UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION REPORT

Docket No. 72-8
Calvert Cliffs
Independent Spent Fuel Storage Installation
Renewed Materials License No. SNM-2505
Amendment No. 11

1 SUMMARY

By letter dated March 26, 2014 (ADAMS Accession No. ML14090A121), as supplemented July 25, (ADAMS Accession No. ML14212A137), October 10 (ADAMS Accession No. ML14288A125), and December 3, 2014 (ADAMS Accession No. ML14337A148), and February 3, (ADAMS Accession No. ML15042A188), and March 10, (ADAMS Accession No. ML15075A350), June 29 (ADAMS Accession No. ML15182A165), September 11 (ADAMS Accession No. ML15258A194), September 25, (ADAMS Accession No. ML15273A466), and November 17, 2015 (ADAMS Accession No. ML15324A051), Exelon Generation Company, LLC (Exelon Generation), submitted amendment request No. 11 to the U.S. Nuclear Regulatory Commission (NRC) for Renewed Materials License No. SNM-2505 for the Calvert Cliffs (CC) Independent Spent Fuel Storage Installation (ISFSI). The amendment authorizes the following:

a. Maximum fuel assembly average initial enrichment of 5 weight percent U-235.

b. Expansion of the ISFSI total capacity from 120 horizontal storage modules (HSMs) to 132 HSMs on the existing site.

c. A new 32PHB Dry Shielded Canister (DSC) design and a new HSM-HB for use at the CC ISFSI.

d. Storage of Westinghouse /AREVA / Combustion Engineering 14X14 fuel in the NUHOMS®-32PHB Dry Shielded Canister system.

The NRC staff (staff) has reviewed the application, including the justifications for the requested changes. As discussed in further detail below in the safety evaluation report (SER), based on the statements and representations in the application, as supplemented, the staff finds that the requested amendment meets the regulatory requirements of Title 10, Code of Federal Regulations (CFR) Part 72.

2 BACKGROUND

The CC ISFSI is co-located on approximately 3.5 acres with CC Nuclear Power Plants, Units 1 and 2, on the west shore of the Chesapeake Bay in Calvert County, Maryland. The amendment will authorize the ISFSI to accommodate up to 132 NUHOMS® Horizontal Storage Modules (HSMs).

3 REVIEW CRITERIA

The staff's evaluation of the requested changes are based on ensuring the CC ISFSI continues to meet the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel

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and 10 CFR Part 20 for radiation protection. The staff followed the guidelines provided in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" in conducting its evaluation. The staff's evaluation focused only on the requested changes to Renewed Materials License No. SNM-2505 and associated technical specifications (TS) requested in the application and did not reassess previously approved portions of the license, TS, and the Updated Safety Analysis Report (USAR) or those areas of the USAR modified by Exelon as allowed by 10 CFR 72.48. The objectives for the following review disciplines are as described below for each of the requested changes.

4 SYSTEM, STRUCTURE, AND COMPONENT (SSC) AND DESIGN CRITERIA EVALUATION

The requested changes do not adversely impact safety functions of the original SSC design. Therefore an evaluation was not required.

5 STRUCTURAL EVALUATION

This section presents the results of the structural evaluation review of the amendment request for the addition of the NUHOMS®-32PHB system to the CC ISFSI. The NUHOMS®-32PHB DSC is designed to accommodate 32 high burn-up pressurized water reactor (PWR) fuel assemblies with Zirlo, Zircaloy-4 and AREVA M-5 cladding. The NUHOMS®-32PHB system consists of the 32PHB DSC, basket and shell assemblies, the HSM-HB and the Transfer Cask (TC). The licensee asserts that the 32 PHB system shares many similarities with the 24P and 32P systems currently approved and in operation at CC. As such, the staff considered previous structural evaluations of the NUHOMS®-32P DSC and the TC as part of this structural evaluation. The staff requested the licensee provide all relevant structural calculations from Section 13.13 of the draft SAR, which are not incorporated by reference. The licensee provided the following references:

Ref	Document No.	Document Title	Rev
13.2	NUH32PHB.0101	Design Criteria Document (DCD) for NUHOMS® 32PHB System for Storage	2
13.42	NUH32PHB.0111	Design Report for the NUHOMS® 32PHB DSC for Storage of Spent Nuclear Fuel	3
13.3	NUH32PHB-0201	NUHOMS® 32PHB Weight Calculation of DSC/TC System	0
	NUH32PHB-0203	PWR Fuel Rod Accident Side Drop Loading Stress Analysis for NUHOMS® 32PHB System	
13.6	NUH32PHB.0204	NUHOMS® 32PHB Canister Structural Evaluation for Storage and Onsite Transfer Loads	1
13.7	NUH32PHB.0205	NUHOMS® 32PHB Basket Evaluation for Storage and Transfer Loads	1
13.9	NUH32PHB-0207	Fuel Rod End Drop Analysis for NUHOMS® 32PHB using LS-DYNA	1
13.10	NUH32PHB-0208	HSM-HB Structural Analysis for NUHOMS® 32PHB System	0
13.11	NUH32PHB-0209	CCNPP-FC Transfer Cask Impact onto the Concrete Pad, LS-DYNA Analysis (80 in Side, Corner, and End Drops)	0
13.12	NUH32PHB-0210	NUHOMS® 32PHB Canister, Basket and Fuel Assemblies Dynamic Load Factors	0
13.13	NUH32PHB-0211	Reconciliation for Transfer Cask CCNPP-FC Structural	1

		Evaluation	
13.14	NUH32PHB-0212	CCNPP-FC Transfer Cask Structural Evaluation – Accident Conditions, 75G Side Drop and 75G Top End Drop Cases	1
13.15	NUH32PHB-0213	NUHOMS® 32PHB Canister Lifting Lug Analysis	0
13.16	NUH32PHB-0214	NUHOMS® 32PHB Reconciliation for Civil Structures	0
	11562-019-ST-05	ISFSI HSM-HB Pad & Approach Slab Design	0

5.1 Discussion

The licensee determined the structural performance of each component for the normal, off-normal and postulated accident conditions described in the design criteria document (DCD) for the NUHOMS®-32PHB System for Storage (Reference 13.2 of the draft SAR). The licensee summarized the normal, off-normal and accident condition loads in Tables 13.3.3, 13.3.4 and 13.3.5 respectively in the draft SAR. The staff used NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" and NUREG-1536, "Standard Review Plan for Spent Fuel Storage Systems at a General License Facility" to facilitate the review of the application. Although NUREG-1536 applies to a general facility license, because this NUREG addresses the design of the storage system, the staff believes that portions of this document are appropriate for this review. The staff reviewed draft SAR Tables 13.3.3, 13.3.4, 13.3.5 and the DCD and concluded they are consistent with Table 3-3 of NUREG-1536 and American Society of Mechanical Engineers (ASME) Boiler & Pressure Vessel Code (ASME Code), Division 1, Subsection NB.

