PRELIMINARY
SAFETY EVALUATION REPORT

Docket No. 72-1004
Standardized NUHOMS® Modular Storage System for Irradiated Nuclear Fuel
Certificate of Compliance No. 1004
Amendment No. 5

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SUMMARY

By letter dated June 29, 2001, as supplemented on June 29 and August 28, 2001, February 21, March 1, March 18, June 3, and July 3, 2002, and January 24, February 6, March 7, April 3,and April 18, 2003, Transnuclear, Inc. (TN) submitted a request to amend Certificate of Compliance (CoC) No. 1004. TN requested approval to add the NUHOMS®-32PT dry storage canister (DSC) to the Standardized NUHOMS® System. This canister is designed to accommodate 32 Pressurize Water Reactor (PWR) fuel assemblies with or without Burnable Poison Rod Assemblies (BPRAs). It is designed for use with the existing NUHOMS® Modular Storage System (HSM) and NUHOMS® transfer cask (TC).

The application, as supplemented, included the necessary engineering analyses and proposed Safety Analysis Report (SAR) page changes. The proposed SAR revisions will be incorporated into the Final Safety Analysis Report (FSAR).

The U.S. Nuclear Regulatory Commission (NRC) staff performed a detailed safety evaluation of the proposed amendment request which is documented in this safety evaluation report (SER). The staff's evaluation and conclusions are based on information submitted by TN on June 29, 2001, as supplemented, requesting an amendment to add the NUHOMS®-32PT DSC to CoC No. 1004. The staff determined that the addition of the NUHOMS®-32PT DSC meets the requirements of 10 CFR Part 72.

1.0 GENERAL INFORMATION

The objective of the review of the general description of the NUHOMS®-32PT DSC[1] 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 the system.

1.1 General Description and Operational Features

The NUHOMS®-32PT DSC is a new DSC design which consists of a fuel basket and a canister body, designed to hold 32 intact standard PWR assemblies, with or without BPRAs. The NUHOMS®-32PT DSC is designed to maintain the fuel cladding temperature below allowable limits during storage, short term accident conditions, short term off-normal conditions, and fuel transfer operations.

The NUHOMS®-32PT DSC system consists of four design configurations; 32PT-S100 short canister, 32PT-L100 long canister, 32PT-S125 short canister and 32PT-L125 long canister. The 100 designates that the canister is qualified for lift with a 100-ton capacity crane, and the 125 designates that the canister is qualified for lift with a 125-ton capacity crane.

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 that provide the necessary criticality control and heat conduction paths from the fuel assemblies to the canister shell. The confinement vessel for the NUHOMS®-32PT DSC consists of a shell which is a welded stainless steel cylinder with an integrally-welded, stainless steel bottom closure assembly; and a stainless steel top closure assembly, which includes the vent and drain system. The NUHOMS®-32PT DSCs are designed and tested to meet the leak tight criteria of ANSI N14.5-1997[2].

The NUHOMS®-32PT DSC will be stored in the previously approved NUHOMS® Modular Storage System (HSM), and transferred in a OS197 or OS197H TC with a radial liquid neutron shield. Those components were only reevaluated during this safety evaluation to the extent that they were compatible with the NUHOMS®-32PT DSC.

The applicant updated Section 7.2.3 of the Standardized NUHOMS® System's FSAR[3] to document the methodology used to determine fuel qualification tables for the NUHOMS 24P and 52B canisters. The qualification tables are presented in Tables 3.1-8a and 3.1-8b of the FSAR. The staff administratively reviewed the updated FSAR Section 7.2.3. The updated information and associated qualification tables appear to be consistent with information previously submitted. Therefore, this update is adequate to reflect the methodology used to generate the fuel qualification tables in Tables 3.1-8a and 3.1-8b of the FSAR.

1.2 Drawings

Section K.1 of the SAR contains the non-proprietary drawings for the NUHOMS®-32PT DSC, 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®-32PT DSC. Specific SSC are evaluated in other sections of this SER.

1.3 DCSS Contents

The NUHOMS®-32PT DSC system is designed to store 32 intact standard PWR fuel assemblies with or without BPRAs. Each NUHOMS®-32PT DSC is designed for a maximum heat load of 24kW/canister and 1.2kW per fuel assembly. Fuel specifications are detailed in Section 1.2.1 of the Technical Specifications (TS).

1.4 Qualification of the Applicant

Appendix M, Section M1.3 of the SAR contains details of the applicant's qualifications and experience regarding its ability to design and fabricate the NUHOMS®-32PT DSC in accordance with an approved 10 CFR Part 72 quality assurance program.

1.5 Evaluation of Findings

F1.1 A general description of the NUHOMS®-32PT DSC is presented in Appendix M, section M.1 of the SAR.

F1.2 Drawings for the SSC important to safety are presented in Appendix M. Section M.1 of the SAR.

F1.3 Specifications for the spent fuel to be stored in the NUHOMS®-32PT DSC are provided in the SAR Appendix M, Section M.2, and TS 1.2.1.

F1.4 The technical qualifications of the applicant are identified in Appendix M, Section M1.3 of the SAR.

F1.5 The quality assurance program was previously approved for the Standardized NUHOMS® System, and is referenced in Section 13 of the SAR.

F1.6 The NUHOMS®-32PT DSC has not been certified under 10 CFR Part 71 for use in transportation.

F1.7 The staff concludes that the information presented in this section of the SAR satisfies the requirements for the general description under 10 CFR Part 72.

1.6 References

1. Amendment 5 to NUHOMS® Certificate of Compliance No. 1005, Revision 6, June 29, 2001, as supplemented.

2. "American National Standard for Radioactive Materials - Leakage Tests on Packages for Shipment," ANSI N14.5 - 1997, American National Standards Institute, Inc., New York, New York, 1997.

3. Transnuclear West, Final Safety Analysis Report of the Standardized NUHOMS® Horizontal Storage System for Irradiated Nuclear Fuel, October 2001, Revision 6.

2.0 PRINCIPAL DESIGN CRITERIA

The objective of evaluating the principal design criteria related to the SSC important to safety is to ensure that they comply with the relevant general criteria established in 10 CFR Part 72[1].

2.1 Structures, Systems, and Components Important to Safety

The SSCs important to safety are summarized in Appendix M, Table M.2-18. Only those features that were not previously approved by the staff for the Standardized NUHOMS® System are addressed in the table.

2.2 Design Basis for SSCs Important to Safety

The NUHOMS®-32PT DSC design criteria summary includes the range of spent fuel types and configurations to be stored, and design criteria for environmental conditions and natural phenomena.

2.2.1 Spent Fuel Specifications

The NUHOMS®-32PT DSC system is designed to store 32 intact standard PWR fuel assemblies with or without BPRAs. Appendix M, Table M.2-1 provides a description of the allowable fuel assembly characteristics. Tables M.2-1 through M.2-15 provide future specification on fuel assemblies and BPRAs to be stored in the NUHOMS®-32PT DSC. There are four design configurations for the NUHOMS®-32PT DSC, the main differences are the thicknesses of the shield plugs and DSC cover plates.

2.2.2 External Conditions

Section M.2.2 of the SAR identifies the bounding site environmental conditions and natural phenomena for which the NUHOMS®-32PT DSC is analyzed. In cases where these did not change, no descriptions were given. External conditions are further evaluated in Sections 3 through 12 of this SER.

2.3 Design Criteria for Safety Protection Systems

A summary of the design criteria for the safety protection systems of the NUHOMS®-32PT DSC, is presented in Section M2.3 of the SAR. Details of the design are provided in Sections M.3 though M.11 of the SAR.

The NUHOMS®-32PT DSC is designed to provide storage of spent fuel for 40 years. The Standardized NUHOMS® System is licensed for 20 years of storage. The fuel cladding integrity is assured by the NUHOMS®-32PT DSC and basket design which limits fuel cladding temperatures and maintains a nonoxidizing environment in the cask cavity. The NUHOMS®-32PT DSC is designed to maintain a subcritical configuration during loading, handling, storage, and accident conditions. A combination of fixed neutron absorbers, soluble boron in the pool, and favorable geometry are employed. The NUHOMS®-32PT DSC shell, closure, and basket are designed and fabricated in accordance with ASME Boiler and Pressure Vessel Code[2] (BP&V), Section III, Subsection NG.

2.4 Evaluation Findings

F2.1 The staff concludes that the principal design criteria for 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, Interim Staff Guidance (ISG), and accepted engineering practices. A more detail evaluation of design criteria and an assessment of the compliance with those criteria is presented in Section 3 through 12 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. American Society of Mechanical Engineers, ASME Boiler And Pressure Vessel Code, Section III, Division 1, 1998 edition including the 2000 Addenda.

3.0 STRUCTURAL EVALUATION

This section presents the results of the structural design review of the amendment request for the addition of the NUHOMS®-32PT DSC to the CoC, and the safety analysis report submitted under 10 CFR Part 72, Subpart L[1]. The review was conducted to assess the safety analysis of the structural design features, the structural design criteria, and the structural analysis methodology to evaluate the expected structural performance capabilities under normal operations, off-normal operations, accident conditions and natural phenomena events for those SSCs important to safety. The NUHOMS®-32PT DSC is to be utilized in the Standardized NUHOMS® System, consisting of the OS197 or OS197H TC, and the NUHOMS Horizontal Storage Module (HSM), Model 80 or 102. The evaluation considers only the canister since as stated in Section M.1, "there is no change to the HSM or the TC as described in the NUHOMS FSAR." In the description, justification, and evaluation of amendment changes provided, it is stated that, "No change to the HSM or TC design is required to accommodate the new canister." The compatibility of the NUHOMS®-32PT DSC for use with the TC and the HSM models identified above is included in the evaluation.

The review was conducted against the appropriate regulations as described in 10 CFR 72.236 that identify the specific requirements for spent fuel storage cask approval and fabrication. The unique characteristics of the spent fuel to be stored are identified as required by 10 CFR 72.236(a) so that the design basis and design criteria that must be provided for the structures, systems and components important to safety can be assessed under the requirements of 10 CFR 72.236(b). The structural evaluation of the SSCs important to safety must also consider and be compatible with the other specific applicable requirements of 10 CFR 72.236 addressing maintaining the spent fuel in a subcritical condition, providing adequate radiation shielding and confinement, providing redundant sealing of the confinement system, providing adequate passive heat removal, providing for wet or dry transfer capabilities, providing for ease of decontamination, providing for a minimum design life of 20 years, providing for testing or other appropriate means to demonstrate acceptable performance under the design conditions. The structural systems are also evaluated to determine if the NUHOMS®-32PT DSC is compatible, to the extent possible, for retrievability of the stored spent fuel. The evaluation also must address whether or not the design, fabrication and testing are conducted under a quality assurance program meeting 10 CFR Part 72, Subpart G, as required by 10 CFR 72.234.

The staff's evaluation and conclusions regarding the acceptability of this canister for use in the Standardized NUHOMS® System with the issuance of a CoC are based on information provided in proposed Amendment No. 5.

3.1 Structural Design of the NUHOMS®-32PT DSC

3.1.1 Structural Design Features

The NUHOMS®-32PT DSC consists of two main structural components that can be described as the cylindrical stainless steel shell confinement vessel or modular canister that in the transport or storage mode is supported by two rails on the inner surface of the cask and the stainless steel basket assembly. Inside the canister is the welded stainless steel basket structure that is supported laterally by eight transition rails against the inner surface of the canister. There are two fabrication options provided for the basket structure. One utilizes

welded 1/4-inch stainless steel plate and the second utilizes 1/4-inch wall stainless steel tube and 1/4-inch stainless steel plate welded together to form the basket structure. The resulting cellular basket structure has tube compartments with a nominal 8.7 inch by 8.7 inch openings. The transition rail structural system is fabricated as a solid section from 6061 aluminum alloy. The four (4) large rails and the four (4) smaller 90-degree quadrant rails are attached to the basket by anchoring the rails at slotted holes to studs that are welded to the basket assembly. The NUHOMS®-32PT DSC basket assembly with the transition rails provide the lateral structural support for the fuel assemblies. Attached to the various tube compartment walls of the basket by machine screws are the neutron absorbing plates and the aluminum thermal plates that are considered as non-structural elements in the design and analysis although they can transmit compressive loads through the thickness of the plate material and add dead loads to the basket assembly. Such plates must maintain their integrity under their own weight for the various conditions. The longitudinal loads from the fuel assemblies are supported by the canister body end cover plates that are stainless steel. The end shield plugs used in the canister are fabricated from carbon steel.

The NUHOMS®-32PT DSC is similar to the NUHOMS®-24B DSC, but with increased fuel assembly capacity. The design has added some dimensional changes to the canister inner volume, by reducing the material thickness. It is also designed as a leak-tight confinement with a top outer cover plate with a test port for leakage testing of the top inner cover plate, and has the bottom cover closure weld for the container that is now in conformance with Subsection NB of the ASME Boiler and Pressure Vessel (BP&V) Code, Section III, Division 1[2]. The confinement boundary is illustrated in Figure M.3-1 of Appendix M and is a positive, fully welded closure system for the container. The baskets used in the NUHOMS®-32PT DSC represents new basket designs. It is noted that the canister is not lifted in a loaded condition by its own lifting lugs which are not important to safety, but is handled in the loaded condition by the lifting fittings of the transfer cask. For transport, the positive closure of the OS197 or OS197H transfer cask, will be used.

The classification of the 32PT DSC canister assembly structural elements are clearly delineated in Table M.2-18 for both of the structural components. The individual structural elements are identified as either “important to safety” or as “not important to safety.” The elements of the canister that are considered important to safety include the canister cylindrical shell, inner and outer top and bottom cover plates, the top and bottom shield plugs, the siphon vent block, the siphon/vent port cover plate, the test port plug, the support ring segment, the grapple ring and support, and the associated weld filler metal. All the elements of the storage basket assembly that are considered important to safety include the basket plates, the basket tubes (if used), the poison plates, the basket rail, the welded studs, washers and hex nuts, and the weld filler metal used for fabrication of the important to safety elements.

The NUHOMS®-32PT DSC will be identified as four separate variants that will define the weight and the size of the canister (32PT-S100, 32PT-S125, 32PT-L100 and 32PT-L125). There is a long and a short version for each of the 100-ton versions and the 125-ton versions. There is a 6-inch difference in the canister lengths between the long and the short configurations and 8-1/2-inches difference in the cavity lengths. The canister outside and inside diameters are identical for all four variants. The loaded dry weights for these four variants of canisters range from 88,000 pounds to 101,200 pounds. The loaded wet weights for these four variants range from 94,700 pounds to 112,500 pounds. The maximum critical lift weight on any NUHOMS®-32PT DSC is approximately 224,000 pounds. The previous evaluation of the lifting trunnions of

the OS197 and OS197HTC defines their critical lift capacity at 208,500 pounds and 250,000 pounds, respectively. Consequently, any of the four variants of the NUHOMS®-32PT DSC can be accommodated by the OS197H TC, but the OS197 TC can only accommodate the 32PT-S100 and 32PT-L100 TCs with the water drained from the DSC cavity.

