complete list of alternative provisions to the ASME Code and the corresponding justification for the 32PTH1 DSC shell and the basket structure is provided in Table U.3.1-1 and Table U.3.1-2, respectively. The staff has reviewed the alternative provisions and found that they are acceptable.

2.4 Evaluation Findings

Based on the review of the submitted material, the staff makes the following findings:

F2.1 The staff concludes that the principal design criteria for the NUHOMS® 61BTH System, NUHOMS® 32PTH1 System, the changes to the NUHOMS® 24PTH DSC, and the changes to the NUHOMS® 32PT DSC are acceptable with regard to meeting the regulatory requirements of 10 CFR Part 72. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices. A more detailed evaluation of design criteria and an assessment of compliance with those criteria is presented in Sections 3 through 14 of the SER.

2.5 References

1. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

2. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.

3. ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Power Plant Components”, American Society of Mechanical Engineers.

3 STRUCTURAL EVALUATION

3.1 Structural Design of the NUHOMS® 61BTH and NUHOMS® 32PTH1 Systems

3.1.1 General Description of Dry Shielded Canisters and Baskets

The NUHOMS® 61BTH systems is a modular canister based spent fuel storage and transfer system, similar to the Standardized NUHOMS® 61BT system described in the UFSAR (Ref. 1). It is designed to accommodate up to 61 intact (or up to 16 damaged and balance intact) BWR fuel assemblies, with the maximum allowable fuel assembly average burnup limited to 62 GWd/MTU, and a minimum cooling time of 3 years. Each NUHOMS® 61BTH DSC consists of a DSC shell assembly (cylindrical shell, canister bottom and top cover plates and shield plugs or shield plug assemblies) and a basket assembly. The DSC basket cells which store damaged fuel assemblies shall be provided with end caps to assure that they are retrievable.

The NUHOMS® 61BTH Type 1 DSC is the same as the NUHOMS® 61BT DSC documented in Appendix K with the following additional features/options; two alternate bottom closure details have been added. Alternate 2 reduces the Bottom Shield Plug by 1", and increases the Inner Bottom Cover Plate by 1". The Inner Bottom Cover Plate and a portion of the DSC cylindrical shell are made of a single forging. Alternate 3 replaces the Outer Bottom Cover Plate, Bottom Shield Plug, Inner Bottom Cover Plate and a portion of the DSC cylindrical shell with a single solid forging. As an option to the hold-down ring, an alternate Top Grid design that is integral with the basket has been added to provide additional flexibility in fuel assembly loading operations.

The NUHOMS® 61BTH Dry Shielded Canister (DSC) is a dual purpose (Storage and Transportation) DSC, with two alternate configurations, designated as NUHOMS® 61BTH Type 1 DSC or Type 2 DSC. The 61BTH DSC is shown in Figure T.1-1. The maximum heat load of 22.0 kW is allowed in Type 1 DSC. The 61BTH Type 2 DSC is provided with thicker cover plates to accommodate the higher internal pressures and the basket is provided with aluminum rails (as shown in Figure T.1-3) to accommodate the higher DSC heat loads of up to 31.2 kW. The Type 2 DSC incorporates the fixed top grid assembly design in lieu of the top hold down ring.

The NUHOMS® 61BTH DSC basket is designed with three alternate neutron absorber plate materials: (a) Borated Aluminum alloy, (b) Boron Carbide/Aluminum Metal Matrix Composite (MMC) and (c) Boral®. For each neutron absorber material, the NUHOMS® 61BTH DSC basket is analyzed for six alternate basket configurations.

The NUHOMS® 61BTH Type 1 DSC is stored in either the Standardized Horizontal Storage Module (HSM) (Model 80 or Model 102 or Model 152 or Model 202 as described in the UFSAR), or the HSM-H described in Appendix P of the UFSAR. A loaded Type 1 61BTH DSC is transferred from a plant's fuel/reactor building either in the OS197/OS 197H Transfer Cask (TC), described in the UFSAR, or a modified version of the OS197FC TC, designated as OS197FC-B. The 61BTH Type 2 DSC is to be stored in the HSM-H and transferred in OS197FC-B only.

The NUHOMS® 61BTH Type 1 and Type 2 baskets are welded assemblies of stainless steel boxes and designed to accommodate 61 BWR fuel assemblies. The basket structure consists of an assembly of stainless steel tubes (fuel compartments) separated by poison plates and surrounded by larger stainless steel boxes and support rails. The basket contains 61 compartments for proper spacing and support of the fuel assemblies.

The basket structure is open at each end and therefore, longitudinal fuel assembly loads are applied directly to the DSC/cask body and not on the fuel basket structure. The fuel assemblies are laterally supported in the stainless steel structural boxes. The basket is laterally supported by the rails and the DSC inner shell. The basket is keyed to the DSC at 180º and therefore its orientation with respect to the DSC always remains fixed. Under normal transfer conditions, the DSC rests on two 3" wide transfer support rails, attached to the inside of the transfer cask at 161.50º and 198.50º.

The NUHOMS® 32PTH1 system consists of the NUHOMS® 32PTH1 DSC, the HSM-H, and the OS200 Transfer Cask (TC). The 32PTH1 DSC and the OS200 TC are modified versions of the 32PTH DSC and OSI87H TC, respectively. The modifications implemented consist of increasing the cavity length in both the 32PTH1 and OS200 TC to allow storage of longer fuel assemblies. In addition, optional solid aluminum rails have been added to the 32PTH1 DSC to increase the heat load capacity.

The 32PTH1 DSC is a 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 40.8 kW. The HSM-H used with the 32PTH1 DSC is the same as that described in the UFSAR Appendix P for use with the 24PTH DSC, with minor modifications to allow storage of the bigger diameter and longer 32PTH1 DSC. These modifications include use of the door described in Appendix T, and a modified restraint structure at the back end of the steel support structure to allow insertion of the 32PTH1 further back into the HSM-H cavity. In addition, certain modifications were made to the HSM-H to increase its seismic capacity.

The HSM-H with these modifications is referred to as the "high seismic" HSM-H (HSM-HS) design option. The OS200 TC is similar to the OS197/OS197H/OS197FC TCs described elsewhere in the UFSAR but with an increased diameter, (same diameter as the OS187H TC of the HD system. Reference to the OS200 is made when there is no option for air circulation in the annulus between DSC and transfer cask, and to the OS200FC when the air circulation option is used. Where the new components had an effect on the structural evaluations presented in the UFSAR, the changes were included. Sections that did not have an effect on the evaluations presented in the UFSAR include a statement that there was no change to the UFSAR. An evaluation of the 32PTH1 DSC shell assembly and basket components and the HSM-H was performed and summarized. The OS200 TC stress evaluations were also summarized.

The 32PTH1 DSC shell assembly is shown on drawings NUH32PTH1-1001-SAR and NUH32PTH1-1002-SAR provided in Chapter U.1, Section U.1.5. Chapter U.1, Figure U.1-1 shows a schematic view of the 32PTH1 DSC. There are three design type configurations for the 32PTH1 DSC with three different lengths as shown in the Table U.1-1 presented in the UFSAR: 32PTH1-S, 32PTH1-M, and 32PTH1-L.

The 32PTH1 DSC basket is designed with 2 alternate options: a Type 1 basket with solid aluminum transition rails, and a Type 2 basket with steel transition rails including aluminum inserts. The Type 1 basket is the preferred option for canisters with high decay heat loads, since the solid aluminum rails allow a more direct heat conduction path from the basket edge to the DSC shell.

The basket structure consists of a grid assembly of welded stainless steel plates or tubes that make up a grid of 32 fuel compartments. Each fuel compartment accommodates aluminum and/or neutron absorbing plates (which are made of either borated aluminum or metal matrix composites such as Boralyn®, Metamic®, Boral®, or equivalent), that provide the necessary criticality control and heat conduction paths from the fuel assemblies to the canister shell. The space between the fuel compartment grid assembly and the perimeter of the DSC shell is bridged by transition rail structures. The transition rails are solid aluminum segments, or welded steel plates that support the basket.

3.1.2 HSM Module Changes

The HSM-H module design for the 32PTH1 system is nearly identical to the design of the HSM-H module provided for the storage of the currently licensed NUHOMS® 24PTH DSC with the following differences provided to accommodate the 32PTH1 DSC:

- The diameter of the access door is increased to accommodate the 32PTH1 DSC, similar to the 32PTH DSC,
- The thickness of the rail stop at the back end of the DSC support structure is reduced to increase the HSM-H cavity length, and
- Flat stainless steel side and roof heat shields are used.

The key design parameters and estimated weights of the HSM-H module are shown in Table U.1-1. Drawing NUH-03-7001-SAR included in Appendix T, Chapter T.1, Section T.1.5, shows the above listed modifications implemented to HSM-H.

3.1.2.1 HSM High Seismic (HSM-HS) Module

An upgraded version of the NUHOMS® HSM-H design, designated as NUHOMS® HSM-HS, was also provided to allow the use of the NUHOMS® system in locations where higher seismic levels exist. The HSM-HS module is designed to withstand maximum acceleration in horizontal direction of 1.0g and a maximum acceleration in vertical direction of 1.0g (compared to 0.3g and 0.25g respectively for HSM-H module).

The modifications implemented to the HSM-H design to meet the upgraded seismic criteria are based on a previously licensed HSM design, and are as listed below:

- The HSM-HS roof is tied to the base unit by steel rods or clamps in the vertical direction and by an interlocking concrete key located between the underside of the roof to restrain relative movement in the horizontal direction;

- Adjacent HSM-HS modules are tied to each other with ties located at the top (roof-to-roof connections) and at the base (base-to-base connections). A minimum of three modules are required in an HSM-HS array; and,

- The ISFSI pad is designed such that the HSM-HS array has 10 feet of space around to allow sliding and retrievability. Drawing NUH-03-7003-SAR included in Section U.1.5, shows the above features of the NUHOMS® HSM-HS module.

3.2 Materials

3.2.1 Materials of Construction and Fuel Payload

All of the canister designs which are the subject of Amendment 10 are of conventional spent fuel canister construction and materials. The structural and confinement components of the canister, along with the structural components of the fuel basket, are fabricated from austenitic stainless steel. The same neutron poison materials as previously employed by this applicant are employed. Thus, the materials of fabrication for Important to Safety (ITS) components are unchanged from those of previous amendment requests.

Some differences in material specifications or operating conditions for non-safety related components were noted in this amendment. Those differences are evaluated in other sections of this Safety Evaluation Report

The fuel payload for the various canister designs did not involve any new types of fuel materials or fuel hardware materials. Thus, no additional consideration of potential adverse chemical or galvanic effects between the canister materials and the fuel payload is required.

3.2.2 Damaged Fuel

3.2.2.1 Damaged Fuel Definition

The applicant provided a definition of damaged fuel in the SAR, Chapter U.1, that is narrower in scope than an all-encompassing definition. Among the differences of this more restricted definition, all fuel meeting the applicant's definition as "damaged" must be capable of being handled by normal means. This precludes inclusion of fuel debris or assemblies with significant structural impairments. Any fuel assemblies which are damaged beyond the definition contained in the SAR are not permitted to be loaded into any of the canisters subject to this amendment.

The staff finds this more restricted definition of damaged fuel to be acceptable.

3.2.2.2 Top and Bottom End Cap for Confinement of Damaged Fuel

The applicant proposed to employ a separate top and bottom end cap for any cell of the fuel basket which contains a damaged fuel assembly. The definition of damaged fuel, in this case, is the restricted definition employed by the applicant. This definition of damaged fuel is narrower in scope than an all-inclusive definition and limits the amount of permissible fuel bundle damage. Normally, a damaged fuel assembly (or fuel debris) is first loaded into a damaged fuel can prior to loading the damaged fuel can into the fuel basket. With the more limited definition of damaged fuel which is employed by the applicant, any fuel bundle approved for loading must be able to withstand normal and off-normal conditions of storage without further degradation of the fuel assembly. Thus there is no need for a completely enclosed damaged fuel can capable of confining any lose fuel debris as is the case for fuel with more extensive damage.

In accordance with the guidance of ISG-2 (Ref. 2), which discusses retrievability criteria for spent fuel, retrievability is required to be demonstrated for normal and off-normal conditions of storage. The structural analysis included in SAR Chapters T.3 and U.3 demonstrates the retrievability of the damaged spent fuel under these conditions.

The staff finds this proposal to be acceptable for use with the applicant’s definition of damaged fuel.

3.2.3 Fuel Basket-Aluminum Components

The applicant employs aluminum alloys 6061-T6 and 1100-O for various non-structural components in the fuel basket. The temperatures that the aluminum components experience during normal conditions of storage may exceed that allowed by the ASME Code for aluminum alloys, which is typically 400^{o}F. Additionally, any temperature at, or above, approximately 200^{o}F is within the creep regime for the aluminum alloys specified. Consequently, long-term creep effects must be evaluated. Additionally, the acceptability of the creep data cited for the temperatures beyond the Code allowed temperature must be assessed. The applicant used this data to predict the creep behavior of the components operating at higher than ASME Code allowed operating temperatures.

The applicant cited creep data compiled by the Aluminum Association in their publication “Properties of Aluminum Alloys: Tensile, Creep and Fatigue Data and High and Low Temperatures”, The Aluminum Association and ASM International, J. G. Kaufman, ed., 1999 (Ref. 3). This reference provides creep data for various aluminum alloys at temperatures above that allowed by the ASME Code. The reference was examined and judged to be acceptable for the intended application.

The applicant performed a proprietary creep strain analysis to determine the effects of an assumed life of greater than 40 years with associated creep strain. This analysis initially assumed the highest design storage condition temperature and accounted for the normal temperature decline with time as the fuel payload cools with time.

For the analysis, the applicant employed the creep properties of alloy 1100 for all analyses because it provides a lower bound on creep strength and would thus conservatively bound the result for 6061 alloy. The creep strain analysis accounted for both primary and secondary creep rates and combined these two different rates (and associated times) to obtain the final total creep strain.

A major factor which considerably reduces the final amount of creep strain is the very low stress level experienced by the various aluminum components. The bounding load on the components is less than 100 psi. For a given temperature and time, creep strain is a power-law function of the applied stress. Consequently, low stresses produce very little creep strain. Additionally, these components are loaded in compression and are somewhat constrained or confined geometrically, which further aids in controlling or minimizing creep deformation.

The creep stain analysis was performed for the assumed operating time of over 40 years. The results of the analysis showed that the maximum accumulated creep strain would be on the order of 0.01%. This value is significantly below the ASME Code criteria that the creep rate not exceed 0.01% per 1000 hours.

The applicant concluded that creep is not a significant consideration in the design of the NUHOMS® fuel basket and the effects of creep-induced strain/distortion upon component geometry are minor and have no significant effect on the overall basket performance.

The staff finds the creep strain analysis result to be acceptable.

3.3 Normal and Off-Normal Conditions

The structural analyses for normal and off-normal operating conditions for the NUHOMS® 61BTH system are presented in section T.3.6. The structural analyses for normal and off-normal operating conditions for the NUHOMS® 32PTH1 system are presented in section U.3.6. In accordance with NRC Regulatory Guide 3.48 (Ref. 4), the design events identified by ANSI/ANS 57.9-1984, (Ref. 5) formed the basis for the accident analyses performed for the standardized NUHOMS® system. Four categories of design events were defined. Design event Types I and II cover normal and off-normal events. Design event Types III and IV cover a range of postulated accident events.

3.3.1 Loads and Loading Conditions

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

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

3.3.2 Analysis Methods

The NUHOMS® 61BTH and the NUHOMS® 32PTH1 DSC shell assembly were analyzed for the normal, off-normal, and postulated accident load conditions using ANSYS finite element models. For the analysis, two basic ANSYS models were developed: a top-end half-length model of the DSC shell assembly, and a bottom-end half-length model of the DSC shell assembly.

The NUHOMS® 61BTH DSC (shell and closure) was designed and will be fabricated as a Class 1 component in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB (Ref. 6), and the alternative provisions to the ASME Code as described in Table T.3.1-2. The principal design loadings for the NUHOMS® 61BTH DSC were provided in Table T.2-14. The applicable load combinations for the NUHOMS® 61BTH DSC were presented in Table T.2-11 and the corresponding stress criteria were presented in Table T.2-12 and Table T.2-13. The NUHOMS® 61BTH system is designed to withstand the effects of severe environmental conditions and natural phenomena such as earthquakes, tornadoes, lightning and floods. Chapter T.11 describes the NUHOMS® 61BTH DSC behavior under these accident conditions. The NUHOMS® 61BTH DSC design, fabrication and testing are covered by Transnuclear Quality Assurance Program, which conforms to the criteria in Subpart G of 10 CFR Part 72 (Ref. 7).

The NUHOMS® 32PTH1 DSC (shell and closure) is designed and will be fabricated as a Class 1 component in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NB (Ref. 6), and the alternative provisions to the ASME Code as described in Table U.3.1-1. The NUHOMS® 32PTH1 DSC is designed to withstand the effects of severe environmental conditions and natural phenomena such as earthquakes, tornadoes, lightning and floods. Chapter U.11 describes the NUHOMS® 32PTH1 DSC behavior under these accident conditions. The NUHOMS® 32PTH1 DSC design, fabrication and testing are covered by Transnuclear's Quality Assurance Program, which conforms to the criteria in Subpart G of 10 CFR Part 72.

3.3.2.1 24PTH DSC Shield Assembly

A Partial Length Shield Assembly (PLSA) for WE 15 x 15 has been added to NUHOMS® 24PTH under this amendment, as described in appendix P of the FSAR.

3.3.2.2 Basket Assemblies

The NUHOMS® 61BTH basket is designed and will be fabricated in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, Article NG-3200 (Ref. 6) and the alternative provisions to the ASME Code as described in Table T.3.1-2. The hypothetical impact accidents are evaluated as short duration, Level D conditions. The stress criteria are taken from Section III, Appendix F of the ASME Code. The basket hold-down ring and the alternate top grid are designed, and will be fabricated and inspected in accordance with the ASME Code Subsections NF, and NG, respectively, to the maximum practical extent.

The basket finite element model described in Section T.3.6.1.3.1 was used to perform the stress calculations for the seismic loads. Since the combined loading (2g axial + 2g transverse + 2g vertical) is non-symmetric, a 360-degree model was used. The canister shell is resting on two rails inside the HSM (3 in. wide x 0.1875 in. thick) at 30^o on either side of the basket/canister centerline. The radial contact elements at the two rail locations were assumed closed. The canister nodes at one location of the rail were held in the circumferential directions to avoid rigid-body motion of the model.

The gap elements between the inside surface of the canister and the basket rails were assumed closed at the 180^o orientation and remaining initial gaps are suitably modified (from 0 in. at 180^o at the bottom to 0.25 in. at 0^o at the top).

The NUHOMS® 32PTH1 basket is designed and will be fabricated in accordance with the rules of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NG, Article NG-3200 and the alternative provisions to the ASME Code as described in Table U.3.1-2.

3.3.2.3 HSM Modules

For the NUHOMS® 61BTH there are no structural design changes to the HSM Model 80, 102, 152, or 202 designs. For the NUHOMS® 32PTH1 HSM-H and HSM-HS Off-Normal Loads, the following structural analyses were conducted:

- Off-Normal Thermal Loads Analysis: this load case is the same as the normal thermal load but with an ambient temperature range from -40°F to 117°F. The results of the thermal analysis for the off-normal condition are summarized in Table U.3.4-1. The temperature distributions for the extreme ambient conditions are used in the analysis for the concrete component evaluation.

- HSM-H Off-Normal Handling Loads Stress Analysis: the evaluation for off-normal handling loads described in Appendix P, Section P.3.6.2.3 (B) and summarized in Table P.3.6-10 remains applicable. The off-normal loads evaluations and analysis results for the HSM-H as described above are also applicable to the HSM-HS. In addition, the HSM-HS is evaluated for off-normal operational handling loads of 110 kips during insertion and 90kips during retrieval. For the HSM-H and HSM-HS loaded with a 32PTH1 DSC, Section U.3.6 provided the thermal evaluation for the normal and off-normal conditions, and Section U.3.7 for the accident conditions. A summary of the forces and moments in the concrete components due to different thermal load cases are summarized in Table U.3.4-1.

3.3.2.4 Transfer Casks

For the NUHOMS® 61BTH with the exception of increased seismic criteria from 0.25g to 0.30g (horizontal) and from 0.17g to 0.20g (vertical), the principal design criteria for the OS197, the OS197H, and the OS197FC-B are the same as that presented in Chapter 3 of the UFSAR. For the NUHOMS® 32PTH1, the top cover plate, top flange, inner liner, structural shell, and bottom assembly are the primary structural members of the OS200 TC. The OS200 transfer cask body structural analyses generally use static nonlinear analysis methods. The stresses and deformations due to the applied loads are generally determined using the ANSYS (Ref. 8) computer program. The resulting stresses are compared with the allowable stresses set forth by ASME B&PV Code, Section III Subsection NC for normal and off-normal conditions. A 3-dimensional ANSYS (Ref. 8) finite element model, constructed primarily from SOLID45 elements, is used to analyze all the load cases. A 180° symmetric 3D model, or a half model, and a 360° 3D model, or a full model, are used. Selection of the model was dependent upon the type and orientation of the load. For example, the transfer load of 2g in all direction requires the full model. Element plots of the 3D finite element models (half model) are shown in Figure U.3.6-30, Figure U.3.6-31 and Figure U.3.6-32.

3.3.3 Analysis Results

For the NUHOMS® 61BTH the maximum calculated DSC shell stresses induced by normal operating load conditions are shown in Table T.3.6-4 for the Type 1 DSC and Table T.3.6-5 for the Type 2 DSC. The calculated stresses for each load case are combined in accordance with the load combinations presented in Table T.2-11. The resulting stresses for the controlling load combinations were reported in Section T.3.7.12 with the ASME Code allowable stresses. For the NUHOMS® 32PTH1 the maximum calculated DSC shell stresses induced by normal operating load conditions were shown in Table U.3.6-2 for the 32PTH1 DSC. The calculated stresses for each load case were combined in accordance with the load combinations presented in Chapter U.2, Table U.2-13. The resulting stresses for the controlling load combinations were reported in Section U.3.7.11 along with the ASME Code allowable stresses.

Based on the results of the evaluations presented and satisfactory explanations and re-analyses performed by the applicant, the staff concluded that there was a reasonable assurance that the damaged fuel assemblies in the NUHOMS® 61BTH DSC and the NUHOMS® 32PTH1 DSC will retain their structural integrity when subjected to normal and off normal conditions of storage and on site transfer loads. Therefore, the retrievability of the damaged fuel assemblies as required by the 10 CFR Part 72.236 regulations was assured under normal and off-normal loads.

3.4 Design Basis Accident Conditions, and Loads

The postulated accident conditions for NUHOMS® 61BTH were addressed in the following FSAR Sections:

A. Tornado winds and tornado generated missiles. (T.3.7.1)

B. Design basis earthquake. (T.3.7.2)

C. Design basis flood. (T.3.7.3)

D. Accidental transfer cask drop with loss of neutron shield. (T.3.7.4)

E. Lightning effects. (T.3.7.6)

F. Debris blockage of HSM and HSM-H air inlet and outlet opening. (T.3.7.7)

G. Postulated DSC leakage. (T.3.7.8)

H. Pressurization due to fuel cladding failure within the DSC. (T.3.7.9)

I. Reduced HSM Air Inlet and Outlet Shielding (T.3.7.10), and

J. Fire and Explosion (T.3.7.11)

The postulated accident conditions for NUHOMS® 32PTH1 were addressed in the following FSAR Sections:

A. Tornado winds and tornado generated missiles. (U.3.7.1)

B. Design basis earthquake. (U.3.7.2)

C. Design basis flood. (U.3.7.3)

D. Accidental TC drop with loss of neutron shield. (U.3.7.4)

E. Lightning effects. (U.3.7.5)

F. Debris blockage of HSM-H air inlet and outlet opening. (U.3.7.6)

G. Postulated DSC leakage. (U.3.7.7)

H. Pressurization due to fuel cladding failure within the DSC. (U.3.7.8)

I. Reduced HSM air inlet and outlet shielding. (U.3.7.9)

J. Fire and explosion. (U.3.7.10)

3.4.1 Analysis Methods

3.4.1 Analysis Methods3.4.1 Analysis Methods3.4.1 Analysis Methods3.4.1 Analysis Methods
3.4.1 Analysis Methods

Each accident condition was analyzed to demonstrate that the requirements of 10CFR72.122 are met and that adequate safety margins exist for the standardized NUHOMS® system design. The resulting accident condition stresses in the NUHOMS® system components were evaluated and compared with the applicable code limits set forth in Section 3.2, Chapter T.2, and Chapter U.2, as applicable. Where appropriate, these accident conditions stresses were combined with those normal operating loads in accordance with the load combinations defined.

3.4.1.1 Tornado Winds and Tornado Missile

For the NUHOMS® 61BTH HSM the applicable design basis tornado (DBT) and tornado missile load parameters were detailed in Section 3.2.1.2 for Models 80/102 and in their respective appendices for Models 152/202. To envelop the effects of wind on an HSM array, a conservative generic analysis was performed with tornado winds assumed to act on a single free-standing HSM (with two end shield walls and a rear shield wall). With the increased weight of NUHOMS® 61BTH DSC the HSM is more stable against the DBT tornado wind and missile effects. The sliding stability analysis was unchanged from the analyses presented in Section 8.2.2. For the HSM-H, results presented in section P.3.7.1 are still bounding.

For NUHOMS® 32PTH1 the applicable design parameters for the design basis tornado (DBT) were not changed from those specified in Chapter P.2, Section P.2.2.1. The determinations of the tornado wind and tornado missile loads acting on the HSM-H are also detailed in that section. The end modules of an array utilize shield walls to resist tornado wind and missile loads. The OS200 TC was designed for the tornado wind and tornado missile loads defined in UFSAR Section 3.2.1.

The stability and stress analyses performed and documented in Appendix P, Section P.3.7.1 to determine the response of the HSM-H to tornado wind pressure loads were applicable for the HSM-H and HSM-HS loaded with a 32PTH1 DSC. The stability analyses were performed using closed-form calculation methods to determine sliding and overturning response of the HSM-H/ HSM-HS array. These analyses conservatively used lower bound HSM-H and DSC weights in the calculation of the stabilizing (resisting moment). A single HSM-H/HSM-HS with both the end and the rear shield walls present was conservatively selected for the stability analyses. The stress analyses were performed using the ANSYS finite element model of a single HSM-H/HSM-HS to determine design forces and moments. These conservative generic analyses enveloped the effects of wind pressures on the HSM-H/HSM-HS array. Thus, the requirements of 10CFR 72.122 are met. In addition, the HSM-H was evaluated for tornado missiles. The adequacy of the HSM-H to resist tornado missile loads was addressed using empirical formulae, and was included in Appendix P, Section P.11.2.3. The missile evaluation in Section P.11.2.3 remains applicable to the HSM-H and HSM-HS loaded with a 32PTH1 DSC.

3.4.1.2 Earthquake

NUHOMS® 61BTH:

HSM and HSM-H Seismic Evaluation:
The seismic results of a 61BTH DSC stored in an HSM are bounded by results presented in Section M.3.7.3.3 for HSM Models 80/102 and in the respective appendices for HSM Models 152/202. The seismic results of a 61BTH DSC stored in an HSM-H are bounded by results presented in Section P.3.7.2.3.

DSC Support Structure Seismic Evaluation:

The seismic results of a 61BTH DSC support structure inside the HSM are bounded by those presented in Section M.3.7.3.4 for HSM Models 80/102 and in the respective appendices for HSM Models 152/202. The seismic results of a 61BTH DSC support structure inside the HSM-H are bounded by those presented in Section P.3.7.11.6.4.

DSC Axial Retainer Seismic Evaluation:

The HSM axial retainer was qualified for a maximum DSC weight of 102 kips in Appendix M. The maximum DSC weight is 93 kips for the 61BTH, Type 2 DSC. Therefore, Appendix M, Section M.3.7.3.5 results for the HSM axial retainer are bounding. The HSM-H axial retainer is qualified for a maximum DSC weight of 110 kips in Appendix P, whereas the maximum DSC weight is 93 kips for the 61BTH, Type 2 DSC. Therefore, Appendix P, Section P.3.7.11.6.7 results for the HSM-H axial retainer are bounding.

Basket Seismic Evaluation:

The basket seismic analysis was performed using the models which were developed for normal and off-normal evaluations. A description of the seismic models, applied loads and associated results is presented in Section T.3.6.1.3.4 B. The basket natural frequency was also calculated in Section T.3.6.1.3.4 D.

TC Seismic Evaluation:

The seismic evaluation for the OS197/OS197H in Chapter 8, Section 8.2.3.2(D), was based on very conservatively derived seismic accelerations of 1.31 g horizontal and 0.84g vertical. These amplified accelerations were obtained by applying amplification factors of 3.5 and 3.3 for the horizontal and vertical directions, respectively, and, furthermore, applying a "multimode" factor of 1.5 to the base seismic criteria values of 0.25g and 0.17g for the horizontal and vertical directions, respectively.

The frequency analysis for a similar NUHOMS® TC documented the NUHOMS®-HD Final Safety Analysis Report (Ref. 10), showed that the TC can be considered a rigid component (the first mode frequency of the TC the NUHOMS®-HD FSAR (Ref.10) is on the order of 69 Hz. This frequency content is well in the rigid range relative to the frequency content of the seismic input motion (33 Hz). Therefore, no significant response amplification is expected due to seismic load for the OS 197 type cask, and, thus, the maximum accelerations used in the seismic evaluation of the OS 197/OS 197H as discussed above are deemed to be more than adequate to meet the increased seismic criteria of 0.3g horizontal and 0.20g vertical. Consequently, the seismic stress evaluations and results as described in the UFSAR are applicable and no further evaluation is required.

The seismic stability evaluation described in Section 8.2.3.2(D) for the TC mounted horizontally in the transfer trailer and subjected to the 0.25g and 0.17g seismic accelerations shows a factor of safety of 2.0 against overturning. For the increased accelerations, the factor of safety is approximately 1.7. Sufficient margin exists to accommodate the increased seismic accelerations.

NUHOMS® 32PTH1:

The seismic criteria for the 32PTH1 DSC, HSM-H and OS200 TC consists of Regulatory Guide 1.60 “Design Response Spectra for Seismic Design of Nuclear Power Plants” with response spectral amplifications anchored to maximum accelerations of 0.3g horizontal and 0.25g vertical. For the NUHOMS® System components that were evaluated in accordance with the rules of the ASME B&PV Code (32PTH1 DSC and OS200 TC) the resulting seismic stresses were evaluated against the ASME Code Service Level C allowable.

The 32PTH1 DSC, HSM-H and OS200 TC were also evaluated to a higher seismic design criteria consisting of an "enhanced" Regulatory Guide 1.60 (Ref. 11) response spectra, anchored to a 1.0g maximum horizontal and vertical direction accelerations, as described in Chapter U.2, Section U.2.2.3. The HSM-H design, modified to accommodate the higher seismic accelerations, was referred to as the HSM-HS. No design modifications were required for the 32PTH1 DSC or the OS200 TC to accommodate the higher seismic loads as the design of these NUHOMS® components was controlled by the accident drop loads. The resulting seismic stresses of the 32PTH1 DSC and OS200 TC due to the higher seismic criteria were evaluated against ASME Code Service Level D allowable.

Based on NRC Regulatory Guide 1.61 “Damping Values for Seismic Design of Nuclear Power Plants” (Ref. 12), a damping value of three (3) percent was used for the 32PTH1 DSC seismic analysis. Similarly, a damping value of seven (7) percent was used for evaluation of the DSC support steel and concrete components of the HSM-H. Based on the evaluation of the frequency content of the loaded HSM-H, the amplified accelerations associated with the design basis seismic response spectra were determined and used for the structural evaluation of the NUHOMS® HSM-H/HSM-HS, OS200 TC and 32PTH1 DSC.

Using the results of the frequency analysis of the HSM-H, the maximum calculated design basis seismic accelerations for the DSC inside the HSM-H were 0.41g transverse and 0.36g axial in the horizontal directions and 0.25g in the vertical direction.

An equivalent static analysis using these seismic accelerations showed that the DSC will not lift off the support rails inside the HSM-H.

The stability of the DSC against lifting off from one of the support rails during a design basis seismic event was evaluated by performing a rigid body analysis, using the 0.41g horizontal and 0.25g vertical input accelerations. The horizontal equivalent static acceleration of 0.41g was applied laterally to the center of gravity of the DSC. The point of rigid body rotation of the DSC was assumed to be the center of the support rail, as shown in Figure U.3.7-1.

The applied moment acting on the DSC was calculated by summing the overturning moments. The stabilizing moment, acting to oppose the applied moment, was calculated by subtracting the effects of the upward vertical seismic acceleration of 0.25g from the total weight of the DSC and summing moments at the support rail. Since the stabilizing moment calculated was greater than that of the applied moment, the DSC will not lift off the DSC support structure inside the HSM-H. The factor of safety (SF) against DSC lift off from the DSC support rails inside the HSM-H obtained from this bounding analysis was: SF = 1.05.

The stability of the DSC inside the HSM-HS for the Level D seismic loads was evaluated by performing seismic non-linear (contact) time history analyses using an LS-DYNA (Ref. 13) model of the HSM-HS loaded with a 32PTH1 DSC, as described in Section U.3.7.2.4. Based on the results of the LS DYNA analyses, the DSC was shown to maintain its position and remain within the DSC support structure. In addition, based on the frequency analysis of the HSM-H (HSM-HS), the maximum calculated seismic accelerations for the DSC inside the HSM-HS when considering the higher seismic criteria were 2.0g transverse and 1.6g axial in the horizontal directions and 1.0g in the vertical direction.

The stresses in the DSC shell due to vertical and horizontal seismic loads for both sets of seismic criteria were determined and included in the appropriate load combinations.

Basket Assembly Seismic Loads Evaluation:

Seismic loads consistent with the 0.3g horizontal and 0.25g vertical maximum accelerations seismic criteria were evaluated for Level C conditions. Seismic loads consistent with the 1.0g horizontal and 1.0g vertical maximum accelerations seismic criteria are evaluated for Level D conditions.

For each seismic load case, the vertical and transverse loads from the fuel assemblies are applied as pressures on the horizontal and vertical panels of the basket. The pressures are calculated using bounding (amplified) acceleration values. The inertia load due to the basket rails and canister is simulated by applying the appropriate accelerations in the vertical, transverse and axial directions. Where not modeled, the weight of the aluminum plates is accounted for by increasing the basket and rail densities. The staff noted that since only 15" length of the basket was modeled, the acceleration in axial direction was increased to account for the entire 144" length.

To simulate the axial stress due to the axial acceleration, one side of the basket was restrained in the z-direction. A row of canister nodes at one of the HSM rail locations was held in circumferential direction to avoid rigid-body motion of the model. The gap element conditions for the deadweight analysis were used for the seismic load analysis. The loads and boundary conditions for the Level C seismic loading condition are shown in Figure U.3.7-2 for the Type I basket model and U.3.7-3 for the Type 2 basket model. The Level D models were similar. Stress analyses were conducted using ANSYS to compute the stresses in both Type 1 and Type 2 basket models. Nonlinear analyses were necessary due to the gap elements used in the model. The total load was gradually applied in small sub-steps. The automatic time stepping program option (AUTOTS) was activated. This option lets the program select the actual size of the load sub-step to obtain a converged solution. Calculated seismic stresses were summarized in Table U.3.7-2 and Table U.3.7-3.

The basket fusion welds and rail stud forces were evaluated at the Level D seismic and -40°F ambient condition for both Type 1 and Type 2 basket configurations. This case represents the storage load case with the maximum fusion weld forces. The maximum fusion weld and stud forces were conservatively computed by taking the Square Root of the Sum of the Squares (SRSS) of the maximum force components of the welds in each direction. The maximum fusion weld forces were found to be 5.71 kips and 6.05 kips for the Type 1 and Type 2 baskets, respectively. These loads are less than the fusion weld capacity and are bounded by the calculated loads for the Accident Drop load cases.

Rail stud stresses were calculated by hand using the maximum forces extracted from the ANSYS results. The transition rail stud stresses were within allowable limits based on an efficiency factor of 0.8 for progressive penetrant test (PT) weld inspection. The maximum rail stud stress for storage load Level D seismic conditions was 14.1ksi compared to an allowable of 45.65ksi.

HSM-HS Seismic Evaluation:

As described in Chapter U.2, Section U.2.2.3, the "high seismic" accelerations for the HSM-H were 1.0g in the horizontal directions and 1.0g in the vertical direction. These seismic accelerations were further amplified based on the results of the frequency analysis of the HSM-H, as documented in Appendix P, Section P.2.2.3. Using the 7% damping amplifications, the resulting accelerations applicable to the HSM-HS analysis were 1.61g, 1.38g and 1.0g in the longitudinal, transverse and vertical directions, respectively. For conservatism, the HSM-HS structural analysis was performed using maximum accelerations of 1.61 g for both horizontal directions and 1.0g for the vertical direction.

An equivalent static analysis of the HSM-HS was performed using the ANSYS model described in Appendix P, Section U.3.7.11.6, and the seismic accelerations of 1.61g horizontally (longitudinal and transverse directions) and 1.0g vertically. These amplified accelerations were determined based on the frequency analysis of the HSM-H (HSM-HS). The responses for each orthogonal direction were combined using the SRSS method. The seismic analysis results are incorporated in the loading combination C 4C (Table U.3.7-23) and C 4S (Table U.3.7-24) for the HSM-HS concrete and support structure components respectively. The load combination results are presented in Section U.3.7.11.6.3.

3.4.1.3 Flood

The design basis flooding load was specified as a 50 foot static load of water and a maximum flow velocity of 15 feet per second. As the source of flooding is site specific, the source, or quantity of flood water will be established by the individual licensee. There was no change in the HSM and HSM-H flooding analysis and the analysis previously submitted in the UFSAR is also bounding for 61BTH. The DSC Type 1 and Type 2 shell stresses for the postulated flood condition were determined using ANSYS models. The maximum DSC shell primary membrane plus bending stress was considerably less than the ASME service level C allowable. The accidental cask drop event will envelop all other accident event combinations. Tables T.3.7-12 through Table T.3.7-18 of the UFSAR presented the summary of maximum stress intensities for each component of the DSC (shell and basket assemblies) calculated for the enveloping normal operating, off-normal, and accident load combinations.

For the 32PTH1 as described in UFSAR Section 3.3.2, the design basis flooding load was specified as a 50 foot static head of water and a maximum flow velocity of 15 feet per second. The stability analysis presented in Appendix P, Section P.3.7.1, including the overturning and sliding evaluations in Appendix P, Section P.3.7.1.1 and P.3.7.1.2, respectively, remained applicable to the HSM-H and HSM-HS loaded with a 32PTH1 DSC. The flooding analysis presented in section U.3.7.3.2 of the UFSAR for DSC demonstrated stability of the DSC under the worst case external pressure due to flooding. The DSC shell stresses for the postulated flood condition were determined using the ANSYS analytical model shown in Figure U.3.6-1 and Figure U.3.6-2. The 21.7 psig external pressure was applied to the models as a uniform pressure on the outer surfaces of the top cover plate, DSC shell and bottom cover plate. The maximum DSC shell primary membrane plus bending stress intensity for the 21.7 psi external pressure was 5.85ksi. This stress was considerably less than the Service Level C allowable primary membrane plus bending stress of 31.5ksi. The maximum primary membrane plus bending stress in the flat heads of the DSC occurred in the inner bottom cover plate. The maximum primary membrane plus bending stress was 2.10ksi. This stress was also considerably less than the Service Level C allowable for primary membrane plus bending.

3.4.1.4 Accidental TC, DSC, Basket Drop and Loss of Neutron Shield

The structural integrity of the standardized NUHOMS® on-site TC, the DSC and its internal basket assembly when subjected to postulated cask drop accident scenarios have been evaluated in relevant Sections of the UFSAR. The staff reviewed these scenarios used to justify compliance with 10 CFR Part 72 requirements. The staff reviewed the structural integrity of damaged fuel cladding for the accident loading conditions associated with 10 CFR Part 72 requirements and found the analyses acceptable. TN has considered the requirements in 10 CFR Part 72.236 (m) for compatibility with removal of stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy. TN is planning to address these in future transport applications under the 10 CFR Part 71 requirements.

The NUHOMS® 61BTH DSC is heavier than the NUHOMS® 52B DSC. Therefore, the expected g loads for the postulated drop accidents would be lower. However, for conservatism, the g loads used for the NUHOMS® 52B analyses were also used for the NUHOMS® 61BTH DSC analyses. A conservative range of drop scenarios were developed and evaluated. During the transfer from the Spent Fuel Pool Building to the ISFSI, the maximum drop height is less than 68". For conservatism 80" was used for the corner drop analysis. Technical Specification 1.2.10 also restricts handling of the loaded transfer cask to a height of less than 80" outside the spent fuel pool building.

In the original submittal of TN's application for Amendment No. 10, the drop scenarios selected were:

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

2. A vertical end drop from a height of 80 inches onto the top or bottom of the transfer cask (two cases). Note that vertical end drop is not a credible event but only considered to show that comer drop is enveloped by the side drop and end drop.

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

The NUHOMS® 32PTH1 DSC is heavier than the NUHOMS® 24P DSC. Therefore, the expected g loads for the postulated drop accidents would be lower. However, for conservatism, the g loads used for the NUHOMS® 24P analyses were also used for the NUHOMS® 32PTH1 DSC analyses. Since the 32PTH1 basket assembly is a new design, the drop scenarios selected in the original submittal of TN's application for Amendment No. 10 were:

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

2. Vertical end drops for the NUHOMS® System are non-mechanistic and thus, no end drops were postulated for the OS200 TC loaded with a 32PTH1 DSC. However, 75g vertical end drop analyses were performed as a means of enveloping the 25g comer drop (in conjunction with the 75g horizontal side drop).

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

TN provided clarifications and proper terminology used in their analyses in response to a staff RAI. TN performed new analyses and revised the relevant SAR Section T for the 61BTH, and Section U for the 32PTH1 as follows.

As described in Revision 4 of the application (Ref. 14), page U.3.5-6, the acceleration time history used for the fuel rod end drop analysis (Figure U.3.5-7) was obtained from LS-DYNA analysis of the TN TC documented in Appendix 3.9.10 (Transfer Cask LS-DYNA Dynamic Impact Analysis) of the FSAR for the NUHOMS® HD Horizontal Modular Storage System For Irradiated Nuclear Fuel (Ref. 10).

At no time during the transfer loading (or unloading) operations is there a need for any lifts of the TC with a loaded DSC. Therefore, the vertical end drops for the NUHOMS® System are non-mechanistic, not credible events and, therefore, no end drops are postulated. Sliding of the DSC out of the transfer cask or tilting of the transfer cask in such a way as to result in a corner drop are also non-mechanistic, highly unlikely events. Nevertheless, for conservatism a corner drop was postulated and evaluated for the NUHOMS® System. Since the end drop is not a credible event for the NUHOMS® System, the response acceleration time history from the corner drop was used for the fuel rod end drop analysis.

The response acceleration time history in the axial direction as shown in Figure 3.9.10-22 (corner drop) of Appendix 3.9.10 (Ref. 10) was not used in the fuel rod end drop analysis. The response acceleration time history shown in Figure 3.9.10-22 (corner drop) of Reference 10 corresponds to the nodal average axial accelerations (parallel to the cask axial direction) of the entire transfer cask lid. This time history may not represent the maximum input to the fuel rod that is closest to the point of impact. Therefore, in order to capture the maximum response of the fuel rod, a nodal acceleration response time history was obtained by differentiation of the nodal velocities in the immediate vicinity of the point of impact (corner of the cask). Figure U.3.5-7 is a new figure generated from the LS-DYNA corner drop result file (post processed from the existing corner drop analysis in Appendix 3.9.10 of Reference 10). Figure U.3.5-7 shows the response acceleration time history in the vertical direction $(\text{axial}^2 + \text{transverse}^2)^{½}$ developed as described in the preceding paragraph. This vertical response time history gives higher g values than response time history in Figure 3.9.10-22 (axial time history). This time history is considered to be bounding since it was developed at the point of corner impact.