5.1.1 Codes and Standards

The licensee listed the applicable codes and standards used for each component for each condition of loading in Draft SAR Tables 13.3.3, 13.3.4 and 13.3.5. The licensee stated in the Draft SAR that the DSC and the basket were designed, fabricated and tested in accordance with ASME Code, Section III, Subsection NB and NG respectively; the TC was designed, fabricated and tested in accordance with ASME Code, Section III, Subsection NF; and the HSM-HB was designed and fabricated in accordance with American Concrete Institute (ACI) 349-97 and ACI 318-95. The licensee provided a list of exceptions to ASME Code, Section III, Subsections NB and NG for the DSC and the basket respectively on drawing number NUH32PHB-30-30, Revision 3. In accordance with Interim Staff Guidance (ISG)-10, the staff reviewed the list of code alternatives and finds that they are acceptable, because they are consistent with those approved for the systems currently in use at the CC ISFSI.

5.2 NUHOMS®-32PHB DSC

The licensee stated that the NUHOMS®-32PHB DSC is similar to the NUHOMS®-32P DSC design currently in use at the CC ISFSI. According to the licensee, the NUHOMS®-32PHB DSC consists of a shell assembly of the same outside dimensions as the NUHOMS®-32P DSC, which provides confinement and shielding; and an internal basket assembly which locates and supports the fuel assemblies, transfers the heat to the cask body wall, and provides for criticality control as necessary to satisfy nuclear criticality safety requirements.

The licensee described the basket as a tube assembly, with aluminum and poison plates in between the tubes for heat transfer and criticality control. Except for the solid aluminum rails added to support the increased heat load, and poison plate material with increased ^{10}B areal

density, the licensee stated that the NUHOMS®-32PHB DSC basket is identical to the NUHOMS®-32P DSC basket.
In addition to fuel with Zircaloy-4 and Zirlo cladding, the licensee stated that the NUHOMS®-32PHB DSC may also contain fuel with M5 cladding.

For the NUHOMS®-32PHB DSC, the staff considered only the portions of the structural system design that are different from the NUHOMS®-32P DSC which encompasses the solid aluminum rails, the M5 cladding, the lifting blocks and the elevated temperatures that are not bounded by the previously approved NUHOMS®-32P design.

DSC Shell and Welds

The licensee qualified the DSC components through stress analysis that considered individual loading conditions based on the load combinations specified in the DCD. Table 5-1 of Reference 13.6 of the draft SAR lists the load combinations that were used in the analysis of the 32P and 32PHB DSC. The licensee asserted that all but four of these load combinations are bounded by the previously evaluated 32P DSC. The load combinations that are bounded by the 32PHB DSC are:

1. Normal Load: Stress due to dead weight of the DSC in the horizontal position with fuel + normal thermal stress at 104°F ambient temperature + normal pressure stress + normal handling load stress.
2. Off-Normal Load: Stress due to dead weight of the DSC in the horizontal position with fuel + normal thermal stress at 104°F ambient temperature + off-normal pressure stress + off normal handling load stress.
3. Off-Normal Load: Stress due to dead weight of the DSC in the horizontal position with fuel + normal thermal stress at 104°F ambient temperature + off-normal pressure stress + normal handling load stress.
4. Accident Load: Stress due to dead weight of the DSC in the horizontal position in the HSB with fuel + accident thermal stress at 104°F ambient temperature + accident pressure stress

Tables 7-3 through 7-6 of Reference 13.6 of the draft SAR lists the associated stresses in the DSC components as a result of the above loading conditions with the stress allowables and the margin of safety. The margin of safety, shown below, must be greater than zero.

$$Margin\ of\ Safety = \frac{Allowable\ Stress}{Actual\ Stress} - 1\ \geq 0$$

The licensee reported that all margins of safety are positive, with the smallest margin of 0.11 occurring in the DSC shell for load combination 1 above.

The licensee re-evaluated the DSC welds in Appendix B of Reference 13.6 of the draft SAR at the bounding temperature of 610°F for the 32PHB DSC. The licensee reported that all margins of safety are positive, with the smallest margin of 0.11 occurring in the bottom inner cover-to-bottom side weld (1/4 inch groove with 1/8 inch covering fillet) during the bottom end drop load case.

Because the margins of safety are greater than zero, the staff finds the DSC shell and weld designs are acceptable.

Aluminum rails

The licensee described the basket structure as an assembly of stainless steel tubes joined by fusion welds and separated by stainless steel support plates, aluminum and poison plates. The stainless steel tube, stainless steel support plates, aluminum and poison plates between fuel compartments is effectively a sandwich panel. The licensee stated that the stainless steel members are the primary structural components and that the aluminum and poison plates provide the heat conduction path from the fuel assemblies to the cask shell wall and also provide criticality control. The licensee asserted that the solid aluminum transition rails perform their function by remaining in place. Based on the licensee's description of the basket assembly, the staff determined that no structural evaluation is required for the solid aluminum rails.

M5 Cladding

The licensee stated that three cladding materials, Zirlo, Zircaloy-4 and AREVA M-5, are used for the fuel assemblies in the NUHOMS®-32PHB DSC. The parameters used for the Zirlo and Zircaloy-4 clad fuel assemblies in the NUHOMS®-32P DSC, which have been analyzed by NRC staff and found to be adequate, are the same as those used for the Zirlo and Zircaloy-4 clad fuel assemblies in the NUHOMS®-32PHB DSC; therefore the staff concludes that the analysis of the fuel assemblies, with Zirlo and Zircaloy-4 cladding, from the NUHOMS®-32P DSC bounds that of the NUHOMS®-32PHB DSC. For the M-5 cladding, the licensee scaled the maximum principle strain by the ratio of Young's Modulus between M-5 and Zircaloy-4 at 750°F, because the deformation of the fuel assembly remains in the elastic region.