To preclude air in-leakage during storage, the canister cavity is pressurized above atmospheric pressure with helium and the canister is tested to meet the leak tight criteria of ANSI N14.5-1997.

3.1.2 Structural Design Criteria

The NUHOMS®-32PT DSC design of the canister confinement vessel (the shell structure) is based on the ASME BP&V Code (1998), Section III, Division 1, Subsection NB, Class 1 Components, as identified in Sections M.2.2.5 and M.2.5 of the SAR amendment, with noted alternatives. The 2000 Addenda to the ASME Code is also incorporated into the design criteria. The specific alternatives to the Code have been identified and documented in Table M.3.1-1 of the SAR amendment. In addition, the welded joints between the top inner and outer cover plates and the cylindrical shell are being designed and fabricated in accordance with ASME Code Case N-595-1 by having the root and final passes of the partial penetration welds examined by dye penetrant testing (PT). For normal loading conditions the stress limits will be based on NB-3200 that for Level A service limits means consistency with NB-3222 and for Level B and Level C the stress limits are consistent with NB-3223 and NB-3224, respectively. For accident loading conditions the stress limits will be based on the Level D service limits defined in NB-3225 and Appendix F.

The NUHOMS®-32PT DSC basket design for the steel elements is also based on the ASME BP&V Code (1998), Section III, Division 1, Subsection NG, for Core Support Structures, as identified in Sections M.2.2.5 and M.2.5 of the SAR amendment, with noted alternatives. The 2000 Addenda to the ASME Code is also incorporated into the design criteria. The specific alternatives have been identified and documented in Table M.3.1-2. For normal loading conditions the stress limits will be based on NG-3200. For Level A service that means consistency with NG-3222, and for Level B and Level C it means that the stress limits are consistent with NG-3223 and NG-3224, respectively. For accident loading conditions the stress limits will be based on the Level D service limits defined in NG-3225 and Appendix F.

For the aluminum structural element of the NUHOMS®-32PT DSC basket assembly, the aluminum transition rail, under normal loading conditions is evaluated under the requirements of NG-3227.1(a). Under the accident loading conditions, the radially confined (except for radial clearances and as-fabricated radial tolerances) solid aluminum rail will conform with the lateral deflections of the basket cell structure, rail cover plate, and the canister shell that confine the rail. The rail must not allow the displacements or stresses of the basket cell structure to be exceeded.

Stability criteria have also been defined for axial and lateral loads for the basket structure. Design stresses under normal conditions are based on considering the Level A primary membrane stress, 2/3 of the yield stress at temperature and the critical buckling stress for a rectangular plate under compression along two opposite edges. Under accident conditions the Level D primary membrane stress, 0.9 of the yield stress at temperature and the same critical buckling stress will be used to define the permitted stress. In addition, based on the results of

finite element analyses the criteria of Appendix F of Section III of the ASME B&PV Code, specifically F-1341.3 will be applied for evaluation of the lateral stability. The criteria of F-1334.3(b) will be used for a supplementary hand calculation to ascertain the stability of members under in-plane compression.

3.1.2.1 Individual Loads

Section M.2.2 and Table M.2-20 of the SAR amendment identify the relevant individual loads, including those resulting from natural phenomena, that the NUHOMS®-32PT DSC system is designed to resist. All analyses completed for the NUHOMS®-32PT DSC reflect the changes in the weights of loaded NUHOMS®-32PT DSC variants as a result of proposed Amendment 5 to the SAR.

3.1.2.1.1 Dead Loads

The maximum weight of the fully loaded (dry condition) NUHOMS®-32PT DSC series is 101,140 pounds with the design value taken as 101,200 pounds. The fully loaded NUHOMS®-32PT DSC series with water (wet condition) has a maximum weight of approximately 112,500 pounds. The maximum weight of a transfer cask with the heaviest NUHOMS®-32PT DSC series is 213,200 pounds. These loads are considered for the design of the system in all of its possible orientations.

3.1.2.1.2 Live Loads

The live loads considered for the design of the NUHOMS®-32PT DSC are the normal handling loads associated with lifting the cask, placing the cask in the TC, down ending the cask in the TC to a horizontal orientation, moving the cask in the TC with the transport trailer, removal from the transport system, and hydraulic insertion into the HSM or extraction from the HSM. The transfer loads include the following loads: axial load of +/- 1.0g, transverse load of +/- 1.0g, vertical load of +/- 1.0g, and under a combined condition of all loads of +/- 0.5g in each of the three directions. The normal design insertion load into the HMS acting axially on the NUHOMS®-32PT DSC is 80,000 pounds and the extraction load is 60,000 pounds. The off-normal design loads for both insertion and extraction are 80,000 pounds acting axially on the NUHOMS®-32PT DSC. These criteria are consistent with those for the 24P, the 52B, and the 61BT DSCs.

3.1.2.1.3 Pressure Loads

The design internal pressure for normal conditions is 15 psig and for the off-normal conditions is 20 psig. The internal test pressure is 12 psig, which is applied without the NUHOMS®-32PT DSC outer top cover plate in place during fabrication, and then 18 psig, which is later used for the entire DSC under the pressure of helium. The accident internal pressure is 105 psig. Tables M.4-7, 4-12, and 4-15 provide the maximum internal pressures during normal, off-normal, and accident conditions that were used in the design and evaluation of the NUHOMS®-32PT DSC.

3.1.2.1.4 Thermal Loads

The thermal loading is based on the NUHOMS®-32PT DSC containing spent fuel rejecting 24kW decay heat with the ambient air temperature range of -40 °F to 117 °F. The thermal evaluation of normal conditions, off-normal conditions and accident conditions are provided in Section M.4 of the amendment to the SAR, with Tables M.4-3 thru M.4-5, M.4-9 thru M.4-11, and M.4-14 providing the calculated temperatures under these various loading conditions on the structural components as a maximum and a minimum temperature. These temperature extremes are expected to occur only for short periods of time, on the order of hours. The range of 0 °F to 100 °F are expected to bound the temperatures that could exist for a period of days. The lifetime average temperature ambient is taken as 70 °F. Thermal conditions are also calculated for other conditions of operation as described in Section M.3.4.4 of the SAR amendment. The design is based on providing adequate clearances between the fuel, the basket, the poison plates and the canister shell that experience temperature differentials and allow free thermal expansion.

3.1.2.1.5 Flood Loads

Flood loading is addressed in Section M.2.2.2 of the amendment. The NUHOMS®-32PT DSC cask system is designed for flood water to a depth of 50 feet and water velocity of 15 feet per second, consistent with the 24P, the 52B, and the 61BT DSCs.

3.1.2.1.6 Tornado Wind and Tornado Missiles

The NUHOMS®-32PT DSC cask system is designed for the same tornado wind loads and tornado missiles as the 24P, the 52B, and the 61BT DSCs. The NUHOMS®-32PT DSC system is evaluated for a design basis tornado wind velocity of 360 mph with a translational velocity of 70 mph and a pressure drop of 3 psig as discussed in Section 3.2.1 of the Standardized NUHOMS® System FSAR. Tornado missiles are listed in Section 3.2.1.2 of the FSAR.

3.1.2.1.7 Seismic

The design earthquake for the NUHOMS®-32PT DSC system is based on an earthquake that produces a horizontal ground acceleration of 0.25g and a vertical acceleration of 0.17g that is consistent with the design earthquake for the 24P, the 52B, and 61BT DSCs. The location of these accelerations is taken at the top of the concrete pad/basemat of the HSM. NRC Regulatory Guides 1.60 and 1.61 are utilized in the seismic design.

3.1.2.1.8 Snow and Ice

The environmental loads on the NUHOMS®-32PT DSC canister and basket, from snow and ice, are negligible or zero, and do not have to be considered since either the TC or HSM will be the loaded component in the NUHOMS®-32PT DSC system from snow or ice. Loads for the HSM are provided in Section 3.2.4 of the FSAR and are consistent with the NUHOMS®-24P, the 52B, and the 61BT DSCs

3.1.2.1.9 Lightning

The environmental effect on the NUHOMS®-32PT DSC canister and basket from lightning will be negligible and does not have to be considered since either the TC or the HSM will surround and protect the canister and its internals from lightning. This is consistent with the criteria for the 24P, the 52B, and the 61BT DSCs.

3.1.2.1.10 Fire and Explosion

The NUHOMS®-32PT DSC system contains no flammable material and the concrete and steel used for the system fabrication can withstand any credible fire hazard. No explosions at an ISFSI are considered credible, since no explosive materials are present in the fission products or cover gases. Externally initiated explosions are considered to be bounded by the design basis tornado generated loads. In order to utilize the NUHOMS®-32PT DSC, licensees are required by 10 CFR Part 72, Subpart K, to confirm that no conditions exist near the ISFSI that would result in pressures due to off-site explosions which would exceed those postulated for tornado wind or missile effects. This is consistent with the 24P, the 52B, and the 61BT DSCs.

3.1.2.2 Loading Combinations

The NUHOMS®-32PT DSC system is subjected to the same loads and load combinations as the existing NUHOMS®-24P, -52B, or the 61BT DSCs. The loading combinations are provided in Table M.2-15. The loading combinations reflect the various operational conditions and events including accidents that may occur during the lifetime of the utilization of the NUHOMS®-32PT DSC. The design calculations reflect evaluations against these combinations. The loading combinations include the following cases:

Non-operational events
Fuel loading
Draining/Drying
Transfer Trailer Loading
Transfer to/from ISFSI
HSM Loading
HSM Storage

Table M.3.6-1 shows the normal operating loads for which the safety-related/important to safety components are designed. Table M.3.6-8 provides the same information for the off-normal operating loads. The loading combinations represent the design events identified by ANSI/ANS 57.9-1984, “Design Criteria for an Independent Spent Fuel Storage Installation” and are in accordance with NRC Regulatory Guide 3.48. These design events are defined in the FSAR in Section 8.1 and 8.2. For the accident events the considerations to be made are based on the accident analysis scenarios identified in Section M.11

3.1.3 Allowable Stresses

The allowable stresses for the NUHOMS®-32PT DSC canister shell are based on the ASME BP&V Code (1998), Section III, Division 1, Subsection NB-3200, for normal and off-normal conditions and Appendix F to Section III for accident conditions. The 2000 Addenda is also incorporated into the design bases. Section M.2.2.5.1.1 and Table M.2-16 of the SAR

amendment provide the detailed guidance for the stress allowables under the various loading conditions and events, including normal, off-normal and accident conditions. The stress allowables are identified with respect to each category of stress, whether as a primary membrane stress, such as induced by internal pressure, a primary membrane plus bending stress that can occur in the shell geometry transition regions, or a bearing stress. Also the various service levels (Level A through Level D) are identified. It is noted that the stress allowables are also based on the temperature conditions of the material that will exist under the specific service conditions. Fatigue considerations are also made for the normal loads that include repetitive loads.

The allowable stresses for the steel elements of the fuel basket assembly are also based on the ASME BP&V Code (1998), Section III, Division 1, Subsection NG-3200, including the 2000 Addenda, for normal and off-normal conditions and Appendix F of Section III for accident conditions except as noted in Table M.3.1-2 listing the Code alternatives. Section M.2.2.5.1.2 and Table M.2-17 of the SAR amendment provide the detailed guidance for the stress allowables under the various loading conditions and events, including normal, off-normal and accident conditions. The stress allowables are identified with respect to each category of stress, whether pure primary shear or a buckling compressive stress. Provisions are identified for addressing such conditions as service temperatures, fatigue, and impact loadings. The numerical values of the stress limits for service at 650 °F for normal and accident conditions are provided in Tables M.3.3-1 and M.3.3-3 of the SAR amendment.

The allowable stresses for the aluminum transition rails are based on the ASME B&PV Code, Section III, Division 1, Subsection NG, Paragraph NG-3227.1(a). Tables M.3.3-4 thru M.3.3-6 of the SAR amendment provide the materials data based on the ASME B&PV Code (1998), Section II, Part D, with 2000 Addenda, and the American Society of Metals (ASM) and the Aluminum Association.

3.1.4 Materials

The applicant provided a general description of the materials of construction in SAR Sections M1.2 and M.3.1. Additional information regarding the materials, fabrication details and testing programs can be found in SAR Section M.9.1. The staff reviewed the information contained in these Sections; Table M.3.1-1, ASME Code Alternatives, and the information presented in the license drawings, to determine whether the NUHOMS®-32PT DSC meets the requirements of 10 CFR 72.24(c) (3) and (4), 72.122(a), (b), (h) and (I), and 72.236(g) and (h). In particular, the following aspects were reviewed: materials selection; brittle fracture; applicable codes and standards; weld design and specifications; and chemical and galvanic corrosion.

3.1.4.1 Structural Materials

The material properties used in the structural analyses are in accordance with the ASME BP&V Code (1998), Section II, Part D, with the 2000 Addenda. Tables M.3.3-1 and M.3.3-3 of the SAR amendment provide the basic mechanical properties of the stainless steel materials. In the structural analysis, the bilinear behavior of the SA-240, types 304 and XM-19 stainless steel, was utilized based on the properties identified in Section M.3.7.5.3.1 and Tables M.3.7-3 of the SAR amendment. The top and bottom shield plugs are fabricated from A36 steel with the material properties from the ASME B&PV Code, Section II, Part D as shown in the SAR amendment, Table M.3.3-2. The durability of the canister shell, basket, and other assembly

components of stainless steel will allow the material to perform its design function beyond the design life of the NUHOMS®-32PT DSC system. In addition, the basket and the interior of the canister shell are under a constant inert helium gas environment once the spent fuel has been loaded and the system sealed with the final structural and confinement welds. The DSC may be fabricated by other than ASME Certificate Holders, and the quality assurance requirements of 10 CFR Part 72, Subpart G and NQA-1 are imposed instead of the requirements of NCA-3800 of the ASME B&PV Code, Section III, Division 1.