Since the end drop is not a credible event for NUHOMS® System, the response time history is based on the corner drop analysis and not the end drop analysis. The response time history due to corner drop will be slightly different when compared with the end drop. During the corner drop, the cask corner will punch into the concrete pad at an angle; therefore the corner drop will have a longer duration and lower pulse amplitude than the end drop. Since a concrete surface is a yielding surface the response will be different than from an impact on an unyielding surface. The results of the response time histories will be different for the different drop conditions. TN performed a top end drop analysis (CE 16x16) based on the unfiltered curve as shown in Figure U.3.5-7. The resulting total strain increased by 0.02% (Table U.3.5-6, page U.3.5-15).

Based on this result, it is concluded that the response time history used in the fuel rod drop analysis is adequate. The staff concurs that the modal frequency results for the TN TC, using the cutoff frequency for filtering as shown in Figure T3.5-15 for 61BTH, and Figure U.3.5-7 for 32PTH1, in Revision 4 of the application (Ref. 14), are reasonable. The maximum strain for all analysis remained below the yield value therefore there is a reasonable assurance that there will be no permanent deformation of the spent fuel rods. In addition, as described in Revision 5 of the SAR, page U.3.5-7, the response time history at the center region of the cask was also used to analyze the fuel rod corner drop. Figure U.3.5-7 shows the time histories for both locations (at center of lid, and at corner impact location). The bounding results are shown in Table U.3.5-6.

These bounding scenarios for the 61BTH system, and the 32PTH1 system assured that the structural integrity of the DSC and spent fuel cladding was not compromised. Analyses of these scenarios demonstrated that the TC will maintain the structural integrity of the DSC confinement boundary avoiding any potential for a release of radioactive materials to the environment due to a cask drop. The structural integrity analyses of the standardized NUHOMS® System on-site TC, DSC and its internal basket assembly when subjected to the postulated TC drop conditions presented in relevant Sections T for the 61BTH, and Section U for the 32PTH1 were reviewed by the staff and the results were found acceptable. Note that for NUHOMS® 61BTH the DSC shell assembly and basket drop analyses were performed using ANSYS finite element models as appropriate. A confirmatory dynamic time history analysis using LS-DYNA was also performed for the basket that showed margin against buckling collapse relative to the 75g acceleration postulated for accidental side drop. A non-linear elastic-plastic analysis was performed considering both the material and geometric non-linearity. A 45° drop orientation was used for this confirmatory analysis. For this CoC amendment request the staff reviewed this analysis and determined the results acceptable for satisfying the requirements of 10 CFR Part 72.

For NUHOMS® 32PTH1 the DSC shell assembly and basket drop analyses were performed using ANSYS and LS-DYNA finite element models as appropriate. A confirmatory dynamic time history analysis using LS-DYNA was also performed for the basket. Since no data was available on the shape of irradiated fuel cladding, a bowing value as indicated in the FSAR was introduced to the bottom two spans (critical spans) for the bottom end drop and top two spans for the top end drop of the fuel cladding in the shape of the lowest buckling mode. The bowing also facilitates axial instability by providing initial out-of-straightness and it also accounts for manufacturing tolerances and distortion from irradiation growth. Figure U.3.5-5 shows the bowing used in all models. A three-dimensional finite element model of the basket and DSC shell was constructed. LS-DYNA was used for the accidental drop cases because it has a relatively more robust contact algorithm which is able to model contact between the different components in the model. Three side drop orientations were evaluated corresponding to 0°, 30° and 45° side drop orientations at 75g and 95g. The structural integrity analyses presented in Sections U.3.7.4.2, U.3.7.4.3, U.3.7.4.4, and U.3.7.4.5 were also reviewed by the staff and the results were found acceptable. For this CoC amendment request the staff reviewed this analysis and determined the results acceptable for satisfying the requirements of 10 CFR Part 72.

In response to a staff RAI the applicant verified the structural integrity of damaged fuel cladding using a fracture mechanics approach. The fracture mechanics analysis was presented by the applicant using three postulated crack geometries. The staff disagreed with the applicant's original understanding of the reorientation of the hydrides (radial and circumferential) in the cladding material, and its effects on the design allowable for high burnup spent fuel. In response to the staff, the applicant submitted a revised analysis, which staff determined to be acceptable.

Only a limited amount of mechanical properties test data exists for high burnup fuel cladding with radial hydrides. Due to the lower stress and hydrogen content expected in low burnup rods, the mechanical properties of Zircaloy cladding with circumferential hydrides was determined to be acceptable for use when analyzing cladding behavior from low burnup rods. However, this is not acceptable for the analysis of high burnup rods where the stress is much higher and considerable hydride reorientation might occur.

The staff reviewed the revised analysis using the fracture mechanics approach to establish the adequacy of structural integrity of cladding of high burnup damaged spent fuel. In view of the fact that there is no consensus or accurate and adequate information available in the industry, at this point in time, with respect to mechanical properties of high burnup nuclear spent fuel, the staff does not currently agree that the allowable stress intensity factor (K_{IC}) as presented in the current application to verify the adequacy of the high burn-fuel is appropriate. Therefore, this value of K_{IC} should not be used for transportation of high burnup fuel without additional justification.

Staff agrees that for the through-wall axial crack in the cladding, the key driving force on the crack is the tensile hoop stress due to internal pressure. Since there is no internal pressure acting on the damaged cladding, the applied K_I would be essentially negligible. As shown in Figure 3-2-1 of RAI #2, the existing axial crack would not propagate further (sustain further damage) due to an applied bending moment. The finite element analysis described in the Amendment 10 SAR Revisions 1 through 3 is to quantify that the applied K_I for an axial crack in a tube under bending or axial load to demonstrate that it is minimal.

However, although the high burnup fracture mechanical properties are not currently considered acceptable to the staff as presented in the FSAR, in view of the fact that the fuel cladding allowable stress intensity factor for high burnup spent fuel (K_{IC}) as specified in the FSAR is an order of magnitude larger than the expected demand on the spent fuel cladding, the staff has determined that, there is a reasonable assurance, that for this application, the structural integrity of the high burnup damaged fuel will be maintained for storage and expected on-site transfer operations.

For NUHOMS® 61BTH Loss of Neutron Shield there was no change in this amendment for the analysis performed in the past.

For NUHOMS® 32PTH1 Loss of Neutron Shield, as this was a post-drop accident thermal condition, the peak stresses resulting from this condition has to be less than the allowable fatigue stress limit per the ASME Code. Fatigue is not a concern for TC. As demonstrated by similar analyses in the past for other NUHOMS® System the TC stresses need not be evaluated.

3.4.1.5 Blockages of HSM Air Inlet and Outlet Openings

The analysis, conservatively postulated the complete blockage of the HSM-H ventilation air inlet and outlet openings on the HSM-H side walls. As the NUHOMS® HSM-Hs are located outdoors, ventilation air inlet and outlet openings could become blocked by debris from floods, tornadoes, etc.. The structural consequences due to the weight of the debris blocking the air inlet and outlet openings were found negligible and bounded by the HSM-H loads induced for a postulated tornado or earthquake.

For the 32PTH1 this accident conservatively postulates the complete blockage of the HSM-H/HSM-HS ventilation air inlet and outlet openings on the HSM-H/HSM-HS side walls. The structural consequences due to the weight of the debris blocking the air inlet and outlet vent openings are negligible and were bounded by the HSM-H/HSM-HS loads induced for a postulated Tornado or Earthquake.

3.4.1.6 DSC Leakage and Accident Pressurization of DSC

The NUHOMS® 61BTH DSC was leak tested to meet the applicable leak-tight criteria of ANSI N14.5 (Ref. 15). The analysis demonstrated that the pressure boundary will not be breached for normal, off-normal and postulated accident conditions. The DSC was also evaluated and designed for internal pressure which bounds the maximum postulated accident pressure.

The 32PTH1 DSC was leak tested to meet the leak tight criteria (1x 10^{-7} std. cm 3/sec) of ANSI N14.5 -1997 (Ref. 14). The analyses of the 32PTH1 demonstrated that the pressure boundary was not breached since it met the applicable stress limits for normal, off-normal and postulated accident conditions.

The NUHOMS® 32PTH1 DSC was evaluated and designed for DSC internal pressures which bound the maximum accident pressures calculated in U.4.6. The pressure boundary stresses due to this pressure load were bounded by the results presented in Table U.3.7-20. Therefore, the 32PTH1 DSC was acceptable for this postulated accident condition.

3.4.2 Load Combinations for DSC, TC, and HSM

The load categories associated with normal operating conditions, off-normal conditions, and postulated accident conditions were described and analyzed in various sections of the SAR. The load combination for the NUHOMS® components important to safety, the fatigue effects on the DSC and the TC were as follows:

The stress intensities in the DSC at various critical locations for the appropriate normal operating condition loads were combined with the stress intensities experienced by the DSC during postulated accident conditions. It was assumed that only one postulated accident event occurs at any one time. The DSC load combinations summarized in Table 3.2-6 were expanded in Table T.2-11. Since the postulated cask drop accidents are by far the most critical, the load combinations for these events envelop all other accident event combinations. Tables T.3.7-12 through T.3.7-18 tabulate the maximum stress intensity for each component of the DSC (shell and basket assemblies) calculated for the enveloping normal operating, off-normal, and accident load combinations. For comparison, the appropriate ASME Code allowable stress intensities were also presented in these tables.

Although the normal and off-normal internal pressures for the NUHOMS® 61BTH DSC are slightly higher relative to the NUHOMS® 52B DSC, the range of pressure fluctuations due to seasonal temperature changes are essentially the same as those evaluated for the NUHOMS® 52B DSC. Similarly the normal and off-normal temperature fluctuations for the NUHOMS® 61BTH DSC due to seasonal fluctuations was essentially the same as those calculated for the NUHOMS® 52B DSC. Therefore, the fatigue evaluation presented in Section 8.2.10.2 of the original SAR remains applicable to the NUHOMS® 61BTH DSC.

For the 32PTH1 system the stress intensities in the DSC at various critical locations for the appropriate normal operating condition loads were combined with the stress intensities experienced by the DSC during postulated accident conditions. It is assumed that only one postulated accident event occurs at any one time. The DSC load combinations summarized in UFSAR Table 3.2-6 were expanded in Table U.2-13 for the 32PTH1 DSC. Since the postulated cask drop accidents were by far the most critical, the load combinations for these events enveloped all other accident event combinations. Tables U.3.7-18 through U.3.7-20 tabulate the maximum stress intensity for each component of the DSC calculated for the enveloping normal operating, off-normal, and accident load combinations. For comparison, the appropriate ASME Code allowable was also presented in these tables.

Although the normal and off-normal internal pressures for the NUHOMS® 32PTH1 DSC are higher relative to the NUHOMS® 24P DSC, the range of pressure fluctuations due to seasonal temperature changes are essentially the same as those evaluated for the NUHOMS® 24P DSC. Similarly, the normal and off-normal temperature fluctuations for the NUHOMS® 32PTH1 DSC due to seasonal fluctuations are essentially the same as those calculated for the NUHOMS® 24P DSC. Therefore, the fatigue evaluation presented in UFSAR Section 8.2.10.2 for the 24P DSC remains applicable to the NUHOMS® 32PTH1 DSC.

The TC calculated stresses due to normal operating loads were combined with the calculated stresses from postulated accident conditions at critical stress locations. The applicant assumed that only one postulated condition could occur at a given time. The load combination of dead load plus drop accident envelops the stresses induced by other postulated accident scenarios. With the increased dead weight of 93,120 lbs the updated limiting factor of safety of 1.22 was calculated for the cask bottom support ring for NUHOMS® 61BTH DSC.

For the 32PTH1 system the load combinations considered for the OS 197/OS197H for normal, off-normal, and postulated accident loadings were shown in UFSAR Table 3.2-7. Service Levels A and B allowable were used for all normal operating and off-normal loadings. Service Levels C and D allowable were used for load combinations which include postulated accident loadings. The TC load combinations presented in UFSAR Table 3.2-7 were also applicable to the OS200 TC. For the OS200 TC evaluations, the load combinations A1 through C2 in UFSAR Table 3.2-7 were addressed by the nine load cases for normal and off-normal loads in Section U.3.6.1.5.3. In these evaluations a bounding 2g load applied in the axial, transverse and vertical direction was used to bound the handling/transfer and Level C seismic load combinations in combination with deadweight. The bounding 2g load case was also combined with thermal loads resulting from the 31.2 kW and 40.8 kW thermal distributions from the thermal analysis. Load combinations D1 through D3 in UFSAR Table 3.2-7 addressed the accident drop load combinations, evaluated in Section U.3.7.4.4. The high seismic criteria of 1g maximum horizontal and vertical accelerations were a Level D event and were considered bounded by the 75g accident drop evaluations. For the TC Fatigue Evaluation there was no change.

The HSM-H evaluations presented in P.3.7.11.5 were bounding for NUHOMS® 61BTH DSC. For 32PTH1 system HSM-H/HSM-HS Load Combination Evaluations presented in Section U.3.7.11.5, and the HSM-H/HSM-HS Stress Analysis presented in Section U.3.7.11.6 were reviewed by the staff and found acceptable.

3.5 Evaluation Findings

The structural evaluation in this amendment has provided reasonable assurance that the NUHOMS® System will allow safe storage of spent fuel. This finding was reached on the basis of a review that considered the regulation, appropriate Regulatory Guides, applicable codes and standards, and accepted engineering practices. The structural design of the storage cask system design meets the relevant requirements of the following regulations:

F3.1 The SAR adequately describes all structures, systems, and components (SSC) that are important to safety, providing drawings and text in sufficient detail to allow evaluation of their structural effectiveness.

F3.2 The applicant has met the requirements of 10 CFR 72.24, "Contents of Application: Technical Information," with regard to information pertinent to structural evaluation.

F3.3 The applicant has met the requirements of 10 CFR 72.26, "Contents of Application," and 10 CFR 72.44(c), "License Conditions," with regard to technical specifications pertaining to the structures of the proposed cask system.

F3.4 The applicant has met the requirements of 10 CFR Part 72.122(b) and (c) and 10 CFR Part 72.24(c)(3). The structures, systems, and components important to safety are designed to accommodate the combined loads of normal, off-normal, accident, and natural phenomena events with an adequate margin of safety. Stresses at various locations of the cask for various design loads were determined by analysis. Total stresses for the combined loads of normal, off normal, accident, and natural phenomena events are acceptable and are found to be within limits of applicable codes, standards, and specifications.

F3.5 The applicant has met the requirements of 10 CFR Part 72.236(b), "Specific requirements for spent fuel storage cask approval." The structural design and fabrication of the NUHOMS® System includes structural margins of safety for those SSC important to nuclear criticality safety. The applicant has demonstrated adequate structural safety for the handling, packaging, transfer, and storage under normal, off-normal, and accident conditions.

F3.6 The applicant has met the requirements of 10 CFR 72.236(l), "Specific Requirements for Spent Fuel Storage Cask Approval." The design analysis and submitted bases for evaluation acceptably demonstrate that the cask and other systems important to safety will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F3.7 The applicant has met the requirements of 10 CFR 72.120, "General Considerations," and 10 CFR 72.122, "Overall Requirements," with regard to inclusion of the following provisions in the structural design: design, fabrication, erection, and testing to acceptable quality standards, adequate structural protection against environmental conditions and natural phenomena, fires and explosions; appropriate inspection, maintenance, and testing; adequate accessibility in emergencies; a confinement barrier that acceptably protects the spent fuel cladding during storage; structures that are compatible with appropriate monitoring systems; and structural designs that are compatible with ready retrieval of spent fuel.

F3.8 The applicant has met the specific requirements of 10 CFR 72.236(e), (f), (g), (h), (i), (j), (k) and (m), as applicable to the structural design for spent fuel storage cask approval. The cask system structural design acceptably provides for the following required provisions: redundant sealing of confinement systems, adequate heat removal without active cooling systems, storage of the spent fuel for a minimum of 20 years, compatibility with wet or dry spent fuel loading and unloading facilities, acceptable ease of decontamination, inspections for defects that might reduce confinement effectiveness, conspicuous and durable marking, compatibility with removal of the stored fuel from the site, transportation, and ultimate disposition by the U.S. Department of Energy.

F3.9 The NUHOMS® systems were described in sufficient detail to enable an evaluation of its structural effectiveness and are designed to accommodate the combined loads of normal, off-normal, accident, and natural phenomena events. The systems are designed to allow handling and retrieval of spent nuclear fuel for further processing or disposal. The staff concludes that no accident or natural phenomena events analyzed will result in damage of the NUHOMS® 61BTH, and the NUHOMS® 32PTH1 DSC that would prevent retrieval of the DSC.

F3.10 A complete structural evaluation of the 61BTH and the 32PTH1 DSC shell assembly and basket components, the HSM-H, HSM-HS, and the OS200 transfer cask has been performed. The structural evaluation shows that the NUHOMS® system design is compatible with the requirements of 10 CFR 72.236 for maintaining the spent fuel in a subcritical condition, providing adequate radiation shielding and confinement, having adequate heat removal capability, providing a redundant sealing of the confinement system, and providing wet or dry transfer capability.

3.6 References

1. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.

2. U.S. Nuclear Regulatory Commission, Interim Staff Guidance - 2 (ISG- 2), "Fuel Retrievability”, Revision 0.

3. Aluminum Association, “Properties of Aluminum Alloys: Tensile, Creep and Fatigue Data and High and Low Temperatures”, The Aluminum Association and ASM International, J. G. Kaufman, ed., 1999.

4. U.S. Nuclear Regulatory Commission, Regulatory Guide 3.48, “Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)”, Revision 1; August, 1989

5. ANSI/ANS 57.9-1984, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type),” Reaffirmed 2000

6. ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Power Plant Components”, American Society of Mechanical Engineers.

7. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

9. ANSYS Engineering Analysis Systems User’s manual for ANSYS Rev. 8.1 and later, Swanson Analysis Systems, Inc. PA

10. NUHOMS® - HD Safety Analysis Report, NRC Docket No. 72-1030. NUHOMS® HD Horizontal Modular Storage System For Irradiated Nuclear Fuel

11. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.60, “Design Response Spectra for Seismic Design of Nuclear Power Plants,” Revision 1; December, 1973

12. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.61 “Damping Values for Seismic Design of Nuclear Power Plants,” Revision 1, December 2007.

13. LSDYNA, version 970, Key Word User’s manual, “Nonlinear Dynamic Analysis”.

14. Transnuclear, Inc., “Revision 4 to Transnuclear, Inc. (TN) Application for Amendment 10 to the Standardized NUHOMS® System (Docket No. 72-1004; TAC No. L24052);” July 28, 2008.

15. American National Standards Institute, ANSI N14.5-1997, “Leakage tests on Packages for Shipments,” January 1997.

4 THERMAL EVALUATION

4.1 Thermal Evaluation

4.1.1 NUHOMS® 61BTH Thermal Evaluation

The thermal evaluations presented in the applicant's Safety Analysis Report (SAR) (Ref.1) included steady-state and transient analyses of the thermal response of the 61BTH Dry Shielded Canister (DSC) system components to a defined set of thermal operating conditions. These operating conditions envelope the thermal conditions expected during all normal, off-normal, and postulated accident operations during loading, transfer, and storage as defined in Chapter T.2 of the SAR.

The thermal analysis methodology used by the applicant for the analysis of the 61BTH DSC, OS197FC-B transfer cask (TC) and a modified version of the Horizontal Storage Model (HSM-H) is provided in Appendix P, Chapter P4 of Revision 9 of the NUHOMS® SAR (NUHOMS® base SAR (Ref. 2)). A description of the thermal analysis for HSM-H and OS197FC-B TC containing the 61BTH DSC for normal, off-normal, and accident conditions of storage and transfer is provided in Sections T.4.4 and T.4.5 of the SAR, respectively.

Section T.4.6 of the SAR describes the thermal analysis of the 61BTH DSC for storage and transfer conditions. The DSC cavity internal pressures are also calculated in Section T.4.6 of the SAR for all storage and transfer conditions. Section T.4.7 of the SAR describes the evaluation performed for loading/unloading conditions.

The effective thermal conductivity of the fuel assemblies in the 61BTH DSC thermal analysis is determined using on the methodology described in Appendix P, Section P.4.8 of the NUHOMS® base SAR. Section T.4.8 of the SAR presents the fuel assembly and DSC basket effective thermal properties for a helium environment, and the effective thermal conductivity for the transfer cask neutron shield.

The applicant's thermal evaluation concludes that the NUHOMS® 61BTH system listed above meets all the design criteria. The staff has conducted an evaluation of the applicant's submittal to determine if it meets the applicable regulations in 10 CFR Part 72 (Ref. 3). The staff's review is documented in this Safety Evaluation Report (SER).

4.1.2 NUHOMS® 32PTH1 Thermal Evaluation

The thermal evaluations presented in the applicant's Safety Analysis Report (SAR) included steady-state and transient analyses of the thermal response of the 32PTH1 Dry Shielded Canister (DSC) system components to a defined set of thermal operating conditions. These operating conditions envelope the thermal conditions expected during all normal, off-normal, and postulated accident operations during loading, transfer and storage as defined in Chapter U.2 of the SAR.

The thermal analysis methodology used by the applicant for the analysis of the 32PTH1 DSC, OS200 Transfer Cask (TC) and a modified version of the Horizontal Storage Model (HSM-H) is provided in Appendix P, Chapter P4 of Revision 9 of the NUHOMS® SAR (NUHOMS® base SAR). A description of the analysis for HSM-H and OS200 TC containing the 32PTH1 DSC for normal, off-normal, and accident conditions of storage and transfer is provided in Sections U.4.4 and U.4.5 of the SAR, respectively.

Section U.4.6 of the SAR describes the 32PTH1 DSC analysis for storage and transfer conditions. The DSC cavity internal pressures are also calculated in Section U.4.6 of the SAR for all storage and transfer conditions. Section U.4.7 of the SAR describes the evaluation performed for loading/unloading conditions.

An evaluation of the effective thermal conductivity of the fuel assemblies to use in the 32PTH1 DSC thermal analysis is based on the methodology described in Appendix P, Section P.4.8 of the NUHOMS® base SAR. Section U.4.8 of the SAR presents the evaluation of the fuel assembly and DSC basket effective thermal properties for a helium environment.

The applicant's thermal evaluation concludes that the NUHOMS® 32PTH1 system listed above meets all the design criteria. The staff has conducted an evaluation of the applicant's submittal to determine if it meets the applicable regulations in 10 CFR Part 72. The staff's review is documented in this Safety Evaluation Report (SER).

4.2 Spent Fuel

4.2.1 Spent Fuel Storage in the 61BTH System

The NUHOMS® 61BTH System is designed to store up to 61 BWR fuel assemblies with 7x7, 8x8, 9x9, or 10x10 rod arrays, manufactured by General Electric, Exxon/ANF, or FANP, or reload fuel manufactured by other vendors that are enveloped by the fuel assembly design characteristics listed in Table T.2-2 of the SAR. Up to 16 of the assemblies may contain damaged fuel, but the remainder must be intact. Reconstituted fuel assemblies are included in the definition of 'intact', if they contain:

- No more than 10 replacement stainless steel rods, OR
- No more than 61 lower enrichment UO_2 rods (replacing Zircaloy-clad enriched UO_2 rods)

A maximum of four reconstituted fuel assemblies with stainless steel rods are permitted in the DSC. All 61 assemblies may be reconstituted assemblies, if the reconstituted rods contained in the assemblies consist only of lower enrichment UO_2 rods.

Damaged fuel is defined as BWR assemblies with missing or partial fuel rods, or fuel rods with known or suspected cladding defects greater than hairline cracks or pinhole leaks. Damaged fuel assemblies may be located only in the 2x2 array of fuel compartments at the four outer corners of the 61BTH basket.

The NUHOMS® 61BTH is designed for unirradiated fuel with an assembly average initial enrichment of less than or equal to 5.0 wt. % U-235, as shown in Table 1-1u of the Technical Specifications (TS). Specific initial enrichment limits defined for each fuel assembly class are shown in Table 1-1v for intact fuel (or reconstituted fuel) and in Table 1-1w for damaged fuel.

The basket for the 61BTH DSC is supported by four rails (R90 rails) on the long flat faces of the rectilinear basket grid and by eight rails (R45 rails) at the 'corners' of the basket grid. In the Type 1 basket design, the R90 and R45 rails consist of a supporting scaffold of stainless steel plates. Thin aluminum shims are inserted between the outer surface of the outer steel plate of an R45 rail and the DSC shell. (The R90 rails do *not* have similar aluminum shims.) In the Type 2 basket design, the R90 rails consist of solid aluminum billets, and the R45 rails are stainless steel plates in essentially the same configuration as in the Type 1 basket, except that each R45 rail has aluminum liner plates bolted to the outer surface of the outer steel plate. (The basket and support rails configuration for the Type 1 basket is identical to that of the 61BT DSC, shown in drawing number NUH-61B-1063-SAR, Revision 0 in Appendix K, Section K.1.5. The geometry of the Type 2 basket and support rails is shown in drawing number NUH61BTH-2002-SAR, sheets 2 and 3, Revision 0, in Appendix T, Section T.1.5.)

Each basket type is designed with six alternate configurations labeled A through F, based on the boron content in the poison plates. The quantity and distribution of boron in the poison plates is controlled by specific manufacturing and acceptance criteria described in chapter T.9 of the SAR. The three neutron absorbers allowed are borated aluminum, BORAL®, or Boron Carbide/Aluminum Metal Matrix Composite (MMC).

For the BWR fuel assemblies, the allowable temperature limits are based on Interim Staff Guidance -11 (ISG-11) (Ref 4). For normal conditions (long-term) of storage and short-term fuel loading and storage operations (which includes welding of the canister lid and drying with an inert gas, backfilling with inert gas, and transfer of the cask to the storage pad), the temperature limit of the fuel cladding must be maintained below 400°C (752°F). The purpose of this limit is to ensure that circumferential hydrides in the cladding will not dissolve and go into solution during fuel loading operations, and that re-precipitation of radial hydrides does not occur in the cladding during storage. (See ISG-11, Rev. 3 for a discussion on hydride reorientation.) ISG-11 also establishes a temperature limit of 570°C (1058°F) for Zircaloy-4 fuel cladding for off-normal storage and all hypothetical accident conditions.

4.2.2 Spent Fuel Storage in the 32PTH1 System

The NUHOMS® 32PTH1 System is designed to store up to 32 unconsolidated, or reconstituted B&W 15x15, WE 17x17, CE 15x15, WE 15x15, CE 14x14, WE 14x14, and CE 16x16 class fuel assemblies (with or without control components) that are enveloped by the fuel assembly design characteristics listed in Table U.2-3 of the SAR. Up to 16 of the fuel assemblies can contain damaged fuel, but the remainder of the assemblies must be intact. Damaged fuel consists of fuel assemblies with non-adjacent damaged grid spacers, missing or partial fuel rods, and may also contain fuel rods with known or suspected cladding defects more severe than hairline cracks or pinhole leaks. However, fuel cladding damage must not be so severe that a fuel pellet could fall out of the rod during handling.

The NUHOMS® 32PTH1 is designed for unirradiated fuel with maximum assembly average initial enrichment of no more than 5.0 wt. % U-235, as shown in Table 1-1aa of the Technical Specifications. Specific initial enrichment limits defined for each fuel assembly class are shown in Table 1-1cc for intact fuel, and in Table 1-1dd for damaged fuel. These limits are a function of soluble boron in the DSC cavity water during loading operations and the boron content in the poison plates of the DSC basket. The five different fixed poison loading configurations for the neutron absorbers in the basket are designated A through E. Minimum boron content of the neutron absorber plates for each design are specified in Table 1-1ff for Boral® or Boron-Aluminum (which is either a metal matrix composite (MMC) or a borated aluminum alloy). TS 1.2.15d, which specifies the requirements for boron concentration in the DSC cavity water for the 32PTH1 DSC, refers to Table 1-1cc and Table 1-1dd for minimum soluble boron concentration limits for the various fuel assembly classes authorized for loading into this DSC.

Two basket types are included in the 32PTH1 DSC design, and are designated Type 1 basket and Type 2 basket. The two designs are identical in all aspects, except for the transition rails. Type 1 basket transition rails are solid aluminum billets that fill the space between the flat basket plates and the curved inner surface of the cylindrical DSC shell. The transition rails for the Type 2 basket consist of a supporting scaffold of stainless steel plates, some of which have thin aluminum plates bolted to the inner surface.

For the PWR fuel assemblies, the allowable temperature limits are based on Interim Staff Guidance No. 11 (ISG-11). For normal (long-term) and off-normal (short-term) conditions of storage, the maximum temperature of the fuel cladding must be maintained below 400ºC (752°F). For normal and off-normal fuel loading and transfer operations (which include welding of the canister lid and drying with an inert gas, backfilling with inert gas, and transfer of the cask to the storage module), the temperature of the fuel cladding must also be maintained below 400°C (752°F). The purpose of the limit is to ensure that circumferential hydrides in the cladding will not dissolve and go into solution during fuel loading operations, and that re-precipitation of radial hydrides does not occur in the cladding during storage. (See ISG-11, Rev. 3 for a discussion on hydride reorientation.) ISG-11 also establishes a temperature limit of 570°C (1058°F) for Zircaloy-4 fuel cladding for hypothetical accident conditions.

4.3 Cask System Thermal Design

4.3.1 Design Criteria for the 61BTH System

The NUHOMS® 61BTH system 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 regulatory limits. Table 4.1 summarizes the four limiting system configurations, showing the permitted variations and combinations of DSC basket type, neutron absorber plates, maximum decay heat load, transfer cask configuration, and storage module design.

Table 4.1 NUHOMS® 61BTH System Configurations

System Configuration	61BTH DSC Basket type	Neutron absorber plate Type	Maximum decay heat load (kW)	Transfer cask	Storage Module
1	1	Borated aluminum, MMC, or Boral®	19.4	OS197 or OS197H or OS197FC-B	HSM Model 80 or HSM Model 102 or HSM Model 152 or HSM Model 202 or HSM-H
2		Borated aluminum	22.0		
3	2	Borated aluminum, MMC, or Boral®	27.4	OS197FC-B	HSM-H
4		Borated aluminum	31.2		

Specific thermal design criteria are established for the thermal analysis of these system configurations, as discussed below.

- Maximum temperatures of the confinement structural components must not adversely affect the confinement function.

- Maximum fuel cladding temperature limit of 400°C (752°F) is applicable to normal conditions of storage and all short-term fuel loading and transfer operations including vacuum drying and helium backfilling of the 61BTH DSC per Interim Staff Guidance (ISG) No. 11, Revision 3.

- No repeated thermal cycling of the fuel cladding with temperature difference greater than 65°C (117°F) during drying and backfilling operations.

- Maximum fuel cladding temperature limit of 570°C (1058°F) is applicable to off-normal storage and accident conditions.

4.3.2 Design Features of the 61BTH System

To enhance heat rejection and shielding capability for the two highest heat load canisters (configurations 3 and 4, see Table 4.1 above), the applicant designed the HSM-H storage module with the following features:

- Twelve evenly spaced 6-inch holes through the web of the I-beam along the axial length of the DSC support structure to increase airflow at the bottom portion of the canister. (Note that in this design, the vented support bar along the contact line between the DSC outer shell and the upper surface of the I-beam is optional. It can be included in a particular storage module, but it is not *required*. Thermal analysis models in the SAR therefore do not include this feature.)

- Increased module cavity height to increase the stack height and reduce the flow resistance in the cavity.

To enhance radial heat transfer within the DSC, the 61BTH design includes:

- Solid aluminum R90 support rails and aluminum plates on the outer face of the stainless steel R45 rails (in the Type 2 basket design) for enhanced radial conduction from the basket to the inner surface of the DSC shell.

- Basket structure that consists of aluminum and aluminum-alloy poison plates to form *continuous* high-conductivity radial heat transfer paths from the fuel compartment walls to the support rails.

- Offsets in the structural steel insert plates to eliminate hot spots.

Within the storage module, the DSC is cooled by buoyancy driven air flow through openings at the base of the HSM-H, which allows ambient air to be drawn into the module. Heated air exits through vents in the top of the shield block in the module ceiling, creating a chimney or “stack” effect. Metal heat shields are placed above and to either side of the DSC to protect the concrete surfaces of the storage module from thermal radiation effects.

The DSC cavity is backfilled with helium gas to aid removal of heat from the fuel assemblies and maintain an inert atmosphere.

The staff verified that all methods of heat transfer internal and external to the storage system are passive. The only active cooling occurs in the OS197FC-B under off-normal conditions when specific transfer time limits have been exceeded. The SAR drawings and summary of material properties provided sufficient detail for the staff to perform an in-depth evaluation of the thermal performance of the system.

4.3.3 Design Criteria for the 32PTH1 System

The NUHOMS® 32PTH1 DSC is contained within the OS200 or OS200FC TC for loading and transfer operations, and within the HSM-H Storage Module for long-term storage. These systems are designed to passively reject decay heat during storage and transfer for normal, off-normal, and accident conditions while maintaining temperatures and pressures within specified regulatory limits. Specific thermal design criteria are established for the thermal analysis of the systems, as discussed below.

- Maximum temperatures of the confinement structural components must not adversely affect the confinement function.

- Maximum fuel cladding temperature limit of 400°C (752°F) is applicable to normal conditions of storage and all short-term fuel loading and transfer operations, including vacuum drying and helium backfilling of the 32PTH1 DSC, per Interim Staff Guidance (ISG) No. 11, Revision 3.

- Thermal cycling of the fuel cladding must not occur with temperature differences greater than 65 °C (117 °F) during drying and backfilling operations.

- Maximum fuel cladding temperature limit of 570°C (1058°F) is applicable to off-normal storage and accident conditions.

4.3.4 Design Features of the 32PTH1 System

The HSM-H is a modified version of the HSM Model 102, described in the NUHOMS® base SAR. To enhance heat transfer rates due to natural convection around the DSC and increase shielding capability, the applicant designed the HSM-H with the following features:

- Twelve evenly spaced 6-inch holes through the web of the I-beam along the axial length of the DSC support structure to increase airflow at the bottom portion of the canister. (Note that this design does ***not*** include a vented support bar along the contact line between the DSC outer shell and the upper surface of the I-beam.)

- Increased module cavity height to increase the stack height and reduce the flow resistance in the cavity.

To enhance radial heat transfer within the DSC, the 32PTH1 design includes:

- Solid aluminum support rails (in the Type 1 basket design) for enhanced radial conduction from the basket to the DSC inner shell surface.

- Use of interlocking slotted aluminum and poison plates to form an “eggcrate” type basket that minimizes gaps between components.

- Close-tolerance interlocking of basket structure plates to minimizes gaps between component plates and between basket plates and the steel fuel compartments.

- Offsets in the structural steel insert plates to eliminate hot spots.

- Aluminum liner plates on inner surfaces of steel transition rails, to enhance radial heat transfer from the basket edge to the DSC shell.

Within the HSM-H storage module, the DSC is cooled by buoyancy-driven air flow through openings at the base of the HSM-H, which allows ambient air to be drawn into the module to cool the DSC. Heated air exits through vents in the top of the shield block, creating a chimney or “stack” effect. Metal heat shields are placed to protect the HSM-H interior concrete surfaces above and to the side of the DSC from thermal radiation.

The design of OS200/OS200FC TC is similar to the design of the OS187 TC described in previous submittals from the applicant. The primary differences are a longer length and provisions in the cask lid and cask base to accommodate forced air circulation in OS200FC.

The staff verified that all methods of heat transfer internal and external to the HSM-H and OS200 systems (and the OS200FC with forced air circulation off) are passive. The only active cooling occurs in the OS200FC under off-normal conditions, when specific transfer time limits have been exceeded. The SAR drawings and summary of material properties provided sufficient detail for the staff to perform an in-depth evaluation of the thermal performance of the system.

4.4 Thermal Load Specifications

4.4.1 Thermal Load Specifications for the 61BTH System

SAR Section T.4.1 discusses the thermal loads. The four system configurations listed in Table 4.1 above with bounding heat loads were analyzed by the applicant for steady-state and transient cases for normal, off-normal, and accident conditions. The staff reviewed these configurations and has reasonable assurance that the cases are bounding.

A total of eight (8) heat load zoning configurations (HLZCs) are allowed for the 61BTH DSCs as shown in Figure T.2-1 through Figure T.2-8 of the SAR. The different DSC types, the maximum decay heat loads, and the applicable HLZCs are summarized in Table 4.2 below.

Forced air cooling must be available in the transfer cask for the 61BTH DSC with Type 2 basket when loaded in the HLZC #5, HLZC #6, or HLZC #7 patterns, with total decay heat up to 31.2 kW. Forced air cooling is also required for this DSC configuration with the HLZC #8 loading pattern and a total decay heat load up to 27.4 kW.

A complete set of thermal analyses for storage in the HSM (or HSM-H), and transfer in the OS197 (or OS197FC-B) TC are presented in the SAR, Appendix T only for the following configurations of the 61BTH DSC;

- Type 1 basket, borated aluminum neutron absorber option, maximum decay heat load 22 kW, with

  - HLZC #1 (uniform)
  - HLZC #2 (non-uniform, 3 active zones)

- Type 2 basket, borated aluminum neutron absorber option, maximum decay heat load 31.2 kW, for storage in the HSM-H, and transport in the OS197FC-B transfer cask, with
  - HLZC #5
  - HLZC #6
  - HLZC #7

Sensitivity analyses demonstrating bounding conditions are also shown for specific cases for the following configurations;

- Type 1 basket, Boral® and MMC neutron absorber options, HLZC #3 and #4, maximum decay heat load 19.4 kW
- Type 2 basket, Boral® and MMC neutron absorber options, HLZC #8, maximum decay heat load 27.4 kW

This selection of limiting cases was examined by the staff in detail, to confirm that the results presented in the SAR Amendment 10, Appendix T fully captured the bounding configurations for the large number of combinations of decay heat load, neutron absorber option, heat loading zone configuration, and basket geometry permitted in the 61BTH DSC.

The primary factor to consider in determining the limiting configuration for each basket design is the maximum permitted decay heat. All other things being equal, the higher the decay heat load, the more limiting the configuration. Therefore, the bounding case(s) are expected to be at 22 kW for the Type 1 basket and 31.2 kW for the Type 2 basket. Similarly, for the same total decay heat load and the same basket geometry, a uniform heat loading pattern is more limiting than a non-uniform distribution with hotter assemblies near the periphery. Therefore, HLZC #1 is expected to be more limiting than HLZC #2 at 22 kW, and HLZC #3 should be more limiting than HLZC #4 at 19.4 kW. This is consistent with the bounding cases selected for analysis, as noted above.

TABLE 4.2 Summary of Limiting Decay Heat Loading Configurations for 61BTH DSC

Heat Loading Zone Configuration	Number of zones	Maximum number of assemblies per zone	Maximum decay heat/ assembly (kW)	Maximum decay heat per zone (kW)	Maximum total decay heat (kW)	Permitted 61BTH DSC configuration(s)
HLZC #1	1	61	0.393	22.0	22.0	Type 1 (with borated Aluminum NP plates) Type 2
HLZC #2	3	25	0.35	8.75	22.0[1]	Type 1 (with borated Aluminum NP plates) Type 2
		24	0.48	11.52		
		12	0.54	6.48		
HLZC #3	1	61	0.350	19.4	19.4	Type 1 Type 2
HLZC #4	4	9	0.22	1.98	19.4[1]	Type 1 Type 2
		16	0.35	5.60		
		24	0.48	11.52		
		12	0.54	6.48		
HLZC #5	2	9	0.35	3.15	31.2[1]	Type 2 (with borated Aluminum NP plates)
		52	0.54	28.08		
HLZC #6	4	9	0.22	1.98	31.2[1]	Type 2 (with borated Aluminum NP plates)
		24	0.48	11.52		
		12	0.54	6.48		
		16	0.70	11.20		
HLZC #7	2	25	0.48	12.0	31.2[1]	Type 2 (with borated Aluminum NP plates)
		36	0.54	19.44		
HLZC #8	4	9	0.35	3.15	27.4[1]	Type 2
		16	0.393	6.288		
		24	0.48	11.52		
		12	0.54	6.48		

(1) Actual assembly decay heat loads must maintain total decay heat load (*and* total decay heat loads per zone) below specified limits.

The thermal performance of Boral® bounds the other two options for neutron absorber plates, since it has the lowest thermal conductivity of the three materials, as shown in the plot in Figure 4.1. Therefore, the Boral® option for the neutron absorber plates is the most limiting of the three, and is, in fact, too limiting for the higher decay heat loads allowed in both the Type 1 and Type 2 DSC designs. Table 4.3 summarizes the winnowing of the DSC combinations, based on decay heat, loading configuration, and neutron absorber option, and shows that the cases selected for analysis in the SAR Appendix T are appropriate for determining the bounding conditions for storage and transfer of the 61BTH DSC.

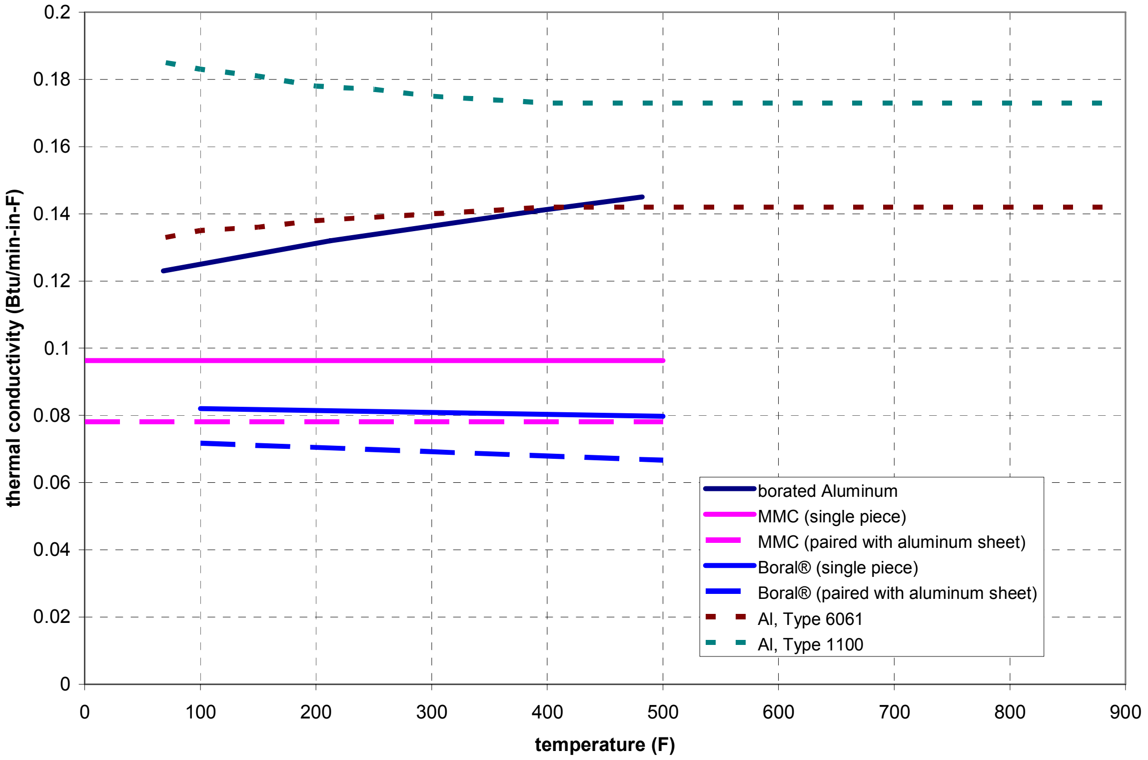


Figure 4.1 Thermal Conductivities for Neutron Absorber Plate Options in 61BTH DSC (from SAR Amendment 10, Appendix T, Section T.4.3)

Table 4.3 Summary of Limiting Configurations for 61BTH DSC

DSC Type	Neutron absorber type	Maximum decay heat load (kW)	Permitted heat loading zone(s) for maximum decay heat load	Bounding configuration(s)
Type 1	Borated Aluminum	22.0	#1, #2	#1⁽¹⁾
	Boral®	19.4	#3, #4	#3⁽¹⁾
	MMC			
Type 2	Borated Aluminum	31.2	#5, #6, #7	(additional analysis required)⁽²⁾
	Boral®	27.4	#8	#8
	MMC			

(1) For the same total heat load, uniform heat loading is bounding over non-uniform loading in which higher decay heat assemblies are on the periphery of the basket. Therefore, HLZC #1 is bounding relative to HLZC #2, and HLZC #3 is bounding relative to HLZC #4.