The staff requested the licensee provide calculation NUH32PHB-0203, Rev 1, "PWR Fuel Rod Accident Side Drop Loading Stress Analysis for NUHOMS®-32PHB System," to verify the scaling factor used by the licensee. The licensee provided the document which contained the material properties of Zircaloy-4 and M-5 cladding at 750°F and established the scaling factor that the licensee used to calculate the maximum principle strain in the M-5 cladding as a result of the 80 inch end drop. For both the Zircaloy-4 and the M-5 cladding, the licensee determined the maximum principle strain is well below the yield strain. As a result, because staff was able to verify that the calculated strain in the material is less than the yield strain the staff concludes that the performance of the M5 cladding under the 80 inch drop scenario is acceptable.

Lifting Lugs

The licensee stated that the lifting lugs are used to lift the DSC and empty the basket and place them in the transfer cask and that all other lifting is accomplished with the transfer cask trunnions. The licensee demonstrated the structural adequacy of the lifting lugs in Reference 13.15 of the draft SAR, which is accomplished through a combination of finite element analysis and hand calculations. The licensee determined the stresses in all components and welds and compared them to their respective stress allowables, which is based on the assumption that the DSC lifting will be in the vertical direction only, using a spreader beam assembly so that the lugs equally share the load and are not subjected to any horizontal loading. The staff reviewed the analysis and finds it acceptable because the reported stresses are less than the stress allowables, and notes that these lugs will only be used to lift the DSC when it is empty and will not be used to lift the DSC when it contains spent fuel.

Findings

F5.1 The SAR and docketed materials relating to the description of confinement structures, systems and components meet the requirements of 10 CFR 72.24 (b).

F5.2 The SAR and docketed materials relating to design criteria, including applicable codes and standards meet the requirements of 10 CFR 72.24 (c)(1), (c)(2), and (c)(4); 10 CFR 72.40 (a)(1); 10 CFR 72.120 (a) and (b); 10 CFR 72.122 (a), (b), (c), (d), (f), (g), (h), (i), (j), (k), and (l); 10 CFR 72.128 (a) ; and 10 CFR 72.236 (b), (e), (f), (g), and (k). The confinement structures meet the guidance provided in applicable parts of Regulatory Guides 1.29, 1.60, 1.61, and 1.92 for protection against seismic events. The confinement structures meet the guidance provided in applicable parts of Regulatory Guides 1.76 and 1.117 for tornado protection.

F5.3 The SAR and docketed materials provide adequate analytical and/or test reports to ensure that structural integrity of the confinement structures and meet the requirements of 10 CFR 72.24 (d)(1), (d)(2), and (i), and 10 CFR 72.122 (b)(1), (b)(2), and (b)(3), (c), (d), (f), (g), (h), (i), (j), (k), and (l).

5.3 Transfer Cask

The licensee stated the NUHOMS®-32PHB DSC is handled, loaded, and sealed in the same manner as the NUHOMS®-32P DSC, before being transported to the ISFSI. The staff notes that because the weight of the transfer cask and trailer loaded with the 32PHB DSC is essentially the same as when loaded with the 32P DSC, the stability is unchanged and that the analysis conducted for tornado effects, flooding and seismic is governed by the 32P DSC analysis. The licensee further stated that the NUHOMS®-32PHB DSC is stored only in the HSM-HB at the ISFSI and that the same transfer cask is used for the NUHOMS®-32PHB, NUHOMS®-24P, and NUHOMS®-32P DSCs. According to the licensee, when utilized with the NUHOMS®-32PHB DSC, the TC may be used in a forced-cooling configuration due to the higher heat load. The licensee stated that the forced-cooling configuration consists of a new cask lid which contains small openings around the periphery that vent out forced air that is injected at the bottom of the cask (through the ram access opening). A 0.5 inch thick spacer disc with wedge shaped protrusions is installed at the bottom of the transfer cask to facilitate air flow coming through the ram access opening to the annular space around the DSC.

Reference 13.13 of the draft SAR is a reconciliation of the TC loaded with both the NUHOMS®-32P DSC and the NUHOMS®-32PHB DSC. According to the licensee, the purpose of the reconciliation is to determine the bounding conditions and to update the analysis as necessary for the cask loaded with the NUHOMS®-32PHB DSC when that condition governs.

The licensee stated that the temperature in the cask loaded with a NUHOMS®-32PHB is lower than when loaded with a NUHOMS®-32P DSC, due to the time limits for transfer operation and the option of forced cooling (FC) for the NUHOMS®-32PHB DSC. The licensee asserted that these time limits are established to ensure that the cask temperatures when loaded with the NUHOMS®-32PHB remain below those of the cask when loaded with the NUHOMS®-32P DSC. Because of this, the licensee used the TC thermal stresses obtained from the previous NUHOMS®-32P DSC analysis for calculations of stresses in the cask loaded with a NUHOMS®-32PHB DSC. Because the temperatures for the TC when loaded with the NUHOMS®-32P DSC NUHOMS bound those when loaded with the NUHOMS®-32PHB DSC, the staff concludes this approach is acceptable.

In cases where the contributing component weight of the NUHOMS®-32P DSC loaded cask is more than the component weight of the NUHOMS®-32PHB DSC loaded cask, the licensee used the more conservative stress result of the previously analyzed NUHOMS®-32P DSC loaded cask. When the converse applied, the licensee increased the previously analyzed stress for the NUHOMS®-32P DSC loaded cask by a ratio of the weights of the contributing components. Because stress is proportional to weight in the elastic region, the staff concludes that this is acceptable for the linear elastic analysis cases.

The licensee stated that of the different loading combinations that apply to the TC, most are bounded by the cask loaded with the NUHOMS®-32P DSC, and those that are bounded by the cask loaded with the NUHOMS®-32PHB DSC are scalable as described above. The licensee reported that all of these conditions produced positive margin between the actual stress and the stress allowable. In Reference 13.14 of the draft SAR, the licensee analyzed two accident conditions (top end drop and horizontal drop) in which the cask loaded with the NUHOMS®-32PHB DSC is not bounded by the cask loaded with the NUHOMS®-32P DSC using a nonlinear static analysis and are summarized below.