3.1.4.2 Nonstructural Materials

The basket assembly structure consists of a grid assembly of welded stainless steel plates or tubes that make up the fuel compartments. Each fuel compartment accommodates aluminum and/or neutron absorbing plates for criticality control. The neutron absorber plates for criticality control are either an alloy (e.g., borated aluminum) or a metal matrix composite (e.g., BorAlyn, METAMIC, Boral, etc.). Additionally, B_4C (boron carbide) pellets enclosed in stainless steel tubes are also used for criticality control. In accordance with Section M.9 of the amendment, appropriate acceptance testing will be used to ensure that the neutron absorbers have the minimum specified ^{10}B loading for borated aluminum, Boral, BorAlyn, METAMIC, and the poison rod assemblies. An 1100 aluminum alloy is also used in the grid assembly as heat transfer plates.

The staff concludes that the aluminum plates used for the grid assembly are suitable for heat transfer. Further, the staff concludes that the neutron absorbers (i.e., plates and rods) will be adequately durable during service life of the cask. The acceptance and qualification for the neutron absorbers are discussed in Chapter 9 of this SER.

3.1.4.3 Welds

The DSC cylindrical shell is assembled using full penetration longitudinal welded joints and circumferential welded joints at the junction between the bottom plate and the shell. These welds are performed in accordance with ASME BP&V Code Section III, Subsection NB-4000. The top outer and inner cover plates are joined to the shell by partial penetration groove welds. The applicant has taken an alternative to the ASME Code, Section III with respect to the design of this redundant closure. All top and bottom end closures welds are multiple-layer welds. All welded components of the basket assembly are performed in accordance with ASME Code, Section III. Radiographic, ultrasonic and liquid penetrant examination requirements of these welds are summarized in Section M.3.1.2.1 of the SAR. All alternatives to the ASME Code are identified in Table M.3.1-1 of the SAR.

The DSC materials of construction (e.g., stainless steel, carbon steel, etc.) are readily weldable using common available welding techniques. The use of an experienced fabricator will ensure that the process chosen for fabrication will yield a durable canister. The DSC welds were well-characterized on the drawings, and standard welding symbols and notations in accordance with American Welding Society (AWS) Standard A2.4, “Standard Symbols for Welding, Brazing, and Nondestructive Examination” were used.

The staff concludes that the welded joints of the NUHOMS®-32PT DSC meets the requirements of the ASME Code. Although the DSC closure welds are partial penetration welds, this configuration will perform its intended structural and confinement functions.

3.1.4.4 Bolting Materials

The NUHOMS®-32PT DSC is an all-welded canister.

3.1.4.5 Coatings

No zinc, zinc compounds, or zinc-based coatings are used on the carbon steel top shield plug of the DSC. The shield plug will be coated with an electroless nickel-phosphorous coating which has been used in the nuclear industry. The coating will protect the steel from excessive oxidation of the surface.

3.1.4.6 Mechanical Properties

Tables M.3.3-1 through M.3.3-6 of the SAR provide material property data for the major materials including: stainless and carbon steels, and aluminum alloys. The values were obtained from ASME Code, Section II, Part D, or other acceptable references. The staff independently verified the temperature dependent values for the yield and ultimate stresses, modulus of elasticity, and coefficient of thermal expansion. The staff concludes that these material properties are acceptable and appropriate for the expected load conditions (e.g., static or dynamic, impact loading, hot or cold temperature, wet or dry conditions) during the license period.

3.1.4.7 Chemical and Galvanic Reactions

In Section M.3.4.1 of the SAR, the applicant evaluated whether chemical, galvanic or other reactions among the materials and environment would occur. The staff reviewed the design drawings and applicable sections of the SAR to evaluate the effects, if any, of intimate contact between various materials of construction during all phases of operation. In particular, the staff evaluated whether these contacts could initiate a significant chemical or galvanic reaction that could result in components corrosion or combustible gas generation. Pursuant to NRC Bulletin 96-04, a review of the DSC system, its contents and operating environments, has been performed to confirm that no operation (e.g., short-term loading/unloading or long-term storage) will produce adverse chemical or galvanic reactions. The DSC is primarily fabricated with stainless and carbon steels, and aluminum. The vacuum drying procedures of SAR Section M.8.1.3, (two cycles of sequentially evacuating and backfilling the cask with the inert helium), and the design, configuration and operation of the vacuum drying equipment will ensure that contamination of the cover gas with air is minimal. The staff concludes that in this dry, inert environment, the DSC components are not expected to react with one another or with the cover gas. Further, oxidation, or corrosion, of the fuel and the DSC internal components will effectively be eliminated during storage.

The applicant identified that small amounts of hydrogen gas may be generated in the DSC prior to the submersion of the transfer cask into the spent fuel pool due to initial passivation state of the aluminum. The applicant conducted tests on aluminum metal matrix composites coupled with 304 stainless steel. The applicant concluded that the small amounts of hydrogen which may be generated during the DSC operation does not result in a safety hazard. To ensure that the safety hazards associated with the ignition of hydrogen gas are mitigated, the procedures of SAR Section M.8.1 and M.8.2 are employed to monitor the concentration of hydrogen gas

during any welding or cutting operations. The staff concludes that these procedures are adequate to prevent ignition of any hydrogen gas that may be generated during welding operation. Further, the potential reaction of the aluminum with the spent fuel pool water will not impact the ability of the aluminum grid plates and the neutron absorbers to perform their intended function because the loss of aluminum metal is negligible.

3.2 Normal and Off-Normal Conditions

3.2.1 Analysis Methods

The NUHOMS®-32PT DSC assembly was analyzed using the finite element method of the ANSYS (Revision 5.6) software package. The model was developed by creating two separate models, one each of the top and bottom half-length of the canister shell and utilizing the symmetry of the shell so that only a quadrant was idealized for the model. This is an acceptable modeling technique because the known stress conditions for most loadings, such as internal pressure, are based on classical unique numerical solutions. With this information it is possible to verify the acceptability of the model in representing the shell halves in the more difficult regions to define stresses without computer capability. Boundary conditions can be imposed to duplicate the prototype behavior. Figures 8.1-14a and 8.1-14b of the FSAR present the two models used for the analyses. The models were three-dimensional models that included the details of the cylindrical shell and the closure plates. For one specific loading condition, addressing the loading arising during the horizontal loading and unloading of the NUHOMS®-32PT DSC via the grapple ring, another finite element model was used as shown in Figure 8.1-15.

The NUHOMS®-32PT DSC basket assembly was also analyzed using a two-dimensional finite element model using the ANSYS software package. The model represented the canister shell, the rails, the basket, and the connections or boundary conditions between them. A minimum of three (3) finite elements were used through the thickness of all parts being represented in the 2D-plane. The section or disk thickness of the 2D model represented one element of the NUHOMS®-32PT DSC system model, and was analyzed as representative of the actual physical prototype. This technique is acceptable because the boundary conditions that can be imposed at the model edges, can be related to the full physical prototype. The model used for the aluminum rails and basket assembly is shown in Figures M.3.6-3 and M.3.6-4. The finite element model also included a representation of the gap spaces that would exist between the basket rails and the inner surface of the canister, the gaps that would exist between the canister and the transport cask, and the connections that exist between the basket and the rails. This latter detail was represented by spring elements, which act in parallel to the contact elements and are defined with non-linear stiffnesses. This provides for the capability to represent drop loadings that can then be analyzed.

3.2.2 Loading Cases Analyzed

The normal operating load cases analyzed for the canister included the dead weight loads, design internal pressure, design external pressure, design basis thermal loads, operational handling loads and design basis live loads. In order to complete the analysis for the operational handling loads there were actually two situations considered. The first addressed the inertia loads associated with on-site handling and transporting the DSC between the fuel handling/loading area and the HSM, and the second associated with loading the DSC into (or

removing the DSC from) the HSM. Each of the loading cases was analyzed for the NUHOMS®-32PT DSC in each of the key orientations. Table M.3.6-1 of the SAR amendment identifies the individual loads and the components to which they apply and Table M.2-15 identifies the loading combinations for normal loads. It is noted that the A-36 steel shield plugs are not specifically analyzed since they are free to expand thermally and serve only as a mass for shielding.

The normal loading cases analyzed for the basket assembly included the dead weight loads, the thermal loads, and handling/transfer loads including side drop loads. In addition, individual elements within the basket assembly were analyzed for the loads to determine the compressive strength and determine the buckling loads, and weld stresses.

The off-normal loading cases evaluated include a jammed DSC either during a loading or an unloading operation, and operation during either the cold temperature extreme of -40°F, or operation during the hot temperature extreme of 117°F. These conditions are included with the off-normal internal pressure in the DSC of 20 psig.

3.2.3 Analysis Results

The results of the various analyses for normal and off-normal loads are shown graphically in Figures M.3.6-6 through M.3.6-13 of the SAR amendment. Table M.3.6-2 presents a summary of the resulting stresses for the various loadings from the normal and off-normal conditions for the NUHOMS®-32PT DSC shell structure. All computed stresses are well within the allowable stress values. Tables M.3.6-5 and M.3.6-6 provide the calculated stresses for the basket assembly elements under the normal loading conditions for the aluminum rails. All stresses are less than the allowables.

3.3 Accident Conditions

3.3.1 Analysis Methods

The analysis methods include static and dynamic analyses utilizing elastic and elasto-plastic methods, as well as classical methods with hand and computer based computations and numerical methods, such as finite element methods. The specific analytical methods used are identified for the particular structural element, component, or assembly being analyzed and the selection of the method for use is influenced by the complexity of the structure, the importance of the structure, the loading conditions, and other characteristics.

The finite element analysis methods described herein in Section 3.2 were also utilized in the analysis of accident conditions. Many of the same idealized models were used for evaluating the accident conditions, with the only difference being the loading conditions imposed. All methods of analysis used for evaluation of the NUHOMS®-32PT DSC are accepted methods and have been previously used for similar analyses.

3.3.2 Loading Cases Analyzed

Section M.3.7 of the SAR amendment addresses the accident load conditions which also, in this document, encompass the loads resulting from natural phenomena. The following loading cases have been addressed.

a. Reduced HSM air inlet and outlet shielding
b. Debris blockage of HSM air inlet and outlet opening
c. Accidental transfer cask drop with loss of neutron shield
d. Pressurization due to fuel cladding failure within the DSC
e. Postulated DSC leakage
f. Design basis flood
g. Tornado winds and tornado generated missiles
h. Lightning effects
i. Design basis seismic event

Loading Case a. is bounded by Loading Case b. for the thermal effects on the structural aspects of the scenario. In addition, the thermal effects of Loading Case b., with the resulting temperatures of the NUHOMS®-32PT DSC components, are listed in Table M.4-14 of the amendment to the SAR. These temperatures were considered in the NUHOMS®-32PT DSC thermal evaluation, and the impact on the canister is encompassed in the analyses. The increased thermal loads on the HSM are bounded by the thermal effects of the NUHOMS®-24P DSC system that is already addressed by the current CoC.

Loading Case c., with the loss of the neutron shield, has no direct impact on the structure, but the initiating event of the transfer cask being dropped is considered. The components of the NUHOMS®-32PT DSC system that are evaluated due to their influence on structural performance are the canister shell, the basket, and the on-site transfer cask. The drop scenarios for the design are for a horizontal side drop from a height of 80 inches with the vertical end drop being an 80 inch drop on the top or the bottom of the transfer cask. The corner drop considered for an 80 inch drop at 30 degrees to the horizontal was found to be enveloped by the end and side drops. The cask side drops consider the various orientations with respect to the two support rails of the canister so as to bound the possible maximum stress orientation for stresses within the canister shell. In addition, for a conservative assumption, the entire fully loaded weight of the DSC is assumed to be on one support rail. For the vertical drop effects on the canister shell, it is conservatively assumed that no energy is absorbed by the cover plates. Inertia loadings are based on the forces associated with the 75g deceleration value used for the Standardized NUHOMS® System. The corner drop produces a 25g loading and the end drop presents a 60g load. The canister shell was also analyzed for buckling under the vertical drop loads. In addition to the analyses for the canister shell, the basket assembly and its various components were also analyzed under these loading conditions for the dropped transfer cask scenario.

Loading Case d. results in a computed maximum internal pressure of 102.9 psig in the canister shell which remains below the accident design pressure of 105 psig.

Loading Case e. has no structural loading implications.

Loading Case f. is the result of specific design bases selected for the cask which must not be exceeded at the location where the NUHOMS®-32PT DSC system is used.

Loading Case g. is the result of the specific analysis of the Standardized NUHOMS® System since the NUHOMS®-32PT DSC should not be directly exposed to tornado effects.

Loading Case h. has no structural loading implications.

Loading Case i. is addressed using Regulatory Guides 1.60 and 1.61. Natural frequencies are determined for the shell bending mode as well as the shell ovalling mode. Spectral accelerations are determined for use in analysis of the seismic loads on the DSC shell and the internal basket. For this loading it was necessary to re-evaluate the HSM for compatibility with the NUHOMS®-32PT DSC since it has a larger weight than the 24P and 52B systems.

3.3.3 Analysis Results

Tables M.3.7-4 and M.3.7-5 of the amendment to the SAR provide the summary results for the enveloping loading cases for the accident load conditions on the basket assembly from the controlling drop loading cases. The highest percentage of the allowable stress calculated was 97% for a condition of combined primary membrane and primary bending, that occurred in the cellular structure of the basket resulting from the 75g side drop. Based on the calculated stresses for the various components of the NUHOMS®-32PT DSC shell structure for the various loading combinations, the highest stresses based on a percentage of the allowable, were as follows based on the stress summaries of Tables M.3.7-8 through M.3.7-10.

For the normal and off-normal conditions, the highest stress calculated for the NUHOMS®-32PT DSC was 94.7% of the allowable for primary membrane plus primary bending of the DSC shell under the normal transfer loading condition. Only one other area was stressed above 90% of the allowable, with most of the maximum values at 60% or less. This stress is reported in Table M.3.7-8.

For the accident conditions for Level C allowable stress limits, the highest stress was 94.5% of the allowable stress under a condition of off-normal unloading, during the hot temperature condition. This calculated stress was located in the outer bottom cover plate and is reported in Table M.3.7-9.

For accident conditions for Level D allowable stress limits, the highest stress was 95.3% of the allowable stress under a condition of an accidental side drop under the hot thermal conditions. The calculated stress was located in the outer top cover plate as a primary membrane plus primary bending stress as reported in Table M.3.7-10.

3.4 Evaluation Findings

F3.1 The SSCs important to safety are described for the NUHOMS®-32PT DSC System in proposed Amendment 5, in sufficient detail to enable an evaluation of their structural effectiveness and are designed to accommodate the combined loads of normal, off-normal, accident and natural phenomena events.

F3.2 The NUHOMS®-32PT DSC System is designed to allow 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 system that will prevent retrieval of the stored spent nuclear fuel.

F3.3 The cask is designed and fabricated so that the spent nuclear fuel is maintained in a subcritical condition under credible conditions. The configuration of the stored spent fuel is unchanged. Additional criticality evaluations are discussed in Section 6 of this SER.