(2) All three HLZC patterns are non-uniform, and therefore it is not obvious which would be the most limiting.

4.4.1.1 Storage and Transfer: Normal and Off-Normal Conditions (61BTH)

The 61BTH DSC components were evaluated by the applicant for normal conditions of storage and transfer over the range of design basis ambient temperatures. Boundary conditions for these cases were assumed to occur for a sufficient duration such that a steady-state temperature distribution existed within the 61BTH DSC components.

For the storage in HSM-H, higher heat loads with borated aluminum for both DSC Type 1 and Type 2 are considered the bounding cases. Analyses of lower heat loads and other neutron absorbers are not performed. For storage of the Type 1 DSC in the HSM (Models 80, 102, 152, or 202), the design heat load of 24 kW for this storage module is assumed bounding on the 61BTH DSC. Therefore, analyses are not performed for the 22 kW decay heat load in the HSM. Instead, DSC shell temperatures obtained with a decay heat load of 24 kW (see Section 8.1.3 of the NUHOMS® base SAR, and Table T.4-28 of the SAR) are used as conservative boundary conditions for detailed analysis of the DSC internal components.

The following ambient conditions are considered for thermal analysis of normal storage and for transfer with the cask horizontal and outside the fuel handling facility:

- Maximum normal ambient temperature of 100°F with insolation, and
- Minimum normal ambient temperature of 0°F without insolation.

4.4.1.1.1 OS197FC-B Transfer Cask: Normal Conditions

The thermal design criteria of the OS197/OS197H/OS197FC-B TC are unchanged from Chapter 3 of the NUHOMS® base SAR.

Operations involving the OS197FC-B TC will occur within the fuel handling facility and outdoors. Ambient temperatures in the range of 0 to 120°F are considered as normal transfer conditions for operations within the fuel handling facility.

The DSC configurations and the associated maximum decay heat loads considered are described in Section T.4.1 of the SAR. The 61BTH DSC with Type 1 basket, which is permitted a maximum decay heat load up to 22 kW, can be transferred within the OS197 or OS197H or OS197FC-B transfer cask. The capability of forced air circulation is not required for the 61BTH DSC with Type 1 basket. The 61BTH DSC with Type 2 basket requires the capability for forced air circulation in the transfer cask when the maximum decay heat load exceeds 22.0 kW (up to a maximum heat load of 31.2 kW). For this configuration, the 61BTH DSC must be within the OS197FC-B transfer cask.

The following ambient conditions are considered for thermal analysis of transfer with the cask vertical, inside the fuel handling facility:

- Maximum normal ambient temperature of 120°F without insolation, and
- Minimum normal ambient temperature of 0°F without insolation.

4.4.1.1.2 OS197FC-B TC Transfer Cask: Off-Normal Conditions

The thermal performance of the 61BTH DSC transfer in the OS197FC-B transfer cask was examined in Section T.4.5.2 of the SAR for the following off normal ambient conditions:

- Maximum ambient temperature of 117°F without insolation (i.e., solar shield in place; horizontal transport)
- Maximum ambient temperature of 120°F for vertical loading within the fuel handling facility.

Technical Specification 1.2.4 for transfer operations specify that a solar shield must be used to provide protection against direct solar radiation for transfer operations when ambient temperature exceeds the normal condition ambient temperature of 100°F. As discussed in Section T.4.5.3.1 of the SAR, the normal transfer conditions are bounded by vertical loading case with off-normal 120°F ambient temperature in the fuel loading area.

4.4.1.1.2.1 Lid Configuration for OS197FC-B TC: External Cooling (Blower Fans)

The OS197FC-B TC differs from the OS197/OS197H/OS197FC TC designs by including a modified top lid and wedge spacers at the bottom of the TC cavity which enable an exit path for air circulation through the TC/DSC annulus. The external air circulation feature may only be used for specific situations during the transfer mode (outside of normal operations), as defined in the Technical Specifications (Section 1.2.18a). The relevant criteria are summarized as follows:

- Type 2 basket in the 61BTH DSC, **and**
- Total decay heat is greater than 22.0 kW **and**
- Specific time limits for transfer are exceeded

This alternate top lid design is nearly identical to the top lid of OS197FC TC shown in Figure P.1-5 of Appendix P of the NUHOMS® base SAR. The details of the modifications necessary to convert a OS197/OS197H TC into a OS197FC-B TC can be found in the applicant's Drawings NUH-03-8000-SAR and NUH-03-8007-SA, included in Section T.1.5 of the SAR.

4.4.1.1.3 HSM-H: Storage Off-Normal Conditions

The thermal performance of the 61BTH DSC within the HSM-H, under the extreme minimum and maximum ambient temperatures indicated below, was evaluated by the applicant for DSCs with both Type 1 and Type 2 baskets. The applicant's analysis for the HSM-H is described in Section T.4.4.4 of the SAR.

Off-normal conditions of storage of the 61BTH DSC within the HSM-H include:

- Maximum off-normal ambient temperature of 117°F with insolation, and
- Minimum off-normal ambient temperature of -40°F without insolation.

For off-normal steady-state analyses, the maximum off-normal ambient temperature boundary condition is represented with a 24-hour average ambient temperature of 105°F. The applicant considers this conservative, based on calculations presented in the NUHOMS® base SAR, Appendix M, Section M.4.5. However, in the HSM-H air flow analysis (see Section T.4.4.3), the steady-state air flow through the storage module is calculated for off-normal conditions assuming an ambient air temperature of 117°F, based on the "stack effect calculations" methodology in the NUHOMS® base SAR, Appendix P, Section P.4.4.3.

The staff has evaluated the effect of this different treatment of the boundary conditions in different parts of the model, and concluded that the approach is conservative. Using the peak ambient temperature in the 'stack effect' calculation results in a smaller driving head for natural convection flow through the storage module, due to the decreasing density of air with increasing temperatures, and also gives a higher air inlet temperature for convection within the storage module. Using the 24-hour averaged ambient temperature for external heat transfer is consistent with the approach of using 24-hour averaged values for insolation on the exposed surfaces of the module.

This yields the steady-state equivalent of the transient response of the system to the diurnal cycle.

4.4.1.2 Accident Analyses (61BTH)

The 61BTH DSC was evaluated for accident conditions of storage and transfer over a range of design basis off-normal ambient temperatures.

4.4.1.2.1 Transfer Cask Accident Evaluations

Three accident scenarios are evaluated for the OS197FC-B TC with the 61BTH DSCs. These accident scenarios are described in Section T.4.5.3.3 of the SAR, and are summarized below.

- The first accident scenario evaluates the effect of loss of the air circulation system and predicts the heat up rate for the 61BTH DSC in the OS197FC-B TC with decay heat load of 31.2 kW. The analysis assumes that the TC and DSC are initially at steady-state under the normal hot condition with air circulation. At time = 0, the air circulation is assumed to be lost and the system begins to heat up. The response of the 61BTH Type 2 DSC with 31.2 kW is assumed bounding on the Type 1 DSC with 22 kW.

- The second accident scenario, the loss of neutron shield, evaluated the potential loss of both the air circulation and the water in the neutron shield. This scenario was evaluated for 31.2 kW and 22 kW in the DSC.

- The third accident scenario evaluated the effect of a 15-minute hypothetical fire on the OS197FC-B TC with the 61BTH DSC. This scenario was evaluated for 31.2 kW in the DSC. (The Type 1 DSC with 22 kW was assumed bounded by the Type 2 DSC with 31.2 kW in this scenario.) The initial temperature condition for the fire accident transient is the same as used for the start of the loss of the neutron shield accident scenario.

4.4.1.2.1.1 Transfer Cask Loss of Neutron Shield and Sunshade

This postulated transfer accident event consists of the 61BTH DSC in the OS197FC-B TC in a 100°F ambient environment with loss of the sunshade, loss of liquid neutron shield, and loss of air circulation. The evaluation completed by the applicant establishes the predicted thermal response for 61BTH DSC decay heat loads of 22.0 and 31.2 kW.

In each case, the accident analysis was a transient that was assumed to start at the point where the maximum operational time allowed without air circulation was reached, as described in Section T.4.5.3.3 of the SAR. The initial conditions for the accident were chose because this yields the hottest allowable operating temperatures within the DSC and TC at the start of the accident, and thus provides a conservative starting point. At the beginning of this transient, the water in the neutron shield jacket is lost (drained) and the air circulation option is assumed to be unavailable.

As described in Section T.4.5.3.3 of the SAR, the accident scenario 'loss of neutron shield' bounds the other accident scenarios for the transfer operation.

4.4.1.2.1.2 Fire

The fire accident scenario consists of a 15-minute hypothetical fire fully engulfing the OS197FC-B TC containing a 61BTH DSC with a decay heat load of 31.2 kW. The postulated worst-case fire accident consists of a 300-gallon diesel fire with a flame temperature of 1475ºF and emittance of 0.9. The maximum duration of the fire event will be operationally controlled through administrative controls limiting the available fuel sources within the vicinity of the TC.

The initial conditions for the fire accident transient are assumed to be steady-state, off-normal conditions of transport, with ambient temperature of 117ºF, forced air circulation on, no solar shield (i.e., maximum insolation), and a water-filled neutron shield. These are essentially the same as the initial conditions for the loss of the neutron shield accident scenario, except for the ambient air temperature, which is assumed to start from hot-normal (100ºF) ambient.

4.4.1.2.1.3 Cask Heatup During Loading

All fuel loading/unloading operations occur when the 61BTH DSC and TC are in the spent fuel pool. The fuel is always submerged in free-flowing pool water permitting heat dissipation. After fuel loading is complete, the TC and DSC are removed from the pool, and the DSC is drained, dried, sealed, and backfilled with helium.

The loading condition evaluated by the applicant for the 61BTH DSC is heatup of the DSC before its cavity is backfilled with helium. This typically occurs during the vacuum drying operation of the DSC cavity with the TC in the vertical position inside the fuel building, and the annulus between the TC and the DSC is full of water. The applicant assumed the initial temperature of the DSC, basket and fuel to be at the bounding value of 225°F, which is based on saturation boiling temperature of the fill water for the pressure at the bottom of the annulus.

The vacuum drying operation is initiated by forcing out the water in the DSC cavity by gas injection (blowdown operation). Helium is used as the medium to remove the water and subsequent vacuum drying occurs with helium at very low pressure (~3-5 torr) in the DSC cavity. This pressure is not low enough to significantly reduce the thermal conductivity through the helium, and conduction heat transfer through the gas is assumed during vacuum drying. Thermal radiation between the basket plates and rails, or between rails and the DSC inner shell surface is conservatively neglected in the analysis. A description of the applicant's evaluation of the vacuum drying condition is provided in Section T.4.7.1 of the SAR.

Between the removal of the cask from the spent fuel pool, and performing the seal weld on the inner lid of the DSC, a technical specification (TS) requirement (TS 1.2.19) as well as procedures outlined in Appendix T, Section T.8.1.2, Steps 15 and 16 and Section T.8.1.3, Steps 6, 18, and 19 ensure that there will be a helium environment present in the DSC.

4.4.1.2.2 HSM-H and 61BTH DSC Accident Evaluations

4.4.1.2.2.1 Blocked Vents

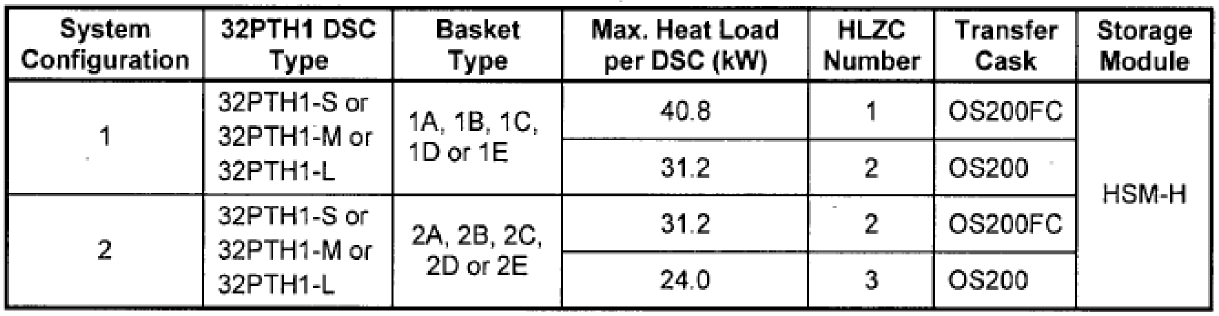
The hypothetical blocked vent accident condition is described in Section T.4.6.8. For analysis purposes, the HSM-H ventilation inlet and outlet openings are assumed to be completely blocked for a 40-hour period. This event is assumed to be concurrent with the occurrence of extreme off-normal ambient temperature of 117°F with insolation. The applicant's description of the analytical model for this accident is presented in SAR Section T.4.4.5. The applicant's results are described in Section T.4.4.7.2, and evaluated in Section T.4.4.8.

A maximum temperature of 426ºF is predicted for the concrete at the end of the 40 hours, which is significantly above the 350ºF limit in NUREG-1536 for accident conditions. The applicant is committed to testing to document that concrete compressive strength will be greater than that used in the structural analysis documented in Section T.3.

4.4.2 Thermal Load Specifications for the 32PTH1 System

SAR Section U.4.1 discusses the thermal loads. Two configurations (defined in Table 4.4) with bounding heat loads were analyzed by the applicant for steady state and transient cases for normal, off-normal and accident conditions. The staff reviewed these configurations and has reasonable assurance that the cases are bounding.

Table 4.4. Maximum Thermal Loading Configurations for the 32PTH1 DSC



System Configuration	32PTH1 DSC Type	Basket Type	Max. Heat Load per DSC (kW)	HLZC Number	Transfer Cask	Storage Module
1	32PTH1-S or 32PTH1-M or 32PTH1-L	1A, 1B, 1C, 1D or 1E	40.8	1	OS200FC	HSM-H
			31.2	2	OS200	
2	32PTH1-S or 32PTH1-M or 32PTH1-L	2A, 2B, 2C, 2D or 2E	31.2	2	OS200FC	
			24.0	3	OS200	

The heat loading zone configurations (HLZC) are defined in Figures U.4-1, U.4-2, and U.4-3 of Appendix U of the SAR submittal. The allowable configurations are outlined below:

- HLZC #1 is a non-uniform loading pattern that is permitted only in the DSC with Type 1 basket (solid aluminum rails). This configuration allows up to 16 assemblies with a maximum decay heat of 1.5 kW, up to 12 assemblies with a maximum decay heat of 1.3 kW, and up to 4 assemblies with a maximum decay heat of 0.6 kW, for a maximum total decay heat of 40.8 kW in the DSC.

- HLZC #2 is a nearly uniform loading pattern that is permitted with either the Type 1 or Type 2 basket. This configuration allows up to 28 assemblies with a maximum decay heat of 0.98 kW and up to 4 assemblies with a maximum decay heat of 0.96 kW, for a maximum total decay heat of 31.2 kW in the DSC.

- HLZC #3 is a uniform loading pattern with maximum decay heat up to 0.8 kW per assembly, for a maximum total decay heat of 24 kW in the DSC. This loading configuration can be used in a DSC with either Type 1 or Type 2 basket.

Forced air cooling must be available in the transfer cask for the DSC with Type 1 basket, when loaded in the HLZC #1 loading pattern with a total decay heat load greater than 31.2 kW (up to 40.8 kW.) Similarly, forced air cooling must be available in the transfer cask for the DSC with Type 2 basket when loaded in the HLZC #2 loading pattern and total decay heat load greater than 24 kW (up to 31.2 kW).

4.4.2.1 Storage and Transfer: Normal and Off-Normal Conditions

The 32PTH1 DSC components were evaluated by the applicant for normal conditions of storage and transfer over the range of design basis ambient temperatures. Boundary conditions for these cases were assumed to occur for a sufficient duration such that a steady-state temperature distribution existed within the 32PTH1 DSC components. The following subsections summarize the peak cladding temperatures reported in the SAR (Appendix U, Revision 3) for normal and off-normal conditions of transfer and storage in the four design basis configurations of the 32PTH1 DSC.

4.4.2.1.1 Transfer Cask (OS200/OS200FC TC): Normal Conditions

Operations involving the OS200 or OS200FC TC occur with the TC/DSC system vertical within the fuel handling facility or horizontal (when loaded onto the transfer skid.) The TC/DSC system is horizontal while in transit to the ISFSI. Operations within the transfer facility are expected to be of short enough duration that analyses presented in the SAR for this configuration are performed as transients. Ambient temperatures in the range of 0° to 120°F are defined as normal transfer conditions for operations within the fuel handling facility. The SAR does not present analysis results for the vertical loading transient under normal conditions. Instead, results are presented for the extreme ambient temperature of 140°F, and these conditions are assumed bounding on normal operations. (See Section 4.4.2.1.2 below for evaluation of off-normal conditions.)

Ambient temperatures in the range of 0°F (without insolation) to 106°F (with insolation) are defined as normal transfer conditions with the TC/DSC horizontal, during transit to the ISFSI. The two limiting configurations that require the availability of forced air circulation (Type 1, HLZC #1, 40.8 kW and Type 2, HLZC #2, 31.2 kW) are analyzed as transients. The other two limiting configurations, which do not need forced air circulation (Type 1, HLZC #2, 31.2 kW and Type 2, HLZC #3), are analyzed assuming steady-state conditions.

The maximum peak cladding temperature for transient conditions, before forced air circulation is activated, is reported at 730°F for the DSC with Type 2 basket, HLZC #2, 31.2 kW decay heat. The maximum steady-state peak cladding temperature where forced air circulation is not required, is reported as 737°F for the DSC with Type 1 basket, HLZC #2, 31.2 kW.

Confirmatory calculations for the TC/DSC system are discussed in Section 4.6.3.2, in connection with evaluation of the modeling approach used to represent the horizontal transfer cask containing the DSC.

4.4.2.1.2 Transfer Cask (OS200/OS200FC TC): Off-Normal Conditions

The thermal performance of the 32PTH1 DSC in the OS200/OS200FC transfer cask is reported in Section U.4.5.1 of the SAR for the following off-normal ambient conditions:

- Maximum ambient temperature of 117°F with solar shield in place, OS200/OS200FC horizontal on transfer skid
- Maximum ambient temperature of 140°F for vertical loading within the fuel handling facility.

Table 4.5 shows the peak cladding temperatures reported in the SAR for off-normal conditions of transfer, and includes both the vertical loading transient within the fuel handling facility and horizontal transfer to the ISFSI. As with the results for normal conditions presented in Section 4.4.2.1.1, calculations are transients for the two DSC configurations that require forced air circulation if specified time limits are exceeded. Calculations are steady-state for the two configurations that do not require forced air circulation.

Table 4.5. Peak Cladding Temperatures for Off-Normal Transfer Conditions

Conditions Evaluated in SAR (regulatory limit: 752ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
	(ºF)				
in TC (vertical in transfer facility)--					
Extreme Ambient (hot)	140	730 (transient)	737	727 (transient)	702
Normal (hot)	120	< 730 (transient)	< 737	< 727 (transient)	< 702
in TC (horizontal, in transit to ISFSI)--					
Normal (hot)	106	722 (transient)	713	728 (transient)	680
Normal (cold)	0	717	665	< 730	624
Off-Normal (hot)	117	722 (transient)	709	730 (transient)	675
Off-Normal (hot) with FC	117	690		669	

The results in Table 4.5 are the basis for the applicant’s assertion that the extreme ambient condition for the vertical loading transient is bounding for all other conditions of transfer, for all configurations of the 32PTH1 DSC in the OS200 transfer cask. The reported peak cladding temperatures for the DSC with Type 2, HLZC #2, 31.2 kW decay heat load appears to be inconsistent with this general assertion. The reported value is 727ºF for this configuration with the TC vertical in the transfer facility under extreme hot ambient conditions, and is 730ºF for the TC horizontal under off-normal hot conditions (with sunshade) in transit to the ISFSI. Because the difference between the two values is small, and since in all cases the peak temperature corresponds to the point at which force air circulation must be activated, it is considered insignificant.

Confirmatory calculations for the TC/DSC system are discussed in Section 4.6.3.2, in connection with evaluation of the modeling approach used to represent the horizontal transfer cask containing the DSC.

4.4.2.1.2.1 Optional Lid Configuration for OS200 TC: External Cooling (Blower Fans)

The OS200 TC is provided with an optional top lid with design features which enable an exit path for air circulation through the TC/DSC annulus. The external air circulation feature may only be used for specific situations during the transfer mode (outside of normal operations) defined in the Technical Specifications (Section 1.2.18b), and summarized as follows:

- If decay heat in the 32PTH1 DSC is greater than 31.2 kW **and** the basket type used is Type 1 (A through F) **and** specific time limits for transfer are not met, or

- If the decay heat is greater than 24.0 kW (but not greater than 31.2 kW) **and** the basket type used is Type 2 (A through F) **and** specific time limits for transfer are not met.

The TC when used with this optional top lid is designated as OS200FC TC. This alternate top lid design is nearly identical to the top lid of OS197FC TC shown in Figure P.1-5 of Appendix P of the NUHOMS® base SAR.

Confirmatory calculations were performed with a detailed model of the DSC using the COBRA-SFS computational thermal-hydraulics code, to evaluate the conservatism of the peak cladding temperature values reported in the SAR, for off-normal conditions with forced air circulation. Table 4.6 compares the results of the confirmatory calculations with the peak cladding temperatures from the applicant’s analyses.

Table 4.6. Confirmatory Calculation Results for Off-Normal Transfer Conditions with Forced Air Circulation vs. Peak Cladding Temperatures Reported in SAR

Off-Normal Transfer Conditions (regulatory limit: 752ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
In TC (horizontal)--	**(ºF)**				
Detailed ANSYS model of DSC (SAR Model)(1)	117	690	no FC	669	no FC
Confirmatory Results—COBRA-SFS model of DSC in TC(2)		683	no FC	660	no FC
Difference SAR vs. Confirmatory		7 ºF		9 ºF	

(1) using DSC shell boundary temperatures from ANSYS model of TC with DSC represented as uniform heat flux boundary.
(2)Computational model for these calculations used heat transfer coefficient correlation (plus radiation) to ambient as external boundary condition.

The comparisons in Table 4.6 show that the steady-state peak cladding temperatures with forced air circulation obtained with the detailed ANSYS model of the DSC with temperature boundary conditions from the SINDA/FLUINT model of the TC are conservative compared to the results obtained with the confirmatory model. With active cooling of the DSC within the transfer cask, the predicted peak cladding temperatures for these two limiting configurations are well below the regulatory limit of 752ºF (400ºC).

4.4.2.1.3 HSM-H: Normal Conditions

For storage in the HSM-H, the applicant performed analyses only for the Type 1 basket, HLZC #1 (40.8 kW) and for the Type 2 basket, HLZC #2 (31.2 kW) in the DSC. The Type 1 basket, HLZC #2 (31.2 kW) in the DSC and the Type 2 basket, HLZC #3 (24.0 kW) in the DSC are assumed to be bounded by the performed analyses.

The following ambient conditions are considered for thermal analysis of normal storage and transfer cases:

- Maximum normal ambient temperature of 106°F with insolation, and
- Minimum normal ambient temperature of 0°F without insolation.

Confirmatory calculations were performed with a detailed model of the DSC using the COBRA-SFS computational thermal-hydraulics code, to evaluate the conservatism of the peak cladding temperature values reported in the SAR. Table 4.7 compares the results of the confirmatory calculations with the peak cladding temperatures from the applicant's analyses.

Table 4.7. Confirmatory Calculation Results for Normal Storage Conditions Compared to Peak Cladding Temperatures Reported in SAR

Normal Conditions of Storage (regulatory limit: 752ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
in HSM-H--	**(ºF)**				
Detailed ANSYS model of DSC (SAR Model)(1)	106	733	< 717	717	< 717
Confirmatory Results—COBRA-SFS model of DSC(2)		725	688	699	
Difference SAR vs. Confirmatory		8 ºF		18 ºF	

(1) Results from latest version of SAR submittal for which revised calculations were submitted to correct modeling error in representation of convection zones around DSC shell behind support rails. Effect of the correction was to increase peak cladding temperatures by about 2 ºF.

(2) DSC shell temperatures from the original SAR submittal (Rev. 0) used as boundary conditions.

The comparisons in Table 4.7 show that the peak cladding temperatures obtained with the detailed ANSYS model of the DSC for normal storage conditions in the HSM-H are conservative compared to the results obtained with the confirmatory model. For the DSC shell temperatures specified as boundary conditions in these analyses, the predicted peak cladding temperatures are below the regulatory limit of 752ºF (400ºC).

The boundary conditions consist of the DSC shell surface temperatures obtained using a detailed ANSYS model of the HSM-H, which is described in the SAR, Section U.4.4.4. In this model, the DSC outer shell is represented with a uniform heat flux distributed along an axial length equivalent to the overall length of the internal basket containing the spent fuel assemblies. Section 4.4.2.1.4 below discusses additional confirmatory calculations evaluating the ANSYS model of the HSM-H, and the conservatism of the DSC shell temperatures obtained with this model.

4.4.2.1.4 HSM-H: Storage Off-Normal Conditions

The thermal performance of the 32PTH1 DSC within the HSM-H, under the off-normal minimum and maximum ambient temperatures indicated below, was evaluated by the applicant for DSCs with both Type 1 and Type 2 baskets. The applicant's analysis for the HSM-H is described in Section U.4.4.4 of the SAR.

Off-normal conditions of storage of the 32PTH1 DSC within the HSM-H include:

- Maximum off-normal ambient temperature of 117°F with insolation, and
- Minimum off-normal ambient temperature of -40°F without insolation.

The boundary conditions for the detailed ANSYS model of the DSC consist of the DSC shell surface temperatures obtained using a detailed ANSYS model of the HSM-H, which is described in the SAR, Section U.4.4.4. In the model of the HSM-H, the DSC outer shell is represented with a uniform heat flux distributed along an axial length equivalent to the overall length of the internal basket containing the spent fuel assemblies.

Confirmatory calculations were performed with a detailed model of the DSC using the COBRA-SFS computational thermal-hydraulics code, to evaluate the conservatism of the peak cladding temperature values reported in the SAR for off-normal conditions. For the purpose of comparison, the boundary conditions from the SAR calculation were used in the confirmatory calculation. (Note that only the hot off-normal condition was analyzed, since an ambient temperature of -40°F is unlikely to present a more severe challenge to heat transfer than 117°F.) Table 4.8 compares the results of the confirmatory calculations with the peak cladding temperatures from the applicant's analyses.

Table 4.8. Confirmatory Calculation Results for Off-Normal Storage Conditions Compared to Peak Cladding Temperatures Reported in SAR

Off-Normal conditions of storage (regulatory limit: 1058ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
In HSM-H--	**(ºF)**				
Detailed ANSYS model of DSC (SAR Model)(1)	117	741	< 724	724	< 724
Confirmatory Results—COBRA-SFS model of DSC(2)		738	701	709	
Difference SAR vs. Confirmatory		3 ºF		15 ºF	
Confirmatory Results—CFD model of DSC within HSM-H	117	701		742	
Difference SAR vs. Confirmatory		40 ºF		-18 ºF	

(1) Results from latest version of SAR submittal for which revised calculations were submitted to correct modeling error in representation of convection zones around DSC shell behind support rails. Effect of the correction was to increase peak cladding temperatures by about 2 ºF.

(2) DSC shell temperatures from the original SAR submittal (Rev. 0) used as boundary conditions.

To evaluate the effect of decoupling the detailed ANSYS model of the DSC from the ANSYS model of the HSM-H, as is done in the applicant's SAR analysis methodology, additional confirmatory calculations were performed with a detailed coupled model of the entire NUHOMS® system constructed for the StarCD computational fluid dynamics code. This model represented the DSC with fine noding resolution comparable to that of the detailed ANSYS model of the DSC described in the SAR. The StarCD model also included a detailed representation of the HSM-H, with noding resolution as detailed as that of the ANSYS model of the HSM-H developed by the applicant. In addition, because StarCD is a computational fluid dynamics code, the model incorporated the hydrodynamics and thermal behavior of the natural convection air flow through the storage module. This confirmatory model could directly calculate conduction, convection, and thermal radiation heat transfer from the DSC outer shell surface, as well as heat transfer interactions with the HSM-H internal surfaces and components, such as the support rail I-beams and thermal shielding.

The comparisons in Table 4.8 show that when using the same boundary conditions, the peak cladding temperatures obtained with the detailed ANSYS model of the DSC are generally conservative compared to the results obtained with the confirmatory models of the DSC. In the comparison in Table 4.8 for the DSC with Type 1 basket, HLZC #1, 40.8 kW, the results obtained with the confirmatory CFD model indicate that the peak cladding temperature predicted with the SAR model is significantly conservative. For the DSC with Type 2 basket, HLZC #2, 31.2 kW, the SAR result is not as conservative as the confirmatory calculation result. The significance of this comparison is evaluated further in Section 4.6.3.2 below, in the discussion of modeling issues. However, the overall results of this evaluation indicate that for off-normal conditions, peak cladding temperatures are expected to remain far below the regulatory limit of 1058ºF (750ºC) for short-term storage conditions, and are not expected to exceed the long-term storage limit of 752ºF (400ºC).

4.4.2.2 Accident Analyses (32PTH1)

The 32PTH1 DSC was evaluated to determine the thermal response during storage and transfer over a range of design basis accident conditions. The thermal response of the DSC within the HSM-H was also evaluated under the extreme ambient temperature of 133°F with maximum insolation.

Four accident scenarios were considered for the OS200 TC with the 32PTH1 DSCs. These accident scenarios are described in Section U.4.5.4.2 of the SAR, and are summarized below.

- The first accident scenario evaluates the effect of interruption of the air circulation system and predicts the heat up rate for the OS200FC TC containing the 32PTH1 DSC with Type 1 basket, HLZC #1, 40.8 kW or with Type 2 basket, HLZC #2, 31.2 kW. (Note that this accident cannot affect the other two configurations of the DSC, since they do not require forced air cooling to maintain temperatures below regulatory limits.) The analysis assumes that the TC and DSC are initially at steady-state under the normal hot condition (117ºF ambient, no insolation) with air circulation. At time = 0, the air circulation is assumed to be lost and the system begins to heat up.

- The second accident scenario evaluates the effect of the loss of the neutron shield water. The transient is initiated from steady-state normal hot condition (117ºF ambient, no insolation), so for the two configurations requiring forced air circulation to reach a steady state within regulatory limits (i.e., Type 1, HLZC #1, 40.8 kW and Type 2, HLZC #2, 31.2 kW), the accident scenario also includes loss of air circulation as well as loss of the water in the neutron shield.

- The third accident scenario evaluates the effect on an undamaged OS200/OS200FC TC of an extreme ambient air temperature of 133°F when loaded with the 32PTH1 with decay heat loads of 40.8 and 31.2 kW. The evaluation addresses the maximum steady-state temperatures that would be achieved without the mitigation of forced air circulation.

- The fourth accident scenario evaluated for the OS200 TC involves a 15-minute hypothetical fire. The initial temperature condition for the fire accident transient is the same as used for the start of the loss of the neutron shield and loss of air circulation accident scenarios.

Two accident scenarios were evaluated for the HSM-H containing the 32PTH1 DSCs. These accident scenarios are described in Section U.4.6.7 of the SAR, and are summarized below.

- The first accident scenario postulates an extreme ambient temperature of 133°F with maximum insolation, conservatively assumed to occur over a sufficient duration for a steady-state temperature distribution to develop in the 32PTH1 DSC within the HSM-H.

- The second accident scenario evaluates the effect of the loss of natural circulation air flow through the HSM-H due to complete blockage of the inlet vent for a period of 40 hours. The transient is initiated from steady-state normal hot condition (117ºF ambient, maximum insolation).

4.4.2.2.1 Transfer Cask Accident Evaluations

The thermal performance of the 32PTH1 DSC in the OS200/OS200FC for accident conditions was evaluated by the applicant primarily using a SINDA/FLUINT half-section of symmetry model of the transfer cask, with the DSC represented using a constant heat flux boundary condition over the exterior surface. Insolation is assumed maximum in all accident scenarios, including the fire transient. The resulting DSC shell temperature distribution for the most limiting accident condition is used to define boundary conditions for the detailed ANSYS model of the 32PTH1 DSC basket. This calculation determines the peak cladding temperature for the limiting transfer accident, which is assumed to bound all other transfer accident conditions.

Table 4.9 summarizes the peak DSC shell temperatures obtained for the four transfer accident scenarios, for the various DSC configurations. Since the SINDA/FLUINT model does not yield temperatures for the DSC internal components, the applicant chose to use the peak DSC shell temperature to evaluate and compare the results obtained for the transient calculations.

Table 4.9. Peak DSC Shell Temperatures from SAR for Transfer Accident Conditions

Conditions Evaluated in SAR (regulatory limit: 1058ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
in TC (horizontal)--	**(ºF)**				
Loss of air circulation(1)	117	> 450 (transient)	476 (FC not required)	> 420	419 (FC not required)
Loss of neutron shield	117	651	578		
Fire accident (at end of fire)	117	451 (transient)	421 (transient)		
Post-fire steady-state	117	646	574		
Accident ambient	133	558	495		

(1) Values reported are for off-normal hot steady state for configurations not requiring forced air circulation (Type 1, HLZC#2, 31.2 kW and Type 2, HLZC#3, 24 kW)

The DSC with Type 2, HLZC #3, 24 kW decay heat load is assumed bounded by the DSC with Type 2, HLZC #2, 31.2 kW, so results for accident conditions are not reported for this lowest decay heat configuration. Since the DSC shell temperature correlates directly with the internal component temperatures, the results in Table 4.12 can be used to infer that loss of the neutron shield (with loss of forced air circulation, if applicable) is the most limiting of the four specified transient scenarios. This leads to the definition of the bounding accident as loss of the neutron shield water, loss of forced air circulation (if applicable), and loss of sunshade at 117ºF ambient temperature. (Note that in all transfer accident scenarios, the sunshade is assumed lost, and insolation is at a maximum.)

4.4.2.2.1.1 Transfer Cask: Bounding Accident

The postulated transfer accident event consists of the 32PTH1 DSC transfer in the OS200 TC in a 117°F ambient environment with loss of the sunshade, loss of the liquid neutron shield, and loss of air circulation (if applicable.) Table 4.9 above shows the results of the evaluations completed by the applicant to establish the predicted thermal response for 32PTH1 DSC decay heat loads of 40.8 and 31.2 kW.

In the cases requiring forced air cooling after a specific time interval (i.e., Type 1, HLZC #1, 40.8 kW or Type 2, HLZC #2, 31.2 kW), the transient accident analysis starting point was assumed to be at the internal temperature distribution when the maximum operational time allowed without air circulation had been reached, as described in Section U.4.5.4.1 of the SAR. This approach yields the hottest allowable operating temperatures within the DSC and TC and thus provides a conservative starting point for the transient. At the beginning of this transient, the water in the neutron shield jacket is assumed lost (drained) and the air circulation option is assumed to be unavailable.

Peak cladding temperatures for transfer accident conditions are reported in the SAR (Revision 3), only for the bounding accident case. Table 4.10 summarizes the results reported from calculations with the detailed ANSYS model of the DSC internals using as boundary conditions the DSC shell temperatures calculated with the ANSYS model of the TC for the bounding accident scenario. Confirmatory calculations for this bounding accident scenario were performed with a detailed COBRA-SFS model that represented the DSC and the TC. The neutron shield was treated as an air gap with conduction and thermal radiation between the inner and outer walls, and the external boundary condition specified with an appropriate heat transfer coefficient correlation for heat transfer to ambient by free convection from a horizontal cylinder. Table 4.10 compares the confirmatory calculation results to the peak cladding temperatures reported in the SAR.

The confirmatory results are in reasonably good agreement with the applicant’s results, as presented in the SAR, for this bounding accident condition, but for the DSC with Type 1 basket (HLZC #1, 40.8 kW) and the DSC with Type 2 basket (HLZC #2, 31.2 kW), the confirmatory results are slightly more conservative than the results presented in the SAR. This is in contrast to the results presented in Tables 4.6, 4.7, and 4.8, which show that the SAR results are more conservative than the confirmatory results for normal and off-normal storage conditions, and for off-normal transfer conditions with forced air circulation cooling. However, the predicted peak cladding temperature values, in every case, are far below the regulatory limit of 1058ºF for these conditions.

Table 4.10 Confirmatory Calculation Results for Bounding Transfer Accident Compared to Peak Cladding Temperatures Reported in SAR

Conditions evaluated in SAR (Regulatory Limit 1058°F)	ambient air	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
in TC (horizontal)--	**(ºF)**				
Detailed ANSYS model of DSC (SAR Model)	117	886	796	858	< 858
Confirmatory Results – COBRA-SFS model of DSC in TC		895	796	877	748
Difference SAR vs Confirmatory		-9 ºF	0 ºF	-19 ºF	

4.4.2.2.1.2 Cask Heatup During Loading

All fuel loading/unloading operations occur when the 32PTH1 DSC and TC are in the spent fuel pool. The fuel is always submerged in free-flowing pool water permitting heat dissipation. After fuel loading is complete, the TC cask and DSC are removed from the pool and the DSC is drained, dried, seal welded, and backfilled with helium.

The loading condition evaluated by the applicant for the 32PTH1 DSC is heatup of the DSC before its cavity is backfilled with helium. This typically occurs during the vacuum drying operation of the DSC cavity with the TC in the vertical position inside the fuel building, and the annulus between the TC and the DSC is full of water. The applicant assumed the initial temperature of the DSC, basket and fuel to be 225°F, based on saturation boiling temperature of the fill water.

Prior to the vacuum drying operation, water in the DSC cavity is forced out of the cavity (blowdown operation) with helium. Subsequent vacuum drying occurs with a helium environment in the DSC cavity.

Between the removal of the cask from the spent fuel pool, and the seal weld on the inner lid of the DSC, a technical specification (TS) requirement (TS 1.2.19) as well as procedures outlined in Appendix U, Section U.8.1.2, Step 16 and Section U.8.1.3, Steps 6, 16, and 17 ensure that there will be a helium environment present in the DSC.

The applicant assumes that the vacuum drying of the DSC does not reduce the pressure sufficiently to reduce the thermal conductivity of the water vapor or helium in the DSC cavity. Therefore, with helium being used for blowdown operation, the applicant credits its presence in the vacuum drying operations.

A description of the applicant's evaluation of the vacuum drying condition is provided in Section U.4.7.1 of the SAR. Table 4.11 below summarizes the peak cladding temperatures reported in the SAR for vacuum drying conditions. The results of confirmatory calculations undertaken by the staff to independently evaluate the thermal response of the system for these conditions are also included in Table 4.11.

Table 4.11. Vacuum Drying Conditions: Peak Cladding Temperatures Reported in SAR

Conditions Evaluated in SAR (regulatory limit: 752ºF)	**Boundary Temperature**	**Type 1, HLZC #1, 40.8 kW**	**Type 1, HLZC #2, 31.2 kW**	**Type 2, HLZC #2, 31.2 kW**	**Type 2, HLZC #3, 24 kW**
in TC (vertical, indoors)--	**(ºF)**				
Detailed ANSYS model of DSC (SAR Model)	225	567	532	602	542
Confirmatory Results—COBRA-SFS model DSC in TC		580	519	574	501
Difference SAR vs. Confirmatory		-13 ºF	13 ºF	26 ºF	41 ºF

4.4.2.2.1.3 Fire

The fire accident scenario evaluated for the OS200 TC involves a 15-minute hypothetical fire. The maximum duration of the fire event will be operationally controlled through administrative controls limiting the available fuel sources within the vicinity of the TC. The initial temperature condition for the fire accident transient is the same as that used for the start of the loss of the neutron shield accident scenario. The peak flame temperature is specified as 1,475ºF, and is assumed to fully engulf the transfer cask for the 15-minute duration of the fire. Following the fire, ambient conditions are defined as 117ºF ambient, with maximum insolation. The results in Table 4-7 show that the fire accident is the least severe of the postulated transfer accident scenarios, and as a transient is less limiting than the hot ambient steady-state condition at 133°F ambient air temperature. This is a reasonable result, due to the extremely short duration of the fire, the relatively low peak flame temperature, and the massive thermal inertia of the TC/DSC system.

4.4.2.2.2 HSM-H Accident Evaluations

The thermal performance of the 32PTH1 DSC in the HSM-H for accident conditions was evaluated using the ANSYS finite element model of the HSM-H. For the steady-state extreme ambient temperature condition, the DSC was represented using a constant heat flux boundary condition over the exterior surface. The DSC shell temperature distribution obtained in this analysis was then used to supply boundary conditions for a separate detailed ANSYS model of the DSC alone. The results in Table 4.12 show that all four design basis configurations for the DSC have peak cladding temperatures far below the regulatory limit of 1058°F for the extreme hot ambient condition. The most limiting design is the DSC with Type 1 basket, HLZC #1, and 40.8 kW decay heat load.

For the blocked vent transient calculation, the DSC internal components were modeled as a homogenized region to account for the thermal inertia of the DSC. The effective thermal properties of the homogenized DSC are calculated as weighted averages of the thermal properties of the internal components. The effective thermal properties of the DSC with Type 2 basket were determined to bound the values obtained for the DSC with Type 1 basket. Therefore, the effective thermal properties of the DSC with Type 2 basket were used in the transient analyses for the DSC for both limiting configurations, at 40.8 kW and 31.2 kW.

As an additional modeling conservatism, closed cavity convection within the HSM-H was conservatively neglected in the transient analysis. The analysis considered only thermal conduction from the DSC to the surrounding air.

The DSC outer shell temperature distribution obtained at 40 hours in the transient calculation was then used to define boundary conditions on the detailed ANSYS model of the DSC alone. The internal component temperatures were then calculated assuming these boundary temperatures represented a steady-state condition. (This approach is documented in Section U.4.8.3 of the SAR.) Table 4.12 shows that the blocked vent transient is predicted to be the limiting transient for storage conditions.

Table 4.12. Peak Cladding Temperatures for Accident Conditions in HSM-H from SAR

Conditions Evaluated in SAR (regulatory limit: 1058ºF)	Ambient Air Temp	Type 1, HLZC #1, 40.8 kW	Type 1, HLZC #2, 31.2 kW	Type 2, HLZC #2, 31.2 kW	Type 2, HLZC #3, 24 kW
In HSM-H	**(ºF)**				
accident ambient (hot)	133	752	< 736	736	< 736
accident (blocked vent at 40 hours)	117	887 (transient)	< 849 (transient)	849 (transient)	< 849 (transient)

4.5 Model Specification

4.5.1 Analysis Model Configuration for Use with the 61BTH System

4.5.1.1 HSM-H Model for Use with the 61BTH System

The analysis model developed by the applicant, described in Section T.4.4.4 of the SAR, determines the HSM-H component temperatures and DSC shell temperature distribution, which is then used in a detailed model of the 61BTH DSC basket (described in Section T.4.6 of the SAR) as boundary conditions to calculate the basket and fuel peak cladding temperatures. The applicant developed a half-symmetry, three dimensional ANSYS® finite element model of the HSM-H loaded with a 61BTH DSC.

The model developed by the applicant is identical to the HSM-H model described in Appendix P, Section P.4.4 of the NUHOMS® base SAR, except for the dimensions of the DSC and HSM-H access port. The model is depicted in Figure T.4-3 of the SAR. The HSM-H model included the DSC shell, shield plugs, the concrete structure, and the heat shields. The DSC contents were not considered for the steady-state analysis runs. The DSC basket and fuel assemblies were homogenized for the blocked vent (accident) transient model. The homogenized basket properties for 61BTH DSC are calculated in Section T.4.8.3 of the SAR.