The licensee analyzed the TC for the 75g top end drop and side drop using ANSYS release 10.0A1 finite element analysis software using material properties at 400°F. The components of interest include: structural shell, inner shell, top cover plate, top flange, bottom support ring, bottom cover plate, RAM access ring, bottom end plate, lead shielding, and bottom neutron shield. The licensee based the acceptance criteria on ASME Division III, Appendix F, Section F1341.2 for Plastic Analysis and F-1341.3 for Limit Analysis Collapse Load. The licensee reported that all but one of the components met the conservative requirements of F-1341.2 for both the top end drop and the side drop. The highest stress ratio (actual stress/stress allowable) for the side drop (0.93) occurred in the inner shell, and the highest stress ratio for the top end drop (0.48) occurred in the top cover plate.

The licensee stated that the stresses in the top cover plate for the side drop exceed the limits of F-1341.2 for plastic analysis, so the licensee performed a detailed analysis in accordance with F-1341.3 to ensure that the overall failure of the top cover plate due to a plastic hinge does not occur. The licensee demonstrated this by increasing the applied load until the solution no longer converged (i.e. failure of the component). The licensee reported that the last point at which the solution converged was at 85.48g and asserted that this satisfies the criteria of F-1341.3 that states that the applied static load must not exceed 90% of the collapse load (70/85.48 = 82%). The licensee's analysis also determined that because of the high deformation at the bottom of the lid, where the cask impacts the ground, the stress in the bottom two lid bolts are very close to the allowable limit (stress ratio = 0.997) due to prying action. Because the stress in the remainder of the bolts is significantly low, the licensee assumed that these are the only bolts that fail and deemed these consequences for the 75g impact acceptable. The staff reviewed the analysis in Reference 13.14 of the draft SAR submittal, including all of the above noted information concerning the transfer cask. Because the TC is not a pressure retaining structure, the purpose of the lid is to remain in place to provide shielding and continued air flow in the FC configuration. The staff determined that if two bolts fail, the remaining 30 bolts will be more than sufficient to hold the lid in place following a drop accident; therefore, the staff finds that the design of the TC for FC operations provides an adequate level of safety against the 75g impact.

Findings

F5.4 The SAR and docketed materials relating to the description of the transfer cask meets the requirements of 10 CFR 72.24 (b),
F5.5 The SAR and docketed materials relating to design criteria, including applicable codes and standards meet the requirements of 10 CFR 72.24 (c)(1), (c)(2), and (c)(4); 10 CFR 72.40 (a)(1); 10 CFR 72.120 (a) and (b); 10 CFR 72.122 (a), (b), (c), (d), (f), (g), (h), (i), (j), (k), and (l); 10 CFR 72.128 (a); and 10 CFR 72.236 (b), (e), (f), (g), and (k). The other SSCs important to safety meet the guidance provided in applicable parts of Regulatory Guides 1.29, 1.60, 1.61, and 1.92 for protection against seismic events. The transfer cask meets the guidance provided in applicable parts of Regulatory Guides 1.76 and 1.117 for tornado protection. The transfer cask meets the guidance provided in Regulatory Guides 1.59 and 1.102 for flood protection.

F5.6 The SAR and docketed materials provide adequate analytical and/or test reports to ensure that structural integrity of the transfer cask and meet the requirements of 10 CFR 72.24 (d)(1), (d)(2), and (i), and 10 CFR 72.122 (b)(1), (b)(2), and (b)(3), (c), (d), (f), (g), (h), (i), (j), (k), and (l).

5.4 HSM-HB

The licensee stated that the HSM-HB is a free standing reinforced concrete structure designed to provide protection and radiological shielding for the 32PHB DSC. Each HSM-HB provides a self-contained modular structure for the storage of the DSC with spent fuel assemblies. A single HSM-HB is capable of storing a NUHOMS®-32PHB DSC containing 32 pressurized water reactor fuel assemblies. The HSM-HB permits heat rejection by natural convection in order to maintain acceptable temperatures.

According to the licensee, each prefabricated HSM-HB is comprised of a base unit and a roof unit assembled together to form a single module. The DSC is supported inside the HSM-HB by the DSC support structure. The DSC support structure (rail support assembly) is comprised of two rail sections, two slotted plates and two rail support plates. The rail support assembly provides support for the DSC during storage and acts as a sliding surface during DSC insertion and retrieval. The modules sit on a reinforced concrete basemat at the ISFSI site.

The licensee stated that each HSM-HB is placed in contact with an adjacent HSM-HB to form an array. The air inlet vents are extending through the front on both sides of the front wall and the air outlet vents are provided in the roof unit. The front wall and the rear wall of the base unit provide support for the rails and the rail extension flanges. The roof unit rests on the front, rear and side walls of the base unit.

The licensee stated that the HSM-HB shield door consists of a rectangular steel plate at the front attached to a circular reinforced concrete block at the rear. Both the steel plate and concrete blocks fit the circular opening in the front wall. Studs that are welded to the circular steel plate anchor the plate to the rear reinforced concrete block. The concrete door provides missile protection and shielding. End shield walls are provided at the ends of a module array to provide the required missile and shielding protection. Similarly, the licensee stated that an additional shield wall is used at the rear of the module for single module rows. Drawing NUH-03-7101 depicts both of these configurations.

According to the licensee, flat panels are used as heat shields on the interior walls of the HSH-HB. The heat shields provide thermal protection for the HSM-HB concrete. The licensee documents the results of the structural evaluation of the HSM-HB subjected to normal, off-

normal and accident loads in Reference 13.10 of the draft SAR.

5.4.1 Model Description

The licensee developed analytical models of a single free standing HSM-HB for the computer program ANSYS. The licensee considered the frame and shear wall action of the HSM-HB concrete components to be the primary structural system resisting the loads evaluated in the models for normal operating, off-normal and postulated accident loads acting on the HSM-HB.