F3.4 The cask and its systems important to safety are evaluated to demonstrate that they will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F3.5 The staff concludes that the structural design of the NUHOMS®-32PT DSC system is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The structural evaluation provides reasonable assurance that the NUHOMS®-32PT DSC system will enable safe storage of spent nuclear fuel. This finding is based on a review that considered the regulation itself, appropriate regulatory guides, applicable industry codes and standards, accepted practices and confirmatory analysis.

3.5 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; Subpart L, "Approval of Spent Fuel Storage Casks."

2. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division 1, 1998 including the 2000 Addenda.

4.0 THERMAL EVALUATION

The staff reviewed the NUHOMS®-32PT DSC thermal design and performed independent confirmatory calculations to assess that the cask and fuel material temperatures are within their allowable values or criteria for normal, off-normal, and accident conditions, as required in 10 CFR Part 72[1]. The staff's independent analyses confirmed that the temperatures of the fuel cladding (fission product barrier) will be maintained below the acceptable limits during DSC loading, draining, drying, and inerting, as well as throughout the planned storage period. The staff's review followed, as appropriate, guidance outlined in Section 4 of NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems,"[2] as well as associated ISG documents.

4.1 Spent Fuel Cladding

The predicted fuel cladding long term storage temperatures were assessed to be below the expected damage thresholds identified in Table M.4-1 of the SAR for the three acceptable heat load configurations, as proposed by the applicant. These configurations are shown in Figures M.4-1, M.4-2, and M.4-3 of the SAR. Tables M.4-2, M.4-8, and M.4-13 of the SAR present the maximum temperature criteria for fuel cladding short term normal conditions, off-normal events, and accident conditions, respectively. The temperature limits for spent fuel cladding are based on the SFPO ISG-11, Revision 2[3]. ISG-11 establishes that a maximum fuel cladding temperature limit of 752°F (400°C) is applicable to both normal conditions of storage and all short term operations. In addition, thermal cycling of cladding temperature with differences greater than 117°F (65°C) during drying or backfilling operations is not permitted per ISG-11. The maximum fuel cladding temperature limit of 1058°F (570°C) is applicable only for accidents or off-normal thermal transient conditions. For the NUHOMS®-32PT DSC unloading operations, the maximum fuel cladding temperature during cask reflood is postulated to be significantly less than the vacuum drying condition because of the presence of water/steam. The reflooding procedure also requires significantly less time than the vacuum drying procedure. Consequently, during cask reflood, a lower temperature rise is expected when compared to the cask vacuum drying operations.

4.2 Cask System Thermal Design

The NUHOMS®-32PT DSC is designed to store 32 intact standard PWR fuel assemblies with or without BPRAs, (supported by the thermal analysis presented in Appendix J of the Standardized NUHOMS® System FSAR) with assembly average burnup, initial enrichment and cooling time as described in Table M.2-1 of the SAR. The DSC is evacuated and backfilled with helium at the time of loading. The DSC is designed to passively reject decay heat during storage and transfer for normal, off-normal and accident conditions while maintaining component temperatures and pressures within the limits specified by the applicant in the SAR.

4.3 Thermal Load Specifications

The maximum total decay heat load per DSC is 24 kW, with a maximum per assembly heat load of 1.2 kW when zoning (preferential loading) is used to distribute the heat load in a nonuniform manner. The loading configurations, based on the decay heat that is approved by the staff, are presented in the Certificate of Compliance (CoC) for the NUHOMS®-32PT DSC.

4.4 Model Specifications

4.4.1 Thermal Properties of Materials

Material property tables for the DSC shell and basket components are included in Section M.4.2 of the SAR. The temperature range for the material properties covers the range of temperatures encountered during the thermal analysis with some exceptions. The extrapolation of material properties for higher temperatures not provided in the SAR is justified by the fact that for most of the DSC materials, thermal conductivity increases with temperature. Therefore, an increase in material thermal conductivities for higher temperatures makes the thermal results presented in the SAR slightly conservative. The applicant stated that material properties, which are determined to be critical to the thermal performance of the design (i.e., emissivity of materials used in radiation heat transfer calculations), will be validated by the quality assurance program.

4.4.2 Use of Effective Thermal Conductivity Models

4.4.2.1 Spent Fuel Effective Thermal Conductivity

The applicant developed models to simulate the effective thermal properties of the fuel with a homogenized material occupying the volume within the basket by using the total fuel active length. The calculated effective thermal conductivity of the fuel assemblies takes credit for conduction and radiation heat transfer only. The fuel assembly with the lowest effective thermal conductivity for the design basis heat load is used to determine the bounding assembly to perform the thermal evaluation of the NUHOMS®-32PT DSC. The applicant calculated the bounding assembly to be the Westinghouse (WE) 14x14 fuel assembly array.

4.4.2.2 Neutron Shield Region Effective Thermal Conductivity

The neutron shield of the OS197/OS197H transfer cask is a water filled jacket surrounding the cask's structural shell. Support ribs act to divide up the void volume within the neutron shield into multiple enclosed regions. Effective thermal conductivity values for these enclosures are obtained by considering a combination of conduction and convection heat transfer through these regions. Using a series of correlations that were developed to model the heat transfer inside vertical and horizontal enclosures, the applicant computed effective thermal conductivities as a function of angular position around the cask circumference. These effective thermal conductivities are correlated to the calculated Nusselt number for each of the circumferential positions of the cask. According to the applicant's calculations, the presence of convection within the shield will enhance the thermal conductivity by a factor of 10 to 20 over that computed assuming conduction only through the shield region.

To justify the assumed modes of heat transfer through the water filled neutron shield region of the transfer cask, the applicant provided a confirmatory computational fluid dynamic (CFD)[4] calculation. The applicant used the CFD calculation to directly determine the flow regime pattern that would exist within the neutron shield at various circumferential positions around the cask. The CFD calculation results confirmed the computed values of effective thermal conductivity within the neutron shield that were determined by the applicant applying a set of semi-empirical relationships for convection inside a generic enclosure.

4.4.3 Boundary Conditions

Thermal analyses were performed for normal conditions involving the following cases:

- maximum normal temperature of 100°F (37.7°C) with insolation
- minimum normal temperature of 0°F (-17.7°C) without insolation
- average ambient temperature of 70°F (21.1°C) with insolation for long term storage

Previous analysis of the HSM and Transfer Cask (TC)[5] furnished the surface temperature of the DSC shell. The maximum calculated DSC temperatures are applied to the DSC surface as boundary conditions for the detailed DSC thermal model. Off-normal conditions for storage and transfer that were analyzed included:

- maximum temperature of 107°F (41.66°C) with insolation
- minimum temperature of -40°F (-40°C) without insolation

As before, previous analyses of the HSM and TC provided the surface temperatures. For transfer operations when ambient temperatures exceed 100°F (37.7°C) up to 117°F (47.2°C), a solar shield is utilized. Steady state, off-normal conditions were assumed prior to the fire accident analysis. A fire temperature of 1475°F (801.6°C), with emittance of 0.9, and a duration of 15 minutes, (based on a full consumption of a 300 gallon diesel fuel source) with complete engulfment of the TC for the duration of the fire accident, was assumed.

4.4.4 Model Configuration

Model dimensions were verified according to the DSC drawings presented in Safety Analysis Report (SAR) Chapter 1. To bound the heat conductance uncertainty between adjacent components, conservative gaps have been included in the model. All heat transfer across these gaps is by gaseous conduction (helium backfill). Assurance of retention of the backfill gas inside the DSC is achieved by meeting the leak tight criteria. The NUHOMS®-32PT DSC thermal analyses consider the effect of the decay heat varying axially along a fuel assembly. The axial heat flux profile utilized is based on the report entitled: "Topical Report on Actinide-Only Burnup Credit for PWR Spent Nuclear Fuel Packages," Office of Civilian Radioactive Waste Management, DOE/RW-0472, Revision 2, September 1998. Within the three-dimensional DSC models, heat is transferred via conduction through fuel regions, the poison plates, steel of the basket and the gas gaps between the poison plate and steel members. All heat transfer across the gaps is by gaseous conduction. Heat is transferred through the basket support rails via conduction. The applicant modeled the performance of the NUHOMS®-32PT DSC using the ANSYS® finite element analysis code which is capable of solving steady state and transient thermal analysis problems in one, two or three dimensions. Models developed for normal storage included a three-dimensional model to represent approximately half of the length of the NUHOMS®-32PT DSC cavity.

4.5 Evaluation of Cask Performance for Normal Conditions

The maximum fuel cladding temperature for long term storage is evaluated by the applicant for each of the three decay heat load zoning configurations that are shown in Figures M.4-1, M.4-2, and M.4-3 of the SAR. The results obtained are compared with the corresponding ISG-11 fuel

cladding temperature limits for long term storage in Table M.4-1 of the SAR. According to the results presented in this table, the bounding case corresponds to Loading Configuration 3 which is shown in Figure M.4-3 of the SAR. For this case a margin of 114°F (63.34°C) against the allowable limit of 752°F (400°C) per ISG-11 was calculated by the applicant for the maximum fuel cladding temperature. The predicted fuel cladding temperatures for short term storage and normal transfer conditions are given in Table M.4-2 of the SAR. The maximum fuel cladding temperatures are below the allowable short term limit of 752°F (400°C) by 32°F (17.77°C) for Loading Configuration 3, which is the loading case calculated by the applicant to be the bounding configuration. Under the minimum temperature condition of 0°F (-17.77°C), the SSCs important to safety continue to perform their safety function. The maximum calculated pressure for normal conditions corresponds to 6.37 psig, which is well below the DSC normal condition design pressure of 15 psig.

4.6 Evaluation of Cask Performance for Off-Normal Conditions

Maximum calculated temperatures for off-normal storage and transfer are given in Table M.4-8 of the SAR. According to this table, the maximum calculated temperature of 715°F (379.44°C) was obtained for the transfer case of Loading Configurations 1 and 3. Since a maximum fuel cladding short term temperature of 720°F (382.22°C) was obtained for normal conditions of transfer, the off-normal maximum fuel temperature is bounded by the normal conditions of transfer. For off-normal conditions the maximum fuel cladding temperatures are below the allowable fuel cladding temperature limit of 752°F (400°C). The maximum calculated pressure for off-normal conditions corresponds to 13.87 psig, which is below the DSC off-normal condition design pressure of 20 psig.

4.7 Evaluation of Cask Performance for Accident Conditions

The maximum cask temperature for the transfer accident case (loss of solar shield and liquid neutron shielding) is 863°F (461°C), which is below the maximum limit of 1058°F (570°C). The maximum calculated temperature for the blocked vent event after 40 hours is 788°F (420°C), which is below the maximum limit of 1058°F (570°C). The maximum calculated pressure for accident conditions corresponds to 101.58 psig, which is close to the DSC design pressure limit of 105 psig. The calculated maximum fire transient DSC surface temperature is 545°F (285°C), which is less than transfer accident maximum DSC surface temperature of 600°F (315°C). Therefore, the NUHOMS®-32PT DSC temperatures and pressures calculated for the loss of solar shield and neutron shielding accident case bound the hypothetical fire accident condition.

4.8 Evaluation of Cask Performance for Loading/Unloading Conditions

The maximum cladding temperature reached during vacuum drying after approximately 33 hours is 678°F (358.88°C). This is below the maximum limit of 752°F (400°C) per ISG-11. The maximum temperature difference for the fuel cladding during drying and backfilling operations is 100°F (55.55°C). This meets the thermal cycling criteria specified by ISG-11, which states that the temperature differences greater than 117°F (65°C) should not be permitted. Steady state maximum fuel cladding temperature during transfer to the ISFSI pad is 720°F (382.22°C). The maximum fuel cladding temperature during cask reflood operations will be significantly less than the vacuum drying condition because of the presence of water and/or steam in the DSC cavity.

4.9 Staff's Confirmatory Analysis of the NUHOMS®-32PT DSC

Confirmatory analyses of the NUHOMS®-32PT DSC thermal design, using the COBRA-SFS finite volume thermal code, were performed by the staff as an independent evaluation of the thermal analysis presented in the applicant's SAR. The staff's three-dimensional thermal model explicitly modeled the fuel assemblies, including individual rods, inside the DSC. It also included an explicit representation of the DSC shell, basket support plates, poison plates, aluminum plates, aluminum transition rails, and helium cover gas. COBRA-SFS thermal calculations were performed for normal condition of storage and differences in peak cladding temperatures between the applicant's results and the staff's confirmatory analysis were found. However the staff found these differences acceptable because the peak cladding temperature predicted by the staff's confirmatory analysis shows an acceptable margin against ISG-11 criteria. Temperature discrepancies were also acceptable to the staff because no safety issue was identified and because of low risk associated to spent fuel dry storage. Therefore, based on its own confirmatory thermal analysis the staff concluded that the applicant's thermal design of the NUHOMS®-32PT DSC is acceptable because it meets the thermal design criteria imposed on this design.

4.10 Evaluation Findings

F4.1 Appendix M, Section M.2 of the SAR describes SSCs important to safety to enable an evaluation of their thermal effectiveness. Cask SSCs important to safety remain within their operating temperature ranges.

F4.2 The NUHOMS®-32PT DSC is designed with a heat-removal capability having verifiability and reliability consistent with its importance to safety. The cask is designed to provide adequate heat removal capacity without active cooling systems.

F4.3 The spent fuel cladding is protected against degradation leading to gross ruptures under accident conditions by maintaining cladding temperatures below 1058°F (570°C). Protection of the cladding against degradation is expected to allow ready retrieval of spent fuel for further processing or disposal.

F4.4 Based on the staff's confirmatory analyses which have indicated that differences in temperature values for normal conditions of storage between the applicant's results and staff's confirmatory analysis results are on the level of acceptable range, the staff finds the design acceptable.

F4.5 The staff concludes that the thermal design of the NUHOMS®-32PT DSC is in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the cask will allow 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 engineering practices.

4.11 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. U.S. Nuclear Regulatory Commission, “Standard Review Plan for Dry Cask Storage Systems,” NUREG-1536, January 1997.

3. U.S. Nuclear Regulatory Commission, Interim Staff Guidance No. 11, Revision 2, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” July 30, 2002.

4. Transnuclear, Inc., Confirmatory Analysis of the Effective Thermal Conductivity Calculation Within the Neutron Shield of the OS197 Transfer Cask Using a CFD Method, Calculation No. NUH32PT.0413, Revision 1.

5. Transnuclear West, Final Safety Analysis Report of the Standardized NUHOMS® Horizontal Storage System for Irradiated Nuclear Fuel, October 2001, Revision 6.