To define the bounding operating condition for the storage module, the HSM (or HSM-H) is assumed to be located in the middle of a double-row array of modules in a back-to-back arrangement. This is modeled with adiabatic boundary surfaces on the sides and back of the ANSYS representation of the HSM-H module. The solar heat load on the storage module roof and front wall is modeled as described in Appendix P, Section P.4.4.4. The decay heat load due to the DSC is applied as a uniform heat flux on the inner surface of the DSC shell over the equivalent length of the internal basket (162 inches).

The air flow rate and air temperature distribution within the model of the storage module are calculated using the ‘stack effect’ analysis documented in Appendix P, Section P.4.4.3, modified only to account for the 61BTH DSC dimensions and heat loads. This analysis consists of a simple one-dimensional energy and momentum balance for the air flow path through the storage module, with the heat transfer rate at the DSC shell exterior surface and module component inner surfaces (e.g., concrete walls, heat shields, support rails, and basemat) calculated with local heat transfer coefficient correlations. Thermal radiation effects are included within the module cavity. Free convection around the circumference of the access port and between the outer surface of the DSC cover plate and the inner surface of the storage module door is included in the applicant’s model. The model represents free convection heat transfer and thermal radiation to the environment from the front face and roof of the storage module with a single combined total heat transfer coefficient (as documented in Section P.4.9.3 of the NUHOMS® base SAR.)

Air flow rates and temperatures were determined for the 31.2 kW and 22 kW configurations, for normal and off-normal ambient conditions. The temperature values are used as boundary conditions on the DSC external surface elements and HSM-H inner surface elements in calculations with the detailed ANSYS model of the HSM-H described above.

4.5.1.2 61BTH DSC Basket/Fuel Assembly Model

The applicant developed a three dimensional (3D) ANSYS model of the 61BTH DSC, described in Section T.4.6.2 of the SAR, to determine the maximum fuel cladding and DSC component temperatures. The 3D DSC model represents a longitudinally full-length, one-half (180°) cross section of the 61BTH DSC. This model includes the DSC shell, shield plugs, basket, and fuel assemblies.

The 3D models representing the DSC with Type 1 and Type 2 baskets are shown in Figures T.4-22 through T.4-25 in the SAR. The fuel assemblies are modeled as homogenized regions within the fuel compartments. The effective thermal properties for the intact and damaged fuels are calculated in Section T.4.8 of the SAR.

The applicant's ANSYS model is comprised of the shell assembly (including the shell, and top and bottom end assemblies) and the basket assembly (including fuel compartment tubes, aluminum and neutron absorber plates, and the R45 and the R90 transition rails). All these DSC components are modeled using ANSYS SOLID70 elements. Radiation between the rails and the DSC shell is modeled using radiation LINK31 elements.

The applicant states that the methodology of this analysis model is identical to that used for 24PTH DSC modeling described in Appendix P, Section P.4.6 of the NUHOMS® base SAR.

The total number of nodes and elements in the ANSYS model are approximately 833,000 for Type 1 and 820,000 for Type 2 baskets. A mesh size of 10x10 is applied in fuel regions. A sensitivity study was performed, and it determined this mesh size to be adequate, as described in Section T.4.6.3. The nominal dimension of the elements used in this region were 0.6", which was more precise than the element size of 0.64" used in the 24PTH DSC model (Appendix P, Section P.4.6.1, of the NUHOMS® base SAR).

The gaps between adjacent basket components were also modeled using SOLID70 elements with helium conductivity. The material properties from Section T.4.2 of the SAR are used for the fuel region. Within the model, heat is transferred via conduction through fuel regions, fuel compartments, aluminum and neutron absorber plates, and the gas gaps between components. The applicant states that good surface contact is expected between adjacent components within the basket structure. However, the applicant bounds the heat conductance uncertainty between adjacent components due to imperfect contact between the neutron absorber material, aluminum and steel basket components, by assuming uniform gaps along the entire surfaces.

The typical gaps used in the applicant's thermal analysis of the 61BTH DSC are summarized in Section T.4.6.2 of the SAR and depicted in Figures T.4-26 through T.4-28 of the SAR.

4.5.1.2.1 61BTH Loading Configurations

Eight (8) HLZCs are allowed for the 61BTH DSC, as shown in Figures T.2-1 through T.2-8 of the SAR. A maximum of 16 damaged fuel assemblies can be stored in the 61BTH DSC. The DSC model with Type 2 basket can accommodate a maximum total heat load up to 31.2 kW. The DSC model with the Type 2 basket includes eight steel R45 rails with aluminum liner plates and four solid aluminum R90 rails. The DSC model with the Type 1 basket can accommodate a maximum total heat load of 22.0 kW. In this model, the R45 and R90 rails are stainless steel with thin aluminum shims. The applicable HLZCs for each DSC type are shown in Table 4.2 of this SER.

4.5.1.3 61BTH DSC in Transfer Cask Model

The applicant developed an analytical thermal model of the NUHOMS® OS197FC-B TC and its 61BTH DSC payload, described in section T.4.5.2 of the SAR, for use with the Thermal Desktop® and SINDA/FLUINT computer programs. A general description of these computer codes is provided in Appendix P, Section P.4.5.2.1 of the of the NUHOMS® base SAR.

The applicant's thermal model of the OS197FC-B TC represents a 180° segment of the cask. The use of a 180° model permits the applicant to accurately simulate the temperature distribution within the cask when the cask is in the horizontal or vertical orientation and the axis of the DSC is eccentric to that of the cask. The applicant assumed symmetry conditions existed along the vertical symmetry plane of the cask.

The applicant's model uses approximately 5,800 nodes, 5,000 solids, and 3,900 planar elements to define the cask body geometry and to provide thermal resolution. The modeling divides the cask circumference into 15° segments with axial lengths of 8 inches or less.

The applicant's model captures an increase in the structural shell thickness at the upper portion of the cask. The thermal model is based on an increase of 1.5-inches to 2-inches, as shown in Figure T.4-11.

Heat transfer across the liquid neutron shield is calculated using effective thermal properties from Appendix M, Section M.4.9. In response to a staff RAI, the applicant provided a further discussion of these effective thermal properties in Section T.4.8.5 of the SAR. The effective thermal properties used for the OS197/OS197H/OS197FC-B were derived for a lower decay heat (22 kW vs. 31.2 kW) and were derived for vertical and horizontal orientations. The application of the horizontal effective conductivity values to the analysis of the vertically oriented OS197 as well as the application of the more conservative conductivity values for the 22kW case to the 31.2 kW case for this amendment are considered to be a reasonable approach by the staff.

Figure T.4-13 of the SAR illustrates the thermal modeling of the cask closure lid and associated NS-3 shielding. The modeling utilizes approximately 1,500 thermal nodes, 900 solids, and 1,000 planar surfaces. For the spacer, the model uses 130 planar surfaces and 130 nodes and 40 solids to represent the stainless steel plates that make up the spacer.

Convection and radiation heat transfer to ambient are considered for the exterior surfaces of the TC. Radiation heat transfer is also considered between the DSC shell and the TC inner cavity surfaces. The emissivity values are listed in Section T.4.2 of the SAR.

Insolation is considered over exterior surfaces of the TC for hot ambient conditions according to orientation and solar absorptivity of surfaces. The solar absorptivity of stainless steel is considered equal to its emissivity value of 0.6. The staff considers this value to be reasonable. The values of the applied solar heat fluxes are not reported in Appendix T, but are documented as identical to the insolation model used in Appendix P, Section P.4.4.4 of the NUHOMS® base SAR. In this approach, insolation is assumed to be 400 gcal/cm^2 on the cask cylindrical shell and 200 gcal/cm^2 on the vertical faces of the cask top and bottom. The heating values used in the calculations with the TC model are averaged over 12 hours.

The applicant performed analyses to determine the thermal performance of the transfer cask for normal, off-normal, and transfer conditions (in both vertical and horizontal orientation, with and without insolation), as well as for the three accident scenarios described above (see SER Section 4.4.1.2.1). The DSC shell temperatures obtained with this model were then applied as boundary conditions on the DSC outer shell in calculations with the detailed ANSYS model of the DSC, to obtain peak DSC component temperatures, including peak fuel cladding temperature. These calculations used the heat loading zone configurations that were determined to be bounding for the different cask configurations in the thermal analysis of the DSC within the storage module.

4.5.2 Analysis Model Specification for Use with the 32PTH1 System

The thermal analysis results presented in the applicant's SAR are obtained using the method and models originally documented in Appendix P of the NUHOMS® base SAR. The primary components of this method are a detailed ANSYS model of the HSM-H, a separate, detailed ANSYS model of the DSC, and a SINDA/FLUINT model of the transfer cask. The method also makes use of subsidiary models, to provide elements of the larger models or to provide coupling between the models of different parts of the system. These include the one-dimensional 'stack flow' model for determining the air flow through the HSM-H, the homogeneous representation of the DSC within the HSM-H for the blocked vent accident analysis, representation of the material properties of system components, and heat input boundary conditions (both internal and external).

The staff sought to confirm the appropriateness of these models and the methods used to implement them, as documented in the SAR. All models and methods were reviewed, but the staff focused primarily on evaluating the effects of decoupling the detailed model of the DSC internals from the models of the HSM-H and the transfer cask, and the simplified one-dimensional model used to determine the free convection air flow through the HSM-H. Particular attention was also devoted to evaluating the approach used to represent heat transfer through the liquid neutron shield of the horizontal transfer cask.

4.5.2.1 HSM-H Model for Use with the 32PTH1 System

The analysis model developed by the applicant, described in Section U.4.4.4 of the SAR, is a half-symmetry, three-dimensional ANSYS finite element model of the HSM-H, including only the outer shell and end shield plugs of the DSC. The DSC internals are represented with a uniform heat flux boundary condition specified on the inner surface of the shell. (This model is identical to the HSM-H model described in Appendix P, Section P.4.4 of the NUHOMS® base SAR, except for the dimensions of the DSC and HSM-H access port.) The model is depicted in Figure U.4-6 of the SAR, and reproduced here in Figure 4.2.

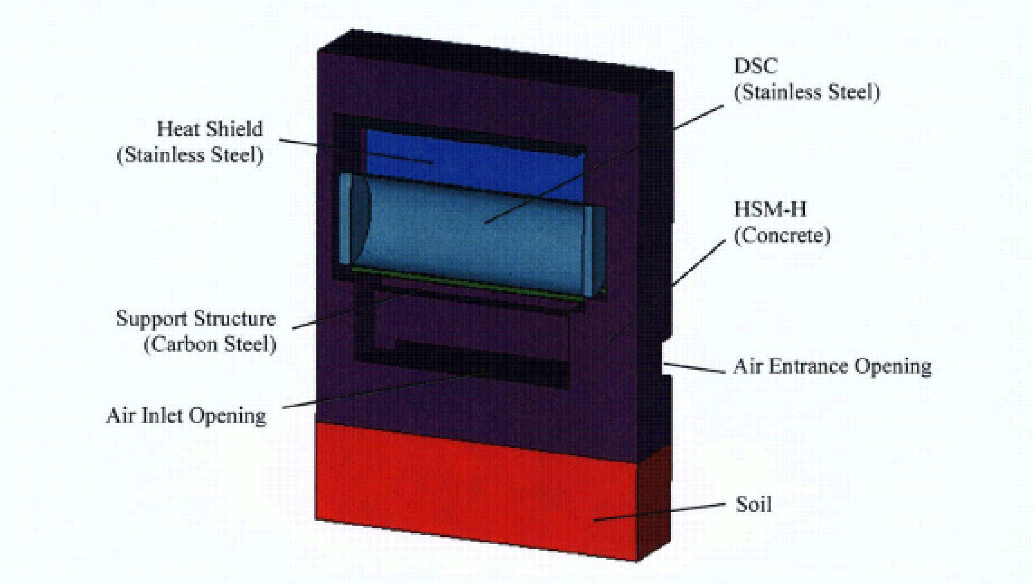
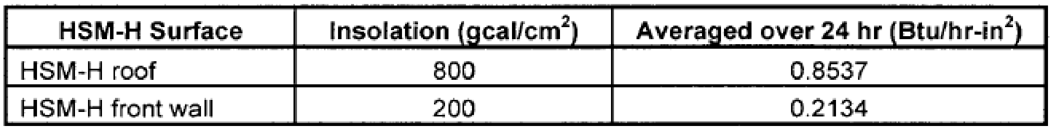


Figure 4.2 Diagram of ANSYS Model of HSM-H (from SAR, Figure U.4-6)

To define the bounding operating condition for the storage module, the HSM-H is assumed to be located in the middle of a double-row array of modules in a back-to-back arrangement. This is modeled with adiabatic boundary surfaces on the sides and back of the ANSYS representation of the HSM-H module. The solar heat load on the HSM-H roof and front wall is modeled as described in Appendix P, Section P.4.4.4 of the NUHOMS® base SAR, with the following insolation values:



HSM-H Surface	Insolation (gcal/cm^2)	Averaged over 24 hr (Btu/hr-in^2)
HSM-H roof	800	0.8537
HSM-H front wall	200	0.2134

(from page U.4-16 of the SAR, Section U.4.4.4)

The decay heat load due to the DSC is applied as a uniform heat flux on the inner surface of the DSC shell over the equivalent length of the internal basket (164.5 inches). This approach yields the following uniform heat flux boundary conditions:

- 2.9965 Btu/hr-in^2 for 31.2 kW heat load
- 3.9184 Btu/hr-in^2 for 40.8 kW heat load

The air flow rate and air temperature distribution within the HSM-H are calculated using the 'stack effect' analysis documented in Appendix P, Section P.4.4.3 of the NUHOMS® base SAR, modified only to account for the 32PTH1 DSC dimensions and heat loads. This analysis consists of a simple one-dimensional energy and momentum balance for the air flow path through the HSM-H, with the heat transfer rate at the DSC shell exterior surface and HSM-H component inner surfaces (e.g., concrete walls, heat shields, support rails, and basemat) calculated with local heat transfer coefficient correlations. Thermal radiation effects are included within the HSM-H cavity, and free convection in the cylindrical gap within the access port, between the outer surface of the DSC cover plate and the inner surface of the HSM-H door is also neglected in the applicant's model. The model represents free convection heat transfer and thermal radiation to the environment from the front face and roof of the HSM-H module with a single combined total heat transfer coefficient (as documented in Section P.4.9.3 of the NUHOMS® base SAR.)

Air flow rates and temperatures were determined for the 31.2 kW and 40.8 kW configurations, for normal and off-normal ambient conditions. The temperature values are used as boundary conditions on the DSC external surface elements and HSM-H inner surface elements in calculations with the detailed ANSYS model of the HSM-H described above.

The staff evaluation found that although the HSM-H model is described in the SAR as conservative, there are potentially non-conservative elements in the applicant's overall approach. Of particular concern are the model simplifications of treating the DSC inner shell as a uniform heat flux boundary condition in the ANSYS model of the HSM-H, and imposing a one-dimensional flow model using heat transfer correlations to determine the flowrate and the air temperature within the HSM-H cavity.

Representing the DSC with a uniform heat flux boundary condition decouples the DSC internal components from the heat transfer behavior within the HSM-H, and inevitably results in flattening of the DSC shell surface temperature gradients (and by extension, those of the HSM-H components.) Using heat transfer correlations to calculate the local rate of heat transfer for surfaces within the HSM-H cavity (including the DSC shell surface) introduces the uncertainty inherent in the correlations into the predicted temperatures. The staff's confirmatory analysis is presented in detail in Section 4.6.3.2 of this SER.

The effect of the decoupled modeling approach used in the SAR analyses on the conservatism of the temperatures predicted for the DSC internals is evaluated in the following subsection.

4.5.2.2 32PTH1 DSC Basket/Fuel Assembly Model

The applicant developed a three dimensional (3D) ANSYS model of the 32PTH1 DSC, described in Section U.4.6.1 of the SAR, to determine the maximum fuel cladding and DSC component temperatures (See Figure 4.3 below). The 3D DSC model represents a half-section of symmetry over the full axial length of the 32PTH1 DSC. This model includes the DSC shell, shield plugs, basket, fuel tubes, and fuel assemblies.

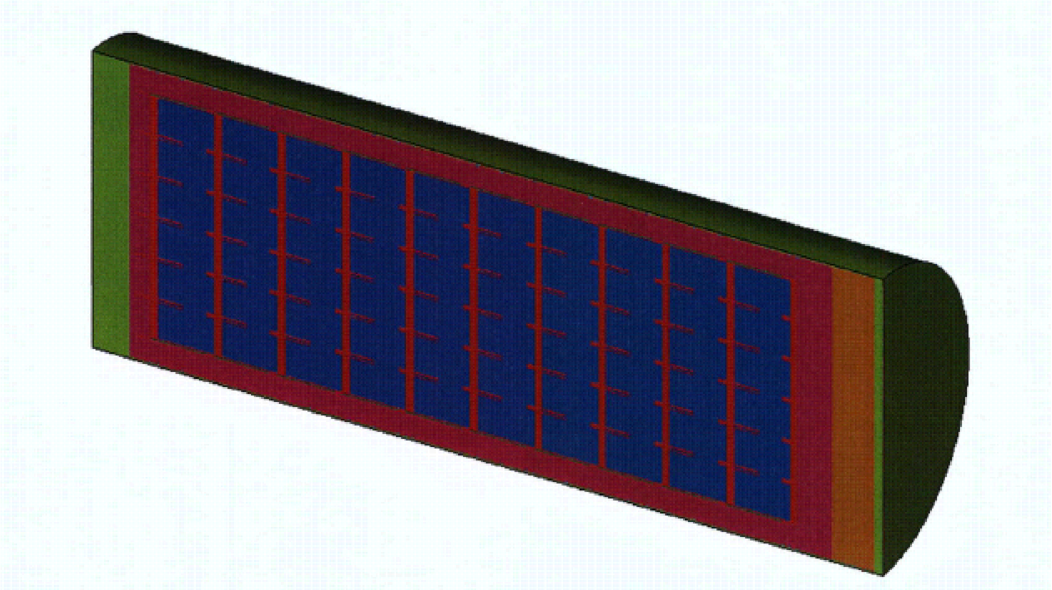


Figure 4.3. Diagram of Detailed ANSYS Model of DSC (from SAR, Figure U.4-45)

The 3D models representing the DSC with Type 1 and Type 2 baskets are shown in Figures U.4-45 through U.4-48 in the SAR. The fuel assemblies are modeled as homogenized regions within the fuel compartments. The effective thermal properties for the intact and damaged fuels are calculated in Section U.4.8 of the SAR.

The applicant's ANSYS model is comprised of the shell assembly (including the shell, and top and bottom end assemblies) and the basket assembly (including fuel compartment tubes, aluminum and neutron absorber plates, and the R45 and the R90 transition rails). All these DSC components are modeled using ANSYS SOLID70 elements. Radiation between the rails and the DSC shell is modeled using radiation LINK31 elements. Axial radiation is also considered between the top and bottom surfaces of the fuel assemblies to the shield plugs.

The DSC with Type 2 basket consists of steel R45 and R90 rails with aluminum inserts. The applicant states that the geometry of this component of the model is identical to the one developed in Chapter 4 of the SAR for the NUHOMS® HD Horizontal Modular Storage System for Irradiated Nuclear Fuel, NRC Docket No. 72-1030, Revision 4, for use in the 32PTH HD SAR analysis (Ref. 5).

The total number of nodes and elements in the ANSYS model are approximately 600,000 for both models (Type 1 and Type 2 baskets). A mesh size of 14x14 is applied in fuel regions. The nominal dimension of the elements used in this region were 0.62", which was more precise than the element size of 0.64" used in the 24PTH DSC model (Appendix P, Section P.4.6.1, of the NUHOMS® base SAR). Additional mesh sensitivity analyses were performed by the applicant to demonstrate that the 14x14 fuel mesh used in the model was reasonable and acceptable (see Section U.4.6.2 of the SAR).

The gaps between adjacent basket components were also modeled using SOLID70 elements with helium conductivity. The material properties from Section U.4.2 of the SAR are used for the fuel region. Within the model, heat is transferred via conduction through fuel regions, fuel compartments, aluminum and neutron absorber plates, and the gas gaps between components. The applicant states that good surface contact is expected between adjacent components within the basket structure. However, the applicant bounds the heat conductance uncertainty between adjacent components due to imperfect contact between the neutron absorber material, aluminum and steel basket components, by assuming uniform gaps along the entire surfaces.

The typical gaps used in the applicant's thermal analysis of the 32PTH1 DSC are summarized in Section U.4.6.1 of the SAR and depicted in Figures U.4-49 through U.4-51 of the SAR.

4.5.2.3 DSC in Transfer Cask Model

The applicant developed an analytical thermal model of the NUHOMS® OS200 TC and its 32PTH1 DSC payload, described in section U.4.5.2 of the SAR, for use with the Thermal Desktop® and SINDA/FLUINT computer programs. A general description of these computer codes is provided in Appendix P, Section P.4.5.2.1 of the of the NUHOMS® base SAR.

The applicant's thermal model of the OS200 TC represents a 180° segment of the cask. The use of a 180° model permits the applicant to accurately simulate the temperature distribution within the cask when the cask is in the horizontal or vertical orientation and the axis of the DSC is eccentric to that of the cask. The applicant assumed symmetry conditions existed along the symmetry plane of the cask.

The applicant's model uses approximately 9,080 nodes, 6,225 solids, and 5,075 planar elements to define the cask body geometry and to provide thermal resolution. The modeling divides the cask circumference into 150 segments with axial lengths of 8 inches or less.

The applicant's model captures an increase in the structural shell thickness at the upper portion of the cask; however, the thermal model is based on an increase of 1.5-inches to 2-inches, instead of the current design configuration calling for an increase from 1.5-inches to 2.38-inches.

The applicant states that the primary impact of this design change is that the effective thermal properties within the adjacent neutron shield sections are reduced by approximately 20% from values presented in Section U.4.2 of the SAR for the portion of the TC affected by this design change (i.e., the column heading 'Middle/Top Sections'). The decrease in the local effective thermal properties is partially offset by the fact that the associated neutron shield width is also reduced by approximately 9% and the fact that the peak system temperatures do not occur at this location.

The applicant evaluated the impact of the design change on the thermal performance of the TC via a sensitivity run for the bounding heat load of 40.8 kW and demonstrated that the design change had a negligible impact on the predicted peak temperatures. Based on the evaluation, the applicant concluded that the use of the thermal model based on the TC design with a change in structural shell thickness from 1.5-inches to 2-inches was valid for the purposes of computing the thermal performance for the current design of the OS200 TC with a structural shell thickness change of 1.5-inches to 2.38-inches. The staff agrees with this conclusion.

The values used for effective neutron shield thermal conductivity across the liquid neutron shield are presented in Section U.4.2 of the SAR, as special material properties for the neutron shield region in the ANSYS model of the OS200 transfer cask. The effective conductivity values used for the OS200 TC are identical to those developed for the OS187H TC in Section 4.9.1 of the SAR for the NUHOMS® HD Horizontal Modular Storage System For Irradiated Nuclear Fuel, NRC Docket No. 72-1030, Revision 4. These values were derived using a standard semi-empirical correlation for the convection heat transfer between concentric cylinders. The SAR analyses for the neutron shield tank does not attempt to solve the complex thermal-hydraulic behavior within the neutron shield tank, relying instead on approximating the heat transfer behavior as conduction through a solid using an effective conductivity model.

The k-effective model used in the analyses in the SAR formulates the effective conductivity as a function of temperature, and for application to the horizontal transfer cask, defines slightly different relationships for different axial regions of the neutron shield annulus. Figure 4.4 illustrates the location of each of these regions along the neutron shield annulus, and Figure 4.5 shows the k_{eff} values[1] defined in each region as a function of temperature. These two figures illustrate particular features of the SAR k-effective model for the neutron shield that could affect the accuracy and conservatism of transfer cask temperatures, and therefore the DSC temperatures, including the peak clad temperature. Specific concerns include:

- the assumption of radially uniform heat transfer rates around the full circumference of each segment of the neutron shield tank annulus
- the assumption that the effect of the stagnant regions at the top and bottom of the annulus (at the line of geometric symmetry) can be ignored

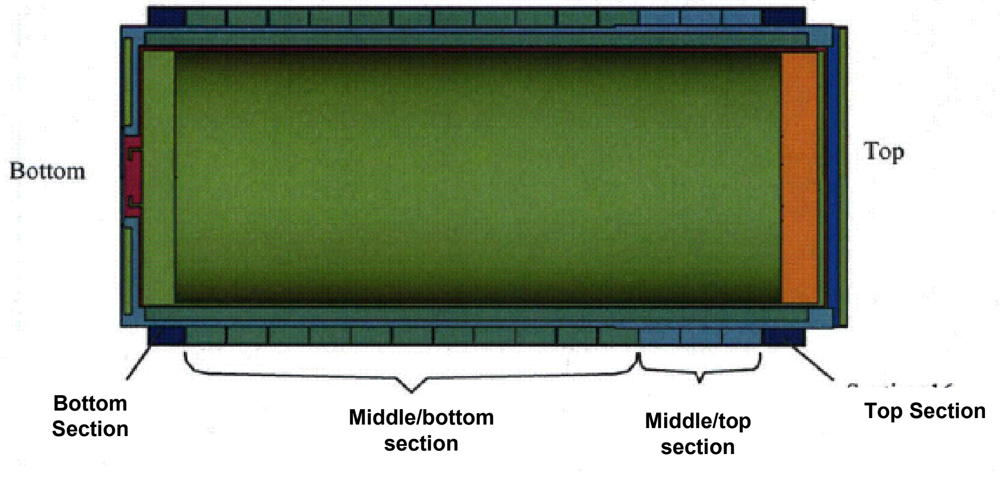


Figure 4.4 Effective Conductivity Regions in SAR Model of OS200 Neutron Shield (adapted from Figure 4-2 of NUHOMS®-HD Amendment 1 SAR)

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[1] The k_{eff} values considered here are for heat transfer in the radial direction. The SAR model uses the thermal conductivity of water for heat transfer in the neutron shield in the axial direction. However, since the main direction of heat transfer is the radial direction, axial heat transfer is ignored in this evaluation.

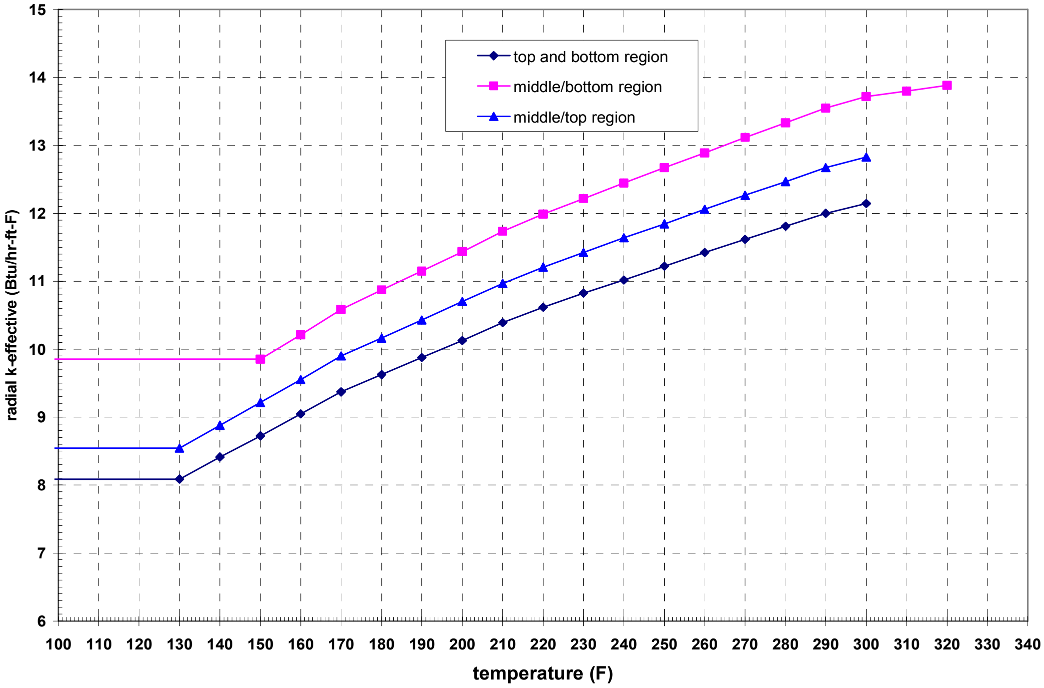

Figure 4.5 Effective Thermal Conductivity in the Radial Direction through OS200 Neutron Shield (SAR model; from p. U.4-10, Section U.4-2)

Figures U.4-17 through U.4-19 of the SAR illustrate the thermal modeling of the cask closure lid and associated NS-3 shielding. The modeling utilizes approximately 1,680 thermal nodes, 1,070 solids, and 1,200 planar surfaces. The incorporation of the geometry for the slots in the closure lid within the thermal model can be seen in SAR Figure U.4-18 'solids' view of the modeled closure lid.

Convection and radiation heat transfer to ambient are considered for the exterior surfaces of TC. Radiation heat transfer is also considered between the DSC shell and the TC inner cavity surfaces. The emissivity values are listed in Section U.4.2 of the SAR.

Insolation is considered over exterior surfaces of the TC for hot ambient conditions according to orientation and solar absorptivity of surfaces. The solar absorptivity of stainless steel is considered equal to its emissivity value of 0.6. The staff considers this value to be reasonable. The values of the applied solar heat fluxes are the same as those described in Section 4.5.2.1 of this SER for insolation on the HSM-H storage module.

The applicant conducted an element/node sensitivity study of the OS200 TC thermal model and concluded that a 30 to 40% increase in the modeling elements results in only a 3% change in the peak temperature and that the selected modeling approach provided an accurate representation of the OS200 TC's thermal performance. The staff reviewed the sensitivity study and agrees with the applicant’s conclusions.

4.5.3 Material Properties

4.5.3.1 Material Properties of the 61BTH System

The material properties used in the applicant's thermal analysis of the storage cask system are listed in Section T.4.2 of the SAR. The applicant provided a summary of the material compositions and thermal properties for all components used in the system. The material properties given reflect the accepted values of the thermal properties of the materials specified for the construction of the storage system. All material properties provided were within the operating temperature ranges of the storage system components.

For the homogenized material representing the fuel assemblies, the applicant described the approach used to determine the thermal properties (density, specific heat, and thermal conductivity) for the ANSYS model of the DSC. Density is calculated as a simple volume-average of the constituent materials of the fuel rods, neglecting the contribution of the fuel assembly hardware (e.g., grids, guide tubes) and helium backfill gas. Since these elements constitute a relatively small fraction of the fuel assembly volume, and the helium gas has a density several orders of magnitude smaller than the UO_2 or Zircaloy, this is an acceptable simplification in the model. The specific heats are determined in a similar manner, using mass-weighted averaging of the specific heat of the UO_2 and Zircaloy comprising the fuel rods.

The effective conductivity model was used to determine the anisotropic axial and transverse thermal conductivity of the homogenized region (see SAR Section T.4.8.) The limiting fuel assembly was determined to be FANP9 9x9-2, since this fuel assembly design yielded the lowest effective conductivity of all fuel designs permitted in the 61BTH.

An approach similar to the fuel effective conductivity model is used for determining the effective thermal properties of the basket (including the basket support rails) for the Type 1 and Type 2 DSC designs is described in Section T.4.8.3. The basket effective density and specific heat are also calculated as volume-weighted and mass-weighted averages, in the same manner as the fuel assembly properties. These properties are needed, along with the thermal properties of the fuel assemblies, to represent the thermal inertia of the DSC in transient analysis, since transients are evaluated using the SINDA/FLUINT model of the transfer cask. The DSC internal temperatures for transients are determined by steady-state calculations using the detailed ANSYS model of the DSC, with external surface boundary conditions at specified points in the SINDA/FLUINT transient calculation.

In Section T.4.8.4, the applicant notes that in the blocked vent transient, heat transfer to the air within the storage module cavity consists only of free convection within a closed cavity. This convection is conservatively neglected in the storage module cavity in the analysis of the blocked vent transient. Presumably, heat transfer through the air is limited to conduction only, but the applicant does not explicitly state this in the SAR.

4.5.3.1.1 Effective Thermal Conductivity within Neutron Shield

Heat transfer through the liquid of the neutron shield of the transfer cask is represented in the SINDA/FLUINT model with an effective thermal conductivity that is intended to capture the effect of conduction and free convection in the liquid. The applicant makes the argument, based on the trends of Rayleigh number and thermal conductivity as a function of temperature, that the effective thermal conductivity values for the neutron shield calculated for a decay heat load of

24 kW[2] in the DSC within the OS197 TC is conservatively bounding on the neutron shield effective thermal conductivity with 31.2 kW in the DSC.

The staff found several discrepancies with the discussion provided in SAR Section T.4.8.5, which, while not affecting the overall conclusions of the staff regarding the acceptability of the system, should be addressed by the applicant in the FSAR that incorporates this amendment.. These discrepancies are highlighted below:

- Figure 4.6 compares the water-filled neutron shield effective conductivity from Appendix M to the values reported in Appendix T (Section T.4.2, item 17). Figure 4.7 presents a similar comparison for the air-filled neutron shield effective conductivity from the two sources. Figure 4.6 shows that the effective conductivity values reported in Appendix T of the SAR, for the water-filled neutron shield, are clearly not the same as the values reported in Appendix M. Figure 4.7, however, shows that the values are exactly the same for the air-filled neutron shield.

- For the water-filled neutron shield, there is also a significant error in the effective conductivity from Appendix T in that the value at 180º fails to approach the value of simple conduction through water (nominally 0.00055 Btu/min-in-F). This behavior is a feature of the compartmentalized neutron shield of the OS197 transfer cask, and would be preserved for any decay heat load in the DSC.

- Since the error in the effective conductivity for the water-filled neutron shield is generally conservative (i.e., except for the bottom segment, the effective conductivity is lower than the values reported in Appendix M), it may not have an adverse effect on the results reported in the SAR Appendix T for the 61BTH DSC in the OS197 transfer cask; however, this error should be corrected, and the applicant should update the documentation and results for the affected calculations in the UFSAR.

Finally, it is not clear to the staff that the Appendix M values of the effective conductivity (for water or air in the neutron shield) are conservative for the 61BTH DSC in the OS197. The effective conductivity model for the neutron shield of the OS197 transfer cask (as documented in Appendix M) has relatively complex dependence on the fluid thermal properties and the local Rayleigh number for the various compartments comprising the neutron shield. It is not intuitively obvious that application of the model at 24 kW will inevitably bound the results of applications at 22 kW and 31.2 kW.

The applicant should justify this assertion, by calculating the appropriate effective conductivity values for the applications in Appendix T, and comparing the results obtained to the values reported in Appendix M.

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[2] Note that the SAR Section T.4.8.5 reports the decay heat load in the Appendix M calculations as 22 kW. The actual decay heat load for the 32PT DSC in Appendix M is 24 kW.

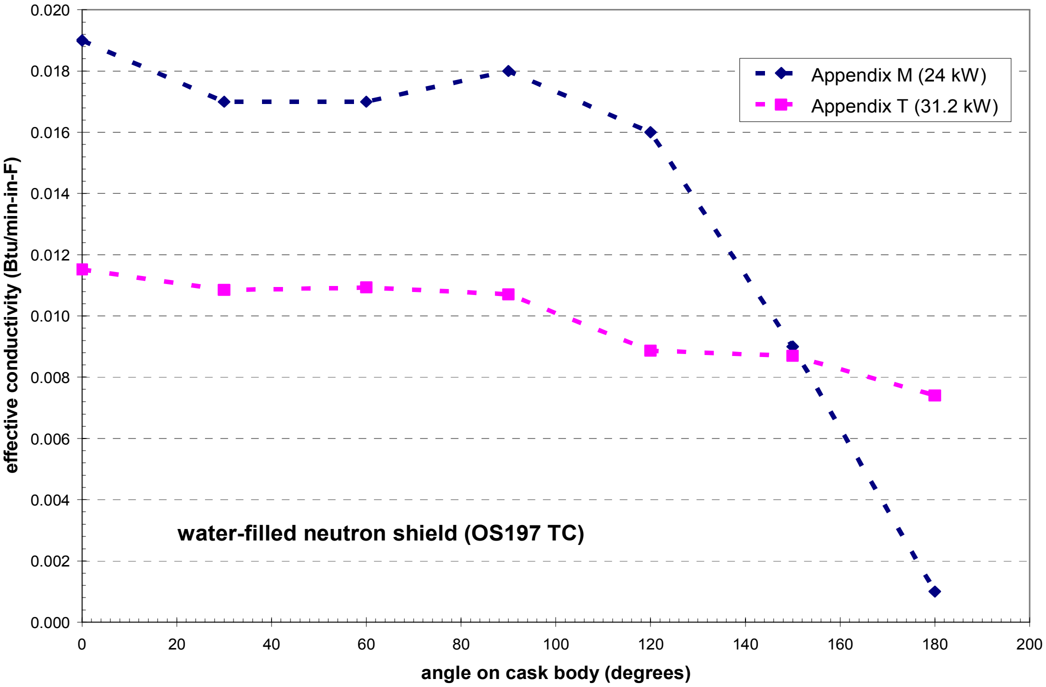


Figure 4.6 Effective Conductivity for Water-filled Neutron Shield (OS197 TC) from SAR

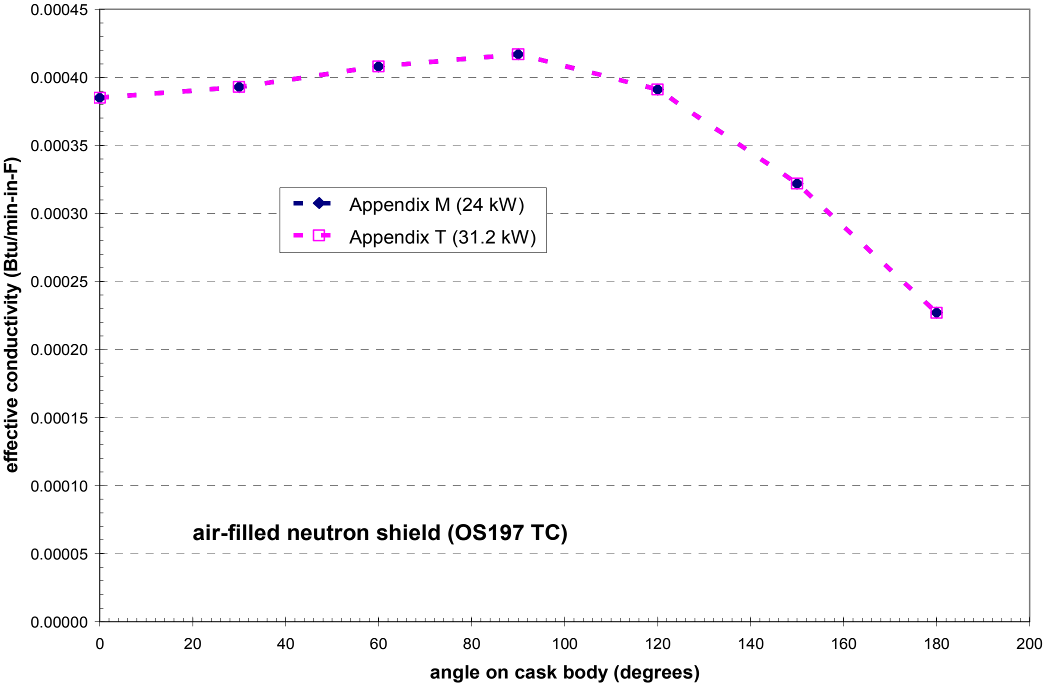


Figure 4.7 Effective Conductivity for Air-filled Neutron Shield (OS197 TC) from SAR

4.5.3.2 Material Properties of the 32PTH1 System

The material properties used in the applicant's thermal analysis of the storage cask system are listed in Section U.4.2 of the SAR. The applicant provided a summary of the material compositions and thermal properties for all components used in the system. The material properties given reflect the accepted values of the thermal properties of the materials specified for the construction of the storage system. All material properties provided were within the operating temperature ranges of the storage system components. For homogenized materials such as the fuel assemblies, the applicant described the source from which the effective thermal properties were derived in SAR Section U.4.8.

4.5.4 Boundary Conditions

Boundary conditions were applied to the models described above to analyze the behavior of the systems under normal, off-normal, and accident conditions. The applicant analyzed the shell model of the DSC in the transfer cask and in the HSM-H to obtain external surface temperatures for the DSC under all conditions. These surface temperatures were then used in the detailed DSC basket/fuel assembly model to determine a maximum fuel cladding temperature for each set of conditions. Ambient temperature and insolation values were tabulated in the SAR for all analyzed conditions.

4.5.4.1 HSM-H

The boundary conditions for HSM-H model are applied using the same methodology described in Appendix P, Section P.4.4 of the NUHOMS® base SAR. Ambient, exit, and mean bulk air temperatures listed in Table T.4-1 of the SAR are used to apply the boundary conditions.

4.5.4.1.1 DSC Heat Load Within HSM-H

The circumference of the DSC within the HSM-H is divided into a few regions for convection boundary conditions as shown in Figures T.4-2 and U.4-7 of the SAR. The bulk air temperatures used in the HSM-H model are summarized in Tables T.4-1, and U4-1. No convection is applied in dead zone in DSC shell-support structure interface. Similar to the DSC circumference, the cross section of the HSM-H cavity is divided into different regions to apply the convection boundary conditions.

4.5.4.1.1.1 61BTH DSC Heat Load Within HSM-H

The methodology used for applying the fuel assembly decay heat load is the same as that used in Appendix P, Section P.4.4.4 of the NUHOMS® base SAR. The decay heat load is considered to be distributed evenly on the radial inner surface of the DSC with a length equivalent to the basket length (164"). The applied maximum decay heat flux for the Type 2 DSC is calculated as follows:

$$\text{Decay heat flux} = \frac{Q}{\pi D_i L} \quad \text{Btu/hr-in}^2$$

where,

Q = decay heat load = 31.2 kW
D_i = inner DSC diameter = 66.25"
L = DSC basket length = 164"

Similar calculations are performed for the Type 2 DSC with a decay heat of 27.4 kW, and the Type 1 DSC with decay heat values of 19.4 kW and 22 kW.

4.5.4.1.1.2 32PTH1 DSC Heat Load Within HSM-H

The methodology used for applying the fuel assembly decay heat load is the same as that used in Appendix P, Section P.4.4.4 of the NUHOMS® base SAR. The decay heat load is considered to be distributed evenly on the radial inner surface of the DSC with a length equivalent to the basket length (164.5"). The applied decay heat flux is calculated as follows (from Page U.4-16 of the SAR):

$$\text{Decay heat flux} = \frac{Q}{\pi D_i L}\ \text{Btu/hr-in}^2$$

where:

Q = decay heat load = 31.2 kW/40.8 kW
D_i = inner DSC diameter = 68.75”
L = DSC basket length = 164.5”

For 31.2 kW heat load, $q = 2.9965\ \frac{\text{Btu}}{\text{hr*in}^2}$

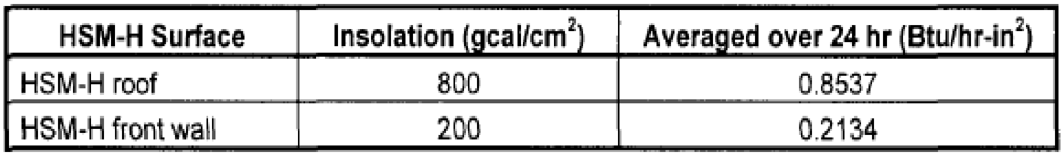
For 40.8 kW heat load, $q = 3.9184\ \frac{\text{Btu}}{\text{hr*in}^2}$

4.5.4.1.2 HSM-H External Loadings

The correlation for convection coefficients over the HSM-H surfaces, including the HSM-H vertical flat surfaces, horizontal surfaces, the side heat shield, the top heat shield and the horizontal DSC cylinder surface are discussed in detail in Appendix P, Section P.4.9 of the NUHOMS® base SAR. Convection and radiation from the HSM-H roof and the front wall to the ambient are combined as a total effective heat transfer coefficient as discussed in Appendix P, Section P.4.9 of the NUHOMS® base SAR. Figures T.4-2 and U.4-7 of the SAR show the convection boundary conditions applied to the HSM-H model.