The licensee used a three dimensional finite element model of the HSM-HB which includes all the concrete components (rear wall, front wall, two side walls and the roof). The licensee used the eight node SOLID73 element with four layers of elements to model the concrete structure. Each node of the eight node brick element has six degrees of freedom. The licensee modeled the DSC using the beam elements BEAM4. The rails and the lateral bracing between the rails (Cross beams) were also modeled using beam elements with appropriate stiffness. The licensee lumped the mass of the DSC at the nodes representing the DSC using the lumped mass element MASS21.

The licensee attached the DSC support structure model to the concrete at several locations (four locations at the rear shelf, four locations in the front shelf and two locations on the front wall opening). Each node of the support structure has three translational and three rotational degrees of freedom. The rails are supported such that they are completely restrained at the front extension plate locations and free to rotate in all three directions and free to translate only in the axial direction at the other supports in the rear and the front shelf locations.

The licensee incorporated the DSC support structure analytical model into the HSM-HB analytical model. The licensee applied the various normal, off-normal and accident loads to the analytical model and computed the internal forces and moments in different members by performing a linear elastic finite element analysis.

The licensee used the node coupling option of ANSYS to represent the appropriate connection between the different concrete components of the HSM-HB model and the connections of the support structure to the concrete structure. For all but the stability analysis, due to applied loading, the licensee considered the model to neither uplift from the basemat (because of its dead weight) nor to slide on the basemat (because of friction). The licensee asserted that the evaluation of the stability of the HSM-HB confirms this consideration. As such, the model is restrained vertically at all nodes on the bottom of the model, and also restrained laterally and axially at all nodes on the bottom of the model to prevent rigid body movement.

5.4.2 Concrete Components

The licensee computed the ultimate shear and moment capacities of the concrete components that comprise the HSM-HB which includes: The upper and lower rear wall, the upper and lower side walls, the roof, the upper and lower front walls, the end shield wall and the rear shield wall. The licensee subjected the ANSYS model to each of the normal, off-normal and accident loads, and computed the nodal stresses in the concrete components for each case. The licensee then post processed the results to determine the maximum axial and shear forces and bending moments in each component and combined these forces using the appropriate load combinations. The licensee compared the maximum axial and shear forces and bending moments within each component resulting from the various combined loading conditions to their

respective axial, shear and moment capacity. In Tables 8-20 and 8-21 of Reference 13.10 of the draft SAR the licensee reported that the ratios of calculated load to the load capacity (calculated/capacity) for all load combinations for all components were less than 1.0. Because the ratios are all less than 1.0, the staff concludes that the concrete components have the required strength capacity to resist the normal, off-normal and accident load combinations.

5.4.3 DSC Steel Support Structure

The licensee stated that the HSM-HB support structure consists of two rail assemblies, each at 30 degrees from the vertical center line of the DSC. Four cross members connect the two rail assemblies (at the time they are shop fabricated) by four gusset plates welded to the rail web and the flanges. However, after the rail assemblies are installed at the ISFSI site, and before the DSC is loaded, the licensee stated the two outer most end cross members are removed. The steel support structure supports the DSC stored inside the module. Using the ANSYS model described earlier, the licensee determined that the stresses in the steel support structure for all load combinations. The licensee reported that for all members of the steel support structure, the calculated stress was less than the stress allowable, including all steel members, bolts and welds. The staff reviewed the calculations in Reference 13.10 of the draft SAR and concludes that because the computed stresses are less than their associated stress allowable, the steel support structure has adequate strength to support the DSC for all normal, off-normal and accident load combinations.

5.4.4 Missile Impact

The licensee evaluated the HSM-HB for tornado generated missile impact for the spectrum of missiles listed in Section 13.3.2.1.4 of the draft SAR. The licensee assessed the missile impact effects in terms of local damage (penetration, perforation, spalling and scabbing) and overall structural response. In the analysis, the licensee considered the 44" thick roof, the 42" thick front wall, the 36" thick end and rear shield walls and the shield door. Using the modified National Defense Research Committee equations for penetration depth, the licensee determined the thickness of the HSM components considered was adequate to resist perforation, spalling and scabbing. With respect to the overall response of the HSM-HB due to tornado missile impact, the licensee used rectangular and triangular forcing functions for the impact load, depending on the torpedo missile. In all cases, the licensee showed that the ductility ratio was less than 10 for all components. The staff reviewed the licensee's calculations. Because the thicknesses of the concrete components are greater than the thickness that typically prevents perforation and scabbing, the staff determines that the design of the concrete components of the HSM is adequate. Additionally, because the ductility ratio is less than 10, consistent with the provisions of ACI-349-97, the staff concludes that the overall response of the HSM as a result of tornado missile impact is acceptable.

5.4.5 Miscellaneous Components

The licensee evaluated the structural performance of various other components that comprise the HSM-HB, to include the heat shields, the concrete covers over the vent openings, concrete embedment and the canister stop plates and welds in Reference 13.10 of the draft SAR.

Heat Shields

The licensee evaluated the heat shields and attachments for normal, off-normal and accident

load combinations in Appendix B of Reference 13.10 of the draft SAR. The staff reviewed the calculations in Appendix B and verified that, in all cases, the actual stress in the given component was less than the stress-allowables for the worst case load combination and is therefore acceptable.

Concrete Vent Covers

The licensee stated that the concrete vent covers are tied to the roof of only one of the side-by-side modules. The licensee designed the cover as a simply supported beam and determined that the moment and shear capacity of the vent cover is greater than the actual load for the worst case load combination. Because the moment and shear capacity of the concrete vent cover is greater than the applied load, the staff finds the design of the concrete vent covers acceptable.

Concrete Embedments

The licensee evaluated the structural adequacy of miscellaneous steel embedments and fasteners used in the concrete connections of the HSM-HB by determining the strength of the embedments and the pullout strength of the concrete. This analysis encompassed the shield wall, shield door, cask restraint, DSC Front Axial Seismic Restraint, DSC Support Rail Extension, Upper Vent Cover, Heat Shields, and other components attached to the concrete HSM via an embedment. The licensee determined that the strength of the steel fasteners and the strength of the concrete against pullout for the fasteners are all greater than the actual loads applied to the embedments. Because the load capacity of the steel fasteners and the capacity of the concrete against pullout is greater than the load applied, the staff finds the design of the embedments acceptable.