5.0 SHIELDING EVALUATION

The staff reviewed the capability of the NUHOMS®-32PT DSC 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[1], 10 CFR 72.104(a)[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 DSC fulfills the acceptance criteria listed in Section 5 of NUREG-1536, "Standard Review Plan for Dry Cask Storage Systems."[3]

5.1 Shielding Design Features and Design Criteria

The applicant requested the addition of a new storage canister, the NUHOMS®-32PT DSC, 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. Therefore, the HSM and TC are not reviewed here except as to how they relate to the NUHOMS®-32PT DSC. The NUHOMS®-32PT DSC will be used to store up to 32 PWR fuel assemblies in one of three configurations. These configurations are described in Figures M.2-1, M.2-2, and M.2-3 of the SAR Appendix M. Table M.5-1 of SAR Appendix M lists the PWR fuel assembly design characteristics used in the analysis. In all cases, the maximum heat load for the canister is 24 kW.

5.1.1 Shielding Design Features

The NUHOMS®-32PT DSC, when used with the Standardized NUHOMS® System provides both gamma and neutron shielding during loading/unloading, transfer, and storage operations. The NUHOMS®-32PT DSC consists of four design configurations as described in Section M.2.1 of the SAR. There are two different canister weights, 100 tons and 125 tons; and two lengths available, long and short. The only difference between these configurations for shielding purposes is the thickness of the shield plugs, which are nominally 1.25 inches thinner on the 100 ton versions. The long versions were selected by the applicant as the bounding shielding case due to the inclusion of BPRAs, which add to the gamma source term.

The 32PT-L100 and L125 consist of a 0.5-inch thick steel canister. The 32PT-L100 has a 7.42 inch thick steel bottom shield plug assembly, and a 8.92 inch thick steel top shield plug assembly. The 32PT-L125 has a 8.67 inch thick steel bottom shield plug assembly, and a 10.16 inch thick steel top shield plug assembly. The TC, as depicted in drawing NUH-03-8000-SAR, consists of a steel shell, lead shielding, and a water jacket. The HSM is constructed of thick concrete walls and a shielded access door. The HSM air inlet paths are designed to preclude radiation streaming.

The staff evaluated the NUHOMS®-32PT DSC shielding design features and found them acceptable. The applicant's analysis provides reasonable assurance that the shielding design of the NUHOMS®-32PT 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®-32PT DSC loaded with spent fuel as described in Section M.2.1 and Table M.5-1 of the SAR.

The SAR analysis provides reasonable assurance that the NUHOMS®-32PT DSC 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.

5.2 Source Specification

The source specification is presented in Section M.5.2 of SAR Appendix M. 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 M.5-1. The B&W 15x15 Mark B assembly type was chosen as the design basis fuel assembly because of its assembly weight and it has the highest initial heavy metal loading (0.475 MTU).

The applicant generated fuel qualification tables for the individual heat loads specified for Configuration 1, 2, and 3 depicted in Figures M.2-1 through M.2-3. The applicant used SAS2H/ORIGEN-S to verify each fuel combination (with and without BPRAs) listed in Tables M.2-5 through M.2-14, 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. The applicant stated this method is consistent with the method used to calculate fuel qualification tables for the Standardized NUHOMS® as described in Section 7.2.3 of the FSAR. As discussed in Section M.5.2.4 of the SAR amendment, the applicant calculated dose rates on the surface of the HSM and TC for the three configurations with ANISN. A sketch of the ANISN model for the HSM and TC are depicted in Figures M.5-31 and M.5-32. The material densities used for the various modeling regions are listed in Table M.5-27. 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 M.5.5.5

Based on the ANISN calculated doses listed in Tables M.5-28 through M.5-37, the applicant determined that Configuration 2 resulted in bounding dose rates for both the HSM and TC. For the HSM, the applicant determined the design-basis source terms for the outer and inner 16 assemblies in Configuration 2 are 41 GWD/MTU, 5-years cooled, and 3.1 wt% enrichment and 30 GWD/MTU, 8-years cooling, and 2.5 wt% enrichment, respectively. For the TC, the applicant determined the design-basis source terms for the outer and inner 16 assemblies in Configuration 2 are 41 GWD/MTU, 5-years cooled, and 3.1 wt% enrichment and 45 GWD/MTU, 23-years cooling, and 3.3 wt% enrichment, respectively.

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 M.2-2. The design-basis burnup/enrichment/cooling time combinations, including model

locations, are listed on page M.5-2 of Appendix M of the SAR. However, contrary to Figure M.2-2, all 16 assemblies in the outer ring are modeled with the 1.2 kW source term. This results in a fuel source term based on a heat load of 28.8 kW compared to 24kW and is conservative. The design basis source terms for the authorized BPRAs are taken from Appendix J of the Standardized NUHOMS® System FSAR, and are added to the fuel source term.

The bounding gamma and neutron source terms were then combined in the shielding models to calculate the dose rates. To correct for changes in the neutron flux outside the fuel zone during irradiation, the masses of the materials in the bottom end fitting, plenum, and top end fitting were multiplied by scaling factors of 0.2, 0.2, and 0.1, respectively. These are the scaling factors recommended in Reference 4 and are considered to provide bounding values. Axial peaking factors are taken from the NUHOMS® MP-187 transportation cask FSAR, which has been approved by NRC to store similar fuel. These peaking factors were derived from work performed by the Department of Energy in support of its topical report for burnup credit. The data provided are shown in Table M.5-15, and are source term peaking factors for 12 axial locations along the assembly.

5.2.1 Gamma Source

Gamma source terms are calculated for each burnup/enrichment combination and are listed in Tables M.5-9 through M.5-11. The design basis BPRA source term is listed in Table M.5-12. The applicant determined that the fuel configuration shown in Figure M.2-2, modified with all 16 outer assemblies containing the 1.2 kW heat load source term, resulted in the design basis gamma source term. The source term for the outer assemblies is calculated using fuel with a burnup of 41 GWd/MTU, 3.1 wt.% enriched U-235, and cooled for 5 years for both the HSM and TC models. The source term for the inner assemblies is calculated using fuel with a burnup of 30 GWd/MTU, 2.5 wt.% enriched U-235, and cooled for 8 years for the HSM models, and using fuel with a burnup of 45 GWd/MTU, 4.1 wt.% enriched U-235, and cooled for 23 years for the TC models. This combination had the largest number of particles closest to the outer shell of the canister.

The hardware activation analysis considered the cobalt impurities in the assembly hardware. The cobalt content is listed in Table M.5-1. The activated hardware source terms are calculated using the hardware masses listed in Tables M.5-6 and M.5-7. Although cobalt impurities can vary, the applicant's assumed values are reasonable and acceptable.

5.2.2 Neutron Source

Neutron source terms are calculated for each burnup/enrichment combination and are listed in Table M.5-14. 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. The appropriate regional volumes are listed in Table M.5-13.

5.2.3 Confirmatory Analyses

The staff reviewed the proposed contents and the assumed hardware cobalt impurities listed in Table M.5-1 of Appendix M of the SAR. The staff has reasonable assurance that the design basis gamma and neutron source terms for the NUHOMS®-32PT DSC are acceptable for the shielding analysis. The staff also reviewed the flux scaling factors for the hardware source terms and the BPRA source term and found them to be appropriate.

The staff reviewed the description in the amendment of the method used to determine the bounding configuration and design-basis source terms, and found it acceptable. The staff notes that use of the ANISN 1-D model to represent the 3-D NUHOMS®-32PT 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 and 51B 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®-32PT DSC storage system with an established radiation protection program as required by 10 CFR Part 20, Subpart B.

The staff performed confirmatory calculations of the source terms for the specified fuel types, burnup conditions, and cooling times. The staff used the Origen[4]-ARP module of SCALE 4.4 and the associated 27 neutron,18 gamma group cross section library. The staff's overall source term calculations were in general agreement with the applicant's calculations. While the staff's neutron source terms were slightly higher than the applicant's, the staff's gamma source terms were much lower than the applicant's. Differences are expected due to the use of different codes and assumptions, and the conservatism introduced by the applicant's total gamma source heat load of 28.8 kW instead of 24 kW. The exterior dose rates are adequately controlled by limits in the CoC for maximum burnup, minimum cooling time, and minimum enrichment.

5.3 Shielding Model Specifications

The shielding analysis was performed with a discrete-ordinate neutron/photon transport code (DORT), a 2-D discrete ordinates code to calculate the dose rates on and around the HSM and TC for Configuration 2. To determine the total off-site dose, the Monte Carlo n-particle transport code (MCNP) computer code was used. The off-site dose models include 1) a 2x10 array of HSMs and, 2) two 1x10 arrays (facing front-to-front) loaded with design basis fuel in the NUHOMS®-32PT DSC.

The applicant also provided supplemental 3-D analysis using the MCNPX code in order to confirm the validity of the 2-D shielding code. This 3-D analysis was itself validated by actual measurements from installed NUHOMS® systems and is shown in Section M.5.4.14, Section M.5.5.4, Figures M.5-29 and M.5-30, and Table M.5-25 and M.5-26. As shown by the results in Table M.5-24, the 2-D DORT analysis bounds the 3-D MCNP analysis.

5.3.1 Shielding and Source Configuration

The shielding source is divided into 12 axial regions as summarized in Table M.5-15. The source is divided into the following regions; in-core, plenum, bottom end fitting, and top end fitting. The poison in the BPRAs is modeled as aluminum because it's a light element with little shielding effect. The fuel compartment material is modeled with only 20% of the steel plates as are actually used to form the fuel compartments, and all of the other basket materials are conservatively neglected in the shielding model which reduces the amount of actual shielding and results in a bounding dose rate. A number of other simplifications and bounding assumptions, that reduce the amount of actual shielding, are discussed in Section M.5.4. The analysis includes streaming paths through the HSM air vents and the TC-DSC gap. The overall design eliminated other potential streaming paths. Evaluation of streaming from narrow and long holes is difficult with the program DORT. While DORT is subject to ray effects, this tends to over-predict radiation streaming.

5.3.2 Material Properties

The composition and densities of the materials used in the shielding analysis are presented in Table M.5-16. For the HSM axial models and all of the TC models, the homogenized fuel assembly region accounts for the UO2; the zircaloy (modeled as pure Zr); the inconel and steel (modeled as pure Fe) present in the in-core region of the assembly; and 20% of the steel plates (also modeled as pure Fe) used to form the fuel compartments. For the HSM lateral model, the analysis was similar except that the homogenized fuel regions also include all of the steel from the DSC basket inner fuel compartment. The materials used in the HSM were previously reviewed and 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 NUHOMS®-32PT DSC was adequately modeled. In addition, the methodologies used are similar to those previously used to support NUHOMS® storage and transportation applications including the 61BT application and the Rancho Seco application, and have been accepted by the staff in the past. A supplemental 3-D analysis (which was benchmarked by measurements of actual installed NUHOMS® systems) provides further assurance that the DORT model is conservative in predicting dose rates. However, the staff notes that as the design complexity of systems increases; including increasing dose rates, source terms, and geometry complexities, a fully 3-D analysis is the more acceptable methodology for shielding design and analysis.

5.4 Shielding Analyses

5.4.1 Computer Programs

The applicant's shielding analysis was performed with DORT, supplemented using MCNPX, and is presented in Section M.5.4 of the SAR. For DORT, the cross section data used are based on the CASK-81 22 neutron, 18 gamma energy group coupled cross section library.

Figures M.5-4 through M.5-8 show simplified pictures of the input model for the DORT code, HSM models; and Figures M.5-19 and M.5-24 show a picture of the input model for the DORT code, TC model, including the welding configuration.

The analysis also makes the assumptions described in Section M.5.4.6 of the SAR. The staff agrees that these assumptions are reasonable and conservative. Finally, the supplemental MCNPX analysis discussed earlier, which is benchmarked by measurements of installed NUHOMS® systems, also shows that the 2-D DORT method is conservative.

5.4.2 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.

5.4.3 Normal Conditions

Appendix M of the SAR presents calculated dose rates for normal condition design-basis dose rates for the HSM and TC in Tables M.5-3 through M.5-5. 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. The dose rates for the TC assume that there is 3 inches of supplemental shielding on top of the DSC during welding. Table M.5-3 also gives the surface peak dose rate at the top of the DSC as approximately 3966 mrem/hr. Exposure from localized peak dose rate may be mitigated by the actual locations of personnel and use of temporary shielding during loading/unloading operations.

Figures M.5-9 through M.5-18 show the calculated dose profiles for the DORT code, HSM models. Figures M.5-20 through M.5-23 and M.5-25 through M.5-28 show the calculated dose profiles for the DORT code, TC models, including the welding orientations. 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.

5.4.4 Accident Conditions

Appendix M of the SAR does not identify an accident that significantly degrades the shielding of the HSM. The bounding accident condition for the HSM considers sliding of an HSM, which creates a 12-inch gap between the concrete HSMs. SAR table M.11-1 shows that the maximum dose rate for this is approximately 1.7×10^{-3} mrem/hr at 600 meters for a 2x10 array of HSMs, based on the results presented in Table M.5-17 for the HSM accident dose rates. The estimated recovery time for this accident is 5 days. Therefore, the estimated dose to a person at 600 meters from the ISFSI would be approximately 0.2 mrem which meets the requirements of 10 CFR Part 72.

The bounding accident condition for the TC considers loss of water from the TC water jacket combined with damaged fuel. This accident causes an increase in the dose rates by a factor of approximately 2.2 times those reported in Section 8.2.5.3.2 of the FSAR. SAR Table M.11-2 shows that the maximum dose rate for this accident is approximately 1670 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 600 meters is approximately 0.09 mrem which meets the regulatory requirements.

5.4.5 Occupational Exposures

The analysis in Appendix M of the SAR used the design basis fuel to estimate occupational exposures for the NUHOMS®-32PT DSC. Section M.10 of the SAR presents the estimated occupational exposures that are based on dose rate calculations in Section 5 of Appendix M to the SAR. The staff's evaluation of the occupational exposures is in Section 10 of this SER.

5.4.6 Off-site Dose Calculations

Section M.10 of the SAR estimates the offsite dose rates from a 2x10 and two 1x10 cask arrays. Tables M.10-7 through M.10-98 present 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®-32PT DSC 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®-32PT DSC. 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 characteristic, 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.

5.4.7 Confirmatory Calculations

The staff performed confirmatory analyses of selected dose rates using the code MCNP version 4C2. The staff based its evaluation on the design features and model specifications presented in the drawings shown in SAR Appendix M. 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®-32PT 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 DSC, 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®-32PT DSC 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.