Insolation is modeled on the surfaces of the HSM-H roof and front wall that are exposed to the ambient. The values of the applied solar heat fluxes are listed below in Table 4.13:

Table 4.13



HSM-H Surface	Insolation (gcal/cm^2)	Averaged over 24 hr (Btu/hr-in^2)
HSM-H roof	800	0.8537
HSM-H front wall	200	0.2134

4.5.4.2 DSC/Basket/Fuel Assembly

4.5.4.2.1 61BTH DSC/Basket/Fuel Assembly

The full 61BTH DSC model (described in SER Section 4.5.1.2) is evaluated for several conditions including normal, transfer, off normal, and accident. DSC Boundary conditions determined from the HSM-H model and from the transfer cask models are utilized, as described below, in the detailed DSC analysis model (described in Section T.4.6 of the SAR).

The DSC shell temperature distributions, determined by the applicant's HSM-H and OS197FC-B ANSYS thermal models (described in Sections T.4.4. and T.4.5 of the SAR, respectively), were used as boundary conditions to calculate the maximum DSC basket and fuel cladding temperatures for the storage and transfer conditions.

4.5.4.2.2 32PTH1 DSC/Basket/Fuel Assembly

The full 32PTH1 DSC model (described in SER Section 4.5.2.2) is evaluated for several conditions including normal, transfer, off normal, and accident. DSC Boundary conditions determined from the HSM-H model and from the transfer cask models are utilized, as described below, in the detailed DSC analysis model (described in Section U.4.6 of the SAR).

The DSC shell temperature distributions, determined by the applicant's HSM-H and OS200 ANSYS thermal models (described in Sections U.4.4 and U.4.5 of the SAR, respectively), were used as boundary conditions to calculate the maximum DSC basket and fuel cladding temperatures for the storage and transfer conditions.

4.5.4.3 DSC in Transfer Cask

4.5.4.3.1 61BTH DSC in Transfer Cask

Ambient temperatures in the range of 0 to 100°F are considered as normal, outdoor transfer conditions, while an ambient temperature of 117°F is considered for the off-normal, hot transfer condition and for transfer accident conditions. A peak ambient temperature of 120°F is considered as hot normal conditions for vertical loading within the fuel handling facility. The analysis in Appendix T does not consider an extreme ambient condition accident for the 61BTH in the OS197 transfer cask.

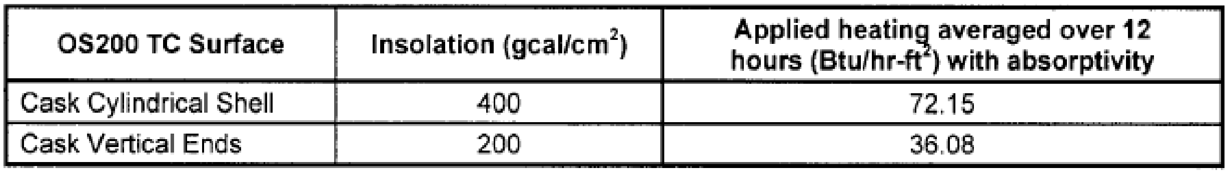
Insolation on the surface of the transfer cask (or sunshade for ambient temperatures greater than 100°F) is defined as 400 $gcal/cm^2$ for the cask cylindrical shell, and 200 $gcal/cm^2$ for the vertical faces of the cask top and bottom. These are applied as a heat flux averaged over twelve hours, with the absorptivity of the surfaces.

4.5.4.3.2 32PTH1 DSC in Transfer Cask

Ambient temperatures in the range of 0 to 106°F are considered as normal, outdoor transfer conditions, while an ambient temperature of 117°F is considered for the off-normal, hot transfer condition and for transfer accident conditions. A peak ambient temperature of 133°F is considered as an accident condition for operations under extreme ambient conditions. The extreme ambient condition accident is not combined with the other transfer accidents.

Insolation on the surface of the transfer cask (or sunshade for ambient temperatures greater than 106°F) is applied as a heat flux with values defined in Table 4.14 below.

Table 4.14



OS200 TC Surface	Insolation (gcal/cm^2)	Applied heating averaged over 12 hours (Btu/hr-ft^2) with absorptivity
Cask Cylindrical Shell	400	72.15
Cask Vertical Ends	200	36.08

4.5.4.4 Accident Conditions

4.5.4.4.1 HSM-H Blocked Vent

The HSM-H model discussed in Sections T.4.4.4 and U.4.4.4 of the SAR (Sections 4.5.1.1 and 4.5.2.1 of this SER) was modified by the applicant to determine the temperature distribution in the HSM-H and the DSC shell for the blocked vent accident case, similar to the methodology described in Appendix P, Section P.4.4.5 of the NUHOMS® base SAR.

The DSC basket including fuel assemblies and the top grid was modeled as two homogenized regions with effective properties for the transient model. Heat generation is applied uniformly on the elements representing the homogenized DSC basket. The effective thermal properties of the homogenized DSC content are calculated in Sections T.4.8.3 and U.4.8.3 of the SAR.

During the blockage of the HSM-H inlet and outlet vents, closed cavity convection will take place within the HSM-H cavity; however, the applicant's analysis considers only the thermal conductivity of air within the HSM-H cavity, neglecting convection within the HSM-H cavity.

The initial temperatures for the blocked vent accident case are identical to the nodal temperatures resulted for the off-normal case with 117°F ambient temperature and maximum solar heat flux.

4.5.4.4.2 Loss of Neutron Shield and Sunshade for Transfer Cask (61BTH System)

The postulated transfer accident event consists of the 61BTH DSC transfer in the OS197FC-B TC in a 117°F ambient environment with loss of the sunshade, liquid neutron shield, and air circulation.

For the Type 2 DSC, the transient accident analysis was assumed to start at the point where the maximum operational time allowed without air circulation had been reached, per the description in Section 4.4.1.2.1.1 of this SER. For the Type 1 DSC, the transient was initiated from steady-state off-normal conditions of transfer (117ºF ambient, with sunshade.) At the beginning of this transient, the water in the neutron shield jacket is lost (drained), the sunshade is lost, and the air circulation option is assumed not to be available.

Under accident conditions where the neutron shield is assumed to be filled with air, radiation exchange is added to the appropriate effective thermal conductivity values. Axial heat transfer within the neutron shield is based on conduction (i.e., a Nusselt number = 1). Heat transfer from the outer skin of the neutron shield is computed based on a natural convection correlation and thermal radiation exchange with an infinite external medium at 117ºF.

4.5.4.4.3 Loss of Neutron Shield and Sunshade for Transfer Cask (32PTH1 System)

The postulated transfer accident event consists of the 32PTH1 DSC transfer in the OS200 TC in a 117°F ambient environment with loss of the sunshade, liquid neutron shield, and air circulation.

In each case, the accident analysis was a transient that was assumed to start at the point where the maximum operational time allowed without air circulation was reached per the description in Section 4.4.2.2.1.1 of this SER. At the beginning of this transient, the water in the neutron shield jacket is lost (drained) and the air circulation option is assumed not to be available.

Under accident conditions where the neutron shield is assumed to be filled with air, radiation exchange is added to the appropriate effective thermal conductivity values. Axial heat transfer within the neutron shield is based on conduction (i.e., a Nusselt number = 1). Heat transfer from the outer skin of the neutron shield is computed based on a natural convection correlation and thermal radiation exchange.

4.5.4.4.4 Fire (61BTH System)

The fire accident is assumed to start from steady-state off-normal conditions, but without a solar shield in place. For the Type 2 DSC, forced air circulation must be on. A 15 minute fire is modeled with fire properties based on the 10 CFR §71.73 (Ref. 6) fire criteria with a flame temperature of 1,475°F and a flame emittance of 0.9. The fire is assumed to fully engulf the TC for the duration of the fire event with the heat transfer between the fire and the TC being via radiation and forced convection.

Following the fire, the ambient condition is set to 117°F with the maximum insolation. The heat transfer between the TC and the ambient is via radiation and natural convection. The emittance of the TC exterior surfaces is raised to 0.8 at the start of the fire event and is assumed to remain constant for the remainder of the transient.

The applicant’s analysis assumes that the liquid neutron shield (water) is present throughout the 15-minute fire transient even though it is expected to be lost and replaced with air very early in the fire transient. This is a conservative assumption that serves to maximize the heat input from the fire to the canister due to the higher conductivity of water when compared to air.

In the post-fire transient, the applicant assumes that water in the neutron shield cavity is lost at the beginning of the postfire transient and is replaced by air. This is a realistic assumption, rather than a conservatism in the analysis, and is appropriate to include in the analysis, as it will tend to inhibit the rate of the heat flow from the canister to the ambient. The postulated “air gap” serves to insulate the DSC and thereby increase temperatures.

The gaps included in the thermal model of the 61BTH DSC basket are not removed for calculating the cladding temperatures during accident conditions. The DSC shell temperature changes by a small amount during the accident fire transient. This change is small during the fire transient due to the large thermal mass of the transfer cask. This shows that heat input from the fire to the DSC is not significant. Since the DSC shell temperature is almost unchanged, the cladding temperatures during the 15-minute fire transient also are almost unchanged. Therefore, the assumption of not removing the gaps during the fire transient has a negligible impact on cladding temperatures.

4.5.4.4.5 Fire (32PTH1 System)

For the fire accident, a 15 minute fire is modeled with fire properties based on the 10 CFR §71.73 (Ref. 6) fire criteria with a flame temperature of 1,475°F and a flame emittance of 0.9. The fire is assumed to fully engulf the TC for the duration of the fire event with the heat transfer between the fire and the TC being via radiation and forced convection.

Following the fire, the ambient condition is set to 117°F with the maximum insolation. The heat transfer between the TC and the ambient is via radiation and natural convection. The emittance of the TC exterior surfaces is raised to 0.8 at the start of the fire event and is assumed to remain constant for the remainder of the transient.

The applicant's analysis assumes that the liquid neutron shield (water) is present throughout the 15-minute fire transient even though it is expected to be lost and replaced with air very early in the fire transient. This assumption serves to maximize the heat input from the fire to the canister due to the higher conductivity of water when compared to air.

In order to maximize the canister temperature during the post-fire transient, the applicant assumes that water in the neutron shield cavity is lost at the beginning of the postfire transient and is replaced by air as the heat flow is now from the canister to the ambient. The postulated "air gap" serves to insulate the DSC and thereby increase temperatures.

The gaps included in the thermal model of the 32PTH1 DSC basket are not removed for calculating the cladding temperatures during accident conditions. The DSC shell temperature changes by a small amount during the accident fire transient. This change is small during the fire transient due to the large thermal mass of the transfer cask. This shows that heat input from the fire to the DSC is not significant. Since the DSC shell temperature is almost unchanged, the cladding temperatures during the 15-minute fire transient also are almost unchanged. Therefore, the assumption of not removing the gaps during the fire transient has a negligible impact on cladding temperatures.

4.5.4.4.6 61BTH Cask Heatup Analysis

The applicant performed a thermal analysis using the three-dimensional model described in Section T.4.6 of the SAR, with decay heat load of 22.0 kW for DSC with Type 1 basket and 31.2 kW for DSC with Type 2 basket at an initial DSC shell surface temperature of 225°F. The initial temperature of the DSC, basket and fuel is assumed to be 225°F, based on the saturation boiling temperature of the fill water at the pressure at the bottom of the cask. Table T.4-25 of the SAR provides the maximum fuel cladding temperatures. Table T.4-26 and Table T.4-27 provide the maximum basket component temperatures for the DSCs with Type 1 and Type 2 baskets, respectively.

A typical temperature distribution for DSC with heat load of 22.0 kW is shown Figure T.4-32. For vacuum drying of 61BTH DSC using helium, the maximum fuel cladding temperatures are 584°F for the DSC with Type 1 basket (22.0 kW/HLZC #1) and 592°F for the DSC with Type 2 basket (31.2 kW/HLZC #7). These maximum cladding temperatures are well below the limit of 752°F.

4.5.4.4.7 32PTH1 Cask Heatup Analysis

The applicant performed a thermal analysis using the three-dimensional model described in Section U.4.6 of the SAR, with decay heat load of 31.2 kW/40.8 kW for DSC with Type 1 basket and 24 kW/31.2 kW for DSC with Type 2 basket at an initial DSC shell surface temperature of

225°F. The initial temperature of the DSC, basket and fuel is assumed to be 225°F, based on the saturation boiling temperature of the fill water. Table U.4-28 of the SAR provides the maximum fuel cladding temperatures. Tables U.4-29 and U.4-30 provide the maximum basket component temperatures for the DSCs with Type 1 and Type 2 baskets, respectively.

A typical temperature distribution for DSC with heat load of 40.8 kW is shown Figure U.4-55. For vacuum drying of 32PTH1 DSC containing 16 damaged fuel assemblies using helium in the 32PTH1 DSC, the maximum fuel cladding temperatures are 581°F for the DSC with Type 1 basket (40.8 kW/HLZC #1) and 619°F for the DSC with Type 2 basket (31.2 kW/HLZC #2). These maximum cladding temperatures are well below the limit of 752°F.

4.6 Thermal Analysis

4.6.1 Temperature Calculations

4.6.1.1 Storage Conditions (61BTH)

Analyses are presented in the SAR only for the HSM-H storage module with the 61BTH DSC with Type 2 basket and maximum decay heat load of 31.2 kW. The 61BTH DSC, with Type 1 basket, which can be stored in the HSM (Models 80, 102, 152, and 202), has a maximum decay heat load of 22 kW. The applicant assumes the thermal performance of the HSM with the 61BTH DSC is bounded by the thermal performance of the HSM for 24 kW, which has been demonstrated in the base SAR. Detailed external surface temperatures for the DSC determined with 24 kW decay heat load are used as boundary conditions for evaluations of the thermal behavior of the DSC internal components.

The HSM-H system has been analyzed with the 61BTH DSC to determine the temperature distribution under long-term storage conditions that envelop normal, off-normal, and accident conditions. The DSC basket is considered to be loaded at design-basis maximum heat loads with BWR assemblies. The HSM-H modules are considered to be arranged in an ISFSI array and subjected to design-basis ambient conditions with insolation. The maximum predicted and allowable temperatures of the components important to safety are discussed in SAR Sections T.4.6.5 for normal, T.4.6.6 for off-normal, and T.4.6.7 for accident conditions. Low (minimum) temperature conditions were also considered for the system.

Table 4.15 below summarizes the peak DSC shell temperatures for normal, off-normal, and accident conditions for the 61BTH DSC configurations in the HSM and HSM-H storage modules. These peak temperatures indicate that for the Type 1 DSC, the limiting configuration is HLZC #1 with 22 kW decay heat. For the Type 2 DSC, the limiting configuration has a total decay heat load of 31.2 kW. However, there is insufficient information, based on analysis of the DSC in the HSM-H, to determine the limiting heat loading configuration.

Table 4.15 Summary of Peak DSC Shell Temperatures for 61BTH DSC in Storage

Storage Conditions	Ambient Temperature	Type 1 DSC (22 kW)	Type 2 DSC (31.2 kW)	Delta T for Type 1 vs. Type 2 peak temperatures
Normal (cold)	0ºF	277ºF	365ºF	88 ºF
Normal (hot)	100ºF	374ºF	436ºF	62 ºF
Off-normal (hot)	117ºF	399ºF	439ºF	40 ºF
Blocked vent accident at 40 hrs	117ºF	611ºF	596ºF	-15 ºF

The results shown in Table 4.15 indicate that the Type 2 DSC is likely to be bounding on the Type 1 DSC for steady-state conditions of storage; however, the difference erodes with increasing temperature, and in the blocked vent accident transient, the Type 1 DSC is hotter than the Type 2 DSC. The DSC shell temperature is directly proportional to the peak fuel cladding temperature, assuming all other factors are the same. For the two DSC designs, there are significant differences in the geometry of the basket support rails. In addition, for the Type 2 DSC, there are different fuel loading patterns to consider at the maximum decay heat load of 31.2 kW. Both of these factors can greatly affect the peak fuel cladding temperature, and it is impossible to say, based on DSC shell temperatures alone, which configuration will have the highest peak fuel cladding temperatures.

The calculated maximum fuel cladding temperatures for fuel assemblies stored in the 61BTH DSC are listed in SAR Tables T.4-12, T.4-17 and T.4-21, for normal, off-normal, and accident conditions, respectively. Maximum fuel cladding temperatures for vacuum drying are presented in SAR Table T.4-25. The applicant’s analysis of the fuel cladding temperatures for the maximum heat load of 31.2 kW (which bounds other heat loads) showed that the fuel cladding temperatures remain below their respective acceptable temperature limits. Table 4.16 below summarizes the peak fuel cladding temperatures corresponding to the peak DSC shell temperatures presented in Table 4.15. These results were obtained in calculations using the detailed ANSYS model of the DSC, with temperature profiles form the storage module evaluation providing boundary conditions in the form of surface temperatures on the DSC outer shell.

These results support the applicant’s claim that the Type 2 DSC is bounding on the Type 1 DSC for normal, off-normal, and accident conditions of storage. The peak fuel cladding temperature is significantly higher for the Type 2 DSC in steady-state storage conditions. For the blocked vent transient at 40 hours, however, the difference has narrowed to only about 3 ºF.

Table 4.16 Summary of Peak Fuel Cladding Temperatures for 61BTH in Storage

Storage Conditions	Ambient Temperature	Type 1 DSC (22 kW)	Type 2 DSC (31.2 kW)	Delta T for Type 1 vs. Type 2 peak temperatures
Normal (cold)	0ºF	598ºF	641ºF	43 ºF
Normal (hot)	100ºF	672ºF	713ºF	41 ºF
Off-normal (hot)	117ºF	691ºF	716ºF	25 ºF
Blocked vent accident at 40 hrs	117ºF	858ºF	861ºF	3 ºF

4.6.1.1.1 Transfer Conditions (61BTH)

Analyses are presented in the SAR for the OS197 transfer cask with the 61BTH DSC with Type 1 and Type 2 basket at their respective maximum decay heat loads. Table 4.17 summarizes the peak DSC shell temperatures obtained with the SINDA/FLUINT model of the transfer cask. The detailed external surface temperatures for the DSC determined in these calculations are used as boundary conditions for evaluations of peak temperatures on the DSC internal components, including the peak fuel cladding temperature.

The results in Table 4.17 demonstrate that compared to the Type 1 DSC, the Type 2 DSC is bounding, when forced air cooling is not used. The peak fuel cladding temperatures corresponding to the DSC shell temperatures obtained in these calculations are listed in Table 4.18. The results in Table 4.18 for the Type 2 DSC (31.2 kW, no FC, transient) cases were obtained with the detailed ANSYS model of the DSC, using DSC shell temperatures from the corresponding transient with SINDA/FLUINT calculations. The results indicate that the peak cladding temperatures for the Type 2 DSC with 31.2 kW are bounding for most conditions, and in all reported cases are below the regulatory limit of 752°F.

Table 4.17 Summary of Peak DSC Shell Temperatures for 61BTH DSC in OS197 TC

Transfer Conditions	Ambient Temperature	Type 1 DSC (22 kW)	Type 2 DSC (31.2 kW, with FC)	Type 2 DSC (31.2 kW, no FC, transient)
Normal (cold), no insolation	0ºF	358ºF	287ºF (steady-state)	408ºF
Normal (hot), with insolation	100ºF	418ºF	376ºF (steady-state)	441ºF
Off-normal (hot), no insolation	117ºF	413ºF	384ºF (steady-state)	437ºF
Vertical loading transient (in transfer facility)	120ºF	429ºF (Boral®, HLZC #3, 19.4 kW)	417ºF (Boral®, HLZC #8, 27.4 kW)	445ºF
		405ºF (borated aluminum, HLZC #1, 22 kW)		
Loss of NS accident	100ºF	484ºF		544ºF (steady-state)

Table 4.18 Summary of Peak Fuel Cladding Temperatures for 61BTH DSC in OS197

Transfer Conditions	Ambient Temperature	Type 1 DSC (HLZC #1, 22 kW)(1)	Type 2 DSC (31.2 kW, with FC, steady-state)	Type 2 DSC (31.2 kW, no FC, transient)
Normal (cold), no insolation	0ºF	653ºF	not reported	690ºF
Normal (hot), with insolation	100ºF	706ºF	not reported	715ºF
Off-normal (hot), no insolation	117ºF	706ºF	not reported	716ºF
Vertical loading transient (in transfer facility)	120ºF	734ºF (Boral®, HLZC #3, 19.4 kW)	not reported	728ºF
		not reported		
Loss of NS accident	100ºF	749ºF(2)	824ºF(2)	

(1) Results for borated aluminum neutron absorbers, unless otherwise identified
(2) Results for post-fire steady-state; same as loss of NS accident steady-state, except ambient temperature is 117ºF, rather than 100ºF.

The time limits for the Type 2 DSC analyses are identified in the SAR as 28 hours for HLZC #5 and #6, and 15 hours for HLZC #7 with 31.2 kW. No time limit is identified for the Type 2 DSC with HLZC #8, 27.4 kW, nor is the peak fuel cladding temperature reported for this case.

Although the general trends in the reported results tend to support the applicant's assertion that the peak cladding temperature remains below applicable regulatory limits for all conditions of transfer and storage for the 61BTH DSC, the applicant should expand the documentation in the UFSAR that incorporates this amendment, to include the following additional information:

- The criteria used to determine the time limits of 15 hours (for HLZC #7) and 28 hours (for HLZC #5 and #6) at which forced air circulation must be switched on in the OS197FC-B transfer cask with 61BTH DSC with Type 2 basket

- Comparative evaluations of the peak DSC component temperatures (including the peak fuel cladding temperature) for the full range of HLZCs permitted in the Type 2 DSC

- A comprehensive evaluation comparing the limiting cases for all Type 1 and Type 2 DSC configurations that are permitted Boral® neutron absorber plates in the basket

While the design, as described, for the 61BTH DSC is acceptable, the staff finds that the results presented in the SAR are not complete, and do not clearly show that the thermal analysis has included all possible combinations that might lead to the limiting configuration for the 61BTH DSC for all conditions of transfer and storage. Additions should be made to the FSAR to provide the information described above.

4.6.1.2 Storage Conditions (32PTH1)

The HSM-H system has been analyzed with the 32PTH1 DSC as contents to determine the temperature distribution under long-term storage conditions that envelop normal, off-normal, and accident conditions. The DSC basket is considered to be loaded at design-basis maximum heat loads with PWR assemblies. The HSM-Hs are considered to be arranged in an ISFSI array and subjected to design-basis ambient conditions with insolation. The maximum predicted and allowable temperatures of the components important to safety are discussed in SAR Sections U.4.6.5 for normal, U.4.6.6 for off-normal, and U.4.6.7 for accident conditions. Low (minimum) temperature conditions were also considered for the system.

The calculated maximum fuel cladding temperatures for fuel assemblies stored in the 32PTH1 DSC are listed in SAR Tables U.4-15, U.4-20 and P.4-24, for normal, off-normal, and accident conditions, respectively. Maximum fuel cladding temperatures for vacuum drying are presented in SAR Table U.4-28. The applicant's analysis of the fuel cladding temperatures for the maximum heat load of 40.8 kW (which bounds other heat loads) showed that the fuel cladding temperatures remain below their respective acceptable temperature limits. Table 4.19 below summarizes the maximum temperatures of key components in the storage system, calculated by the applicant, for various environmental conditions.

Table 4.19 Maximum Temperatures (°F) of Key System Components (40.8 kW)
(Source: SAR Tables U.4-2, U.4-3, U-4.15, and U.4-16, U.4-20, U.4-24, U.4-25)

Component (HSM-H/DSC)	Normal Storage 106°F Ambient	Off-Normal 117°F Ambient	Normal Transfer 106°F Ambient	Blocked Vent Accident @ 40 Hrs.	Transfer loss of sunshade, neutron shield, & air circulation 117°F Ambient
DSC shell	**484**	**491**	**n/a**	**682**	**n/a**
Concrete	**290**	**301**	**n/a**	**465**	**n/a**
Top heat shield	**264**	**278**	**n/a**	**458**	**n/a**
Side heat shield	**261**	**275**	**n/a**	**515**	**n/a**
DSC Support Rail	**347**	**358**	**n/a**	**603**	**n/a**
32PTH1 DSC with Type 1 Basket – Heat Load Zone Configuration #1					
Fuel cladding	**733**	**741**	**722**	**887**	**886**
Fuel Compartment	**701**	**710**	**683**	**865**	**858**
Neutron Absorber	**701**	**710**	**683**	**865**	**858**
R45 & R90 Rails	**511**	**520**	**506**	**685**	**692**

4.6.1.3 Accident Conditions- Blocked Vents

The blocked vent accident analysis is presented in SAR Sections T.4.4.5, T.4.4.7.2, U.4.4.5, and U.4.4.7.2 (for the HSM-H) and Sections T.4.6.8.1, and U.4.6.7.1 (for the DSCs). The analyses predicted the component and cladding temperatures for a 40 hour blockage. Results of the applicant's calculations are presented in SAR Tables T.4-21 and U.4-24 for fuel cladding, and Tables T.4-22, T.4-23, U.4-25 and U.4-26 for DSC components.

The applicant's results for the 117°F ambient blocked vent conditions for the **61BTH** system, presented in SAR Table T.4-3 demonstrate that the maximum concrete temperature at the end of 40 hours in the blocked vent accident is 426°F for a 31.2 kW heat load. This is above the 350°F limit given in the SRP (NUREG 1536 (Ref. 7)) for accident conditions.

The applicant's results for the 117°F ambient blocked vent conditions for the **32PTH1** system, presented in SAR Table U.4-3, demonstrate that the maximum concrete temperature at the end of 40 hours in the blocked vent accident is 403°F and 465°F for 31.2 kW and 40.8 kW heat loads, respectively. This is above the 350°F limit given in the SRP (NUREG 1536) for accident conditions.

In order to account for the effect of higher concrete temperature on the concrete compressive strengths, the applicant's structural analysis of HSM-H concrete components, presented in Chapters T.3 and U.3 of the SAR is based on a 10% reduction in concrete material properties. The applicant will conduct testing to document that concrete compressive strength will be greater than that used in the structural analysis documented in Chapter U.3 of the SAR. This is considered an area for inspection follow-up by the NRC staff.

Based on this analysis, the staff finds reasonable assurance that the fuel cladding integrity and the confinement boundary will not be compromised during the blocked vent transient. In addition, the added testing of concrete samples, to ensure structural integrity of concrete at elevated temperatures, provides additional support to the staff's findings.

4.6.1.4 Accident Conditions- Loss of Neutron Shield and Sunshade for Transfer Cask

The applicant analyzed an accident involving loss of water from the annular neutron shield region of the transfer cask, no fan convection, and loss of required sunshade during the transfer of the DSC to the HSM-H. The temperatures reported by the applicant in SAR Tables T.4-10 and U.4-10 for components and Tables T.4-21 and U.4-24 for fuel cladding, were below all material limits. The staff reviewed this analysis and accepted it for this particular application.

4.6.1.5 Accident Conditions – Fire

4.6.1.5.1 Fire (61BTH System)

The applicant analyzed a fire accident for the DSC in the transfer cask using the methodology presented in SAR Section T.4.5.3.3. The initial temperatures for the fire analysis were assumed to be at the point where the maximum operational time allowed for transfer without air circulation was reached per the description in Section 4.4.1.2.1.1 of this SER.

The applicant's analysis demonstrates that, with the exception of the exterior surfaces of the cask, the thermal mass of the DSC and cask components absorbs the heat flux from the fire without a significant increase in temperature. SAR Figure T.4-21 presents the predicted transient temperature response for the OS197FC-B TC and the 61BTH DSC shell with 31.2 kW of decay heat loading under the evaluated hypothetical fire event. The figure demonstrates, with the exception of the exterior surfaces of the cask, the maximum cask component temperatures achieved under the fire accident scenario will occur during the post-fire steady-state condition.

A comparison of the post-fire steady-state temperatures in each table with those for the 'loss of neutron shield' accident scenario in the same table shows that the 'loss of neutron shield' temperatures bound, by a slight margin, those seen for the post-fire steady-state condition. This occurs because the sooting and oxidation of the exterior surfaces that is assumed for the fire event raises the surface emissivity, thus increasing the heat transfer between the cask and the ambient.

Based on these analyses, the staff has reasonable assurance that the cladding integrity and the confinement boundary will not be compromised during the fire or post-fire transients.

4.6.1.5.2 Fire (32PTH1 System)

The applicant analyzed a fire accident for the DSC in the transfer cask using the methodology presented in SAR Section U.4.5.3. The results of the analysis are discussed in SAR Section U.4.5.4.2. The initial temperatures for the fire analysis were assumed to be at the point where the maximum operational time allowed for transfer without air circulation was reached per the description in Section 4.4.2.2.1.1 of this SER.

The applicant's analysis demonstrates that, with the exception of the exterior surfaces of the cask, the thermal mass of the DSC and cask components absorbs the heat flux from the fire without a significant increase in temperature. SAR Figures U.4-26 and U.4-38 present the predicted transient temperature response for the OS200 TC and the 32PTH1 DSC shell with 40.8 and 31.2 kW of decay heat loading, respectively, under the evaluated hypothetical fire event. The figures demonstrate, with the exception of the exterior surfaces of the cask, the maximum cask component temperatures achieved under the fire accident scenario will occur during the post-fire steady-state condition.

Tables U.4-10 and U.4-14 of the SAR present the peak component temperatures achieved with decay heat loads of 40.8 and 31.2 kW, respectively, at the end of the fire (i.e., 15 minutes into the transient) and for the post-fire steady-state condition. A comparison of the post-fire steady-state temperatures in each table with those for the 'loss of neutron shield' accident scenario in the same table shows that the 'loss of neutron shield' temperatures bound those seen for the post-fire steady-state condition.

No specific evaluation for the 32PTH1 DSC with HLZC #3 (i.e., 24 kW of decay heat loading) is provided. Instead, the results for 24 kW are bounded by those for 40.8 and 31.2 kW.

Based on the applicant's analyses, the staff has reasonable assurance that the cladding integrity and the confinement boundary will not be compromised during the fire or post-fire transients.

4.6.1.6 Cask Heatup Analyses

4.6.1.6.1 Cask Heatup Analyses (61BTH System)

The applicant performed a thermal analysis using the three-dimensional model described in Section T.4.6 of the SAR, with decay heat load of 31.2 kW/27.4 kW for DSC with Type 2 basket and 22.0 kW/19.4 kW for DSC with Type 1 basket at an initial DSC shell surface temperature of 225°F. The initial temperature of the DSC, basket and fuel is assumed to be 225°F, based on the saturation boiling temperature of the fill water at the pressure at the bottom of the cask. Table T.4-25 of the SAR provides the maximum fuel cladding temperatures. Tables T.4-26 and T.4-27 of the SAR provide the maximum basket component temperatures for the DSCs with Type 1 and Type 2 baskets, respectively.

A typical temperature distribution for DSC with heat load of 22.0 kW is shown Figure T.4-32 of the SAR. For vacuum drying of 61BTH DSC using helium, the maximum fuel cladding temperatures are 584°F for the DSC with Type 1 basket (22.0 kW/HLZC #1) and 592°F for the DSC with Type 2 basket (31.2 kW/HLZC #7). These maximum cladding temperatures are well below the limit of 752°F.

4.6.1.6.2 Cask Heatup Analyses (32PTH1 System)

The applicant performed a thermal analysis using the three-dimensional model described in Section U.4.6 of the SAR, with decay heat load of 31.2 kW/40.8.0 kW for DSC with Type 1 basket and 24 kW/31.2 kW for DSC with Type 2 basket at an initial DSC shell surface temperature of 225°F. The initial temperature of the DSC, basket and fuel is assumed to be 225°F, based on the saturation boiling temperature of the fill water. Table U.4-28 of the SAR provides the maximum fuel cladding temperatures. Tables U.4-29 and U.4-30 of the SAR provide the maximum basket component temperatures for the DSCs with Type 1 and Type 2 baskets, respectively.

A typical temperature distribution for DSC with heat load of 40.8 kW is shown in Figure U.4-55 of the SAR. For vacuum drying of 32PTH1 DSC containing 16 damaged fuel assemblies using helium in the 32PTH1 DSC, the maximum fuel cladding temperatures are 581°F for the DSC with Type 1 basket (40.8 kW/HLZC #1) and 619°F for the DSC with Type 2 basket (31.2 kW/HLZC #2). These maximum cladding temperatures are well below the limit of 752°F.

4.6.2 Pressure Analysis

4.6.2.1 Pressure Analysis (61BTH)

In SAR Section T.4.6.6.4, the applicant describes the internal pressure calculation for the 61BTH DSC, loaded with fuel with a maximum burnup of 62 GWd/MTU, for all storage and transfer operations. The limiting fuel assembly type considered in the applicant's evaluation is the FANP9 9x9-2 fuel assembly (refer to SAR Chapter T.2.1).

The calculations account for the DSC free volume, the quantities of DSC backfill gas, fuel rod fill gas, and fission products and the average DSC cavity gas temperature. Average helium temperatures within 61BTH DSC were taken from the results in section T.4.6.6.3 of the SAR.

The percentage of CCs rods ruptured during normal, off-normal and accident conditions is assumed to be 1%, 10% and 100%, respectively, similar to the assumptions for the fuel rod rupturing. The maximum amount of gas released to the DSC cavity from the CCs for normal, off-normal and accident conditions is given in Table T.4-30 of the SAR.

The maximum DSC cavity internal pressure limits are summarized in Table 4.20 below.

Table 4.20 Summary of Internal DSC Pressure for Storage Conditions

Condition	Maximum Allowable Pressure (psig)	
	Type 1 DSC	Type 2 DSC
Normal	10	15
Off-Normal	20	20
Accident	65	120

4.6.2.2 Pressure Analysis (32PTH1)

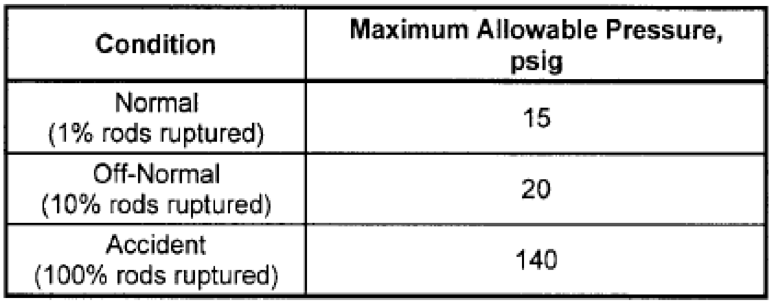
In SAR Section U.4.6.5.4, the applicant describes the internal pressure calculation for the 32PTH1 DSC, loaded with fuel with a maximum burnup of 62 GWd/MTU, for all storage and transfer operations. The limiting fuel assembly type considered in the applicant's evaluation is the BW 15x15 fuel assembly with control components (refer to SAR Chapter U.2).

The calculations account for the DSC free volume, the quantities of DSC backfill gas, fuel rod fill gas, and fission products and the average DSC cavity gas temperature. Average helium temperatures within 32PTH1 DSC were calculated based on 32PTH1-S, with Type 1 basket (with aluminum R45 and R90 rails), which bounds thermally 32PTH1-M and 32PTH1-L configurations. The effect of control components (CCs) on the DSC internal pressure is also included in this calculation.

The percentage of CCs rods ruptured during normal, off-normal and accident conditions is assumed to be 1%, 10% and 100%, respectively, similar to the assumptions for the fuel rod rupturing. The maximum amount of gas released to the DSC cavity from the CCs for normal, off-normal and accident conditions is given in Table U.4-33 of the SAR.

The maximum DSC cavity internal pressure limits are summarized in Table 4.21, below.

Table 4.2.1 Maximum Allowable Pressure



Condition	Maximum Allowable Pressure, psig
Normal (1% rods ruptured)	15
Off-Normal (10% rods ruptured)	20
Accident (100% rods ruptured)	140

4.6.2.3 Normal Conditions of Storage and Transfer

The maximum pressure for normal conditions of storage and transfer occurs when the **61BTH** DSC is in the fuel building during vertical transfer with an ambient temperature of 120°F and no insolation. The average helium temperature is 382°F (842°R) for the Type 1 DSC, and 377°F

(837°R) for the Type 2 DSC. (See SAR Table T.4-16.) Per the SRP (NUREG 1536), 1% of the fuel pins are assumed to be ruptured.

The maximum pressure for normal conditions of storage and transfer occurs when the **32PTH1-S** (31.2 kW/HLZC #2) loaded with FAs with control components is in the OS200 transfer cask with an ambient temperature of 106°F and insolation. The average helium temperature is 553°F (1013°R). (See SAR Table U.4-35.) Per the SRP (NUREG 1536), 1% of the fuel pins are assumed to be ruptured.

4.6.2.4 Off-Normal Conditions

4.6.2.4.1 Off-Normal Conditions (61BTH System)

In SAR Section T.4.6.7.6, the applicant evaluated the internal pressure of the DSC for off-normal conditions. The maximum internal pressure for off-normal conditions of storage and transfer occurs when the 61BTH DSC is in the OS197FC-B transfer cask with an ambient temperature of 117°F and sunshade. Per the SRP (NUREG 1536), the percentage of fuel rods ruptured for off-normal cases is 10%.

A summary of the maximum off-normal operating pressures for the 61BTH DSC configurations are presented in SAR Table T.4-20.

4.6.2.4.2 Off-Normal Conditions (32PTH1 System)

In SAR Section U.4.6.6.6, the applicant evaluated the internal pressure of the DSC for off-normal conditions. The maximum internal pressure of 18.65 psig for off-normal conditions of storage and transfer occurs when the 32PTH1-S DSC with Type 1 basket with heat load of 31.2 kW (HLZC #2) loaded with FAs with control components is in vertical OS200 transfer cask in fuel building with an ambient temperature of 140°F and no insolation. Per the SRP (NUREG 1536), the percentage of fuel rods ruptured for off-normal cases is 10%.

A summary of the maximum off-normal operating pressures for the various 32PTH1 DSC configurations are presented in SAR Table U.4-23.

4.6.2.5 Accident Conditions

4.6.2.5.1 Accident Conditions (61BTH System)

In SAR Section T.4.6.8.5, the applicant evaluated the internal pressure of the DSC for accident conditions. The maximum accident pressure for the 61BTH DSC (31.2 kW) occurs during transfer in the OS197FC-B TC under maximum off-normal ambient temperature of 117°F, concurrent with loss of the solar shield, loss of liquid neutron shield, and loss of air circulation.

For this condition the average helium temperature was 615°F (1075°R). Per the SRP (NUREG 1536), the percentage of fuel rods ruptured for this accident event is 100%. During the blocked vent case, the average helium gas temperature was 654°F (1114°R). However, since no DSC drop event can occur in conjunction with a blocked vent event, the maximum fraction of fuel pins that can be ruptured is limited to 10%. Therefore, the maximum block vent accident pressure at 40 hours is bounded by maximum transfer accident pressure.

A summary of the maximum accident operating pressures for the various 61BTH DSC configurations are presented in SAR Table T.4-24.

Based on review of the applicant's pressure analyses, the staff found reasonable assurance that the internal cask pressures remain below the cask design pressure for normal, off-normal, and accident conditions.

4.6.2.5.2 Accident Conditions (32PTH1 System)

In SAR Section U.4.6.7.4, the applicant evaluated the internal pressure of the DSC for accident conditions. The maximum accident pressure of 126.34 psig occurs during the 32PTH 1-S DSC with heat load of 40.8 kW (HLZC #1) transfer in the OS200 TC under maximum off-normal ambient temperature of 117°F, concurrent with loss of the solar shield, loss of liquid neutron shield, and loss of air circulation.

For this condition the average helium temperature was 727°F (1187°R) (see SAR Table U.4-35). Per the SRP (NUREG 1536), the percentage of fuel rods ruptured for this accident event is 100%. During the block vent case, the average helium gas temperature was 727°F (1187°R). However, since no DSC drop event can occur in conjunction with a blocked vent event, the maximum fraction of fuel pins that can be ruptured is limited to 10%. Therefore, the maximum block vent accident pressure at 40 hours is bounded by maximum transfer accident pressure.

A summary of the maximum accident operating pressures for the various 32PTH1 DSC configurations are presented in SAR Table U.4-27.

Based on review of the applicant's pressure analyses, the staff found reasonable assurance that the internal cask pressures remain below the cask design pressure for normal, off-normal, and accident conditions.

4.6.2.6 Pressure During Unloading of Cask

For unloading operations, each DSC is filled with the spent fuel pool water through its siphon port. During this filling operation, the DSC vent port is maintained open with effluents routed to the plant's off-gas monitoring system. The DSC operating procedures recommend that the DSC cavity atmosphere be sampled prior to introducing any reflood water in the DSC cavity.

Initially, the pool water is added to the DSC cavity containing hot fuel and basket components, some of the water will flash to steam causing internal cavity pressure to rise. This steam pressure is released through the vent port. The applicant's procedures specify that the flow rate of the reflood water 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 the reflood event. The reflood for the DSC is considered as a Service Level D event and the design internal pressure of the DSC is 120 psig for both the 61BTH and the 32PTH1 DSC reflood. Therefore, there is sufficient margin in the DSC internal pressure during the reflooding event to assure that the DSC will not be over pressurized.

The maximum fuel cladding temperature during reflooding event is significantly less than the vacuum drying condition owing to the presence of water/steam in the DSC cavity. The analysis results presented in SAR Table T.4-25 show that the maximum cladding temperature during vacuum drying is 592°F for the 61BTH, and the results presented in SAR Table U.4-28 show that the maximum cladding temperature during vacuum drying is 619°F. Hence, the peak cladding temperature during the reflooding operation will be less than 592°F for the 61BTH, and less than 619°F for the 32PTH1.

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

The staff reviewed the applicant's analysis of reflood operations and found adequate assurance that the DSC pressure would be maintained below applicable limits.

4.6.2.7 Pressure During Cask Loading

As discussed in the previous section, the DSC pressure remains below the limits for all operating conditions. In addition, the applicant is required by their Technical Specifications to have procedures in place to prevent exceeding pressure limits in the DSC during loading.

4.6.3 Confirmatory Analyses

4.6.3.1 Confirmatory Analyses for the 61BTH

No confirmatory analyses were performed by the staff for the 61BTH DSC. The evaluation of the model used in Appendix U to calculate the flow of air, by natural convection in the HSM-H as an element of the calculations to arrive at the DSC shell temperatures applies equally to Appendix T, as the same model is used.

Similarly, the fully coupled 3-dimensional computational fluid dynamics (CFD) model utilizing the Star-CD code from CD-Adapco, Inc. that was developed to evaluate the 32PTH1 DSC in the HSM-H provides indirect confirmation of the analyses with the HSM-H model in Appendix T. The confirmatory analyses with StarCD showed that the HSM-H can accommodate a DSC with a maximum decay heat load of 40.8 kW, which is significantly above the maximum decay heat load allowed in the 61BTH. The StarCD model showed that the applicant's model of the HSM-H is conservative for decay heat loads up to 40.8 kW.

4.6.3.2 Confirmatory Analyses for the 32PTH1

The staff sought to confirm several aspects of the design of the 32PTH1 DSC and the HSM-H for this amendment application. The staff focused on the flow of air, by natural convection, in the HSM-H to arrive at the DSC shell temperatures that were subsequently used for the determination of the peak fuel cladding temperatures for the 32 PTH1 DSC. Transfer conditions were also evaluated.

Summary of efforts:

- Star-CD HSM-H model (Section 4.6.3.2.1)
- Star-CD DSC model (Section 4.6.3.2.2)
- Star-CD Neutron Shield Model (Section 4.6.3.2.3)

4.6.3.2.1 Analysis of HSM-H

The staff built a fully coupled, 3-dimensional computational fluid dynamics (CFD) model utilizing the Star-CD code from CD-Adapco, Inc. The model featured all the geometric details of both the 32 PTH1 DSC as well as the HSM-H storage model. Fuel assemblies were modeled using an effective conductivity approach.