5.4.6 Stability of the HSM-HB

In order to establish the boundary conditions for the finite element model described above, and to determine that the HSM-HB satisfies the overturning and sliding criteria required by NUREG-1567 and provided in DCD, the licensee performed a stability analysis of the HSM-HB (overturning and sliding) and the DSC inside the HSM-HB (uplift from rails) subjected to different accident loads. In addition to the sliding and overturning analysis of a single HSM-HB, the licensee also performed an analysis of the sliding and uplift of the roof unit on the base unit of the HSM-HB.

The licensee analyzed the five load cases below for overturning and sliding on a single free standing module or a roof unit:

1. Seismic Load
2. Flooding of the ISFSI site with current acting on walls
3. Tornado Generated Wind Loads
4. Massive Missile Impact Loads
5. Blast Pressure

The licensee stated that the HSM-HB and shield walls are connected by tension elements at the upper and lower parts of the side wall and the rear wall to prevent sliding/overturning separation from each other during an earthquake or tornado. Therefore, for stability analysis, the licensee

considered a single loaded HSM-HB with one end shield wall (Configuration 1) and a single loaded HSM-HB without any end shield wall (Configuration 2), unless noted otherwise. For Configuration 2, the licensee also analyzed for a minimum weight DSC and an empty HSM. The staff notes that these two configurations are conservative for several reasons:

1. End shield walls or two empty modules are specified at the end of the array for shielding purposes. The empty modules allow expansion of the existing array. The presence of this additional weight provides more resistance to movement as well as increases the moment arm for the resisting force, further increasing the resistance to overturning.
2. As more modules are added to the array, the resistance to overturning or sliding will be further increased, because the moment arm associated with the restoring moment will be increased as well as the weight of the entire system.
3. Even if the modules do not act as one solid structure (i.e. the tension bars break), the presence of a loaded module in contact with another will provide more resistance to movement, either sliding or tipping, than for a single module.
4. The licensee does not consider the rear shield walls in their calculations.
5. Note 2 of drawing NUH-03-7101 specifies a minimum of two modules.

<u>HSM-HB Overturning and Sliding Due to Seismic Load</u>

The licensee used 0.37g and 0.20g for the horizontal and vertical accelerations for the HSM-HB respectively, and 0.43g and 020g for the horizontal and vertical accelerations of the DSC in the HSM-HB respectively. These inertial loads are based on the modal frequencies of the HSM-HB and the DSC in the HSM-HB and are calculated in Reference 13.10 of the draft SAR. Additionally, the licensee determined that the worst case combination of accelerations to be 100% in the horizontal direction and 40% in the vertical direction as is recommended by American Society of Civil Engineers (ASCE) 4-98.

The licensee determined the lowest factor of safety against overturning to be 1.04, as a result of the seismic load applied to the second configuration described above. The licensee considered this to be acceptable because they do not consider the seismic load to be a sustained load. Although the factor of safety for overturning is less than 1.1 as specified in Table 3-3 of NUREG-1536, the staff finds this acceptable because of the conservatisms noted above and because of the presence of additional HSMs, which will increase the resistance to overturning.

For the sliding cases, the licensee used a coefficient of friction between the concrete HSM-HB and the concrete basemat of 0.6, which the staff notes is consistent with ACI 349-97 for concrete placed against hardened concrete not intentionally roughened. The licensee used horizontal and vertical accelerations of 0.37g and 0.2g respectively to evaluate the two configurations. The licensee reported the factor of safety for all cases were greater than the required 1.1, with the lowest being 1.43. Because the factor of safety is greater than 1.1, consistent with Table 3-3 of NUREG-1536, the staff determines that the HSM-HB will not slide due to the design seismic event.

<u>HSM-HB Overturning due to Flooding</u>
The licensee's considered flood load consists of 50 feet of water moving at a velocity of 15 feet per second. The licensee reported factors of safety for Configuration 1 and Configuration 2 to

be 1.62 and 1.21 respectively which are both greater than the required 1.1. The staff reviewed the stability calculations for the flood load and requested the licensee justify why the overturning moment due to the drag force of the water was multiplied by a factor of 0.5. The licensee responded that the calculation considered two modules aligned in the direction of the flood water velocity, so that both resist the force, but only one is exposed to the force. Furthermore, because the HSMs are constructed in units of 12 configured in a 2x6 array, in an array of six HSMs with modules in contact, the total flood load would be distributed among all six and be further reduced. The staff reviewed the licensee's response and determined their rationale is reasonable because it is consistent with the methodology that was used for Certificate of Compliance 72-1004, FSAR, "Final Safety Analysis Report for the Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel," Appendix P (ADAMS Accession No. ML14255A191). Additionally, as stated by the licensee, and determined by the staff, the presence of additional HSMs will further increase the resistance to overturning the HSM-HB sliding due to flood.

Using the postulated flood load and a coefficient of friction between the concrete HSM-HB and the concrete basemat of 0.6, the licensee analyzed the HSM-HB for sliding for both configurations. The licensee reported that the factors of safety against sliding due to a flood load for all configurations are all greater than 1.1. The staff reviewed the licensee's sliding calculations and determines that, because the factor of safety is greater than 1.1, consistent with Table 3-3 of NUREG-1536, the HSM-HB will not slide due to the design flood forces described above.

HSM-HB Overturning Due to Tornado Generated Wind Load

The licensee calculated the maximum design basis tornado generated wind loads to be 234 pounds per square foot (psf) and 148 psf (suction) on the windward and leeward walls in an HSM-HB array. The licensee also applied a suction pressure of 207 psf to the roof of each HSM-HB in the array. The licensee stated that the critical module is the one on the leeward side that is subjected to the suction pressure of 148 psf. The licensee analyzed the HSM-HB for overturning for both configurations and determined the factors of safety are all greater than the required 1.1. The staff reviewed the licensee's calculations and, because the factor of safety against overturning is greater than 1.1 for both configurations, finds that the HSM-HB will not overturn due to the design tornado generated wind forces.