4. Luksic, A.T., et al., Revised Uranium-Plutonium Cycle PWR and BWR Model for the ORIGEN Computer Code, ORNL/TM-6051, Oak Ridge National Laboratory, Oak Ridge, TN, 1978.

6.0 CRITICALITY EVALUATION

6.1 Criticality Design Characteristics and Features

The applicant requested an amendment to add the NUHOMS®-32PT DSC. The applicant revised the TS 1.2.1 and 1.2.15 to add fuel assembly specifications and a minimum boron concentration for the new NUHOMS®-32PT basket. The applicant included the following fuel assembly classes as contents in TS 1.2.1: B&W 15x15, WE 17x17, CE 15x15, WE 15x15 and the CE 14x14. The TS also includes Table 1-1g which specifies a minimum number of poison rod assemblies (PRAs) depending on the average initial enrichment of the fuel assemblies. In addition to the PRAs, the applicant revised TS 1.2.15 to require a minimum boron concentration of 2500 ppm for all fuel assemblies while loading the -32PT basket.

6.2 Criticality Model

The applicant performed a criticality analysis for all fuel assembly types that will go in the NUHOMS®-32PT DSC system. The applicant used the 44GROUPNDFB5 cross section set with the KENO V.a code in the SCALE 4.4 system to perform the criticality evaluation.

The applicant explicitly modeled the fuel assemblies in the -32PT basket with a soluble boron level of 2500 ppm in the water. The applicant evaluated the cask both for enrichments that require and that do not require the PRAs. The applicant assumed that fresh water was in the gap between the pellets and the fuel rod cladding. The applicant evaluated this configuration both with and without BPRAs. In addition to varying the water density to determine optimum moderation, the applicant performed a parametric study to evaluate the effects of such things as fuel assembly location in the basket slot, variation of basket dimensions such as transition rails, poison plate thickness, and basket tube thickness.

6.3 Criticality Analysis

The applicant's maximum calculated k-eff was 0.9409, including the Monte Carlo uncertainty, which is less than the upper subcritical limit of 0.9411, from the applicant's benchmarking evaluation.

The applicant also performed a sensitivity analysis to account for uncertainties in the material properties of the poison plates (boron-10 loading). The applicant reduced the B-10 loading of the poison plates to 40.5 weight % of the minimum loading shown on the drawings. The reduced loading variation started with the center 14.4 inches (10% of the axial length of the chevron) and increased 10% at a time until the entire chevron was assumed to be at the reduced boron loading. A chevron is defined as the two orthogonal poison plates within a basket tube. One of the four center fuel compartments was chosen since it should be at the highest flux location within the basket. The applicant has shown that the reduced boron loading of a single chevron, over the full length, only increases the k-eff of the package by approximately 0.2%Δk. The applicant has shown that reducing the boron concentration in the most reactive location of one chevron by over 50% from the minimum loading does not significantly increase the k-eff of the system.

The staff performed confirmatory criticality calculations using KENO V.a with the 238GROUPNDFB5 cross section set in the SCALE 4.4 system. The staff's model is similar to the applicant's. The staff's model initially included borated water in all locations containing water. The staff evaluated the reactivity of the system with fresh water in the fuel rod gap, similar to the applicant. The staff's maximum calculated k-eff was 0.9338 for B&W 15x15 fuel assemblies with a maximum enrichment of 3.9 weight % and four sets of PRAs. The staff's results agreed with the applicant's.

The staff also performed verification of the applicant's sensitivity analysis. The staff performed a similar sensitivity analysis as the applicant. The staff's analysis was for 3.3 weight % B&W 15x15 fuel assemblies, that are not required to contain PRA rods. The staff also varied the water density to ensure that the most reactive condition was determined. The maximum k-eff increase determined by the staff was 0.2%Δk, from 0.9192 to 0.9224, which agrees with the applicant's calculated increase in k-eff. Additionally, the staff performed the calculation for a reduced boron level in two chevrons in the center of the basket. The staff calculated a k-eff increase to 0.9255 for the reduced boron in the second chevron, which is only a 0.5%Δk increase.

6.4 Benchmarking Evaluation

The applicant performed a benchmarking analysis for the SCALE 4.4 system. The applicant chose 121 critical experiments, which are included in NUREG/CR-6361, Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages. The applicant determined the Upper Subcritical Limit (USL) using method one from NUREG/CR-6361. The applicant evaluated the USL for a number of parameters, such as enrichment, fuel rod pitch, water/fuel volume ratio, assembly separation, and average energy group causing fission. The most limiting USL was calculated based on the limiting value for each parameter and the lowest USL was taken to be the bounding value. The applicant determined the bounding USL to be 0.9411.

6.5 Evaluation Findings

F6.1 The cask and its spent fuel transfer systems are designed to be subcritical in all configurations.

F6.2 The criticality design is based on favorable geometry and soluble poisons in the spent fuel pool. Based on the information provided in the application and the staff's own confirmatory analyses, the staff concludes that the NUHOMS®-32PT DSC meets the acceptance criteria specified in 10 CFR Part 72.

F6.3 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-effhave been applied.

7.0 CONFINEMENT EVALUATION

The staff reviewed the NUHOMS®-32PT DSC confinement features and capabilities to ensure a) that any radiological releases to the environment will be within the limits established by the regulation[1], and b) that the spent fuel cladding will be protected against degradation that might lead to gross ruptures during storage, as required in 10 CFR 72.122(h)(1). This amendment was also reviewed to determine whether the NUHOMS®-32PT DSC fulfills the acceptance criteria listed in Section 7 of NUREG-1536, Standard Review Plan for Dry Cask Storage Systems[2], and applicable Interim Staff Guidance documents (ISGs). The staff's conclusions are based on information provided in the NUHOMS®-32PT DSC SAR.

7.1 Confinement Design Characteristics

A description of the confinement boundary is given in Sections M.1.2.1, M.2.3, M.3.1.2.1, M.7.1.1, and Figure M.3-1 of the amendment request. The confinement boundary consists of a shell which is a welded stainless steel cylinder with an integrally-welded, stainless steel bottom closure assembly; and a stainless steel top closure assembly, which includes the vent and drain system. The inner top cover plate has two penetrations for the vent and siphon ports which are closed with welded cover plates. The outer top and bottom cover plates provide redundant sealing of the confinement system. The system is designed to be leaktight as defined by American National Standard for Leakage Tests on Packages for Shipment of Radioactive Materials, ANSI N14.5-1997. The outer top cover plate has a single penetration to leak test the closure welds. This is closed with a welded cover plate after testing to complete the redundant sealing of the confinement boundary. The welds forming the confinement boundary are described in detail in Sections M.3.1.2.1 and M.7.1.3 of the SAR.

The redundant closure of the DSC satisfies the requirements of 10 CFR 72.236(e) for redundant sealing of confinement systems.

The DSC is designed, fabricated, and tested in accordance with the applicable requirements of the ASME BP&V Code Section III, Subsection NB to the maximum extent practicable. Exceptions to the ASME Code are listed in SAR Section M.3.1.2.3 and Table M.3.1-1 and M.3.1-2. The staff concludes that the description of the confinement boundary satisfies the requirements of 10 CFR 72.24(c)(3).

The applicant's proposed procedures for drying and evacuating the cask interior during loading operations were reviewed by the staff to ensure that the design is acceptable for the pressures that may be experienced during storage. The staff finds that this design, if fabricated and tested in accordance with the SAR requirements, will maintain the confinement boundary. Maintaining a stable vacuum pressure of 3 mm Hg for 30 minutes during vacuum drying provides reasonable assurance the moisture content in the NUHOMS®-32PT DSC will be acceptably low during its service life. The NUHOMS®-32PT DSC is designed to be leaktight and is tested to a leak rate of 1×10^{-7} atm cm^3/sec, as defined in ANSI N14.5-1997. This testing confirms that the amount of helium lost from the NUHOMS®-32PT DSC over the approved storage period is negligible. Thus, an adequate amount of helium will remain in the canister to maintain an inert atmosphere and to support the heat transfer during the storage period.

For normal storage conditions, the NUHOMS®-32PT DSC uses multiple confinement barriers provided by the fuel cladding (for intact fuel), and the NUHOMS®-32PT DSC to assure that the confinement system will reasonably maintain confinement of radioactive material. The canister is backfilled with an inert gas (helium) to protect against cladding degradation. Section 3 of the SER shows that all confinement boundary components are maintained within their code-allowable stress limits during normal storage conditions. Section 4 of the SER shows that the peak confinement boundary component temperatures and pressures are within the design-basis limits for normal conditions of storage.

Welding and weld examinations are evaluated in Section 3.1.4.3 of this SER and include the following; multiple surface and volumetric examinations, pneumatic pressure testing, and leakage rate testing on the finished shell and the inner cover plate at the fabricator; leakage rate testing of the closure welds (inner top cover plate and vent and siphon port cover plates) after loading the spent fuel; and multiple surface and dye penetrant examinations on the redundant confinement boundary.

The applicant described the canister inspection and test acceptance criteria in Section M.9 of the SAR. The closure weld examination and acceptance criteria are included in Sections 1.2.4.a and 1.2.5 of the TS. The staff finds that this is acceptable provided that all NDE personnel, both at the fabricator and at the loading site, are qualified in accordance with applicable standards and codes such as SNT-TC-1A. This is a requirement of ASME Section V, Article 1, Paragraph T-140.

The staff analyzed any possible chemical and galvanic reactions in Section 3.1.4.7 of this SER and concluded that in this dry, inert environment, the DSC components are not expected to react with one another or with the cover gas. Further, oxidation, or corrosion, of the fuel and the DSC internal components will effectively be eliminated during storage.

The all-welded construction of the NUHOMS®-32PT DSC with the redundant closure, extensive inspection and testing, ensures that no release of radioactive material for normal storage and on-site transfer will occur.

7.2 Confinement Monitoring Capability

For redundant seal welded closures, continuous monitoring of the closure is not necessary because there is no known plausible, long-term degradation mechanism which would cause the seal welds to fail. Periodic surveillance and monitoring of the storage module thermal performance, as well as the licensee's use of radiation monitors are adequate to ensure the continued effectiveness of the confinement boundary. The staff finds this adequate to enable the licensee to detect any closure degradation and take appropriate corrective actions to maintain safe storage conditions.

7.3 Nuclides with Potential Release

Since the NUHOMS®-32PT DSC is designed, fabricated, and tested to meet the leak tight criteria of ANSI N14.5-1997, there is no contribution to the radiological consequences due to a potential release of canister contents.

7.4 Confinement Analysis

The confinement boundary is welded and tested to meet the leak tight criteria of ANSI N14.5-1997 and is shown to maintain confinement during all normal, off-normal, and hypothetical accident conditions. Also, the temperature and pressure of the canister are within the design-basis limits. Therefore, no discernable leakage is credible. As discussed in Section 10 of this SER, the staff finds that the NUHOMS®-32PT DSC meets the requirements of 10 CFR 72.104(a) and 10 CFR 72.106(b).

7.5 Maximum Pressure Loads

The maximum design basis internal pressures in the NUHOMS®-32PT DSC are 10, 20, and 105 psig for normal, off-normal, and accident conditions of storage, respectively. For calculating the maximum internal pressures, the applicant assumed that 1% of the fuel rods are damaged for normal conditions, up to 10% of the fuel rods are damaged for off-normal conditions, and 100% of the fuel rods will be damaged following a design basis accident event. A minimum of 100% of the fill gas and 30% of the fission gases (e.g., H-3, Kr and Xe) within the ruptured fuel rods, are assumed to be available for release into the DSC cavity. The staff agrees with these assumptions used to calculate the maximum internal pressures.

7.6 Misloading

The NUHOMS®-32PT DSC may store PWR fuel assemblies arranged in any of three alternate heat zoning configurations with a maximum decay heat of 1.2 kW per assembly and a maximum heat load of 24 kW per canister. These different loading patters are shown in figures M.2-1 through M.2-3 in the SAR. Currently, the NRC staff believes that a misloading, or inadvertent placement of a fuel assembly with too high of a heat load in an incorrect location, is a credible event. However, the applicant has included additional administrative requirements to help minimize the possibility of a misloading occurring. These additional requirements are included as additional checks in Chapter M.8, and assure that a “double contingency” criteria is applied for misloading of an assembly, BPRA, or PRA hardware. These requirements are summarized as: a) the utility must prepare loading maps of fuel assemblies including control components and PRAs (if required) to be loaded in a given canister before fuel load based on technical specification, b) this loading map is required to be independently verified before any fuel loading, c) additional independent verification that the loading map is followed correctly and accurately is required after the fuel is loaded but before the top shield plug is placed, and d) to load poison rod assemblies (PRAs), steps are added to the procedures to require verification of the number of PRAs based on maximum enrichment of fuel assemblies selected for loading. The current staff position is that the consequences of a misloading accident are not safety significant. With the additional administrative requirements in place, the overall risk from a misloading is considered low.

7.7 Supportive Information

Supportive information or documentation includes drawings of the NUHOMS®-32PT DSC confinement boundary and applicable pages from referenced documents.

7.8 Evaluation Findings

F7.1 Section M.7 of the SAR describes confinement SSCs important to safety in sufficient detail to permit evaluation of their effectiveness.

F7.2 The design of the NUHOMS®-32PT DSC adequately protects the spent fuel cladding against degradation that might otherwise lead to gross ruptures. Section 4 of the SER discusses the relevant temperature considerations.

F7.3 The design of the NUHOMS®-32PT DSC provides redundant sealing of the confinement system closure joints using dual welds on the canister lid and closure.

F7.4 The NUHOMS®-32PT DSC has no bolted closures or mechanical seals. The confinement boundary contains no external penetrations for pressure monitoring or overpressure protection. No instrumentation is required to remain operational under accident conditions. Since the NUHOMS®-32PT DSC uses an entirely welded redundant closure system, no direct monitoring of the closure is required.

F7.5 The confinement system is leaktight for normal conditions and anticipated occurrences, thus the confinement system will reasonably maintain confinement of radioactive material. Section 10 of the SER shows that the direct dose from the NUHOMS®-32PT DSC satisfies the regulatory requirements of 10 CFR 72.104(a) and 10 CFR 72.106(b).

F7.6 The confinement system has been evaluated by analysis. Based on successful completion of specified leakage tests and examination procedures, the staff concludes that the confinement system will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F7.7 The staff concludes that the design of the confinement system of the NUHOMS®-32PT DSC is in compliance with 10 CFR Part 72 and that the applicable design and acceptance criteria have been satisfied. The evaluation of the confinement system design provides reasonable assurance that the NUHOMS®-32PT DSC will allow safe storage of spent fuel. This finding 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.