As with the applicant's ANSYS model of the HSM-H documented in the SAR, the HSM-H module was represented in StarCD as hottest central module in double row of adjacent storage units, assuming:

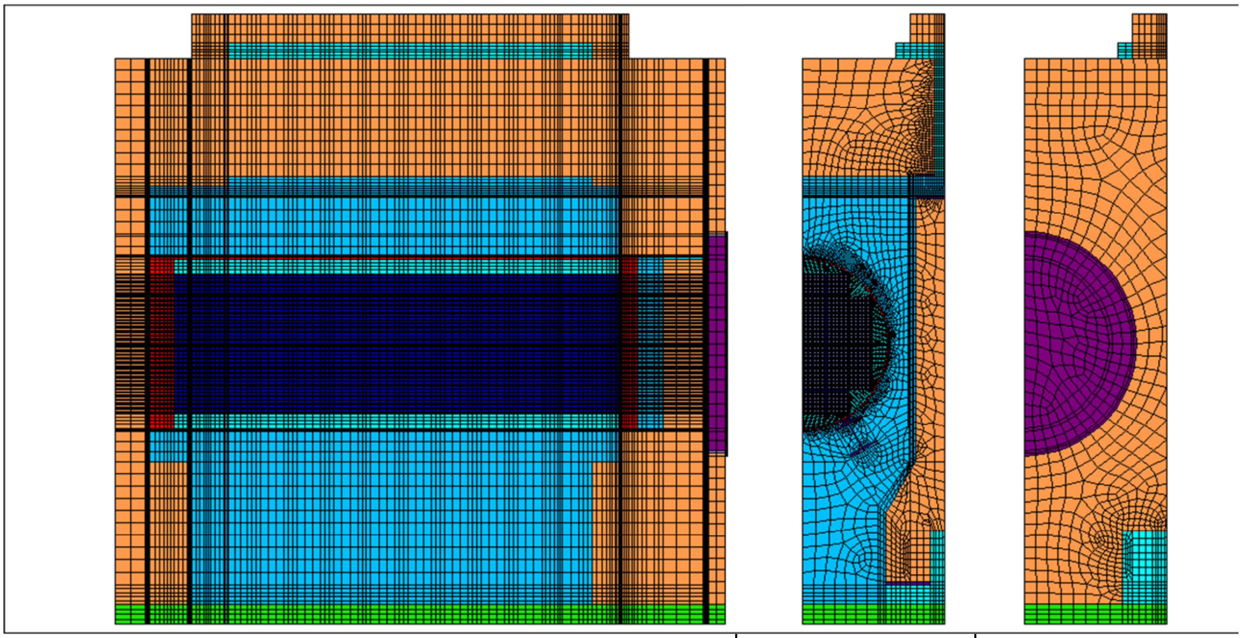
- geometric and heat transfer symmetry about vertical plane through central axis of DSC and module (permits modeling ½ section of DSC and HSM-H storage unit)
- Adiabatic planes assumed on side walls and back wall of HSM-H storage unit
- Natural convection and thermal radiation heat transfer to ambient on front face and top of HSM-H unit external surfaces

Figure 4.8 shows cross-section diagrams of the StarCD model, including the DSC within HSM-H. The detailed noding of the DSC is shown in Figure 4.9. This approach was used for the limiting decay heat load canister configurations:

- Type 1 basket (solid Al rails), HLZC #1, heat load 40.8 kW (highest permitted heat loading conditions for Type 1 basket)
- Type 2 basket (steel rails with Al inserts), HLZC #2, heat load 31.2 kW (highest permitted heat loading conditions for Type 2 basket)

Boundary conditions for the StarCD calculations were defined for limiting off-normal hot storage conditions from SAR; maximum insolation, ambient temperature of 117°F (47°C) and highest heat load for each DSC configuration.

Figure 4.8 Diagram of StarCD Model of HSM-H and DSC (for confirmatory calculations)



Cross-section at axial symmetry plane

Cross-section of interior mid-plane

Front view of module face

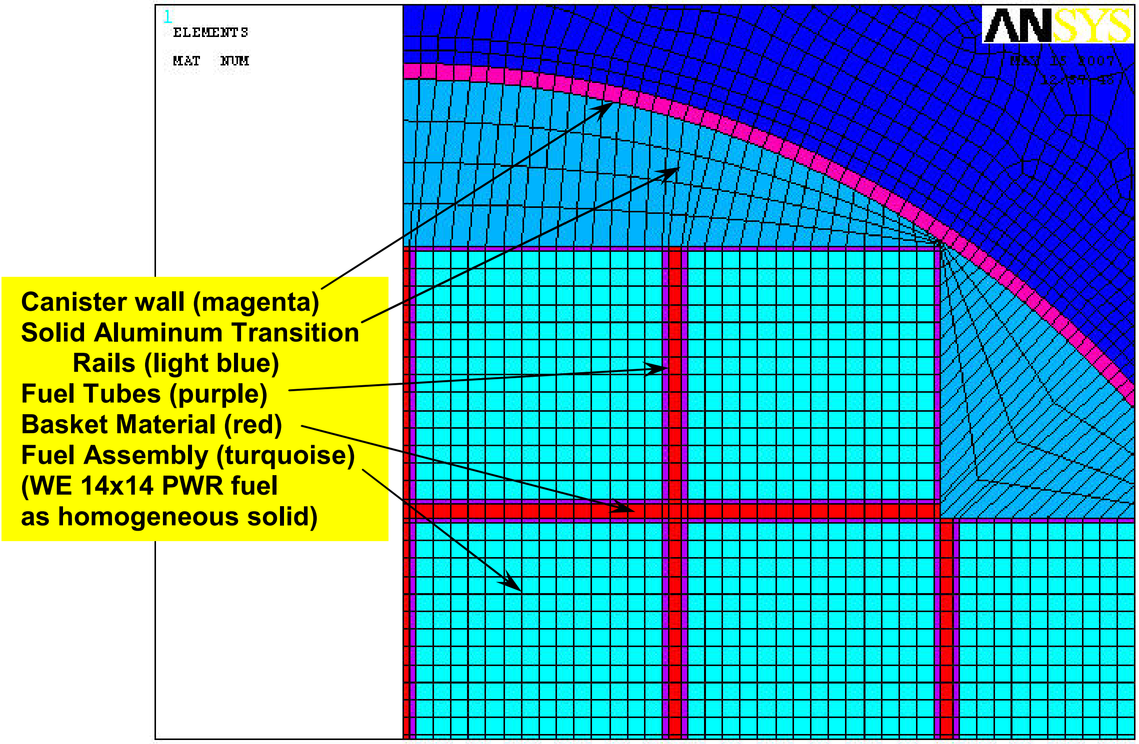


Figure 4.9 Detailed DSC modeling in StarCD (for confirmatory calculations)

The detailed representation of the DSC used in the StarCD model was verified by comparison with the detailed DSC model developed for the COBRA-SFS thermal-hydraulics code. The close agreement obtained for internal components, including the peak clad temperature shows that the finite element modeling in StarCD gives an appropriate representation of temperature distributions within fuel assemblies and throughout the DSC basket and rails. Because the COBRA-SFS code yields good agreement with the detailed ANSYS model of the DSC (when using the same boundary conditions as described in SER Section 4.4 above), this comparison verifies that the StarCD model results are directly comparable to the results obtained with the detailed ANSYS model of the DSC. Figure 4.10 below shows color thermographs of the surface temperatures obtained with the StarCD model with 40.8 kW in the DSC (Type 1, HLZC #1). Figure 4.11 shows a qualitative comparison with the ANSYS results obtained for this case, for the HSM-H and the DSC outer shell surface.

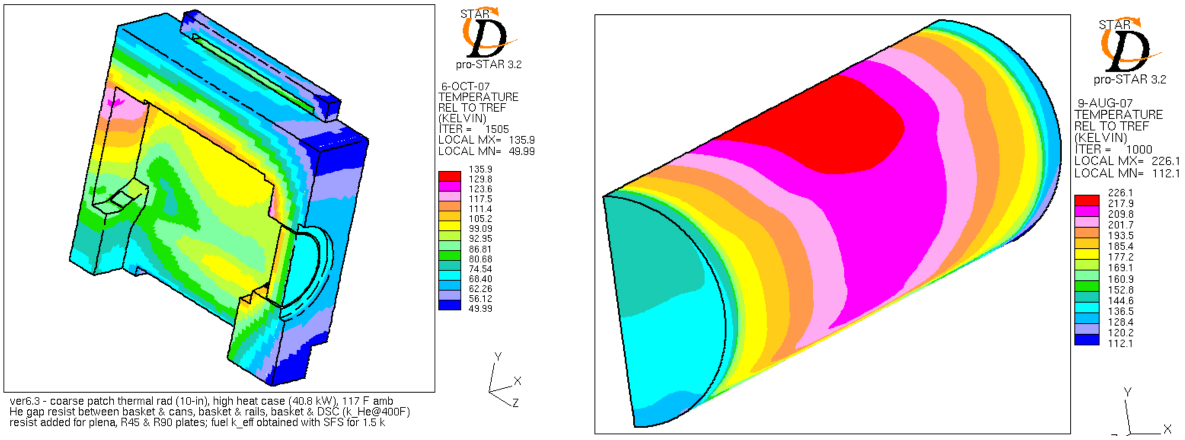


Figure 4.10 StarCD Model Surface Temperature Results for HSM-H and DSC (Type 1, HLZC #1, 40.8 kW; components shown separately for clarity)

The graphics in Figures 4.10 and 4.11 do not use the same scale, so the colors are not directly comparable, but it appears that the temperature distribution shows more distinct variation in the StarCD solution, compared to the ANSYS model solution from the SAR. This is shown quantitatively in Figure 4.12, with a plot of the axial temperature along the length of the DSC outer shell at selected radial locations (i.e., the top of the DSC, 45° from the top, at 90° on the side, at 135°, and at the bottom of the DSC.) The temperature profiles predicted with ANSYS are considerably flattened, in comparison to the more sharply peaked distributions obtained with the StarCD model. At any given radial position around the circumference of the DSC, the temperatures predicted with the ANSYS model from the SAR are generally higher than the DSC shell temperatures obtained with the integrated StarCD model, which solves directly for the heat transfer to the air flowing through the HSM-H.

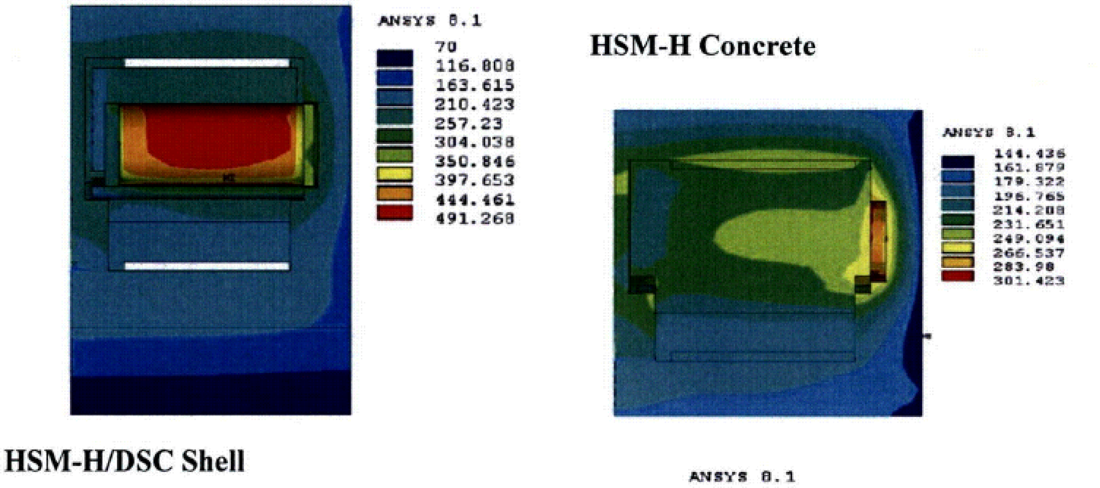


Figure 4.11 ANSYS HSM-H Model Surface Temperature Results for HSM-H and DSC shell (from Figure U.4-9, off-normal storage condition, with 40.8 kW in DSC)

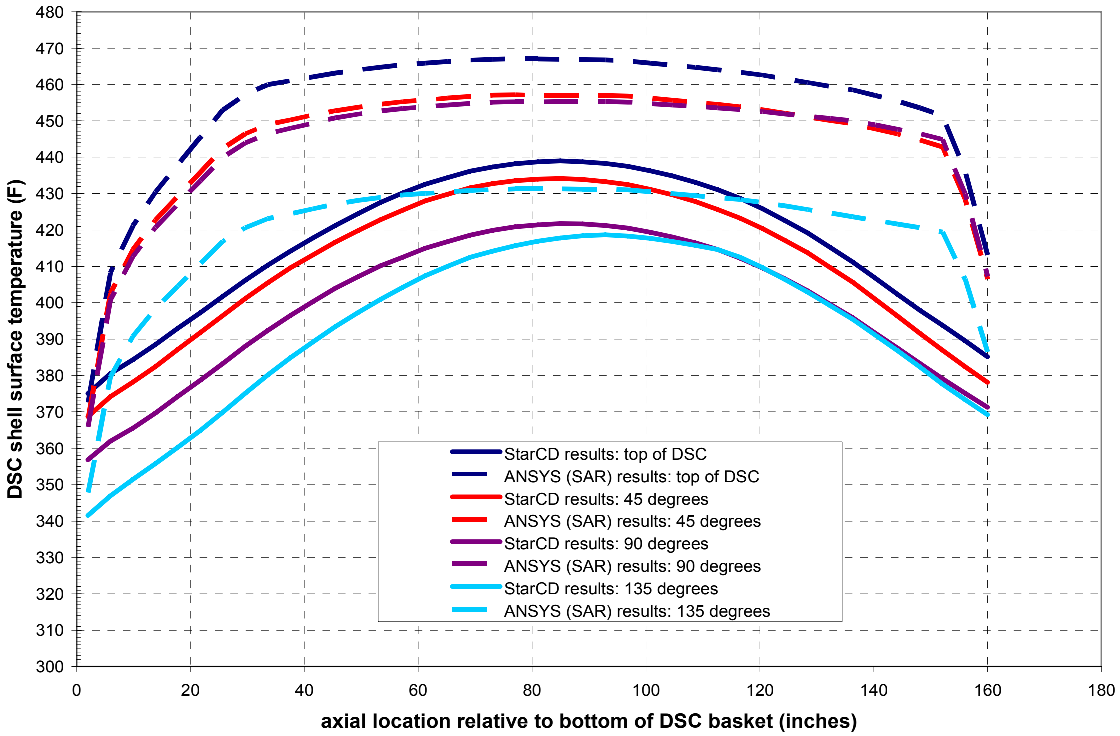


Figure 4.12 Direct Comparison of DSC shell outer temperature results from StarCD model and ANSYS model[3] from the SAR.

These results indicate that the modeling approach used in the SAR is conservative, in that it tends to over-estimate the DSC shell temperatures, and predicts a greater area of the DSC

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[3] Note that the SAR temperatures in Figure 4.12 are from Rev. 0 of the SAR, before correcting the dead zone angle on the DSC shell from 4.2° to 18.9°. The overall effect of the correction is to increase the predicted peak DSC shell temperature by 18-25 °F. Because the one-dimensional stack effect model for air flow and air temperature boundary conditions is unaffected by this correction (see Revision 3 of the SAR), the general shape of the temperature profiles would remain unchanged.

surface to be at the higher temperatures. The component temperatures reported in the SAR for the HSM-H have a similar conservative bias, as shown by the comparison of peak temperatures and air flow rate, in Table 4.22 below.

Table 4.22. Peak HSM-H Component Temperatures for 40.8 kW (ºF)— StarCD Results Compared to ANSYS Results in SAR

Component	Ambient Air	StarCD model HSM-H and DSC (Type 1, HLZC #1)	ANSYS HSM-H (heat flux on DSC inner shell surface*)	Difference
Peak DSC shell temperature	117	441	491	50 ºF
Peak concrete temperature		277	301	34 ºF
Exit air temperature		201	216	15 ºF
Mean air temperature		159	167	8ºF
Total air mass flow rate	117	0.792 kg/sec	0.73 kg/sec	~8%

*Note: these results are for calculation with corrected dead zone angle, as reported in the SAR.

The temperature results obtained with the StarCD model tend to confirm that the ANSYS model used in the thermal analysis of the HSM-H is conservative. The comparison for the most limiting case (DSC with Type 1 basket, HLZC #1, 40.8 kW) indicates that the HSM-H peak temperatures and the DSC shell temperatures are conservative with respect to a CFD model that represents the HSM-H and DSC as an integrated system. The total air flow rate is also conservative for the SAR model, compared to the flow rate predicted with the detailed CFD solution in StarCD.

4.6.3.2.2 Analysis of DSC

In the StarCD model of the HSM-H system, the DSC was represented in detail comparable to that of the detailed ANSYS model of the DSC used in the SAR analyses. A diagram of the DSC portion of the StarCD model is shown in Figure 4.10 above, and contains the following significant features;

- Fuel assemblies modeled as homogeneous solid material, with 14x14 rectangular mesh, using k-effective for WE 14x14 fuel at 1.5 kW decay heat. (Note that this input is identical to the k-effective values used in the ANSYS model in the SAR.)

- Stainless steel fuel tubes represented with 1x14 mesh on each face, for a total of 56 nodes per fuel tube.

- Aluminum and aluminum alloy poison plates comprising the basket plates represented with fine mesh matching fuel assembly and fuel tube mesh.

- Steel support plate between R90 transition rail and Al/Boral plates for Type 1 basket modeled with zero-thickness elements with equivalent thermal resistance of steel plate.

- Transition/support rails represented with fine mesh, 4 node layers thick.

- Type 2 support rails (steel with Al liners) modeled using anisotropic k-effective from SAR.

- DSC shell represented with a single layer of fine mesh nodes.

- Contact resistances due to gaps between adjacent components (i.e., DSC shell, support rails, basket plates, and fuel tubes) modeled with gap sizes specified in the SAR (see Chapter U.4), using equivalent thermal resistances.

The peak DSC component temperatures in Table 4.23 show that the results obtained with the ANSYS model of the DSC alone (using the DSC shell temperatures from the ANSYS model of the HSM-H) are conservative compared to the results obtained for the confirmatory calculations with the integrated StarCD model. The peak component temperatures are on the order of 50 ºF lower in the StarCD model, compared to the results obtained with the SAR methodology. This comparison tends to confirm the assertion in the SAR that the decoupled model has sufficient conservatisms in the general approach for the overall results to be conservative, relative to a more realistic representation of the flow and heat transfer behavior within the DSC, and within the HSM-H.

Table 4.23. Peak DSC Component Temperatures (ºF)—
StarCD Confirmatory Results Compared to ANSYS Results Reported in SAR

Component	Ambient Air	StarCD model (HSM-H and DSC)[1]	COBRA-SFS DSC model[2]	ANSYS DSC model[1,3]	Delta T (StarCD vs. ANSYS)
Fuel cladding	117	701	710	741	40 ºF
Fuel compartment		656	658	710	54 ºF
Neutron absorber plate (basket)		656	658	710	54 ºF
Transition rail		481	498	520	42 ºF
DSC external shell (calculated from integrated model)		441			
DSC external shell (as boundary condition)	117		441	491	50 ºF

[1] Type 1 basket, HLZC #1, 40.8 kW decay heat load
[2] using DSC shell temperatures from StarCD
[3] boundary temperatures from HSM-H model DSC outer shell surface (ANSYS model) with corrected dead zone angle, as reported in the SAR, Revision 3.

4.6.3.2.3 Analysis of OS200 TC Neutron Shield

The staff's review of the OS200 TC included confirmatory analysis performed with a CFD model of the neutron shield tank, using StarCD and StarCCM+, an advanced version of StarCD. The purpose of this analysis was to evaluate the conservatism claimed for the SAR model, and determine the significance of radially varying heat transfer rates around the circumference of the annulus.

Figure 4.13 shows a simplified diagram of the computational grid defined to represent the neutron shield tank. The tank consists of annular segments approximately 12 inches long, separated by thin steel fins[4]. The model represents a half-section of symmetry of the central

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[4] Small holes in the fins for filling and draining of the neutron shield tank are neglected in this analysis. The modeled segment is treated as isolated from the adjacent segments of the tank.

segment of the tank, and assumes adiabatic boundary conditions at the plane of the segment centerline, and at the central plane of the fin. The model extends radially from the inner surface of the transfer cask to the outer shell of the neutron shield tank. The shrinkage gap between the lead gamma shield and transfer cask structural steel was neglected, as were the thermal effects of welds connecting the fins to the cask shell and neutron shield outer skin.

Direct simulation of the thermal and hydrodynamic behavior of a horizontal annulus in which natural convection can occur is a challenging problem. The wide range of spatial and time scales for the flow field results in generally slow convergence of the solution. Segregated solvers, in which the energy and momentum equations are partially decoupled to speed the solution procedure, generally cannot achieve the same steady-state solution as is obtained by running the problem as a long transient. This indicates that the decoupling over-simplifies the physical behavior of the system in a way that cannot be recovered in the process of iterating to a solution for this configuration. For natural convection problems, CFD code convergence relies upon having a fixed reference density in some part of the problem, for example as a specified temperature at an inlet or exit boundary. This reference is not physically available in the closed system of the annulus and this is believed to be a direct cause of the difficulty observed in obtaining steady state solutions for this problem.

In short, even CFD models use approximations and simplifications of physical phenomena that are important driving forces in free convection flow and heat transfer in an enclosure, and in this situation do not give solutions directly from first principles. It is necessary to carefully evaluate the results of calculations, if possible by comparison to relevant experimental data, and verify steady-state solutions with transient calculations.

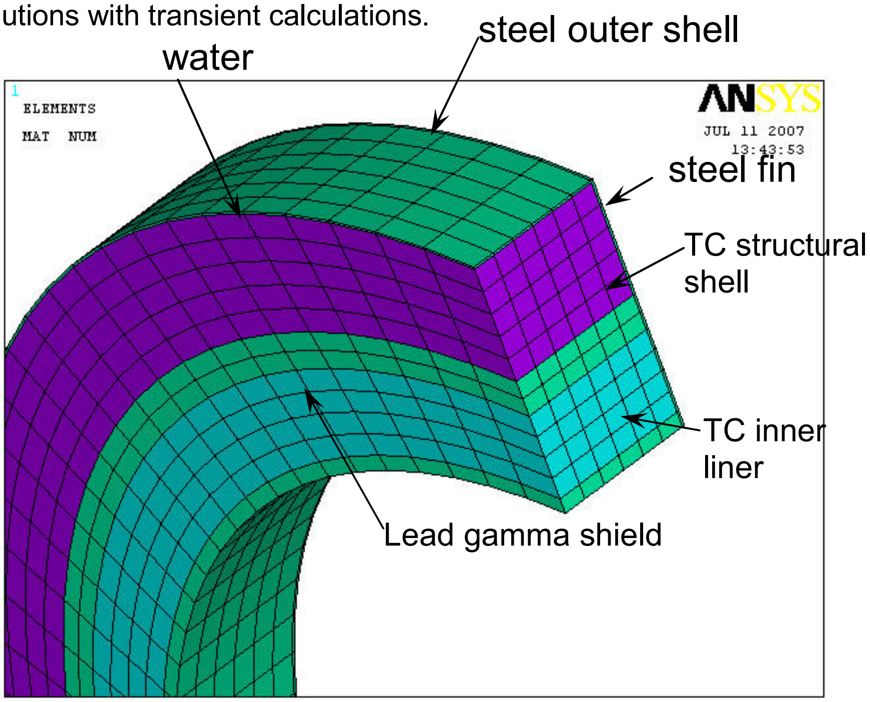

Figure 4.13 Diagram of CFD Model of OS200 Neutron Shield Segment

Calculations with StarCD and StarCCM+ eventually produced steady-state results with the coupled solver in StarCCM+ that were consistent with transient results obtained with the segregated solver in StarCD (and further verified with transient calculations using the segregated solver in StarCCM+). Representative examples of results are presented in Figure

4.14, showing the radial variation of effective Nusselt number around the annulus, from 0º at the top to 180º at the bottom. The effective Nusselt number is determined at a given radial position from the temperatures calculated at that location for the inner and outer surface of the annulus and the local heat flux at the outer boundary. The Nusselt number determined from the CFD solution is compared to the Nusselt number calculated for the average fluid temperature at a given radial position, using the k-effective model for the neutron shield presented in the SAR. This plot shows that the SAR k-effective model significantly simplifies the heat transfer behavior in the neutron shield annulus. It does not capture the effect of the sharp decrease in heat transfer rate in the bottom 40º to 60º of the annulus, specifying only a uniform value over the full circumference of the neutron shield.

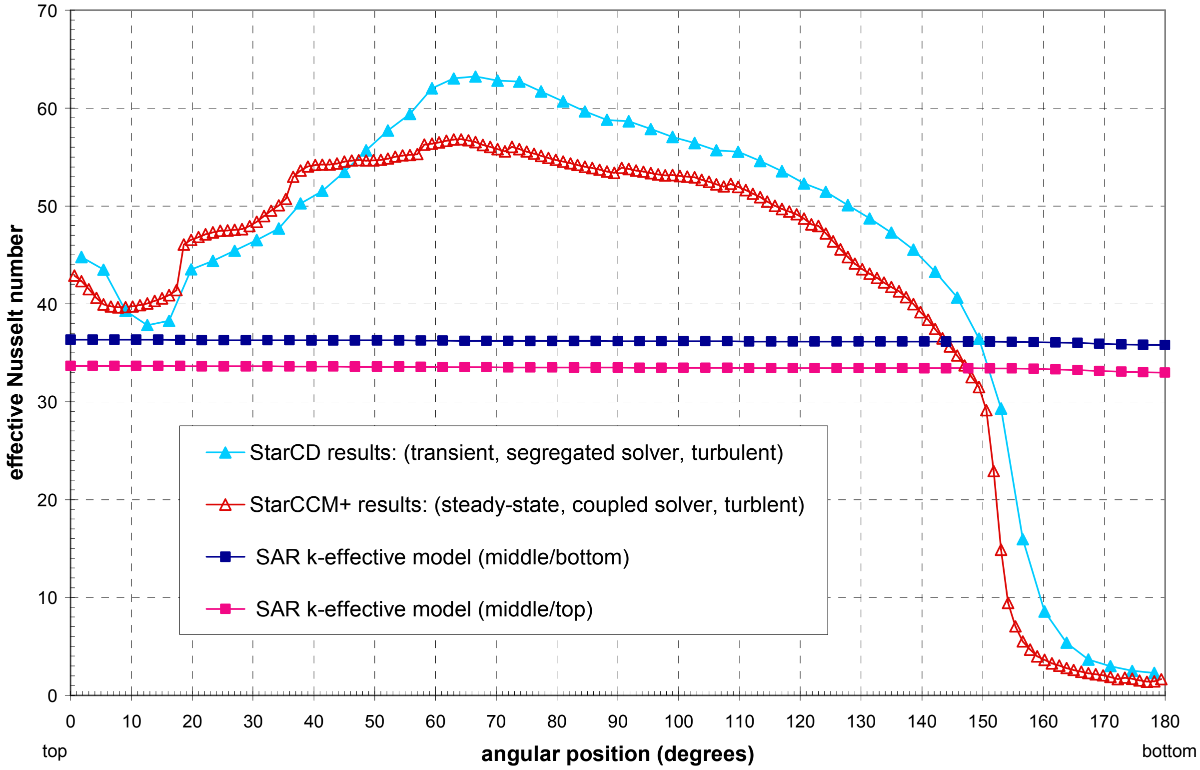

Figure 4.14. Representative Results of CFD Modeling of OS200 Neutron Shield Segment Compared to SAR k-effective Model of Neutron Shield

The Nusselt number values should not be taken as a definitive description of the heat transfer behavior in the OS200 neutron shield. However, these results can be taken as a reasonably realistic picture of the distribution of the heat transfer rate around the circumference of the neutron shield annulus. This provides a basis for evaluating the k-effective model for the neutron shield, as presented in the SAR.

The CFD results show that although the k-effective model for the neutron shield may be conservative over most of the circumference of the horizontal annulus, it is clearly not conservative over the bottom portion of the tank, spanning a region of approximately 60º, centered on the vertical axis through the horizontal tank. This constitutes approximately one-sixth of the circumference of the tank, and as such, could significantly erode the conservatism for the neutron shield k-effective model.

To evaluate the effect of a radially non-uniform Nusselt number on the peak temperatures obtained in the DSC, additional confirmatory calculations were performed with a detailed COBRA-SFS model of the DSC within the transfer cask. This model included the representation of the DSC that was used in the evaluations described above for confirmatory calculations in the storage module, but in addition included detailed representation of the transfer cask, including the non-uniform air gap between the DSC outer shell and the TC inner liner. The neutron shield tank was modeled in a manner similar to that used in the detailed SAR model, with an effective thermal conductivity defined for the neutron shield. Calculations were performed with uniform and radially varying effective thermal conductivity values, as illustrated in Figure 4.15. These calculations were performed for the limiting configuration[5] without forced air cooling, which is the DSC with Type 1 basket, HLZC #2, 31.2 kW.

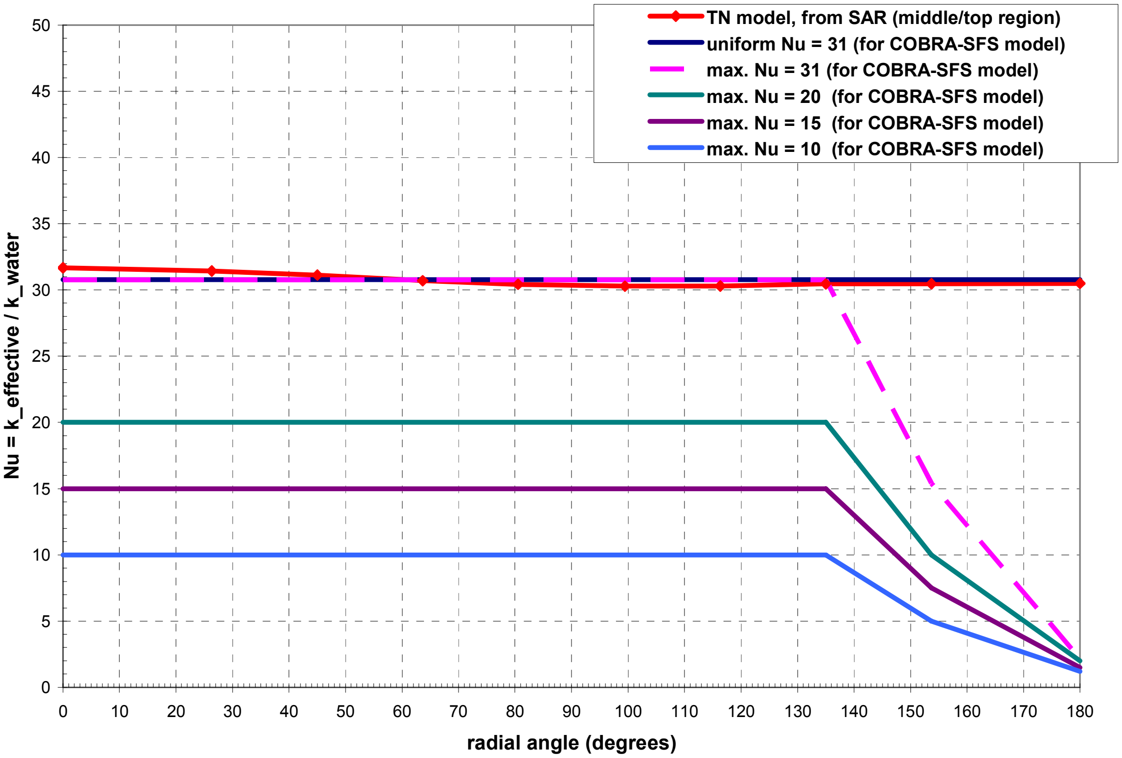

Figure 4.15. Variation of Assumed Neutron Shield Effective Nusselt Number for OS200 TC

The results of these calculations are shown in Table 4.24, compared to the corresponding limiting condition results from the SAR, and the Regulatory limit on peak cladding temperature for transfer conditions. For a Nusselt number corresponding to the SAR model (i.e., uniform Nu = 31), the COBRA-SFS results predict a peak clad temperature of 733°F. This is consistent with the bounding value of < 737°F reported in the SAR. For the case where this nominal Nu = 31 is assumed to decrease to a value of Nu = 2 in the bottom region of the neutron shield annulus, the COBRA-SFS calculation predicts a slightly higher peak clad temperature of 738°F. Further

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[5] The DSC with Type 1 basket, HLZC #1, 40.8 kW in the OS200 TC, although technically the most limiting, requires forced air cooling if transfer operations are not completed within the specific time limit for this configuration, and therefore must be analyzed as a transient. For configurations with unlimited transfer time, the peak internal temperatures for the DSC are conservatively calculated for steady-state conditions.

reductions in the nominal value of the Nusselt number (and including a decrease to nearly pure conduction at the bottom of the annulus) results in correspondingly higher peak cladding temperature predictions. However, these values remain above the regulatory limit. Even with the very conservative value of Nu = 10, the peak clad temperature is predicted to remain below the Regulatory limit, although by a very small margin.

Table 4.24. Peak Fuel Cladding Temperatures for Off-normal Conditions of Transport in OS200 TC-Range of Assumed Nusselt Numbers for Neutron Shield Annulus

Nusselt Number		COBRA-SFS DSC in TC model	ANSYS DSC model[1,2]	Delta T (COBRA vs. Regulatory limit of 752°F)
Top and sides	bottom	(°F)		
31 (uniform)		733	< 737	19 ºF
31	2	738		14 ºF
20	2	741		11 ºF
15	1.5	744		8 ºF
10 (uniform)		749		3 ºF
10	1.2	750		2 ºF

[1] Type 1, HLZC #2, 31.2 kW ; boundary temperatures from SINDA/FLUINT model DSC outer shell surface

[2] Specific results are not included in the SAR for horizontal off-normal transfer. Vertical off-normal conditions at 140°F are assumed bounding on all other normal and off-normal transfer conditions for this configuration.

Although the conservatism of the SAR model for the effective conductivity of the neutron shield cannot be directly confirmed or quantified, the confirmatory calculations show that the model is sufficiently conservative for this application. Assuming k-effective models that are two to three times more conservative and the SAR model yields peak clad temperatures that are below the Regulatory limit of 752ºF. An extremely conservative estimate of Nu = 10 (with or without including the significant decrease in heat transfer rate at the bottom of the annulus) is required for the predicted peak cladding temperature to approach the Regulatory limit.

For configurations designated for transfer only in the OS200FC transfer cask, corresponding to the 32PTH1 with Type 1 basket, HLZC #1, and decay heat load greater than 31.2 kW (up to 40.8 kW) and the 32PTH1 with Type 2 basket, HLZC #2, and decay heat load greater than 24 kW (up to 31.2 kW), the staff has reasonable assurance that the peak temperatures in the system will not exceed regulatory limits before the end of the time limit for transfer without active cooling, and that cooling with forced air will maintain the system below all applicable temperature limits.

4.6.4 Conclusion

The staff has determined that the designs of the 61 BTH and 32PTH1 DSCs are acceptable and meet all the thermal requirements in 10 CFR Part 72.

Future reviews of amendments to the NUHOMS® system design may be significantly expedited if the applicant submits the following information:

(1) Experimental results that provide insight into the behavior of a liquid in a horizontal annulus (such as in the OS197 TC), and validation of the analysis methodology chosen by the applicant, for the temperature ranges and geometries directly applicable to the transfer cask neutron shield designs used for transfer of the various DSC designs.

(2) Experimental results that provide insight into the behavior of a liquid in a cylindrical annulus, and validation of the analysis methodology chosen by the applicant, for the temperature ranges and geometries directly applicable to the transfer cask neutron shield designs used for transfer of the various DSC designs.

(3) A fully coupled CFD analysis of the NUHOMS® system DSC within the HSM/HSM-H, including fuel assemblies (or an effective representative of the same) which will provide a direct solution to temperatures and flows within the system.

4.7 Evaluation Findings

F4.1 The staff finds that the thermal SSCs important to safety are described in sufficient detail in Sections T.1, T.4, U.1 and U.4 of the SAR to enable an evaluation of their effectiveness. Based on the applicant's analyses, there is reasonable assurance that the system is designed with a heat removal capability consistent with its importance to safety. The staff also finds that there is reasonable assurance that analyses of the systems demonstrate that the applicable design and acceptance criteria have been satisfied for the storage of the authorized fuel assemblies.

F4.2 The staff has reasonable assurance that the temperatures of the cask SSCs important to safety will remain within the predicted operating temperature ranges and that cask pressures under normal and accident conditions were determined correctly.

F4.3 The staff has reasonable assurance that the system provides adequate heat removal capacity without active cooling systems for the 61BTH.

F4.4 The staff has reasonable assurance that the HSM-H storage system provides adequate heat removal capacity without active cooling systems for all permitted loading configurations of the 32PTH1 DSC with Type 1 and Type 2 baskets.

F4.5 The staff has reasonable assurance that the OS200/OS200FC transfer cask system provides adequate heat removal capacity without active cooling systems for configurations that are designated for transfer in the OS200/OS200FC transfer cask.

F4.6 The staff has reasonable assurance that the spent fuel cladding will be protected against degradation that leads to gross ruptures by maintaining the clad temperature below maximum allowable limits and by providing an inert environment in the cask cavity.

F4.5 The staff finds that the thermal design of the system is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied; however, the UFSAR that incorporates this amendment should be updated with information discussed in Sections 4.5.3.1.1 and 4.6.1.1.1 of this SER. The evaluation of the thermal design provides reasonable assurance that the system will allow safe storage of spent fuel for a certified life of 20 years. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

4.8 References

1. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.
2. Transnuclear, Final Safety Analysis Report of the Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel, January 2006, Revision 9.
3. U.S. Code of Federal Regulations, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste,” Title 10, Part 72.
4. Interim Staff Guidance -11 (ISG-11), "Cladding Considerations for the Transportation and Storage of Spent Fuel,” Revision 3, November 2003.
5. Transnuclear, Inc., NUHOMS® HD Horizontal Modular Storage System For Irradiated Nuclear Fuel, NRC Docket No. 72-1030
6. U.S. Code of Federal Regulations, “Packaging and Transportation of Radioactive Material,” Title 10, Part 71.
7. U.S. Nuclear Regulatory Commission, Standard Review Plan for Dry Cask Storage Systems, NUREG-1536, January 1997.

5 SHIELDING EVALUATION

The staff reviewed changes to the shielding analysis for the NUHOMS® 32PT and 24PTH DSCs to determine if these components continue to provide adequate protection against direct radiation from the canister contents when used with the Standardized NUHOMS® System. The staff also reviewed the capability of the NUHOMS® 61BTH and 32PTH1 DSCs to provide adequate protection against direct radiation from the canister contents when used with the Standardized NUHOMS® System. The regulatory requirements for providing adequate radiation protection to licensee personnel and members of the public include 10 CFR Part 20 (Ref. 1), 10 CFR 72.104(a) (Ref. 2), 10 CFR 72.106(b), 10 CFR 72.212(b), and 10 CFR 72.236(d). Because 10 CFR Part 72 dose requirements for members of the public include direct radiation, effluent releases, and radiation from other uranium fuel-cycle operations, an overall assessment of compliance with these regulatory limits is evaluated in Section 10 of this SER. This amendment was also reviewed to determine whether the NUHOMS® 32PT, 24PTH, 61BTH, and 32PTH1 DSCs fulfill the acceptance criteria listed in Section 5 of NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems.” (Ref. 3)

5.1 Shielding Design Features and Design Criteria

The applicant requested changes to the allowable contents for the NUHOMS® 32PT and 24PTH DSCs. These changes do not result in any revisions to the shielding design features and design criteria, as the new contents are bounded by the previously approved contents with respect to source terms and resulting external dose rates.

The applicant also requested the addition of two new storage canisters, the NUHOMS® 61BTH and 32PTH1 DSCs, for use with the Standardized NUHOMS® Horizontal Modular Storage System, which includes the HSM and the TC. There were no changes to the HSM, which is described in the Standardized NUHOMS® System FSAR. There are two new TC designs, one for the NUHOMS® 61BTH DSC and another for the NUHOMS® 32PTH1 DSC, which are evaluated in the applicant’s shielding analysis.

The NUHOMS® 61BTH DSC will be used to store up to 61 BWR fuel assemblies in one of eight configurations involving two DSC types. These configurations are described in Figures T.2-1, through T.2-8 of the SAR Appendix T. Table T.2-2 of SAR Appendix T lists the BWR fuel assembly design characteristics for the NUHOMS® 61BTH DSC. The maximum heat load for Type 1 DSC is 22.0 kW, while the maximum for a Type 2 DSC is 31.2 kW.

The NUHOMS® 32PTH1 DSC will be used to store up to 32 PWR fuel assemblies in one of three configurations, involving three DSC types, each with two available basket rail configurations. These configurations are described in Figures U.2-1, U.2-2, and U.2-3 of the SAR Appendix U. Table U.2-3 of SAR Appendix U lists the PWR fuel assembly design characteristics for the NUHOMS® 32PTH1 DSC. The maximum heat loads for Heat Load Zoning Configurations 1, 2, and 3 are 40.8 kW, 31.2 kW, and 24.0 kW, respectively.

5.1.1 Shielding Design Features

5.1.1.1 NUHOMS® 61BTH DSC

The NUHOMS® 61BTH DSC, when used with the Standardized NUHOMS® System provides both gamma and neutron shielding during loading/unloading, transfer, and storage operations. The NUHOMS® 61BTH DSC consists of eight design configurations as described in Section T.2.1 of the SAR. There are two different canister types, which differ primarily in the material used for construction of the structural rails on the periphery of the canister internals. The Type 1 canister has steel rails, while the Type 2 canister has aluminum rails, which results in improved heat transfer properties and allows for higher heat loads and radiation source terms.

The 61BTH DSC consists of a 0.5-inch thick steel canister, with a total of 7.42 inches of steel in the bottom of the canister and 8.92 inches of steel in the top shield plug assembly. The 61BTH DSC may be transferred in the previously evaluated OS197/OS197H TC, as described in the Standardized NUHOMS® System FSAR, or in the OS197FC-B, which has a modified lid and bottom plate to accommodate additional air flow. The Type 2 61BTH DSC must be transferred in the OS197FC-B for heat loads exceeding 22.0 kW. The 61BTH DSC may be stored in either the HSM or the HSM-H. Each is constructed of thick concrete walls and a shielded access door. The HSM and HSM-H air inlet paths are designed to preclude radiation streaming. The Type 2 61BTH DSC must be stored in the HSM-H for heat loads exceeding 22.0 kW, as it is designed for increased heat transfer.

The staff evaluated the NUHOMS® 61BTH DSC shielding design features and found them acceptable. The applicant’s analysis provides reasonable assurance that the shielding design of the NUHOMS® 61BTH DSC, when used with the Standardized NUHOMS® System, meets the regulatory requirements of 10 CFR Part 20, 10 CFR 72.104(a), and 10 CFR 72.106(b).

5.1.1.2 NUHOMS® 32PTH1 DSC

The NUHOMS® 32PTH1 DSC, when used with the Standardized NUHOMS® System provides both gamma and neutron shielding during loading/unloading, transfer, and storage operations. The NUHOMS® 32PTH1 DSC consists of three design configurations as described in Section U.2.1 of the SAR. There are three different canister lengths, the 32PTH1-S, 32PTH1-M, and 32PTH1-L, each of which can have alternative material used for construction of the structural rails on the periphery of the canister internals. The Type 1 canister has aluminum rails, which results in improved heat transfer properties and allows for higher heat loads and radiation source terms, while the Type 2 canister has steel rails.