HSM-HB Sliding Due to Tornado Generated Wind Load

Using the maximum design basis tornado generated wind loads and a coefficient of friction between the concrete HSM-HB and the concrete basemat of 0.6, the licensee analyzed the HSM-HB for sliding for all configurations. The licensee reported the factors of safety against sliding due to tornado generated wind loads are all greater than the required 1.1, consistent with Table 3-3 of NUREG-1536, with the exception of an empty module which is 1.02. As a result, the licensee stated that a minimum of two empty modules must be placed at the end of a single module array. The staff notes that the single module is conservative as noted earlier and that the addition of more HSMs to the array will provide further resistance to sliding and, accordingly, the staff determines that the HSM-HB will not slide as a result of the design tornado generated wind forces.

HSM-HB Stability due to Tornado Missile impact

The licensee evaluated the stability (overturning and sliding) due to the impact of the postulated

design basis tornado generated missile consisting of a 4000 lb. automobile traveling horizontally at 195 fps on a single HSM-HB with two end shield walls. For the stability of the HSM-HB under the missile impact load, the force due to the deformable massive missile impact was applied to the structure at the most adverse location. The licensee determined the following:

- A loaded module will rotate approximately 0.60 degrees from vertical and is therefore stable against overturning as tip-over does not occur until the module rotates to an angle of more than 24.65 degrees.
- A massive missile impact on a single loaded HSM-HB with an end shield wall will slide the module approximately 0.34 inches. The sliding distance will be significantly reduced by the presence of more than one module and therefore the sliding displacement is insignificant.
- An empty module or a module with a minimum DSC weight will rotate approximately 0.83 degrees from vertical and is therefore stable against overturning as tip-over does not occur until the module rotates to an angle of more than 24.01 degrees.
- An empty module or a module with a minimum DSC weight will slide approximately 0.47 inches. The sliding distance will be significantly reduced by the presence of more than one module and therefore the sliding displacement is insignificant.

The staff notes that for combined tornado effects, Regulatory Guide (RG) 3.3.2 suggests the tornado wind load and tornado generated missile load be added together, and provides an acceptable method for combining the effects. The licensee considered these two loads independently, but did not consider the additive effect they have on overturning and sliding. Based on the conservatisms noted above and the safety factors against each of the loads, and after considering a combined tornado load, the staff finds that the HSM-HBs provide an adequate level of resistance to overturning due to the design tornado generated effects (wind force and missile force).

Sliding of Roof on Base

The licensee analyzed the sliding of the roof on the base as a result of seismic, flood, tornado wind and tornado missile loads. In the case of seismic, flood and tornado wind loads, the licensee determined that the weight of the roof is sufficient to prevent the roof from sliding and that the front and rear shear keys in the roof that interlock with the base, prevent movement due to a tornado missile. Furthermore, the licensee demonstrated that the shear stress developed in the shear key is less than the capacity of the reinforced concrete. The staff reviewed the licensee's calculations and finds that the calculations demonstrate that the HSM-HB roof will not slide nor detach from the base due to the postulated environmental phenomena.

Stability of DSC on the Support Rails inside the HSM-HB

The licensee evaluated the performance for the DSC against lifting off of the support rails and sliding on the rails as the result of a seismic event. Using 0.43g in the horizontal direction and 0.20g in the vertical direction, the licensee determined the factor of safety against lift-off from the rails is 1.23. The DSC will slide on the rails, but according to the licensee, the canister stop plates and the seismic retainers will provide restraint. In Reference 13.10 of the SAR, the licensee demonstrated that the load on the retainers for a seismic event is less than the load for normal and off-normal handling and is therefore bounded by these loads. The analysis

indicates that the bending stress and shear stress in the retainers as well as the associated weld stresses is less than the stress allowables for the respective material. The staff reviewed the licensee's analysis and finds that because the factor of safety for lift-off is greater than 1.1, and because the calculated stress in the components of the support structure are less than their respective stress allowables, the DSC will remain on the support rails in the event of a design basis seismic event.

Blast Pressure

The licensee considered a single loaded HSM-HB with two end shield walls. The licensee assumed the explosion (blast) pressure to be a triangular pulse pressure time history with a frontal pressure of 60 psi and side/roof positive pressure of 24 psi and duration of 36 milliseconds. As a result of this blast pressure, the licensee determined a single module with two end shield walls will slide 0.14 inches. The staff reviewed the licensee's analysis, confirmed the analytical methodology used by the licensee, and finds that the performance of the HSM-HB as a result of the applied design blast pressure is acceptable, because the presence of additional modules will preclude sliding.

Findings

F5.7 The SAR and docketed materials relating to the description of reinforced concrete structure meet the requirements of 10 CFR 72.24 (b).

F5.8 The SAR and docketed materials relating to design criteria, including applicable codes and standards meet the requirements of 10 CFR 72.24 (c)(1), (c)(2), and (c)(4); 10 CFR 72.40 (a)(1); 10 CFR 72.120 (a) and (b); 10 CFR 72.122 (a), (b), (c), (d), (f), (g), (h), (i), (j), (k), and (l); 10 CFR 72.128 (a); and 10 CFR 72.236 (b), (e), (f), (g), and (k). The concrete structures meet the guidance provided in applicable parts of Regulatory Guides 1.29, 1.60, 1.61, 1.92, and 1.122 for protection against seismic events. The concrete structures meet the guidance provided in applicable parts of Regulatory Guides 1.76 and 1.117 for tornado protection.

F5.9 The SAR and docketed materials provide adequate analytical and/or test reports to ensure that structural integrity of the concrete structures and meet the requirements of 10 CFR 72.24 (d)(1), (d)(2), and (i), and 10 CFR 72.122 (b)(1), (b)(2), and (b)(3), (c), (d), (f), (g), (h), (i), (j), (k), and (l).

5.5 Reinforced Concrete Pad

In response to the staff's request for the safety analysis of the ISFSI pad(s) expanding the previously analyzed total allowable deployment number of 120 in the Calvert Cliffs ISFSI USAR to the proposed 132 HSMs, the licensee submitted Reference 13.16 of the draft SAR. The licensee stated that the purpose of the storage pad and the approach slab are to support the HSM-HBs and to support transfer operations respectively for normal, off-normal and accident conditions. The licensee determined the plan dimensions, thickness, and reinforcement size and placement based on the provisions of ACI 349-06. Based on the storage pad and approach slab size, and reinforcement placement, the licensee determined the minimum factor of safety (capacity/actual load) for flexure, shear and soil bearing pressure are all greater than 1.0. The staff reviewed the calculations in the licensee's submission and determines that, because the factors of safety for flexure, shear and soil bearing pressure are greater than 1.0, the design of the storage pad and approach slab are consistent with the provisions of ACI 349-

06, and are therefore acceptable.