7.7 References

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

2. U.S. Nuclear Regulatory Commission, Standard Review Plan for Dry Cask Storage Systems, NUREG-1536, January 1997.

8.0 OPERATING PROCEDURES

The review of the technical bases for the operating procedures is to ensure that the applicant's SAR presents acceptable operating sequences, guidance, and generic procedures for key operations. The procedures for the NUHOMS®-32PT DSC, as described in Section M.8 of the SAR are very similar to those previously approved by the staff for the Standardized NUHOMS® System[1].

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 NUHOMS®-32PT DSC to identify any damage that may have occurred since receipt inspection.

8.1.1 Fuel Specifications

The procedures described in Section M.8 of the SAR 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 NUHOMS®-32PT DSC. It outlines appropriate administrative controls to preclude a cask misloading.

8.1.2 ALARA

The ALARA practices utilized during operations are discussed in Section 10.5 of this SER and are found to be acceptable.

8.1.3 Draining, Drying, Filling and Pressurization

Section M.8 of the SAR clearly describes draining, drying, filling and pressurization procedures for the NUHOMS®-32PT DSC that will provide reasonable assurance that an acceptable level of moisture remains in the cask and the fuel is stored in an inert atmosphere. The procedures are similar to those previously approved by the staff for the Standardized NUHOMS® System.

8.1.4 Welding and Sealing

Welding and sealing operations of the NUHOMS®-32PT DSC are similar to that 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 by TS 1.2.4a for the NUHOMS®-32PT DSC demonstrate that the inner top cover plate is leak tight as defined by ANSI N14.5-1997[2].

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 NUHOMS®-32PT DSC to the storage location are similar to those previously reviewed by the staff for the Standardized NUHOMS® System are bounded by Section M.11 of the SAR. Monitoring operations include daily surveillance of the HSM air inlets and outlets in accordance with TS 1.3.1, and temperature performance is monitored on a daily basis in accordance with TS 1.3.2. Occupational and public exposure estimates are evaluated in Section M.10 of the SAR. 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.

Section M.8 provides unloading procedures similar to 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 cask vent pressure does not exceed 20 psig to prevent damage to the cask.

Section M.8 provides a discussion of ALARA practices that should be implemented during unloading operations, 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

F8.1 The NUHOMS®-32PT DSC is compatible with wet loading and unloading. General procedure descriptions for these operations are summarized in Section M.8 of the applicant's SAR. Detailed procedures will need to be developed and evaluated on a site-specific basis.

F8.2 The welded cover plates of the cask 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 conditions

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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 conditions.

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 NUHOMS®-32PT DSC 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 West, Final Safety Analysis Report of the Standardized NUHOMS® Horizontal Storage System for Irradiated Nuclear Fuel, October 2001, Revision 6.

2. ANSI N14.5, “Leakage Tests on Packages for Shipment,” February 1998.

9.0 ACCEPTANCE TESTS AND MAINTENANCE PROGRAMS

9.1 Acceptance Tests

All materials and components will be procured with certification and supporting documentation to assure compliance with procurement specifications.

9.1.1 Visual and Nondestructive Examination Inspections

Upon receipt at the fabricator's facility, inspections are performed to ensure that the components conform to the fabrication specification and drawings.

The applicant has also committed to performing dimensional measurements (e.g., plate thickness) and visual examination of the material for evidence of defects such as cracks, porosity, blisters, or foreign inclusions. The DSC confinement boundary is fabricated and inspected in accordance with ASME BP&V Code[1] Section III, Subsection NB. Two alternatives to the ASME Code are identified in Table M.3.1-1 and M.3.1-2 of the SAR and include:

(1) Partial penetration welds of the top outer and inner cover plates of the containment shell joints. Note that this alternative does not apply to other shell confinement welds, i.e., the longitudinal and circumferential welds applied to the DSC shell, and the inner bottom plate cover plate-to-shell weld, which comply with ASME Code, Section III, Subsection NB-4243 and NB-5230.

(2) Root and final layer surface liquid penetrant examination of the top outer and inner cover plates of the containment shell welds.

The staff reviewed these alternatives, and the corresponding justifications, and found them to be acceptable.

The nondestructive examination (NDE) of weldments is well characterized in the drawings and discussed in Sections M.3.1.2.1 and M.9.1.2 of the SAR. Standard NDE symbols and/or notations are used in accordance with AWS 2.4, "Standard Symbols for Welding, Brazing, and Nondestructive Examination." Fabrication inspections include visual (VT), liquid penetrant (PT), ultrasonic (UT), and radiographic (RT) examinations, as applicable.

9.1.2 Leakage Testing

The NUHOMS®-32PT DSC is designed to be leaktight and is tested to a leak rate of $1x10^{-7}$ atm cm3/sec, as defined in ANSI N14.5. The confinement boundary testing includes; leakage rate testing on the finished shell and the inner cover plate at the fabricator, and leakage rate testing of the closure welds (inner top cover plate, and vent and siphon port cover plates) after loading the spent fuel. The staff finds that this is acceptable provided that all personnel performing the leak rate testing, both at the fabricator and at the loading site, are qualified in accordance with applicable standards and codes (such at SNT-TC-1A[2]).

9.1.3 Neutron Absorber Tests

The applicant has also committed to performing dimensional measurements (e.g., plate thickness) and visual examination of the material for evidence of defects such as cracks, porosity, blisters, or foreign inclusions.

9.1.4 Qualification Test Program

The applicant submitted procedures for qualifying a Metal Matrix Composite for both major and minor processing changes.

Major processing changes, such as billet formation by processes other than hot vacuum pressing or CIP/vacuum sintering, or direct rolling of the billet, shall be subject to testing to qualify the materials produced as a result of these major processing changes. Testing shall include exposure of the absorber to a radiation field to assess the effects of radiolysis, exposure of the absorber material to the full range of service temperatures, and immersion of the fabricated absorber in pool water to simulate the cask environment during loading. The qualification tests and test samples should be evaluated for the following effects: uniformity of ^{10}B, and dimension and weight changes due to material instability (e.g., cracking, spalling, debonding of absorber cladding from the poison matrix material or the matrix material from the poison particles, embrittlement, galvanic reactions, hydrogen generation in spent fuel pool water, weight reduction due to outgassing, oxidation, or hydriding). Other examples of major processing changes include the following:

(1) B_4C (boron carbide) content of > 15 volume % for BorAlyn or equivalent, or
(2) B_4C content of > 40 volume % for Metamic or equivalent, or
(3) Product theoretical density < 98%, or
(4) More than 5% of B_4C powder at 40 microns, and more than 20% of B_4C powder at 25 microns.

Minor process changes that do not have an adverse effect on the particle bonding, microstructure, or uniformity of the B_4C particle distribution, may be accepted by engineering review. Section M.9.1.7.3.2.2 of the SAR amendment discusses these changes.

Staff concludes that the testing for major and minor processing changes will ensure the acceptability and durability of the resulting neutron absorber product over the licensed service life.

9.1.4.1 Borated Aluminum Acceptance Testing, Neutronic

In general, the acceptance testing of the thermal neutron absorber plate material for the NUHOMS®-32PT DSC is based upon the testing requirements specified in the FSAR for the NUHOMS®-61BT DSC. In the SAR amendment for the NUHOMS®-32PT DSC, a new method for plate rejection was presented. In this method, all areal densities that are determined by neutron transmission tests on materials for a given lot, may be converted to volume densities. After statistical treatment of coupon data taken for a lot, a minimum thickness criterion can be developed for rejection of plates in the lot, based upon a thickness criterion. The staff finds this new method for plate rejection to be acceptable.

9.1.4.2 ^{10}B Areal Density Testing of Poison Plates

In general, the acceptance testing of the thermal neutron absorber plate material for the NUHOMS®-32PT DSC is based upon the testing requirements specified in the FSAR for the NUHOMS®-61BT in which it was assumed that "...the uniformity of the boron-10 distribution is verified by the qualification testing and need not be verified in the production because of the high reproducibility of powder metallurgical techniques and the fineness of the boron carbide particles used."

In response to questions regarding staff concerns related to acceptance testing of the absorber plate materials for the NUHOMS®-32PT DSC, the applicant demonstrated that any credible in-homogeneity for the materials in question would not have a significant influence on the effective neutron multiplication factor, k-eff, as described below. Upon completion of staff's confirmatory calculations, staff accepted the applicant's argument. The results of a similar set of confirmatory calculations for the NUHOMS®-61BT DSC were also performed and they are documented in the SER for the TN MP-197[3] transportation package.

The uniformity of the absorber plate materials had been accepted during the review of the NUHOMS®-61BT DSC, for plates to be given 90% credit in computation of the effective neutron multiplication factor, k-eff. This was done using the results of qualification tests that ensure uniformity and acceptance test measurements on coupons for each production batch of plates. The coupon measurements are made during acceptance test procedures that incorporate a statistical analysis of results of measured values taken on coupons used to represent adjacent absorber plates of a production run. When the measured values from the coupons representing plates from a lot or heat of material have little statistical variability, it supports the conclusion that large areas can not contain less than the minimum specified value. This is especially true when, as is often the case, the mean value is also much higher than the minimum required value. However, the statistical analysis ensures, with 95% confidence, that no more than 5% of the area is below the minimum specified content. The "uniformity" question is whether or not this 5% (with low boron content) of a plate can be in clusters or in linear streaks, due to production effects on homogeneity of the dispersion of the B_4C particles within the aluminum alloy matrix. This question of non-uniformity is important as it may lead to a significant increase in the effective neutron multiplication factor, k-eff

The applicant chose to determine, through calculations, the significance (effect on the effective neutron multiplication factor, k-eff) of having a localization of the areas that have a very low percentage of these absorber particles. TN conducted criticality analyses to establish the significance of a very unlikely event, which is that a set of plates (a chevron at a critical location in the basket) is composed of material with absorber plates, that contain "low boron content." Further, in the calculation this chevron is placed in a critical location near the center of the basket. The significance of this event was estimated by comparing the results of k-eff values computed for the case in which the basket contained this chevron of low boron content, with the results normally obtained for the basket with all plates being normal (containing material having 100% of the specified minimum).

Credit taken in the computation of effective values of k-eff for these "normal" plates is 90%. The "low boron content" areas are assumed to be material that contains only 45% of that credited in the rest of the plates. Therefore the assumed (credited) boron content in the "low boron areas" of the plate is modeled as 90% of 45%, or 40.2% of the minimum required boron

content. In addition, calculations were made for various cases in which various fractions of the plate are assumed to contain the material with "low boron content" and these areas were given only 40.5% credit. These fractional values of the 144 inch long plate are (in inches); 14.4, 28.8, 43.2, 57.6, 72.0, 86.4, 100.18, 114.2, 129.6, and 144.

With the full 90% credit, which is normally taken, the value of k-eff is 0.9256. The results of calculations for the computed worst case (144 of 144 inches credited with 40.5% of the specified boron content) are as follows. Using two adjacent plates (a full chevron) and considering that 100% of each plate contains 45% of the specified minimum boron content, the value of k-eff is 0.9275. Hence, the difference in computed k-eff values between the normal case and the worst case is of the order of 0.002. The computed effects for the other cases yielded differences that are about the same as or less than the effects for the full plate. The staff conducted confirmatory calculations on computed values of k-eff, to determine the significance of having one full chevron, and two full chevrons, with low boron contents. These results are presented in SER Section 6 on Criticality, and they support and confirm the results presented by the applicant.

On the basis of calculations conducted by the applicant and confirmed by the staff, it is concluded that a large area of neutron absorber plates with an unusually low boron content would not have a significant effect on criticality for the NUHOMS®-32PT DSC loading configuration. Therefore, no additional tests on homogeneity beyond those for coupons taken from the plate materials are required. These specified coupon tests are presented in SAR Section M.9.1.7.3.1.3 on acceptance testing. The tests include neutron radioscopy which directly measures the distribution of boron, and neutron transmissivity, which directly measure effectiveness of the ^{10}B content over the area of about 1 cm^2 . Staff agrees that, together with statistical analyses, the results of acceptance tests for poison plate materials ensures that the production process is under control and that the boron content meets the minimum specified and that the distribution of ^{10}B required for the application is adequate to ensure its efficacy.

9.2 Evaluation Findings

F9.1 Sections M.3, M.7, and M.9 of the SAR describe the applicant's proposed programs for pre-operational testing and initial operations of the NUHOMS®-32PT DSC. Section M.9.2 discusses the maintenance program.

F9.2 SSCs important to safety will be designed, fabricated, erected, tested and maintained to quality standards commensurate with the importance to safety of the function they are intended to perform. Section M.2 of the SAR identifies the safety importance of SSCs, and Section M.3 presents the applicable standards for the design, fabrication, and testing.

F9.3 The applicant will examine and test the NUHOMS®-32PT DSC to ensure that it does not exhibit any defects that could significantly reduce its confinement effectiveness. Sections M.3, M.7, and M.9 describe this inspection and testing.

F9.4 Cask marking and data plate information are discussed in the Standardized NUHOMS® System FSAR and were not reviewed for this amendment.

F9.5 The staff concludes that the acceptance tests and maintenance program for the NUHOMS®-32PT DSC are in compliance with 10 CFR Part 72, and that the applicable acceptance criteria have been satisfied. The evaluation of the acceptance tests and maintenance program provides reasonable assurance that the cask will allow safe storage of spent fuel throughout its licensed term. 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.

9.3 References.

1. American Society of Mechanical Engineers, ASME Boiler And Pressure Vessel Code, Section III, Division 1, 1998 edition including the 2000 Addenda.

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

3. Transnuclear, Inc. NUHOMS® - MP197 Transportation Packaging, Safety Analysis Report, Docket NO. 71-9302.'

10. RADIATION PROTECTION EVALUATION

The staff reviewed the radiation protection design features, design criteria, and the operating procedures of the NUHOMS®-32PT DSC which will be used with the Standardized NUHOMS® Horizontal Storage Module to ensure that the DSC will meet the regulatory dose requirements of 10 CFR Part 20, 10 CFR 72.104(a), 10 CFR 72.106(b), 10 CFR 72.212(b), and 10 CFR 72.236(d)[1]. This amendment was also reviewed to determine whether the NUHOMS®-32PT DSC fulfills the acceptance criteria listed in Section 10 of NUREG-1536, Standard Review Plan for Dry Cask Storage Systems[2]. The staff's conclusions are based on information provided in Amendment 5 to the NUHOMS® FSAR.

10.1 Radiation Protection Design Criteria and Design Features

10.1.1 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.