The 32PTH1 DSC consists of a 0.5-inch thick steel canister. The 32PTH1-S and 32PTH1-M DSCs have a total of 8.75 inches of steel in the bottom of the canister and 12 inches of steel in the top shield plug assembly. The 32PTH1-L DSC has a total of 6.5 inches of steel in the bottom of the canister and 10 inches of steel in the top shield plug assembly. The 32PTH1 DSC may be transferred in the OS200 TC, which is similar to the OS197FC TC described in the Standardized NUHOMS® System FSAR. The 32PTH1 DSC must be stored in the HSM-H storage module.

The staff evaluated the NUHOMS® 32PTH1 DSC shielding design features and found them acceptable. The applicant's analysis provides reasonable assurance that the shielding design of the NUHOMS® 32PTH1 DSC, when used with the Standardized NUHOMS® System, meets the regulatory requirements of 10 CFR Part 20, 10 CFR 72.104(a), and 10 CFR 72.106(b).

5.1.2 Shielding Design Criteria

The overall radiological protection design criteria are the regulatory dose requirements in 10 CFR Part 20, 10 CFR 72.104(a), 10 CFR 72.106(b), and maintaining occupational exposures as-low-as-reasonably-achievable (ALARA). The applicant analyzed the NUHOMS® 61BTH DSC loaded with spent fuel as described in Section T.2.1 of the SAR, and the NUHOMS® 32PTH1 DSC loaded with spent fuel as described in Section U.2.1 of the SAR.

The SAR analysis provides reasonable assurance that the NUHOMS® 61BTH and 32PTH1 DSCs can meet the regulatory requirements in 10 CFR Part 20, 10 CFR 72.104(a), and 10 CFR 72.106(b). Dose rates must meet the limits incorporated into the technical specifications for both the HSM and the TC.

5.2 Source Specification

5.2.1 NUHOMS® 32PT DSC

The applicant revised the allowable contents to allow the following control components (CCs): Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies (TPAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. The source terms for these additional CCs will be bounded by the source term energy distribution for the previously approved Burnable Poison Rod Assemblies (BPRAs), which is given in Table M.5-12 of the SAR, and by the maximum gamma source per assembly in Table 1-1ee of the TS.

5.2.2 NUHOMS® 61BTH DSC

The source specification for the NUHOMS® 61BTH DSC is presented in Section T.5.2 of SAR Appendix T. The gamma and neutron source term calculations were performed with the SAS2H/ORIGEN-S modules of the SCALE 4.4 computer code. The fuel types considered in this application are listed in Table T.2-2. The GE-2,3 7x7 Type G2A assembly type was chosen as the design basis fuel assembly because it has the highest initial heavy metal loading (0.198 MTU).

The applicant generated fuel qualification tables for the individual heat loads specified for Zone 1 through 6, with fuel from Heat Load Zoning Configurations 1 through 8, depicted in Figures T.2-1 through T.2-8. The applicant used SAS2H/ORIGEN-S to verify that each fuel combination listed in Tables T.2-5 through T.2-10, resulted in decay source terms below the individual assembly heat limits.

The applicant used ANISN, a 1-D discrete ordinates code, to examine the relative source strength of each fuel combination, based on the resulting ANISN dose. The applicant subsequently determined the design-basis source term for bounding shielding calculations of the HSM and TC. The applicant stated this method is consistent with the method used to calculate fuel qualification tables for the Standardized NUHOMS® 24PTH as described in Chapter P.5 of Appendix P of the FSAR. As discussed in Section T.5.2.4 of the SAR amendment, the applicant calculated dose rates on the surface of the HSM and TC for the eight Heat Load Zoning Configurations with ANISN. A sketch of the ANISN model for the TC is depicted in Figure T.5-2. The material densities used for the various modeling regions are listed in Table T.5-20. The ANISN model used the CASK-81 22 neutron, 18 gamma cross section library and ANSI/ANS-6.1.1-1977 flux-to-dose conversion factors. An example ANISN input file is included in Section T.5.5.5.

Based on the ANISN calculated doses determined for fuel of various burnup/enrichment/cool time combinations in the OS197FC TC, an example of which is given in Table T.5-29 of the SAR, the applicant determined the configuration that resulted in bounding dose rates for the TC. Canister total source terms were then calculated for the design basis assembly for the design basis burnup/enrichment/cooling time combinations and the loading configuration described in Figure T.2-2. The design-basis burnup/enrichment/cooling time combinations, including model locations, are listed on pages T.5-3 and T.5-4 of Appendix T of the SAR. The bounding gamma and neutron source terms were then combined in the shielding models to calculate the dose rates.

5.2.2.1 Gamma

Gamma source terms are calculated for each burnup/enrichment combination and are listed in the SAR. The hardware activation analysis considered the cobalt impurities in the assembly hardware. The activated hardware source terms are calculated using the hardware masses listed in the SAR. Although cobalt impurities can vary, the applicant's assumed values are reasonable and acceptable.

5.2.2.2 Neutron

Neutron source terms are calculated for each burnup/enrichment combination and are listed in the SAR. The applicant calculated the neutron source terms for use in the shielding models by multiplying the individual assembly sources by the number of assemblies in the region and then dividing by the appropriate region volume.

5.2.2.3 Confirmatory Analyses

The staff performed confirmatory source term evaluations using the SCALE 5.1 computer code with the SAS2H/ORIGEN-S isotopic depletion and decay sequence with the 44-GROUP ENDF/B-V cross section library. Using irradiation parameter assumptions similar to the applicant's, the staff obtained bounding source terms that were similar to, or bounded by, those determined by the applicant.

5.2.3 NUHOMS® 32PTH1 DSC

The source specification for the NUHOMS® 32PTH1 DSC is presented in Section U.5.2 of SAR Appendix U. The gamma and neutron source term calculations were performed with the SAS2H/ORIGEN-S modules of the SCALE 4.4 computer code. The fuel types considered in this application are listed in Table U.2-3. The B&W 15x15 assembly type was chosen as the design basis fuel assembly because it has the highest initial heavy metal loading (0.490 MTU).

The applicant generated fuel qualification tables for the individual heat loads specified for Configurations 1, 2, and 3 depicted in Figures U.2-1 through U.2-3. The applicant used SAS2H/ORIGEN-S to verify that each fuel combination listed in the SAR, including CCs, resulted in decay source terms below the individual assembly heat limits.

The applicant used ANISN, a 1-D discrete ordnance code, to examine the relative source strength of each fuel combination, based on the resulting ANISN dose. The applicant subsequently determined the design-basis source term for bounding shielding calculations of the HSM and TC. An example ANISN input file is included in Appendix U.5.5.4 of the SAR.

Based on the ANISN calculated doses, the applicant determined the configuration that resulted in bounding dose rates for both the HSM and TC. Canister total source terms were then calculated for the design basis assembly for the design basis burnup /enrichment/cooling time combinations and the loading configuration described in Figure U.5-3. The design-basis burnup/enrichment/cooling time combinations, including model locations, are listed on page U.5-2 of Appendix U of the SAR. The bounding gamma and neutron source terms were then combined in the shielding models to calculate the dose rates.

5.2.3.1 Gamma

Gamma source terms are calculated for each burnup /enrichment combination and are listed in the SAR. The hardware activation analysis considered the cobalt impurities in the assembly hardware, including the in the bounding CCs. The activated hardware source terms are calculated using the hardware masses listed in the SAR. Although cobalt impurities can vary, the applicant's assumed values are reasonable and acceptable.

5.2.3.2 Neutron

Neutron source terms are calculated for each burnup/enrichment combination and are listed in the SAR. The applicant calculated the neutron source terms for use in the shielding models by multiplying the individual assembly sources by the number of assemblies in the region and then dividing by the appropriate region volume.

5.2.3.3 Confirmatory Analyses

The staff performed confirmatory source term evaluations using the SCALE 5.1 computer code with the SAS2H/ORIGEN-S isotopic depletion and decay sequence with the 44-GROUP ENDF/B-V cross section library. Using irradiation parameter assumptions similar to the applicant's, the staff obtained bounding source terms that were similar to, or bounded by, those determined by the applicant. The exterior dose rates are adequately controlled by limits in the CoC for cooling time, and enrichment.

5.3 Shielding Model Specifications

5.3.1 NUHOMS® 61BTH DSC

For all bounding external dose rate calculations, the Monte Carlo n-particle transport code (MCNP) computer code was used. The off-site dose models include various storage module arrays loaded with design basis fuel.

5.3.1.1 Shielding and Source Configuration

The radiation source is modeled as an explicit basket with smeared fuel compositions within the basket cells. Conservative material compositions and axial peaking factors are applied. A number of other simplifications and bounding assumptions, that reduce the amount of actual shielding, are discussed in the SAR. The analysis includes streaming paths through the HSM air vents and the TC-DSC gap.

5.3.1.2 Material Properties

The composition and densities of the materials used in the shielding analysis are presented in Tables T.5-19 and T.5-20 of the SAR. Various conservative material representations are used in the shielding model for the HSM and TC. The materials used in the HSM and TC were previously reviewed and found accepted by the staff.

The staff evaluated the shielding models and found them acceptable. The material compositions and densities used were appropriate and provide reasonable assurance that the DSC, TC, and HSM were adequately modeled. In addition, the methodologies used are similar to those previously used to support NUHOMS® storage and transportation applications, and have been accepted by the staff in the past.

5.3.2 NUHOMS® 32PTH1 DSC

For all external dose rate calculations, the Monte Carlo n-particle transport code (MCNP) computer code was used. The off-site dose models include various storage module arrays loaded with design basis fuel.

5.3.2.1 Shielding and Source Configuration

The radiation source is modeled as an explicit basket with smeared fuel compositions within the basket cells. Conservative material compositions and axial peaking factors are applied. A number of other simplifications and bounding assumptions, that reduce the amount of actual shielding, are discussed in the SAR. The analysis includes streaming paths through the HSM air vents and the TC-DSC gap.

5.3.2.2 Material Properties

The composition and densities of the materials used in the shielding analysis are presented in Tables U.5-12 and U.5-13 of the SAR. Various conservative material representations are used in the shielding model for the HSM and TC. The materials used in the HSM and TC were previously reviewed and found accepted by the staff.

The staff evaluated the shielding models and found them acceptable. The material compositions and densities used were appropriate and provide reasonable assurance that the DSC was adequately modeled. In addition, the methodologies used are similar to those previously used to support NUHOMS® storage and transportation applications, and have been accepted by the staff in the past.

5.4 Shielding Analyses

5.4.1 NUHOMS® 61BTH DSC

5.4.1.1 Computer Programs

The applicant used the one-dimensional discrete ordinates code ANISN in order to determine the bounding source term with respect to external dose rates. The staff notes that use of the ANISN 1-D model to represent the 3-D NUHOMS® 61BTH DSC shielding system results in uncertainties. However, the use of ANISN in the shielding analysis is essentially limited to evaluating the relative changes in dose rates versus relative changes in source terms for the various combinations of burnup, cooling time, and enrichment. The staff finds the use of ANISN acceptable for this specific design and contents for the following reasons: (1) higher energy gamma source terms dominate public dose rates and any ANISN related uncertainties should be relatively systematic for each fuel combination; (2) the use of ANISN has been previously approved for the 24P, 52B, and 32PT canisters; (3) the staff has incorporated specific dose rate limits in Technical Specifications for the HSM and TC based on bounding dose rates; and (4) the general licensee will operate the NUHOMS® 61BTH DSC storage system with an established radiation protection program as required by 10 CFR Part 20, Subpart B.

The applicant used MCNP for all bounding external dose rate calculations. The MCNP three dimensional Monte Carlo neutral particle transport code is a standard in the nuclear industry for performing neutron and photon shielding analyses. The staff agrees that the code and cross-section data used by the applicant are appropriate for this particular application and fuel system.

The staff performed confirmatory source term evaluations using the SCALE 5.1 computer code with the SAS2H/ORIGEN-S isotopic depletion and decay sequence with the 44-GROUP ENDF/B-V cross section library.

5.4.1.2 Flux-to-Dose-Rate Conversion

The SAR uses the ANSI/ANS Standard 6.1.1-1977 flux-to-dose rate conversion factors to calculate dose rates, which are acceptable.

5.4.1.3 Normal Conditions

Appendix T of the SAR presents calculated dose rates for normal condition design-basis dose rates for the HSM and TC. The dose rates for the HSM are dominated by the gamma component. This is expected due to the thick concrete walls of the HSM. Due to the conservatism in the analysis, the staff has reasonable assurance that dose rates will be below the dose rate criteria specified in the TS.

For the transfer cask, there is a significant contribution from neutron radiation to the dose rates, in addition to the more dominant gamma component. Two dose rate calculations were performed for the TC during fuel loading operations, one each for decontamination and welding, as discussed in Section T.5.4.9 of the SAR. Table T.5-5 gives the surface peak dose rate at the top of the DSC as approximately 2190 mrem/hr during welding operations. Exposure from localized peak dose rate may be mitigated by the actual locations of personnel and the use of temporary shielding during loading/unloading operations.

The dose profiles for the TC at various distances show that the dose rates significantly decrease from peak locations to the edges of the top, bottom, and sides of the cask. The calculated average dose rates are below the dose rate criteria specified in the TS, thus the staff has reasonable assurance that the user will be able to meet the TS limits for the transfer cask dose rates.

5.4.1.4 Accident Conditions

Appendix T of the SAR does not identify an accident that significantly degrades the shielding of the HSM. The bounding accident condition for the TC considers loss of the neutron shield and steel neutron shield jacket from the TC. This accident causes a significant increase in the external dose rates. Table T.11-2 of the SAR shows that the maximum dose rate for this accident is approximately 1.5 E4 mrem/hr at 1 meter from the cask surface. For an 8 hour recovery time, the estimated dose rate to a member of the public at 500 meters is less than 1 mrem, which meets the regulatory requirements.

5.4.1.5 Occupational Exposures

The analysis in Appendix T of the SAR used the design basis fuel to estimate occupational exposures for the NUHOMS$^{®}$ system. Section T.10 of the SAR presents the estimated occupational exposures that are based on dose rate calculations in Section 5 of Appendix T to the SAR. The staff's evaluation of the occupational exposures is in Section 10 of this SER.

5.4.1.6 Off-site Dose Calculations

Section T.10 of the SAR estimates the offsite dose rates from various cask arrays. Section T.10 presents the calculated offsite annual doses for these arrays at distances of 6 to 600 meters based on 100% occupancy exposure time. These generic off-site calculations demonstrate that the NUHOMS® system is capable of meeting the offsite dose criteria of 10 CFR 72.104(a).

Section 10 of this SER evaluates the overall off-site dose rates from the NUHOMS® system. The staff has reasonable assurance that compliance with 10 CFR 72.104(a) can be achieved by general licensees. The general licensee must perform a site-specific evaluation, as required by 10 CFR 72.212(b), to demonstrate compliance. The actual doses to individuals beyond the controlled area boundary depend on several site specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and atmospheric conditions. In addition, 10 CFR 72.104(a) includes doses from other fuel cycle activities such as reactor operations. Consequently, final determination of compliance with 10 CFR 72.104(a) is the responsibility of the general licensee.

A general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public as required by evaluation and measurements. An engineered feature for radiological protection, such as a berm, is considered important to safety and must be evaluated to determine the applicable quality assurance category.

5.4.1.7 Confirmatory Calculations

The staff performed confirmatory analyses of selected dose rates using the MAVRIC sequence of the SCALE 5.1 code system, with the Monaco three dimensional Monte Carlo shielding analysis code. The staff based its evaluation on the design features and model specifications presented in the drawings shown in SAR Appendix T. Limiting fuel characteristics, and the burnup and cooling time, are included in the TS, as are the dose rates of the TC and HSM. The staff's calculated dose rates were in reasonable agreement with the SAR values or were generally lower due to the applicant's conservative loading assumptions. The staff found that the SAR has adequately demonstrated that the NUHOMS® 61BTH DSC is designed to meet the criteria of 10 CFR 72.104(a) and 72.106.

5.4.2 NUHOMS® 32PTH1 DSC

5.4.2.1 Computer Programs

The applicant used the one-dimensional discrete ordinates code ANISN in order to determine the bounding source term with respect to external dose rates. The staff notes that use of the ANISN 1-D model to represent the 3-D NUHOMS® 32PTH1 DSC shielding system results in uncertainties. However, the use of ANISN in the shielding analysis is essentially limited to evaluating the relative changes in dose rates versus relative changes in source terms for the alternate combinations of burnup, cooling time, and enrichment. The staff finds the use of ANISN acceptable for this specific design and contents for the following reasons: (1) higher energy gamma source terms dominate public dose rates and any ANISN related uncertainties should be relatively systematic for each fuel combination; (2) the use of ANISN has been previously approved for the 24P, 52B, and 32PT canisters; (3) the staff has incorporated specific dose rate limits in Technical Specifications for the HSM and TC based on bounding dose rates; and (4) the general licensee will operate the NUHOMS® 32PTH1 DSC storage system with an established radiation protection program as required by 10 CFR Part 20, Subpart B.

The applicant used MCNP for all bounding external dose rate calculations. The MCNP three dimensional Monte Carlo neutral particle transport code is a standard in the nuclear industry for performing neutron and photon shielding analyses. The staff agrees that the code and cross-section data used by the applicant are appropriate for this particular application and fuel system.

The staff performed confirmatory source term evaluations using the SCALE 5.1 computer code with the SAS2H/ORIGEN-S isotopic depletion and decay sequence with the 44-GROUP ENDF/B-V cross section library.

5.4.2.2 Flux-to-Dose-Rate Conversion

The SAR uses the ANSI/ANS Standard 6.1.1-1977 flux-to-dose rate conversion factors to calculate dose rates, which are acceptable.

5.4.2.3 Normal Conditions

Appendix U of the SAR presents calculated dose rates for normal condition design-basis dose rates for the HSM and TC. The dose rates for the HSM are dominated by the gamma component. This is expected due to the thick concrete walls of the HSM. Due to the conservatism in the analysis, the staff has reasonable assurance that dose rates will be below the dose rate criteria specified in the TS.

For the transfer cask, there is a significant contribution from neutron radiation to the dose rates, in addition to the more dominant gamma component. Two dose rate calculations were performed for the TC during fuel loading operations, one each for decontamination and welding, as discussed in Section U.5.4.9 of the SAR. Table U.5-3 gives the surface peak dose rate at the top of the DSC as approximately 833 mrem/hr during decontamination operations. Exposure from localized peak dose rate may be mitigated by the actual locations of personnel and use of temporary shielding during loading/unloading operations.

The dose profiles for the TC at various distances show that the dose rates significantly decrease from peak locations to the edges of the top, bottom, and sides of the cask. The calculated average dose rates are below the dose rate criteria specified in the TS, thus the staff has reasonable assurance that the user will be able to meet the TS limits for the transfer cask dose rates.

5.4.2.4 Accident Conditions

Appendix U of the SAR does not identify an accident that significantly degrades the shielding of the HSM. The bounding accident condition for the TC considers loss of the neutron shield and steel neutron shield jacket from the TC. This accident causes a significant increase in the external dose rates. Table U.5-2 of the SAR shows that the maximum dose rate for this accident is approximately 3760 mrem/hr at 1 meter from the cask surface. For an 8 hour recovery time, the estimated dose rate to a member of the public at 500 meters is less than 1 mrem, which meets the regulatory requirements.

5.4.2.5 Occupational Exposures

The analysis in Appendix U of the SAR used the design basis fuel to estimate occupational exposures for the NUHOMS® system. Section U.10 of the SAR presents the estimated occupational exposures that are based on dose rate calculations in Section 5 of Appendix U to the SAR. The staff's evaluation of the occupational exposures is in Section 10 of this SER.

5.4.2.6 Off-site Dose Calculations

Section U.10 of the SAR estimates the offsite dose rates from various cask arrays. Section U.10 presents the calculated offsite annual doses for these arrays at distances of 6 to 600 meters based on 100% occupancy exposure time. These generic off-site calculations demonstrate that the NUHOMS® system is capable of meeting the offsite dose criteria of 10 CFR 72.104(a).

Section 10 of this SER evaluates the overall off-site dose rates from the NUHOMS® system. The staff has reasonable assurance that compliance with 10 CFR 72.104(a) can be achieved by general licensees. The general licensee must perform a site-specific evaluation, as required by 10 CFR 72.212(b), to demonstrate compliance. The actual doses to individuals beyond the controlled area boundary depend on several site specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and atmospheric conditions. In addition, 10 CFR 72.104(a) includes doses from other fuel cycle activities such as reactor operations. Consequently, final determination of compliance with 10 CFR 72.104(a) is the responsibility of the general licensee.

A general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public as required by evaluation and measurements. An engineered feature for radiological protection, such as a berm, is considered important to safety and must be evaluated to determine the applicable quality assurance category.

5.4.2.7 Confirmatory Calculations

The staff performed confirmatory analyses of selected dose rates using the MAVRIC sequence of the SCALE 5.1 code system, with the Monaco three dimensional Monte Carlo shielding analysis code. The staff based its evaluation on the design features and model specifications presented in the drawings shown in SAR Appendix U. Limiting fuel characteristics, and the burnup and cooling time, are included in the TS, as are the dose rates of the TC and HSM. The staff's calculated dose rates were in reasonable agreement with the SAR values or were generally lower due to the applicant's conservative loading assumptions. The staff found that the SAR has adequately demonstrated that the NUHOMS® 32PTH1 DSC is designed to meet the criteria of 10 CFR 72.104(a) and 72.106.

5.5 Evaluation Findings

F5.1 Section 5 of the SAR, sufficiently describes shielding SSCs important to safety in sufficient detail to allow evaluation of their effectiveness.

F5.2 Radiation shielding is sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F5.3 The staff concludes that the design of the radiation protection system of the NUHOMS® 32PT, 24PTH, 61BTH, and 32PTH1 DSCs, when used with the appropriate HSM and TC, are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the NUHOMS® 32PT, 24PTH, 61BTH, and 32PTH1 DSCs will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

5.6 References

1. U.S. Code of Federal Regulations, Standards for Protection Against Radiation, Title 10, Part 20.

2. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

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

6 CRITICALITY EVALUATION

The staff reviewed changes to the criticality analysis for the NUHOMS® 32PT and 24PTH DSCs when used with the Standardized NUHOMS® System as well as the capability of the NUHOMS® 61BTH and 32PTH1 DSCs to provide adequate protection against any inadvertent criticality from the canister contents when used with the Standardized NUHOMS® System.

6.1 Criticality Design Criteria and Features

The applicant requested the addition of two new storage canisters, the NUHOMS® 61BTH and 32PTH1 DSCs, for use with the Standardized NUHOMS® Horizontal Modular Storage System, which includes the HSM, HSM-H, and the TC. There is one new HSM design, the HSM-HS, a high seismic option for use with the 32PTH1 DSC. There are two new TC designs, one for the NUHOMS® 61BTH DSC and another for the NUHOMS® 32PTH1 DSC, which are evaluated in the applicant's criticality analysis.

The NUHOMS® 61BTH DSC will be used to store up to 61 BWR fuel assemblies in one of eight configurations involving two DSC types. These configurations are described in Figures T.2-1, through T.2-8 of the SAR Appendix T. Table T.2-2 of the UFSAR (Ref. 1) Appendix T lists the BWR fuel assembly design characteristics for the NUHOMS® 61BTH DSC.

The NUHOMS® 32PTH1 DSC will be used to store up to 32 PWR fuel assemblies in one of three configurations, involving three DSC types, each with two available basket rail configurations. These configurations are described in Figures U.2-1, U.2-2, and U.2-3 of the SAR Appendix U. Table U.2-3 of SAR Appendix U lists the PWR fuel assembly design characteristics for the NUHOMS® 32PTH1 DSC.

The applicant also requested changes to the allowable contents for the NUHOMS® 32PT and 24PTH DSCs. These include the addition of PWR fuel assemblies with various Control Components for all fuel assemblies except the CE 15x15 in the 32PT basket, and the addition of the WE 15x15 Partial Length Shield Assemblies (PLSAs) to the 24PTH DSC. The addition of PLSAs are bounded by the initial analysis of the 24PTH DSC.

6.1.1 Criticality Design Features

6.1.1.1 NUHOMS® 61BTH DSC

The NUHOMS® 61BTH DSCs consist of eight design configurations as described in Section T.2.1 of the SAR. The design of the NUHOMS® 61BTH is similar to the previously approved 61BT DSC, but is slightly modified to accommodate higher heat loads. The typical cask consists of an inner stainless steel shell, a lead gamma shield, a stainless steel structural shell, and a hydrogenous neutron shield. There are two different canister types, which differ primarily in the material used for construction of the structural rails on the periphery of the canister internals. The Type 1 canister has steel rails, while the Type 2 canister has aluminum rails. The NUHOMS® 61BTH DSC is designed with three alternate neutron absorber materials with each material analyzed for six different ^{10}B loadings to accommodate the variability of the allowable fuel enrichment levels. The Type 1 DSC can be stored in either the HSM or HSM-H module described in Appendix P of the UFSAR, while the Type 2 DSC is only allowed to be stored in the HSM-H module.

The staff evaluated the NUHOMS® 61BTH DSC criticality design features and found them to be acceptable. The applicant's analysis provides reasonable assurance that the criticality safety design of the NUHOMS® 61BTH DSC, when used with the Standardized NUHOMS® System, meets the regulatory requirements of 10 CFR Part 72 (Ref. 2).

6.1.1.2 NUHOMS® 32PTH1 DSC

The NUHOMS® 32PTH1 DSC has two different canister types, which differ primarily in the material used for construction of the structural rails on the periphery of the canister internals. The Type 1 canister has steel rails, while the Type 2 canister has aluminum rails. Criticality safety is ensured by the use of fixed neutron absorbers in the basket, soluble boron in the pool, and favorable basket geometry.

There are also five different basket types for each canister that vary the boron content in the basket poison plates, designated A through E, which results in ten different basket configurations, differing in both fixed poison loading and transition rails. In addition to the fixed neutron absorbers, the spent fuel pool is credited in the analysis for having varying levels of boron concentration, from 2000-3000 ppm.

The staff evaluated the NUHOMS® 32PTH1 DSC criticality safety design features and found them to be acceptable. The applicant's analysis provides reasonable assurance that the criticality safety design of the NUHOMS® 32PTH1 DSC, when used with the Standardized NUHOMS® System, meets the regulatory requirements of 10 CFR Part 72.

6.2 Fuel Specification

6.2.1 NUHOMS® 61BTH DSC

The 61BTH DSC is capable of storing BWR fuel assemblies with or without fuel channels and as intact or damaged fuel assemblies as authorized contents and are specified in Table T.6-2. The design basis fuel used in the criticality analysis for the NUHOMS® 61BTH system is the GE 10x10 fuel assembly, which was found the be the most reactive assembly of those authorized to be stored in the NUHOMS® 61BTH DSC system.

6.2.2 NUHOMS® 32PTH1 DSC

The NUHOMS® 32PTH1 DSC is capable of transferring and storing a maximum of 32 intact PWR assemblies, or up to 16 damaged and 16 intact assemblies (for a total of 32 assemblies), with an initial enrichment of up to 5.0 weight percent. Allowable fuel types evaluated include the WE 17x17, CE 16x16, BW 15x15, CE 15x15, WE 15x15, CE 14x14, and WE 14x14 as well as accompanying Control Components. The most reactive intact fuel design evaluated is the B&W 15x15 Mark B-10 assembly.

6.2.3 NUHOMS® 32PT DSC

The applicant revised the allowable contents to allow the following control components (CCs): Control Rod Assemblies (CRAs), Rod Cluster Control Assemblies (RCCAs), Thimble Plug Assemblies (TPAs), Axial Power Shaping Rod Assemblies (APSRAs), Orifice Rod Assemblies (ORAs), Vibration Suppression Inserts (VSIs), Neutron Source Assemblies (NSAs), and Neutron Sources. These additional CCs are bounded by the criticality analysis previously approved for Burnable Poison Rod Assemblies (BPRAs).

6.2.4 NUHOMS® 24PTH DSC

The applicant revised the allowable contents to allow PLSAs for the Westinghouse 15x15 class of fuel assemblies. PLSAs are similar to standard fuel assemblies, however, a portion of the active fuel is replaced by stainless steel rods. This reduces the amount of fuel that would be present in the previously reviewed configuration, and therefore is bounded by the previous safety evaluation.

6.3 Criticality Analysis

6.3.1 NUHOMS® 61BTH DSC

To justify the addition of the new DSC Types 1 & 2, the applicant performed a criticality analysis using the 44-GROUP ENDF/B-V cross section set with the KENO V.a code in the SCALE 4.4 system. The applicant's criticality models for the NUHOMS® 61BTH DSC are similar to those previously approved for the 61BT DSC described in Appendix K of the UFSAR and are modified to account for the differences in the fixed poison and the basket periphery rails and water holes, and to account for the NUHOMS® 61BTH Type 1 and Type 2 DSC designs. Several models were developed to evaluate the criticality safety of the NUHOMS® 61BTH to ascertain the most reactive fuel configuration for both the intact and damaged conditions for both the NCT and credible HAC. These models looked at single and double breaks as well as rod pitch variations.

For the both the normal and damaged fuel configurations of the NUHOMS® 61BTH DSC, the most reactive fuel was evaluated to be the GE 10x10 fuel assemblies. The normal model consists of 92 intact fuel rods, and included both the gap and the cladding, and two large water holes. In addition, the fuel cladding OD is reduced to conservatively bound fuel manufacturing tolerances, and no credit is taken for the cask neutron shield and outer steel skin. The damaged fuel assembly models assumed 45 intact fuel assemblies and 16 damaged fuel assemblies, located in the four 2x2 compartments in the corners of the basket. It was modeled as containing 95 fuel rods and five water pin locations.

The applicant explicitly modeled the fuel assemblies utilizing fresh water in the gap between the pellets and the fuel rod cladding. In addition, the applicant evaluated all combinations of fuel assembly class, basket type, and applicable poison plates. The applicant reduced the total boron content of the modeled poison plates, using 90% credit for the boron in the borated aluminum and the Boron carbide-aluminum metal matrix composite (MMC) poison plates, and 75% credit for the Boral® poison as specified in Section T.9. In all instances the bounding analyses demonstrate that the maximum k_{eff} of the NUHOMS® 61BTH DSC remains below the regulatory limit of 0.95 including all biases and uncertainties for all credible conditions.

The staff performed confirmatory criticality calculations using the SCALE 5 system with the 238-GROUP ENDF/B-V cross section library. The staff's model is similar to the applicant's in that it included fresh water in the fuel rod gap, and used the appropriate boron credit of up to 90% for the fixed neutron poison plates. The staff selected the most reactive cases demonstrated by the applicant's analysis for the NUHOMS® 61BTH DSC for both NCT and HAC. In all instances the staff's maximum calculated k_{eff} was consistent with that of the applicant.

Based on the information provided in the application and the staff's own confirmatory analyses, the staff concludes that the NUHOMS® 61BTH DSC meets the acceptance criteria specified in 10 CFR Part 72.

6.3.2 NUHOMS® 32PTH1 DSC

The 32PTH1 DSC has three alternative length configurations designated as Type 32PTH1-S (short length), -M (medium length), or –L (long length), and has a slightly larger diameter than the previously approved DSC to accommodate an increased loading capacity. The NUHOMS® 32PTH1 has two alternate basket types with either aluminum or steel rails, and has three alternate neutron absorber materials, with each material having up to five different ^{10}B loadings, as described above in 6.1.1.2. The NUHOMS® 32PTH1 also utilizes the soluble boron concentration in the spent fuel pool to maintain subcriticality. The NUHOMS® 32PTH1 is stored in a HSM-H module that has the diameter of the access door increased to accommodate the new diameter, and uses spacers to adjust for the various length configurations. In addition, an alternate high-seismic option designated as HSM-HS is added to the NUHOMS® 32PTH1 DSC configuration. Several models were developed to evaluate the criticality safety of the NUHOMS® 32PTH1 DSC to ascertain the most reactive fuel configuration for both the intact and damaged conditions for both the NCT and credible HAC and take account of the fabrication tolerances, fuel clad OD, fuel assembly locations, fuel assembly type, initial enrichments, fixed poison loading, soluble boron concentration and storage of CCs.

For the both the normal and damaged fuel configurations of the NUHOMS® 32PTH1 DSC, the applicant used an analysis methodology similar to that used for the NUHOMS® 24PTH DSC described in Appendix P of the UFSAR to determine the most reactive assembly type for each assembly class, and then determined the most reactive configuration for the basket and fuel assembly position. Then the maximum allowable initial enrichment was found for each fuel assembly class as a function of basket poison type and soluble boron concentration. Since Control Components (CCs) are allowed to be stored in the NUHOMS® 32PTH1 DSCs (including BPRAs, CRAs, TPAs, APSRAs, CEAs, VSAs, ORAs, and NSAs), the CCs were evaluated as authorized contents and no credit was taken for either the cladding or absorbers that may be present in a given CC, and was instead replaced with $^{11}B_4C$.

For the both the normal and damaged fuel configurations of the NUHOMS® 32PTH1 DSC, the most reactive fuel was evaluated to be the B&W 15x15 Mark B-10 fuel assemblies. The normal model consists of 32 fuel assemblies with a minimum fuel compartment tube ID, minimum fuel compartment tube thickness, a poison thickness of 0.075 inches and minimum assembly-to-assembly pitch. For damaged fuel, the most reactive scenario is when the fuel rods are in near optimum pitch for all assembly classes except for the WE 15x15 assemblies, where the double shear scenario is the most reactive configuration.

The applicant explicitly modeled the fuel assemblies utilizing fresh water in the gap between the pellets and the fuel rod cladding. In addition, the applicant evaluated all combinations of fuel assembly class, basket type, and applicable poison plates, with a variable amount of soluble boron in the water based on the enrichment level. The applicant reduced the total boron content of the modeled poison plates, using 90% credit for the boron in the borated aluminum and the Boron carbide-aluminum metal matrix composite (MMC) poison plates, and 75% credit for the Boral® poison as specified in Section U.9. In all instances the bounding analyses demonstrate that the maximum k_{eff} of the NUHOMS® 32PTH1 DSC remains below the regulatory limit of 0.95 including all biases and uncertainties for all credible conditions.

The staff performed confirmatory criticality calculations using the SCALE 5 system with the 238-GROUP ENDF/B-V cross section library. The staff's model is similar to the applicant's in that it included fresh water in the fuel rod gap and used the appropriate boron credit of up to 90% for the fixed neutron poison plates. The staff selected the most reactive cases demonstrated by the applicant's analysis for the NUHOMS® 32PTH1 DSC for both NCT and HAC. In all instances the staff's maximum calculated k_{eff} was consistent with that of the applicant.

Based on the information provided in the application and the staff's own confirmatory analyses, the staff concludes that the NUHOMS® 32PTH1 DSC meets the acceptance criteria specified in 10 CFR Part 72.

6.4 Computer Programs

6.4.1 NUHOMS® 61BTH DSC

The applicant used the three dimensional Monte Carlo SCALE-4.4 package to explicitly model the cask and canister configurations analyzed using the 44-GROUP ENDF/B-V cross section set with the KENO V.a multigroup code. The applicant appropriately considered the neutron spectrum of the NUHOMS® 61BTH DSC.

6.4.2 NUHOMS® 32PTH1 DSC

The applicant used the three dimensional Monte Carlo SCALE-4.4 package to explicitly model the cask and canister configurations analyzed using the 44-GROUP ENDF/B-V cross section set with the KENO V.a multigroup code. The applicant appropriately considered the neutron spectrum of the NUHOMS® 32PTH1 DSC.

6.5 Benchmark Comparisons

6.5.1 NUHOMS® 61BTH DSC

The applicant used the CSAS25 module of the SCALE-4.4 package to perform their criticality analysis using the 44-GROUP ENDF/B-V cross-section library because it yielded a small bias as determined by 125 benchmark calculations. The benchmark problems used were representative of commercial light water reactor fuels and utilized water moderation, boron neutron absorbers, unirradiated fuel, close reflection, and uranium oxide fuel. The problems encompassed a wide range of uranium enrichments, fuel pin pitches, assembly separation, and fixed neutron absorbers in order to test the ability of the code to accurately calculate k_{eff}.

Using NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor fuel in Transportation and Storage Packages" Method 1 (Ref. 3), the applicant calculated the Upper Subcritical Limit (USL) and added an administrative margin of 0.05 to arrive at a minimum USL of 0.9415.

The staff reviewed the applicant's benchmark analysis and agrees that the critical experiments chosen are relevant to the cask design. The staff found the applicant's method for determining the USL acceptable. The staff also verified that only biases that increase k_{eff} have been applied.

6.5.2 NUHOMS® 32PTH1 DSC

The applicant used the CSAS25 module of the SCALE-4.4 package to perform their criticality analysis using the 44-GROUP ENDF/B-V cross-section library because it yielded a small bias as determined by 121 benchmark calculations. The benchmark problems used were representative of commercial light water reactor fuels and utilized water moderation, boron neutron absorbers, unirradiated fuel, close reflection, and uranium oxide fuel. The problems encompassed a wide range of uranium enrichments, fuel pin pitches, assembly separation, and fixed neutron absorbers in order to test the ability of the code to accurately calculate k_{eff}.

Using NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor fuel in Transportation and Storage Packages" (Ref. 3), the applicant calculated the Upper Subcritical Limit (USL) and added an administrative margin of 0.05 to arrive at a minimum USL of 0.9417.

The staff reviewed the applicant's benchmark analysis and agrees that the critical experiments chosen are relevant to the cask design. The staff found the applicant's method for determining the USL acceptable. The staff also verified that only biases that increase k_{eff} have been applied.

6.6 Evaluation Findings

F6.1 Section 6 of the SAR, sufficiently describes criticality safety SSCs important to safety in sufficient detail to allow evaluation of their effectiveness.

F6.2 Criticality safety of the Standardized NUHOMS® System as amended is sufficient to meet the criticality safety requirements of 10 CFR Part 72.

F6.3 The staff concludes that the criticality safety design of the NUHOMS® 32PT, 24PTH, NUHOMS® 61BTH, and 32PTH1 DSCs, when used with the appropriate HSM and TC, are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of package design provides reasonable assurance that the NUHOMS® 32PT, 24PTH, 61BTH, and 32PTH1 DSCs will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

6.7 References

1. Transnuclear, Inc., "Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0," January 12, 2007.

2. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

3. U.S. Nuclear Regulatory Commission, NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor fuel in Transportation and Storage Packages," January 1997.

7 CONFINEMENT EVALUATION

7.1 Confinement Design Characteristics

The NUHOMS® 32PTH1 system is designed to store up to 32 intact PWR fuel assemblies with a heat load of up to 40.8 kW. The NUHOMS® 61BTH system is designed to store up to 61 BWR fuel assemblies with a heat load of up to 31.2 kW. Both systems are designed to accommodate of up to 16 damaged fuel assemblies with the balance of the assemblies being intact. For both systems, the maximum average initial enrichment is 5 % weight, the maximum average burnup is 62 GWd/MTU, and the minimum cooling time is 3 years. The resulting source term from these fuel parameters is significant and would not be bounded by the methods typically employed by the staff to estimate the source term for a postulated release. Hence, the applicant has appropriately decided to make the confinement boundary leaktight.

7.2 Confinement Monitoring Capability

The confinement boundary for both systems is comprised of the DSC (dry shielded canister) shell, inner bottom cover plate, inner top cover plate, siphon & vent block, siphon & vent port cover plate, and the welds that join them together. The applicant has stipulated that the confinement boundary is designed and tested to meet the leaktight criteria of ANSI N14.5 (1997) (Ref. 1). The operating procedures Section T.8.1.4 Step 4 and U.8.1.4, Step 4, both require leaktight testing (i.e., 1.0E-7 ref cc/sec) in accordance with Technical Specification 1.2.4a, for the inner top cover plate weld and the vent/siphon port plate weld. Confinement boundary welds made during fabrication of the DSC are all volumetrically inspected in accordance with Section NB of the ASME Code (Ref. 2) to help assure their structural integrity.

It should be noted that these designs employ the use of an optional test port plug in the outer cover plate to leak test the inner top cover plate and vent/siphon welds to the leaktight criteria of ANSI 14.5-1997 (Ref. 1). If this option is not utilized then a temporary helium leak test head is used to test the inner cover plate and vent/siphon welds to the leaktight criteria, prior to installing the outer cover plate. When using the optional test port plug in the outer cover plate, the applicant will first test the inner cover plate and vent/siphon port welds with a less sensitive leak test method to 10^{-4} atm cc/sec; thereby saving the operation of installing this temporary helium leak test head. This less sensitive method is used to provide assurance that the inner cover plate welds are not leaking prior to installing the outer cover plate, which would have to be removed to repair any leaking weld.

The applicant has determined the maximum pressures possible under normal, off-normal and accident conditions. For each of these conditions, they used the standard SRP assumption of postulating 1%, 10%, and 100% rod failure for normal, off-normal, and accident conditions, respectively, in the determination of the amount of fission gas and initial rod fill gas contributing to the DSC pressure.

The applicant amended their operating procedures for ‘DSC Drying and Backfilling’ to note that the vacuum pump needs to be either shut off, or its suction open to atmospheric pressure, when performing the pressure rise test. This replaces the instruction to just shut the isolation valve to the vacuum pump, which could lead to an invalid test if the valve was leaking.

The staff finds, based on a review of the information provided in the SAR, that the confinement system meets the requirements of 10 CFR Part 72.

7.3 Evaluation Findings

F7.1 The staff finds, based on a review of the information provided in the SAR, that the confinement system meets the requirements of 10CFR Part 72.

7.4 References

1. American National Standards Institute, ANSI N14.5-1997, "Leakage tests on Packages for Shipments," January 1997.

2. ASME Boiler and Pressure Vessel Code, Section III, "Rules for Construction of Nuclear Power Plant Components", American Society of Mechanical Engineers.

8 OPERATING PROCEDURES

The review of the technical bases for the operating procedures is to ensure that the applicant's SAR (Ref. 1) presents acceptable operating sequences, guidance, and generic procedures for key operations. The procedures for the 61BTH DSC and 32PTH1 DSC, as described in Sections T.8.1, and U.8.1 of the SAR, respectively, are very similar to those previously approved by the staff for the Standardized NUHOMS® System (Ref. 2).

8.1 Cask Loading

Detailed loading procedures must be developed by each user.

The loading procedures described in the SAR include appropriate preparation and inspection provisions to be accomplished before cask loading. These include cleaning and decontaminating the transfer cask and other equipment as necessary, and performing an inspection of the 61BTH and 32PTH1 DSCs to identify any damage that may have occurred since receipt inspection. The procedures for DSC cavity boron concentration during filling (TS 1.2.15d) are specific to the 32PTH1 DSC design.

8.1.1 Fuel Specifications

The procedures described in SAR Section T.8.1.2 for the 61BTH DSC and U.8.1.2 for the 32PTH1 DSC provide for fuel handling operations to be performed in accordance with the general licensee's 10 CFR Part 50 license and requires independent, dual verification, of each fuel assembly loaded into the 61BTH and 32PTH1 DSCs. It outlines appropriate procedural and administrative controls to preclude a cask misloading.

8.1.2 ALARA

The ALARA practices utilized during operations are discussed in Section 10.4 of this SER.

8.1.3 Draining, Drying, Filling and Pressurization

SAR Sections T.8.1.3 and U.8.1.3 describe draining, drying, filling and pressurization procedures for the 61BTH and 32PTH1 DSCs, respectively. These procedures provide reasonable assurance that an acceptable level of moisture remains in the cask and the fuel is stored in an inert atmosphere. The procedures for helium backfill pressure (TS 1.2.3a) are the same as those previously approved by the staff for the Standardized NUHOMS® System. Sealing operations for dye penetrant testing of the closure welds are performed in accordance with TS 1.2.5.

8.1.3.1 Draining a loaded canister under inert atmosphere

During the canister loading/unloading process, an inert environment must be maintained to prevent excessive oxidation of any fuel pellets that may be exposed to the external environment due to cladding breaches. Guidance provided in ISG-22 (Ref. 3) describes staff approved measures to avoid oxidation of any fuel pellets that may be exposed. The applicant has specified in the loading procedures and TS that water removal (or water introduction during unloading) must be accomplished with a helium backfill to preclude air entry. The applicant's procedures satisfy the staff guidance of ISG-22.