10.1.2 Design Features

Sections 3.3.1 and 7.1 of the Standardized NUHOMS® System FSAR, and Section M.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®-32PT 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 and transfer cask that provide 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®-32PT 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 Occupational Exposures

Section M.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 M.10-1 of the amendment request shows the estimated number of personnel, the estimated time, the estimated dose rates, and 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 M.5 of the amendment request, the generic operating procedures in Section M.8 of the request, 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 1.80 person-rem for the 100 ton configuration and 3.8 person-rem for the 125 ton configuration. 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 Public Exposures From Normal and Off-Normal Conditions

Section M.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 for Configuration 2 (see Figure M.2-2). Figure M.10-1 depicts estimated dose rate versus distance curves. Table M.10-2 specifies distances at which the regulatory design limit of 25 mrem/yr can be achieved. An array of 20 NUHOMS®-32PT DSCs loaded with design basis

fuel and placed in the HSM is below regulatory limits at approximately 500 meters for two parallel but separated 1x10 arrays and at approximately 600 meters for 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®-32PT 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., berm). 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 applicant for a site license.

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.

A requirement has been added as TS 1.1.9 regarding the use of engineered features used for radiological protection. The TS 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).

10.4 Public Exposures From Accidents and Events

Section M.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 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).

10.5 ALARA

Sections M.5, M.7, and M.10 of the SAR presents evidence that the NUHOMS®-32PT DSC radiation protection design features and design criteria address ALARA requirements, consistent with 10 CFR Part 20 and Regulatory Guides 8.8[3] and 8.10[4]. 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. Because the TC may have to be drained when used with the NUHOMS®-32PT DSC and a 100-ton or 125-ton crane, the occupational dose rates may be higher than when loading other approved canisters. Each plant will have to consider the use of this canister with respect to their particular ALARA implementation philosophy.

The staff evaluated the ALARA assessment of the NUHOMS®-32PT 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.

10.6 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®-32PT DSC is designed to facilitate decontamination to the extent practicable.

F10.4 The SAR amendment adequately evaluates the NUHOMS®-32PT DSC and its 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®-32PT DSC is designed to assist in meeting these requirements.

F10.7 The staff concludes that the design of the radiation protection system of the NUHOMS®-32PT DSC 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®-

32PT DSC 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.

10.7 References

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

2. U.S. Nuclear Regulatory Commission, Standard Review Plan for Dry Cask Storage Systems, NUREG-1536, January 1997.

3. 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.

4. 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.

11.0 ACCIDENT ANALYSES

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 analyses 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
- fulfilled the applicable regulatory requirements.

11.1 Off-Normal Operations

Off-normal operations are Design Event II as defined by ANSI/ANS 57.9[1]. These events can be expected to occur with moderate frequency or on the order of once per year. The NUHOMS®-32PT DSC off-normal operations are described in Section M.11 of the SAR. In several instances, Section M.11 takes credit for analysis contained in the Standardized NUHOMS® FSAR which was previously approved by the staff.

The off-normal transfer loads, extreme temperature, and pressure effects are the events that can be expected to occur on the order of once per year of operation. The situation of a jammed DSC in the loading or unloading mode of operation relative to the HSM presents the most significant stress levels in the DSC for off-normal operations. As discussed in Section 3.2.2 and 3.2.3 herein, the resulting stresses are within the allowables based on the design criteria. The maximum primary membrane stress induced in the DSC under the off-normal conditions occurs in a combined loading condition of the extreme hot temperature, with the off-normal internal pressure and the off-normal unloading handling load. This occurs in the outer bottom cover plate that is not part of the containment boundary. The stress is approximately 36% of the allowable.

For the containment boundary the maximum primary membrane stress under the same conditions, except occurring during the loading of the HSM, is 26% of the allowable. This occurs in the inner bottom cover plate. For the maximum stress for primary membrane plus primary bending, the calculated stress is approximately 91% of the allowable. This occurs again in the outer bottom cover plate and does not impact the containment boundary. The maximum primary membrane plus primary bending in the DSC shell is not controlled by the off-normal loads, but by the normal loads. The NUHOMS®-32PT DSC is designed and tested to the leak tight criteria of ANSI N14.5. The off-normal conditions have been evaluated in accordance with the ASME BP&V Code, and the resulting stresses are below the allowables. The estimated quantity of radionuclides expected to be released annually to the environment due to off-normal events is zero.

11.2 Hypothetical Accidents

Accident events and conditions are Design Event III and IV, as defined by ANSI/ANS 57.9, "Design Criteria for an ISFSI," 1992. The NUHOMS®-32PT DSC postulated accidents are described in Section M.11 of the SAR. In several instances, Section M.11 takes credit for analysis contained in the Standardized NUHOMS® FSAR which was previously approved by the staff.

The postulated accidents that have been considered and discussed in Section 3.3 herein have been evaluated for impact on the structural systems. Included are the following accidents: tornado winds/tornado missiles, earthquake, flood, lightning, accidental cask drop, blockage of the vent system, and pressurization from fuel cladding failure.

The response of the structural system of the NUHOMS®-32PT DSC for the tornado winds and tornado missiles is enveloped by the previous studies and evaluations of other Standardized NUHOMS® DSCs (24P and 52B).

The NUHOMS®-32PT DSC was evaluated for its response within the HSM supporting structure, for the seismic loading consisting of a peak horizontal ground acceleration of 0.25g and a peak vertical ground acceleration of 0.17g at the top of the supporting concrete slab foundation. The resulting loading of the NUHOMS®-32PT DSC at its support locations was determined to be 0.40g horizontally and 0.17g vertically. The applicant considered the two possible modes of vibration of the DSC, and it was determined that the ovalling mode would control the response of the DSC with spectral accelerations of 1.0g horizontally and 0.68g vertically. These were increased by a factor of 1.5 to account for any multimode excitation, resulting in design values of 1.5g horizontal and 1.0g vertical. Under the loading combinations with these seismic loads, the resulting stresses within the NUHOMS®-32PT DSC shell, were approximately 82% of the allowable stress for primary membrane stress and approximately 94% of the allowable stress for primary membrane plus primary bending. The stability of the NUHOMS®-32PT DSC on the support rails inside the HSM, was evaluated based on rigid body motion with the resulting factor of safety being 1.2.

In addition to the seismic effects on the DSC containment boundary, the seismic effects on the basket structure were considered. Since the 2.0g handling loads are greater than the seismic loading of 1.5g horizontally and 1.0g vertically, the capability of the basket structure bounds the seismic loading. The existing design of the DSC support structure within the HSM and the HSM itself, bounds the demands of the NUHOMS®-32PT DSC. In addition, the behavior of the NUHOMS®-24P DSC in the transfer cask and trailer assembly has been evaluated previously and a safety factor of 2.0 against overturning resulted. The NUHOMS®-24P DCSC weight bounds the NUHOMS®-32PT DSC for an overturning evaluation, hence the safety factor for the NUHOMS®-32PT DSC would be even greater than 2.0 against overturning.

For flood conditions the NUHOMS®-32PT DSC design reflects the same design conditions used for the previous DSC models of the NUHOMS system of a 50 foot static head of water and a maximum flow velocity of 15 feet per second. The stability conditions of the HSM, with the NUHOMS®-32PT DSC in the HSM (the heaviest DCS models), are improved over those already considered acceptable for the HSM loaded with NUHOMS®-24P DSC or the 52B DSC. The NUHOMS®-32PT DSC shell stresses under the flooding condition loads for primary membrane plus primary bending are approximately 10% of the allowable stress, while the maximum stress

in one of the flat end heads occurs in the inner bottom cover plate at only approximately 5% of the allowable stress. This also represents the primary membrane plus the primary bending stress.

The NUHOMS®-32PT DSC is protected from the effects of lightning by either the TC or the HSM with no induced physical loading on the containment vessel.

The following evaluations have been performed for an accidental drop, with the g-loads imposed on the Standardized NUHOMS® system with the use of the loaded NUHOMS®-32PT DSC. The NUHOMS®-32PT DSC shell assembly, the basket assembly, the TC and the TC with the neutron shield removed configurations, have been evaluated. The drops considered were a horizontal side drop of 80 inches, a vertical end drop of 80 inches on either end, and an oblique corner drop from a height of 80 inches at an angle of 30-degrees from the horizontal. As previously established and accepted in Section 8.2.5.1.C. of the FSAR, it is stated that a static equivalent deceleration of 75g is a conservative design value based on the expected maximum decelerations of 59g for an end drop and 49g for a side drop, both onto a 36-inch thick under-reinforced concrete slab. In addition, a static equivalent deceleration of 25g was previously found acceptable for the equivalent static value for the corner drop loading. Analyses are performed for a 60g vertical end drop as a means of enveloping the 25g corner drop in conjunction with the 75g horizontal drop. The NUHOMS®-32PT DSC shell under the 75g side drop is stressed to approximately 92% of the allowable stress under ASME service level D allowables for primary membrane plus primary bending. The maximum stress in the end cover plate portion of the containment boundary is approximately 95% of the allowable stress, and occurs in the outer top cover plate for primary membrane plus primary bending. The DSC shell was also evaluated for buckling under the end drop conditions, with the results indicating that buckling will not occur.

The NUHOMS®-32PT DSC basket assembly was also evaluated against the drop scenarios. For the 75g horizontal side drop, the calculated stress in the spent fuel support grid is approximately 97% of the allowable stress. The end drop loading on the basket assembly affects only the self-weight stresses on the basket assembly, since the spent fuel assemblies do not react axially on the basket structure. The axial stresses within the basket grid and transition rails cause no more than 25% of the allowable stress. The stability of the basket assembly under side loading was also evaluated for the aluminum transition rail assemblies. Two software analyses packages were used for the analyses, and in all cases the limiting g-loads were well in excess of the 75g design load. These calculations were also completed using hand calculations that showed no instability issues which would control the design. Under the post accident condition with loss of sunshade and loss of the neutron shield, Table M.4-14 identifies that the basket assembly temperature can rise to 852 °F, an increment of 52 degrees over the temperature vs. allowable stress data for the XM-19 plate material. The alternative to the ASME Code identified in Table M.3.1-2 under Section III, NG-3000 and Section II, Part D, Table 2A, is acceptable based on the low stress levels at this temperature.

The drop analyses for the TCs remain as provided and accepted in Section 8.2.5.2 of the FSAR since the previously analyzed payload weights exceed that of the NUHOMS®-32PT DSC.

The structural effects of the blockage of air inlet and outlet vents, are bounded by the earthquake and tornado, and the thermal impacts are considered in the various loading

combinations consistent with the loading scenarios that include the accident internal pressure of 105 psi. The resulting stresses are well within the allowables.

11.3 Evaluation Findings

F11.1 The SSCs of the NUHOMS®-32PT DSC are adequate to prevent accidents and to mitigate the consequences of accidents and natural phenomena events that do occur.

F11.2 The spacing of casks is discussed in Sections 1 and 4 of the Standardized NUHOMS® System FSAR. The staff has previously reviewed and approved the cask spacing to ensure accessibility of the equipments and services required for emergency response.

F11.3 The applicant has evaluated the NUHOMS®-32PT DSC to demonstrate that it will reasonably maintain confinement of radioactive material under credible accident conditions.

F11.4 An accident or natural phenomena event will not preclude the ready retrieval of spent fuel for further processing or disposal.

F11.5 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 or 72.106.

F11.6 The staff concludes that the accident design criteria for the NUHOMS®-32PT DSC 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 demonstrated 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. American Nuclear Society, ANSI/ANS-57.9, "Design Criteria for an Independent Spent Fuel Storage Installation (dry Storage Type)," 1992

12.0 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 NUHOMS®-32PT DSC, in concert with the Standardized NUHOMS® Storage System, are clearly defined in the CoC and TS.

12.2 Technical Specifications

Based on the addition of the NUHOMS®-32PT DSC to the Standardized NUHOMS® Storage System, the TS have been revised to accommodate the new DSC 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®-32PT DSC system, in concert with the Standardized NUHOMS® Storage System.

12.3 Evaluation of Findings

F12.1 Table 12-1 of this SER lists the TS for the NUHOMS®-32PT DSC, in concert with the Standardized NUHOMS® Storage System. These TS are further discussed in Section 12 of the SAR, and are part of the CoC.

F12.2 The staff concludes that the conditions for use of the NUHOMS®-32PT DSC, in concert 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.

Table 12-1

Standardized NUHOMS® Horizontal Modular Storage System Technical Specifications for use with the NUHOMS®-32PT DSC

1.1 General Requirements and Conditions

- 1.1.1 Regulatory Requirements for a General License
- 1.1.2 Operating Procedures
- 1.1.3 Quality Assurance
- 1.1.4 Heavy Loads Requirements
- 1.1.5 Training Module
- 1.1.6 Pre-Operational Testing and Training Exercise
- 1.1.7 Special Requirements for First System in Place
- 1.1.8 Surveillance Requirements Applicability
- 1.1.9 Supplemental Shielding

1.2 Technical Specifications, Functional and Operating Limits

- 1.2.1 Fuel Specifications
- 1.2.2 DSC Vacuum Pressure During Drying
- 1.2.3 24P and 52B DSC Helium Backfill Pressure
- 1.2.3a 61BT and 32PT DSC Helium Backfill Pressure
- 1.2.4 24P and 52B DSC Helium Leak Rate of Inner Seal Weld
- 1.2.4a 61BT and 32PT DSC Helium Leak Rate of Inner Seal Weld
- 1.2.5 DSC Dye Penetrant Test of Closure Welds
- 1.2.6 Deleted
- 1.2.7 HSM Dose Rates with a Loaded 24P, 52B or 61BT DSC
- 1.2.7a HSM Dose Rates with a Loaded 32PT DSC Only
- 1.2.8 HSM Maximum Air Exit Temperature
- 1.2.9 Transfer Cask Alignment with HSM
- 1.2.10 DSC Handling Height Outside the Spent Fuel Pool Building
- 1.2.11 Transfer Cask Dose Rates
- 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
- 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
- 1.2.16 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

1.3 Surveillance and Monitoring

- 1.3.1 Visual Inspection of HSM Air Inlets and Outlets (Front Wall and Roof Birdscreen)
- 1.3.2 HSM Thermal Performance

13.0 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.

14.0 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 addition of the NUHOMS®-32PT DSC.

CONCLUSIONS

The staff performed a detailed safety evaluation of the proposed CoC amendment request and found that the addition of the NUHOMS®-32PT DSC does not reduce the safety margin for the Standardized NUHOMS® Horizontal Modular Storage System. Based on the statements and representations contained in the applicant's SAR, and the conditions of the CoC, the staff concludes that the addition of the NUHOMS®-32PT DSC to the approved contents of the Standardized NUHOMS® Horizontal Modular Storage System meets the requirements of 10 CFR Part 72.

Issued with Certificate of Compliance No. 1004, Amendment 5,
on __________________.