The staff finds this operating method to comply with 10 CFR 72.122(h) (Ref. 4).

8.1.3.2 Hydrogen monitoring

During the phases of the loading/unloading operations when water is in the fuel canister, some amount of hydrogen may be evolved as a result of radiolysis and/or the insignificant amount of corrosion which occurs to canister internals. Generally, the amount of hydrogen produced is not significant, but when confined beneath the closure lids, a burnable concentration could accumulate if substantial operational delays occurred while water is in the canister and the lid is in place.

To alleviate this potential problem, hydrogen monitoring and mitigation is now specified by the loading/unloading procedures provided in SAR Chapters T.8 and U.8 for the 61BTH and 32PTH1, respectively, and incorporated by reference into the TS.

The staff finds this precaution to be acceptable.

8.1.4 Welding and Sealing

Welding and sealing operations of the 61BTH and 32PTH1 DSCs are similar to those previously approved by the staff for other DSCs used with the Standardized NUHOMS® System. The procedures include monitoring for hydrogen during welding operations. As discussed in Section 7.0 of this SER, leak checks performed according to TS 1.2.4a for the 61BTH and 32PTH1 DSCs demonstrate that the inner top cover plate is “leak tight” as defined by ANSI N14.5 - 1997 (Ref. 5). Sealing operations invoke TS 1.2.5 for dye penetrant testing of the closure welds.

8.2 Cask Handling and Storage Operations

All handling and transportation events applicable to moving the 61BTH and 32PTH1 DSCs to the storage location are similar to those previously reviewed by the staff for the Standardized NUHOMS® System and are bounded by Sections T.11 and U.11 of the SAR for the 61BTH and 32PTH1 DSCs, respectively. Technical Specification 1.2.18a and 1.2.18b provide time limits for the completion of transfer operations for the Type 2 61BTH and 32PTH1 DSCs, respectively.

Monitoring operations include daily surveillance of the HSM or HSM-H air inlets and outlets in accordance with either TS 1.3.1, or temperature performance as monitored on a daily basis in accordance with TS 1.3.2.

Occupational and public exposure estimates are evaluated in Sections T.10 and U.10 of the SAR for the 61BTH and 32PTH1 DSCs, respectively. Each cask user will need to develop detailed cask handling and storage procedures that incorporate ALARA objectives of their site-specific radiation protection program.

8.3 Cask Unloading

Detailed unloading procedures must be developed by each user.

Sections T.8 and U.8 provide similar unloading procedures for the 61BTH DSC and 32PTH1 DSCs, respectively, as those previously approved by the staff for use with the Standardized NUHOMS® System. The procedures provide a caution on reflooding the DSC to ensure that the vent pressure does not exceed 20 psig to prevent damage to the canister.

Sections T.8 and U.8 provides a discussion of ALARA practices that should be implemented during unloading operations for the 61BTH and 32PTH1 DSCs, respectively; however, detailed procedures incorporating provisions to mitigate the possibility of fuel crud particulate dispersal and fission gas release must be developed by each user.

8.4 Evaluation Findings

Based on a review of the submitted material, staff makes the following findings:

F8.1 The 61BTH and 32PTH1 DSCs are compatible with wet loading and unloading. General procedure descriptions for these operations are summarized in Sections T.8 and U.8 of the applicant's SAR for the 61BTH and 32PTH1, respectively. Detailed procedures will need to be developed and evaluated on a site-specific basis.

F8.2 The welded cover plates of the canister allow ready retrieval of the spent fuel for further processing or disposal as required.

F8.3 The DSC geometry and general operating procedures facilitate decontamination. Only routine decontamination will be necessary after the cask is removed from the spent fuel pool.

F8.4 No significant radioactive waste is generated during operations associated with the independent spent fuel storage installation (ISFSI). Contaminated water from the spent fuel pool will be governed by the 10 CFR Part 50 license.

F8.5 No significant radioactive effluents are produced during storage. Any radioactive effluents generated during the cask loading will be governed by the 10 CFR Part 50 license.

F8.6 The technical bases for the general operating procedures described in the SAR are adequate to protect health and minimize danger to life and property. Detailed procedures will need to be developed and evaluated on a site-specific basis.

F8.7 Section 10 of the SER assesses the operational restrictions to meet the limits of 10 CFR Part 20. Additional site-specific restrictions may also be established by the site licensee.

F8.8 The staff concludes that the generic procedures and guidance for the operation of the 61BTH and 32PTH1 DSCs are in compliance with 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied. The evaluation of the operating procedure descriptions provided in the SAR offers reasonable assurance that the cask will enable safe storage of spent fuel. This finding is based on a review that considered the regulations, appropriate regulatory guides, applicable codes and standards, and accepted practices.

8.5 References

1. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.

2. Transnuclear, Final Safety Analysis Report of the Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel, January 2006, Revision 9.
3. Interim Staff Guidance -22 (ISG-22), "Potential Rod Splitting Due to Exposure to an Oxidizing Atmosphere During Short-Term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel,” May 2006
4. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

5. American National Standards Institute, ANSI N14.5-1997, “Leakage tests on Packages for Shipments,” January 1997.

9 ACCEPTANCE TEST AND MAINTENANCE PROGRAMS

9.1 Acceptance Tests

The acceptance test procedures applicable to the NUHOMS® 61BTH and NUHOMS® 32PTH1 systems are similar to those previously reviewed by the staff for the Standardized NUHOMS® System (Ref. 1) and are bounded by Sections T.9 and U.9 of the SAR (Ref. 2) for the 61BTH and 32PTH1 DSCs, respectively, other than those specifically listed in Section 9.1.1, below.

9.1.1 Neutron Poison Material Acceptance Tests

The staff has reviewed the procedures and requirements imposed during the manufacturing and testing of the three different neutron poison materials employed by the applicant in the various Standardized NUHOMS® canister models. The staff found no significant changes to the manufacturing or testing of production lots of the three types of neutron poison materials.

Since the neutron poison materials are proprietary materials which are not controlled by any nationally recognized standard, additional controls are necessary to ensure consistency of these materials from batch to batch. To address this need for consistency, the applicant has incorporated by reference into the TS certain sections of SAR Chapters T.9 and U.9. A separate Sub-Chapter 9 discusses each of the different canister designs within this amendment. These chapters discuss the critical parameters and tests that must be controlled to ensure consistency in the production of neutron poison materials. Incorporation of the critical parameters of production and testing into the TS effectively “freezes” the production and testing methods used to manufacture the neutron poisons and avoids any unreviewed changes to manufacturing methods.

The staff finds that the appropriate controls for manufacturing and testing are imposed. There is reasonable assurance that the consistency of these proprietary materials will remain unchanged.

9.2 Evaluation Findings

F9.1 The staff finds that the appropriate controls for manufacturing and testing are imposed. There is reasonable assurance that the consistency of these proprietary materials will remain unchanged.

9.3 References

1. Transnuclear, Final Safety Analysis Report of the Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel, January 2006, Revision 9.

2. Transnuclear, Inc., “Application for Amendment 10 of the NUHOMS® Certificate of Compliance No. 1004 for Spent Fuel Storage Casks, Revision 0,” January 12, 2007.

10 RADIATION PROTECTION REVIEW

The staff reviewed amendments to the radiation protection design features, design criteria, and the operating procedures of the Standardized NUHOMS® System to ensure that it will continue to meet the regulatory dose requirements of 10 CFR Part 20 (Ref. 1), 10 CFR 72.104(a), 10 CFR 72.106(b), 10 CFR 72.212(b), and 10 CFR 72.236(d) (Ref. 2). This amendment was also reviewed to determine whether the Standardized NUHOMS® System continues to fulfill the acceptance criteria listed in Section 10 of NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems" (Ref. 3). The staff's conclusions are based on information provided in Amendment 10 to the NUHOMS® FSAR (Ref. 4).

10.1 Changes to NUHOMS® 32PT and 24PTH

The changes made to the allowable contents for the NUHOMS® 32PT and 24PTH DSCs are not expected to effect the radiation protection evaluation. The external dose rates for the NUHOMS® 32PT and 24PTH systems with revised contents are bounded by those previously determined for the systems.

10.2 NUHOMS® 61BTH DSC

10.2.1 Radiation Protection Design Criteria and Design Features

10.2.1.1 Design Criteria

The radiological protection design criteria are the limits and requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106. This is consistent with NRC guidance. As required by 10 CFR Part 20 and 10 CFR 72.212, each general licensee is responsible for demonstrating site-specific compliance with these requirements. The TS also establish dose limits for the TC and HSM that are based on calculated dose rate values which are used to determine occupational and off-site exposures.

The TS also establish exterior contamination limits for the DSC to keep contamination levels below 2,200 dpm/100 cm^2 for beta and gamma radiation, and 220 dpm/100 cm^2 for alpha radiation.

10.2.1.2 Design Features

Sections 3.3.1 and 7.1 of the Standardized NUHOMS® System FSAR, and Section T.10 of the amendment request, define the radiological protection design features which provide radiation protection to operational personnel and members of the public. The FSAR is not included in this review except for how it relates to the NUHOMS® 61BTH DSC radiological protection. The radiation protection design features include the following:

- the thick-walled concrete HSM that provides radiation shielding,
- the design of the HSM air inlets paths which includes sharp bends to preclude radiation streaming,

- a recess in the HSM access opening to dock and secure the transfer cask during DSC transfer to reduce occupational exposure,

- the thick canister shield plug on both ends of the canister that provides occupational shielding during loading/unloading and transfer operations,

- the confinement system that consists of multiple welded barriers to prevent atmospheric release of radionuclides, and is designed to maintain confinement of fuel during accident conditions,

- the system design allows for water in the DSC/TC annulus which is then sealed which reduces occupational dose rates and minimizes contamination of the DSC exterior,

- the use of water in the DSC cavity (except when drained to use the crane) to reduce occupational dose rates,

- the low-maintenance design that reduces occupational exposures during ISFSI operation, and,

- the implementation of ALARA principles into the cask design and operating procedures that reduce occupational exposures.

No changes were required for this review to the design features that address process instrumentation and controls, control of airborne contaminants, decontamination, radiation monitoring, auxiliary shielding devices and other ALARA considerations. Therefore, these were not reviewed.

The staff evaluated the radiation protection design features and design criteria for the NUHOMS® 61BTH DSC as used with the HSM and found them acceptable. The SAR analysis provides reasonable assurance that use of the NUHOMS® 61BTH DSC can meet the regulatory requirements in 10 CFR Part 20, 10 CFR 72.104(a), and 10 CFR 72.106(b). Sections 5, 7, and 8 of the SER discuss staff's evaluations of the shielding features, confinement systems, and operating procedures, respectively. Section 11 of the SER discusses staff evaluations of the capability of the shielding and confinement features during off-normal and accident conditions.

10.2.2 Occupational Exposures

Section T.8 of the amendment request discusses general operating procedures that general licensees will use for fuel loading, DSC/TC operations, DSC transfer into the HSM, and fuel unloading. Table T.10-1 of the amendment request shows the estimated number of personnel, the estimated time, the estimated dose rates, the tasks involved, and the estimated dose to load one canister. The estimated occupational doses are based on estimations from the direct radiation calculations in Section T.5 of the SAR, the generic operating procedures in Section T.8 of the SAR, and on operational experience. The dose estimates indicate that the total occupational dose in loading a single canister with design basis fuel into the HSM is approximately 2.37 person-rem. The applicant indicated that the general licensees may choose to modify the sequence of operations, and will also use ALARA practices to mitigate occupational exposure.

10.2.3 Public Exposures From Normal and Off-Normal Conditions

Section T.10.2 of the amendment request presents the calculated direct radiation dose rates at distances beyond 100 meters from a sample cask array configuration loaded with design basis fuel. Figures T.10-1, T.10-2, and T.10-3 depict estimated dose rate versus distance curves for various arrays of the HSM-H, HSM Model 102, and HSM Model 80, respectively. An array of 20 NUHOMS® 61BTH DSCs loaded with design basis fuel and placed in the HSM-H or HSM Model 102 is below regulatory limits at approximately 300 meters from the array, and the same array in the HSM Model 80 is below regulatory limits at approximately 400 meters from the array. This assumes 100% occupancy for 365 days.

The staff evaluated the public dose estimates during normal and off-normal conditions and found them acceptable. The primary dose pathway to individuals beyond the controlled area during normal and off-normal conditions is from direct radiation (including skyshine). The canister is leaktight and the confinement function is not affected by normal or off-normal conditions therefore, no discernable leakage is credible. A discussion of the staff's evaluation and confirmatory analysis of the shielding calculations are presented in Section 5 of the SER.

The staff has reasonable assurance that compliance with 10 CFR 72.104(a) can be achieved by each general licensee. The general licensee using the NUHOMS® 61BTH DSC with the HSM must perform a site-specific evaluation, as required by 10 CFR 72.212(b) to demonstrate compliance with 10 CFR 72.104(a). The actual doses to individuals beyond the controlled area boundary depend on several site-specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and use of engineered features (e.g., berms). In addition, the dose limits in 10 CFR 72.104(a) include doses from other fuel cycle activities such as reactor operations. Consequently, final determination of compliance with 10 CFR 72.104(a) is the responsibility of each site license. Additionally, a requirement in TS 1.1.9 states that engineered features (e.g. earthen berms, shield walls) that are used to ensure compliance with 10 CFR 72.104(a) by each general licensee are to be considered important to safety and must be appropriately evaluated under 10 CFR 72.212(b).

The general licensee will also have an established radiation protection program as required by 10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public, as required in 10 CFR Part 20, Subpart D by evaluations and measurements.

10.2.4 Public Exposures From Accidents and Events

Section T.11 of the amendment request summarizes the calculated dose rates for accident conditions and natural phenomena events to individuals beyond the controlled area. The confinement function of the canister is not affected by design-basis accidents or natural phenomena events thus there is no release of contents.

The amendment analysis indicates that the worst case shielding consequences results in a dose at the controlled area boundary that meets the regulatory requirements of 10 CFR

72.106(b). Section T.11 of the amendment request discusses corrective actions for each design-basis accident.

The staff evaluated the public dose estimates from direct radiation from accident conditions and natural phenomena events and found them acceptable. A discussion of the staff's evaluation and any confirmatory analysis of the shielding and confinement analysis is presented in Sections 5 and 7 of this SER. A discussion of the staff's evaluation of the accident conditions and recovery actions are presented in Section 11 of the SER. The staff has reasonable assurance that the effects of direct radiation from bounding design basis accidents and natural phenomena will be below the regulatory limits in 10 CFR 72.106(b).

10.2.5 ALARA

Sections T.5, T.7, and T.10 of the SAR present evidence that the NUHOMS® 61BTH DSC radiation protection design features and design criteria address ALARA requirements, consistent with 10 CFR Part 20 and Regulatory Guides 8.8 (Ref. 5) and 8.10 (Ref. 6). The overall ALARA requirements are discussed in the Standardized NUHOMS® FSAR, and were not reviewed for this amendment. Each site licensee will apply its existing site-specific ALARA policies, procedures, and practices for cask operations to ensure that personnel exposure requirements in 10 CFR Part 20 are met.

The staff evaluated the ALARA assessment of the NUHOMS® 61BTH DSC and found it acceptable. Section 8 of the SER discusses the staff's evaluation of the operating procedures with respect to ALARA principles and practices. Operational ALARA policies, procedures, and practices are the responsibility of the site licensee as required by 10 CFR Part 20. In addition, the TS establish dose rates and surface contamination limits ensure that occupational exposures are maintained ALARA.

10.3 NUHOMS® 32PTH1 DSC

10.3.1 Radiation Protection Design Criteria and Design Features

10.3.1.1 Design Criteria

The radiological protection design criteria are the limits and requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106. This is consistent with NRC guidance. As required by 10 CFR Part 20 and 10 CFR 72.212, each general licensee is responsible for demonstrating site-specific compliance with these requirements. The TS also establish dose limits for the TC and HSM that are based on calculated dose rate values which are used to determine occupational and off-site exposures.

The TS also establish exterior contamination limits for the DSC to keep contamination levels below 2,200 dpm/100 cm^2 for beta and gamma radiation, and 220 dpm/100 cm^2 for alpha radiation.

10.3.1.2 Design Features

Sections 3.3.1 and 7.1 of the Standardized NUHOMS® System FSAR, and Section U.10 of the amendment request, define the radiological protection design features which provide radiation protection to operational personnel and members of the public. The FSAR is not included in this review except for how it relates to the NUHOMS® 32PTH1 DSC radiological protection. The radiation protection design features include the following:

- the thick-walled concrete HSM that provides radiation shielding,
- the design of the HSM air inlets paths which includes sharp bends to preclude radiation streaming,
- a recess in the HSM access opening to dock and secure the transfer cask during DSC transfer to reduce occupational exposure,
- the thick canister shield plug on both ends of the canister that provides occupational shielding during loading/unloading and transfer operations,
- the confinement system that consists of multiple welded barriers to prevent atmospheric release of radionuclides, and is designed to maintain confinement of fuel during accident conditions,
- the system design allows for water in the DSC/TC annulus which is then sealed which reduces occupational dose rates and minimizes contamination of the DSC exterior,
- the use of water in the DSC cavity (except when drained to use the crane) to reduce occupational dose rates,
- the low-maintenance design that reduces occupational exposures during ISFSI operation, and,
- the implementation of ALARA principles into the cask design and operating procedures that reduce occupational exposures.

No changes were required for this review to the design features that address process instrumentation and controls, control of airborne contaminants, decontamination, radiation monitoring, auxiliary shielding devices and other ALARA considerations. Therefore, these were not reviewed.

The staff evaluated the radiation protection design features and design criteria for the NUHOMS® 32PT DSC as used with the HSM and found them acceptable. The SAR analysis provides reasonable assurance that use of the NUHOMS® 32PTH1 DSC can meet the regulatory requirements in 10 CFR Part 20, 10 CFR 72.104(a), and 10 CFR 72.106(b). Sections 5, 7, and 8 of the SER discuss staff's evaluations of the shielding features, confinement systems, and operating procedures, respectively. Section 11 of the SER discusses staff evaluations of the capability of the shielding and confinement features during off-normal and accident conditions.

10.3.2 Occupational Exposures

Section U.8 of the amendment request discusses general operating procedures that general licensees will use for fuel loading, DSC/TC operations, DSC transfer into the HSM, and fuel unloading. Table U.10-1 of the amendment request shows the estimated number of personnel, the estimated time, the estimated dose rates, the tasks involved, and the estimated dose to load one canister. The estimated occupational doses are based on estimations from the direct radiation calculations in Section U.5 of the SAR, the generic operating procedures in Section U.8 of the SAR, and on operational experience. The dose estimates indicate that the total occupational dose in loading a single canister with design basis fuel into the HSM is approximately 2 person-rem. The applicant indicated that the general licensees may choose to modify the sequence of operations, and will also use ALARA practices to mitigate occupational exposure.

10.3.3 Public Exposures From Normal and Off-Normal Conditions

Section U.10.2 of the amendment request presents the calculated direct radiation dose rates at distances beyond 100 meters from a sample cask array configuration loaded with design basis fuel. Figure U.10-1 depicts the estimated dose rate versus distance curve for the NUHOMS® 32PTH1 DSC in the HSM-H. An array of 20 NUHOMS® 32PTH1 DSCs loaded with design basis fuel and placed in the HSM is below regulatory limits at approximately 300 meters for either two parallel but separated 1x10 arrays or a 2x10 array. This assumes 100% occupancy for 365 days.

The staff evaluated the public dose estimates during normal and off-normal conditions and found them acceptable. The primary dose pathway to individuals beyond the controlled area during normal and off-normal conditions is from direct radiation (including skyshine). The canister is leaktight and the confinement function is not affected by normal or off-normal conditions therefore, no discernable leakage is credible. A discussion of the staff's evaluation and confirmatory analysis of the shielding calculations are presented in Section 5 of the SER.

The staff has reasonable assurance that compliance with 10 CFR 72.104(a) can be achieved by each general licensee. The general licensee using the NUHOMS® 32PTH1 DSC with the HSM must perform a site-specific evaluation, as required by 10 CFR 72.212(b) to demonstrate compliance with 10 CFR 72.104(a). The actual doses to individual beyond the controlled area boundary depend on several site-specific conditions such as fuel characteristics, cask-array configurations, topography, demographics, and use of engineered features (e.g., berms). In addition, the dose limits in 10 CFR 72.104(a) include doses from other fuel cycle activities such as reactor operations. Consequently, final determination of compliance with 10 CFR 72.104(a) is the responsibility of each site license. Additionally, a requirement in TS 1.1.9 states that engineered features (e.g. earthen berms, shield walls) that are used to ensure compliance with 10 CFR 72.104(a) by each general licensee are to be considered important to safety and must be appropriately evaluated under 10 CFR 72.212(b).

The general licensee will also have an established radiation protection program as required by

10 CFR Part 20, Subpart B, and will demonstrate compliance with dose limits to individual members of the public, as required in 10 CFR Part 20, Subpart D by evaluations and measurements.

10.3.4 Public Exposures From Accidents and Events

Section U.11 of the amendment request summarizes the calculated dose rates for accident conditions and natural phenomena events to individuals beyond the controlled area. The confinement function of the canister is not affected by design-basis accidents or natural phenomena events thus there is no release of contents.

The amendment analysis indicates the worst case shielding consequences results in a dose at the controlled area boundary that meets the regulatory requirements of 10 CFR 72.106(b). Section U.11 of the amendment request discusses corrective actions for each design-basis accident.

The staff evaluated the public dose estimates from direct radiation from accident conditions and natural phenomena events and found them acceptable. A discussion of the staff's evaluation and any confirmatory analysis of the shielding and confinement analysis is presented in Sections 5 and 7 of this SER. A discussion of the staff's evaluation of the accident conditions and recovery actions are presented in Section 11 of the SER. The staff has reasonable assurance that the effects of direct radiation from bounding design basis accidents and natural phenomena will be below the regulatory limits in 10 CFR 72.106(b).

10.3.5 ALARA

Sections U.5, U.7, and U.10 of the SAR presents evidence that the NUHOMS® 32PTH1 DSC radiation protection design features and design criteria address ALARA requirements, consistent with 10 CFR Part 20 and Regulatory Guides 8.8 (Ref. 5) and 8.10 (Ref. 6). The overall ALARA requirements are discussed in the Standardized NUHOMS® FSAR, and were not reviewed for this amendment. Each site licensee will apply its existing site-specific ALARA policies, procedures, and practices for cask operations to ensure that personnel exposure requirements in 10 CFR Part 20 are met.

The staff evaluated the ALARA assessment of the NUHOMS® 32PTH1 DSC and found it acceptable. Section 8 of the SER discusses the staff's evaluation of the operating procedures with respect to ALARA principles and practices. Operational ALARA policies, procedures, and practices are the responsibility of the site licensee as required by 10 CFR Part 20. In addition, the TS establish dose rates and surface contamination limits ensure that occupational exposures are maintained ALARA.

10.4 Evaluation Findings

F10.1 The SAR amendment sufficiently describes the radiation protection design bases and design criteria for the SSCs important to safety.

F10.2 Radiation shielding and confinement features are sufficient to meet the radiation protection requirements of 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106.

F10.3 The NUHOMS® 61BTH and 32PTH1 DSCs are designed to facilitate decontamination to the extent practicable.

F10.4 The SAR amendment adequately evaluates the NUHOMS® 61BTH and 32PTH1 DSCs and their systems important to safety to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and accident conditions.

F10.5 The SAR amendment sufficiently describes the means for controlling and limiting occupational exposures within the dose and ALARA requirements of 10 CFR Part 20.

F10.6 Operational restrictions necessary to meet dose and ALARA requirements in 10 CFR Part 20, 10 CFR 72.104, and 10 CFR 72.106 are the responsibility of the site licensee. The NUHOMS® 61BTH and 32PTH1 DSCs are designed to assist in meeting these requirements.

F10.7 The staff concludes that the design of the radiation protection system of the NUHOMS® 61BTH and 32PTH1 DSCs when used with the HSM, is in compliance with 10 CFR Part 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the NUHOMS® 61BTH and 32PTH1 DSCs will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, and acceptable engineering practices.

10.5 References

1. U.S. Code of Federal Regulations, Standards for Protection Against Radiation, Title 10, Part 20.

2. U.S. Code of Federal Regulations, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor - Related Greater Than Class C Waste, Title 10, Part 72.

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

4. Transnuclear, Final Safety Analysis Report of the Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel, February, 2008, Revision 10.

5. U.S. Nuclear Regulatory Commission, Information Relevant to Ensuring that Occupational Radiation Exposures Will Be As Low As is Reasonably Achievable, Regulatory Guide 8.8, Revision 3, June 1978.

6. U. S. Nuclear Regulatory Commission, Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As is Reasonably Achievable, Regulatory Guide 8.10, Revision 1-R, May 1977.

11 ACCIDENT ANALYSIS EVALUATION

The purpose of the review of the accident analyses is to evaluate the applicant's identification and analysis of hazards, as well as the summary analysis of systems responses to both off-normal and accident or design-basis events. This ensures that the applicant has conducted thorough accident analyses as reflected by the following factors:

- identified all credible accidents,
- provided complete information in the SAR,
- analyzed the safety performance of the cask system in each review area, and,
- fulfilled all applicable regulatory requirements

11.1 Off-Normal Conditions

Off-normal operations are Design Event II as defined by ANSI/ANS 57.9 (Ref. 1). These events can be described as not occurring regularly, but can be expected to occur with moderate frequency (on the order of once per year). The NUHOMS® 61BTH system and 32PTH1 system off-normal events are described in Sections T.11.1 and U.11.1 of the SAR, respectively. The off-normal events that are considered for the NUHOMS® 61BTH system and 32PTH1 system are off-normal transfer loads, extreme temperatures and a postulated release of radionuclides. The off-normal transfer loads and the extreme temperatures have been analyzed and reported in the appropriate sections of this report. The off-normal event for release of radionuclides assumes failed fuel rods; however, because the canister is designed and tested to leaktight criteria, the estimated quantity of radionuclides due to this off-normal event is zero. Chapter 7 of this SER provides the staff's confinement evaluation.

11.2 Accident Events and Conditions

Accident events and conditions are Design Event III and IV as defined in Reference 1. They include natural phenomena and human-induced low probability events. The NUHOMS® 61BTH and 32PTH1 systems are designed to accommodate postulated accidents that are described in Sections T.11 and U.11 of the SAR, respectively. The applicant updated the accident analysis found in Chapter 8.0 of the Standardized NUHOMS® SAR (Ref. 2), based on the unique features of the NUHOMS® 61BTH and 32PTH1 systems. The accident events that were reviewed and updated and the associated safety evaluation are provided in Table 11-1 below.

Table 11-1 Accident Event Safety Evaluation

Accident Event	Safety Analysis Report Sections	Safety Evaluation
Reduced HSM Air Inlet and Outlet Shielding	SAR T.11.2.1 provides the analysis for the 61BTH Type 1 DSC stored in HSM models 80/102. Not applicable to HSM-H used to store 61BTH Type 2 and 32PTH1 DSCs or HSM Models 152 and 202 used to store 61BTH Type 1 DSCs.	HSM Model 152, 202, and HSM-H models are designed with the elimination of the 6-inch gaps between HSMs. Therefore, for these models shifting of the HSM such that an HSM in the middle of the array is separated and rest against the adjacent HSM side wall is not credible. For the HSM models 80/102, TN evaluates the off-site radiological effects that result from a partial loss of adjacent Standardized HSM shielding. This scenario leads to an increase in air scattered and direct doses from the 12 inch gap between the separated HSMs. The increased doses from this event for the 61BTH DSC Type 1 canister are a fraction of the 10 CFR 72.106 requirements.
Earthquake	SAR T.11.2.2 and T.3.7.2 describe the accident evaluation analysis that was revised as a result of the addition of the 61BTH DSC. SAR U.11.2.2, and U.3.7.2 describe the accident evaluation analysis that was revised as a result of the addition of the 32PTH1 DSC and the HSM-HS (high-seismic version of the HSM-H)	SER Section 3 provides an evaluation of the response of the NUHOMS® 61BTH and 32PTH1 Systems to an earthquake
Extreme Wind and Tornado Missiles	SAR T.11.2.3 and T.3.7.1 describe the accident evaluation analysis that was revised as a result of the addition of the 61BTH DSC SAR U.11.2.3, and U.3.7.1 describe the accident evaluation analysis that was revised as a result of the addition of the 32PTH1 DSC and the HSM-HS	SER Section 3 provides an evaluation of the response of the NUHOMS® 61BTH and 32PTH1 Systems to extreme wind and tornado missiles

Accident Event	Safety Analysis Report Sections	Safety Evaluation
Flood	SAR T.11.2.4 and T.3.7.3 for the 61BTH DSCs and HSM-H SAR U.11.2.4 and U.3.7.3 for the 32PTH1 DSC and HSM-H and HSM-HS	SER Section 3
Accidental Transfer Cask Drop	SAR T.11.2.5 and T.3.7.4 for the 61BTH DSC SAR U.11.2.5 and U.3.7.4 for the 32PTH1 DSC	SER Section 3 for the structural analysis, SER Section 4 for the thermal analysis and SER Section 5 for the radiological analysis associated with the loss of neutron shield.
Lightning	SAR T.11.2.6 for the 61BTH System and SAR U.11.2.6 for the 32PTH1 System	There is no change to the analysis provided in Chapter 8.2.6 of the SAR for the lightning analysis. The analysis demonstrates that lightning does not pose a risk to the safe storage of fuel in the Standardized NUHOMS® system. The staff has previously found this analysis to be acceptable and believes the analysis in SAR Chapter 8.2.6 bounds the 61BTH and the 32PTH1 Systems.
Blockage of Air Inlet and Outlet Openings	SAR T.11.2.7, T.4 for the thermal analysis and T.3 for the structural analysis for the 61BTH System SAR U.11.2.7, U.4 for the thermal analysis and U.3 for the structural analysis for the 32PTH1 System.	SER Section 3 for the thermal analysis and SER Section 4 for the structural analysis.
DSC Leakage	SAR T.11.2.8 for the 61BTH DSC SAR U.11.2.8 for the 32PTH1 DSC	DSC leakage is not considered a credible accident scenario. Chapter 7 of the SER provides the confinement evaluation.
Accident Pressurization of DSC	SAR T.11.2.9 for the 61BTH DSC SAR U.11.2.9 for the 32PTH1 DSC	The DSC is designed to withstand pressure as a Level D condition. SER Chapter 4 provides the thermal evaluation. SER Chapter 3 provides the structural evaluation

Accident Event	Safety Analysis Report Sections	Safety Evaluation
Fire and Explosion	SAR T.11.2.10 and T.4.6.8.3 for the 61 BTH DSC SAR U.11.2.1.10 and U.4.5.4.2 for the 32PTH1 DSC	SER Chapter 4
Accident Temperatures	SAR U.11.2.11 for the 32PTH1 DSC	SER Chapter 4

11.3 Evaluation of Findings

Based on a review of the submitted information, the staff makes the following findings:

F11.1 Structures, systems, and components of the NUHOMS® 61BTH and 32PTH1 Systems are adequate to prevent accidents and to mitigate the consequences of accidents and natural phenomena events that do occur.

F11.2 The applicant has evaluated the NUHOMS® 61BTH and 32PTH1 Systems to demonstrate that it will reasonably maintain confinement of radioactive material under credible accident conditions.

F11.3 An accident or natural phenomena event will not preclude the ready retrieval of spent fuel for further processing or disposal.

F11.4 The spent fuel will be maintained in a subcritical condition under accident conditions. Neither off-normal nor accident conditions will result in a dose, to an individual outside the controlled area, that exceeds the limits of 10 CFR 72.104(a) or 72.106(b), respectively.

F11.5 The staff concludes that the accident design criteria for the NUHOMS® 61BTH and 32PTH1 Systems are in compliance with 10 CFR Part 72 and the accident design and acceptance criteria have been satisfied. The applicant's accident evaluation of the cask adequately demonstrates that it will provide for safe storage of spent fuel during credible accident situations. This finding is reached on the basis of a review that considered independent confirmatory calculations, the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

11.4 References

1. ANSI/ANS 57.9-1984, “Design Criteria for an Independent Spent Fuel Storage Installation (Dry Type), Reaffirmed 2000

2. Transnuclear, Final Safety Analysis Report of the Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel, January 2006, Revision 9.

12 CONDITIONS FOR CASK USE - TECHNICAL SPECIFICATIONS

The purpose of the review of the technical specifications for the cask is to determine whether the applicant has assigned specific controls to ensure that the design basis of the cask system is maintained during loading, storage, and unloading operations.

12.1 Conditions for Use

The conditions for use of the 61BTH and 32PTH1 DSC, in conjunction with the Standardized NUHOMS® Storage System, are clearly defined in the CoC and TS. In addition, the change of contents for the 32PT DSC and the 24PTH DSC are clearly defined in the CoC and TS.

12.2 Technical Specifications

Based on the addition of the NUHOMS® 61BTH and 32PTH1 systems to the Standardized NUHOMS® Storage System, the TS have been revised to accommodate the new DSCs and the fuel types to be stored in the DSC. These changes have been identified in the TS attachment to the CoC.

Table 12-1 lists the TS for use of the NUHOMS® 61BTH and 32PTH1 systems, in concert with the Standardized NUHOMS® Storage System.

12.3 Technical Specification Sections

12.3.1 TS Section 1.1.1, Use of Weathering Steel

The TS incorporate a paragraph which requires the use of atmospheric corrosion resisting steel (“weathering steel”) for certain HSM interior structural components at any ISFSI site located in a coastal marine environment. This is due to the more corrosive nature of the air at sea coast locations. The TS specify that any load bearing carbon steel component which is part of the HSM must contain at least 0.20% copper as an alloy addition. This alloy addition is what produces weathering steels which have significantly enhanced corrosion resistance to atmospheric corrosion, especially in coastal marine atmospheres.

Independent studies previously conducted for TN, and reviewed by the NRC staff, have amply demonstrated the efficacy of weathering steels under the environmental conditions experienced by HSM interior structural components and in coastal marine atmospheres.

The staff finds this addition to the TS to be appropriate for ensuring the longevity of carbon steel HSM interior structural components.

12.3.2 TS Section 1.1.11, Hydrogen Monitoring

Hydrogen monitoring and mitigation is now specified by the loading/unloading procedures provided in SAR Chapter 8 and incorporated by reference into the TS.

The staff finds this precaution to be acceptable.

12.3.3 TS Section 1.2.1, Control Components

Control components such as burnable poison rod assemblies (BPRA's) are included as authorized contents. The staff has previously reviewed the potential for chemical or galvanic reactions that could result from the introduction of these materials into the DSC loading and storage environments. The staff has found that there are no materials contained in these control elements which would react adversely with the canister, canister interior components, neutron poison, or fuel cladding.

Therefore, the staff finds that 10 CFR 72.122(c)(4) is satisfied.

12.3.4 TS Section 1.2.1, Neutron Poisons

All canister designs employ a neutron poison to control criticality. All of the poisons employed by the applicant consist of a boron bearing aluminum composite of varying types. The staff has previously reviewed and accepted these proprietary materials. However, since these materials are proprietary and thus not controlled by a nationally recognized standard, their critical characteristics for manufacturing and quality control are incorporated into the TS by reference.

Those critical characteristics are described in several specially marked sections of SAR Chapter 9 for each canister design. These special sections of the SAR are specifically noted within the SAR as license conditions. Thus, those governing paragraphs may not be changed without prior NRC staff review. This effectively "freezes" the manufacturing and acceptance testing for these materials to a known standard, previously reviewed and accepted by the NRC staff. Any changes to the critical characteristics of manufacturing or testing of these materials would require prior NRC review and approval.

The staff finds the specified critical characteristics to be acceptable for controlling the manufacture and testing of these proprietary, important-to-safety materials.

12.3.5 TS Section 1.2.4, Helium leak test

A provision was added to the SAR and incorporated into the TS to extend the helium leakage rate test (limit of 10 exp -4 reference cc/sec.) to the vent and drain port covers since these were not previously specifically mentioned in the SAR or TS. Since these welded components are a part of the confinement boundary, they must be tested to ensure they comply with the overall leakage rate limit for the canister design.

Note that TS 1.2.4 applies only to the 24P and 52B DSC's. These DSC's are not considered “leaktight” as described in the “Basis” section of the TS, thus no helium leakage test to the “leaktight” provisions of 10 exp -7 reference cc/sec. in ANSI N14.5 – 1997 (Ref. 1), is required. For these two designs, a leakage test to 10 exp -4 reference cc/sec is sufficient.

The staff finds the inclusion of the vent and drain port covers as part of the overall leakage rate measurement test to be in compliance with the staff intent of ISG-18 (Ref. 2).

12.3.6 TS Section 1.2.4a, Helium leak test

The inner top cover seal weld and vent and drain port cover plate welds of the 61BT, 32PT, 24PHB, 61BTH, and 32PTH1 are all helium leakage rate tested to the “leak tight” standard (10 exp -7 reference cc/sec.) of ANSI N14.5 - 1997.

The staff finds this to be in compliance with the guidance of ISG-15 (Ref. 3) and ISG-18.

12.4 Changes to Standardized NUHOMS® Certificate of Compliance

In the CoC for Amendment 9, Condition 6 stated in part that all Standardized NUHOMS® Systems must be fabricated and used in accordance with CoC No. 1004 Amendment 9. This Condition has been deleted. General licensees may use either the current issue of the certificate or previously approved amendments of the certificate for storage under the provisions of 10 CFR 72.10.

12.4.1 CoC Change

The applicable guidance associated with the Change to CoC 1004, former Condition 6 can be found in **draft** Regulatory Issue Summary, “Implementation of CoC Amendments to Previously Loaded Spent Fuel Storage Casks” (ML072400233). This RIS informs addressees of NRC requirements concerning the implementation of a 10 CFR Part 72 dry storage cask Certificate of compliance amendment to a cask loaded under the original CoC or an earlier amendment thereto (“previously loaded cask”). The RIS states that it is the NRC’s practice to consider each CoC amendment as a new design basis. Thus, each CoC amendment requires an NRC rulemaking before the amendment is effective. Requiring that all Standardized NUHOMS® Systems must be fabricated and used in accordance with CoC No. 1004 Amendment 9 is inconsistent with the guidance provided in the draft RIS and the requirements contained in 10 CFR Part 72. Therefore, removal of Condition 6 is considered acceptable to staff.

12.5 Evaluation of Findings

Based on a review of the submitted information, the staff makes the following findings:

F12.1 Table 12-1 of this SER lists the TS for the NUHOMS® 61BTH and 32PTH1 Systems, in conjunction with the Standardized NUHOMS® Storage System. These TS are included as Appendix A of the CoC.

F12.2 The staff concludes that the conditions for use of the NUHOMS® 61BTH and 32PTH1 Systems, and the change of contents for the 24PTH and 32PT DSC in conjunction with the Standardized NUHOMS® Storage system, identify necessary TS to satisfy 10 CFR Part 72 and that the applicant acceptance criteria have been satisfied. The TS provide reasonable assurance that the cask will provide for safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

F12.3 The staff concludes that the CoC for the Standardized NUHOMS® System provides reasonable assurance that the cask will provide for safe storage of spent fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted practices.

12.6 References

1. American National Standards Institute, ANSI N14.5-1997, “Leakage tests on Packages for Shipments,” January 1997.

2. Interim Staff Guidance – 18 (ISG-18), “The Design and Testing of Lid Welds on Austenitic Stainless Steel Canisters as the Confinement Boundary for Spent Fuel Storage”, Revision 1; October, 2008.

3. Interim Staff Guidance – 15 (ISG-15), “Materials Evaluation”, Revision 0; January, 2001.

Table 12-1

Standardized NUHOMS® Horizontal Modular Storage System Technical Specifications for use with the NUHOMS® 61BTH and 32PTH1 Systems

1.2.11 Transfer Cask Dose Rates with a Loaded 24P, 52B, 61BT, or 32 PT DSC
1.2.11aTransfer Cask Dose Rates with a Loaded 24PHB DSC
1.2.11bTransfer Cask Dose Rates with a Loaded 24PTH-S or 24PTH-L DSC
1.2.11cTransfer Cask Dose Rates with a Loaded 24PTH-S-LC DSC
1.2.11d Transfer Cask Dose Rates with a Loaded 61BTH DSC
1.2.11e Transfer Cask Dose Rates with a Loaded 32PTH1 DSC
1.2.12 Maximum DSC Removable Surface Contamination
1.2.13 TC/DSC Lifting Heights as a Function of Low Temperature and Location
1.2.14 TC/DSC Transfer Operations at High Ambient Temperatures (24P, 52B, 61BT, 32PT, 24PHB, 24PTH, or 61BTH only)
1.2.14a TC/DSC Transfer Operations at High Ambient Temperatures (32PTH1 DSC Only)
1.2.15 Boron Concentration in the DSC Cavity Water for the 24P Design Only
1.2.15a Boron Concentration in the DSC Cavity Water for the 32PT Design Only
1.2.15b Boron Concentration in the DSC Cavity Water for the 24PHB Design Only
1.2.15c Boron Concentration in the DSC Cavity Water for the 24PTH Design Only
1.2.15d Boron Concentration in the DSC Cavity Water for the 32PTH1 Design Only
1.2.16 Provision of TC Seismic Restraint Inside the Spent Fuel Pool Building as a Function of Horizontal Acceleration and Loaded Cask Weight
1.2.17 61BT DSC Vacuum Drying Duration Limit
1.2.17a 32PT DSC Vacuum Drying Duration Limit
1.2.17b 24PHB DSC Vacuum Drying Duration Limit
1.2.17c 24PTH DSC Vacuum Drying Duration Limit
1.2.18 Time Limit for Completion of 24PTH DSC Transfer Operation
1.2.18a Time Limit for Completion of Type 2 61BTH DSC Transfer Operation
1.2.18b Time Limit for Completion of 32PTH1 DSC Transfer Operation
1.2.19 61BTH and 32PTH1 DSC Bulkwater Removal Medium

1.3 Surveillance and Monitoring

1.3.1 Visual Inspection of HSM or HSM-H Air Inlets and Outlets (Front Wall and Roof Birdscreen)
1.3.2 HSM or HSM-H Thermal Performance

13 QUALITY ASSURANCE

The purpose of this review and evaluation is to determine whether TN has a quality assurance program that complies with the requirements of 10 CFR Part 20, Subpart G. The staff has previously reviewed and accepted the TN quality assurance program in the Standardized NUHOMS® Horizontal Modular Storage System FSAR.

14 DECOMMISSIONING

The decommissioning evaluation was previously reviewed and approved in the Standardized NUHOMS® Horizontal Modular Storage System FSAR. There were no changes proposed by the applicant in the addition of the NUHOMS® 61BTH and 32PTH1 systems.

15 CONCLUSION

The NRC staff has performed a comprehensive review of the CoC amendment request and found that the following changes do not reduce the safety margin for the Standardized NUHOMS® System:

- addition of a dry shielded canister (DSCs) designated the NUHOMS® 61BTH DSC and accompanying changes to accommodate this DSC,

- addition of a DSC designated the NUHOMS® 32PTH1 DSC and accompanying changes to accommodate this DSC. TN also added an alternate high-seismic option of the horizontal storage module for storing the 32PTH1 DSC,

- allow storage of Westinghouse 15x15 Partial Length Shield Assemblies in the NUHOMS® 24PTH DSC, and,

- allow storage of Control Components in the NUHOMS® 32PT DSC

The areas of review addressed in NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems,” January 1997, are consistent with the applicant’s proposed changes. The Certificate of Compliance has been revised to include the TN requested changes. Based on the statements and representations contained in TN’s application, as supplemented, the staff concludes that the changes described above to the approved contents of the Standardized NUHOMS® System meets the requirements of 10 CFR Part 72.

Issued with Certificate of Compliance No. 1004, Amendment No. 10 on _Draft_______ .