Findings

F5.10 The SAR and docketed materials relating to the description of the concrete pad meet the requirements of 10 CFR 72.24 (b).

F5.11 The SAR and docketed materials relating to design criteria, including applicable codes and standards meet the requirements of 10 CFR 72.24 (c)(1), (c)(2), and (c)(4); 10 CFR 72.40 (a)(1); 10 CFR 72.120 (a); 10 CFR 72.122 (a), (b), (c), (d), (f), (g), (h), (i), (j), (k), and (l); 10 CFR 72.128 (a) and (b); and 10 CFR 72.236 (b), (e), (f), (g), and (k).

F5.12 The SAR and docketed materials provide adequate analytical and/or test reports to ensure that structural integrity of the concrete pad and meet the requirements of 10 CFR 72.24 (d)(1), (d)(2), and (i), and 10 CFR 72.122 (b)(1), (b)(2), and (b)(3), (c), (d), (f), (g), (h), (i), (j), (k), and (l).

5.6 TS Evaluation

5.6.1 The following requested TS changes required a staff structural evaluation:

Renewed Material License No. SNM-2505 Section 15. The proposed amendment adds acceptance standards for liquid penetrant tests of the double closure seal welds at the bottom end of the DSC for the NUHOMS®-32PHB DSC. The acceptance standards for the NUHOMS®-24P DSC and the NUHOMS®-32P DSC remain the same.

TS 3.1.1(7) – Currently, the maximum fuel assembly mass to be placed in the NUHOMS®-24P and NUHOMS®-32P DSCs, including control components, shall not exceed 1450 lbs (658 kg). This proposed amendment adds a new requirement that the maximum fuel assembly mass to be placed in the NUHOMS®-32PHB DSC shall not exceed 1375 lbs (625 kg) excluding control components. The current maximum fuel assembly mass limit remains the same for the NUHOMS®24P and NUHOMS®-32P DSCs.

TS 3/4 3.2.2.1 changed as a result of the amendment. TS 3.2.2.1(a) applies to the NUHOMS®-24P and -32P and constitutes the old TS 3.2.2.1. TS 3.2.2.1(b) is a new TS that proscribes the liquid penetrant acceptance standard for the NUHOMS®-32PHB.

5.6.2 Staff Evaluation

Renewed Material License No. SNM-2505 Section 15 – The licensee added the acceptance standards for liquid penetrant tests of the double closure seal welds at the bottom end of the for the NUHOMS®-32PHB DSC which is to be accomplished in accordance with ASME Code Section III, Division 1, Subsection NB-5350 (1998 with addenda up to and including 1999). The staff reviewed this acceptance standard and determined that it is identical to the acceptance standard for the NUHOMS®-32P and -24P. Because the only difference is the code year, the staff finds this license condition acceptable. The staff notes that these welds must also pass a radiographic examination in accordance with ASME Code Section III, Division 1, Subsection NB-5231 (1998 with addenda up to and including 1999).

TS 3.1.1(7) – The licensee states that the maximum weight of an AREVA fuel assembly without a control element assembly inserted is 1354 lbs. After adding weight due to corrosion, hydrogen absorption, debris and other unknown issues, the licensee proposes a weight limit of 1375 lbs. per fuel assembly for the NUHOMS®-32PHB. The licensee stated that control assembly elements are not included in the 1375 lbs. weight limit because the length of the fuel assembly with the control element assembly inserted would physically preclude placement of the top shield plug and closure of the NUHOMS®-32PHB DSC. The licensee previously evaluated the NUHOMS-32PHB DSC, transfer equipment and HSM for the bounding fuel assembly element weight used for the NUHOMS®-32P and -24P (1450 lbs.) and staff conducted a review of that evaluation (ADAMS Accession No. ML051010242). The staff finds the TS for the maximum weight of a fuel assembly element for the NUHOMS®-32PHB DSC acceptable, because it is bounded by the analysis of the NUHOMS®-32P and -24P (1450 lbs.).

TS 3/4 2.2.1 - The proposed change renumbers the original TS that applied to the NUHOMS-24P and -32P and adds the liquid penetrant acceptance standards to the closure weld of the 32PHB DSC. As was the case for Renewed Material License No. SNM-2505 Section 15, the only difference between the acceptance standards for the 24P, the 32P, and the 32PHB is the code year (evaluated above and found to be acceptable).

6 THERMAL EVALUATION

6.1 Background and Amendment Requests

The licensee submitted the request for approving the storage of high burnup fuel (HBF) with a higher heat load in the NUHOMS®-32PHB DSC (32PHB DSC in this SER). The 32PHB DSC is stored in the HSM-HB at the CC ISFSI. The same TC is used for 32PHB DSC as used for 32P DSC and 24P DSC.

The thermal review is necessary in order for the NRC to evaluate the following five requests:

a. Expansion of the ISFSI total capacity from 120 HSMs to 132 HSMs on the existing site.

b. A new 32PHB DSC design and a new HSM-HB for use at the CC ISFSI.

c. Modification to TS 3.1.1(5) and TS 3.4.1.1 for 32PHB DSC.

d. Addition of new 3.3.2.1, 3.3.2.2, and 3.3.3.1 for 32PHB DSC.

e. The new surveillance requirements (SR) in SR 4.3.3.1.

6.2 Expansion of CC ISFSI Capacity

The licensee requested approval to expand the ISFSI total capacity from the 120 HSMs to 132 HSMs at CC ISFSI. The request is to increase the amount of uranium allowed to be stored in the ISFSI and ensure sufficient capacity to support continued power plant operation through the currently approved 60-year operating licensing period.

The staff reviewed the expansion described in Section 2.0 of the draft SAR Attachment (1) in the amendment application and determined that the proposed increase in ISFSI capacity from 120 HSMs to 132 HSMs is acceptable because there is no change in the maximum heat load

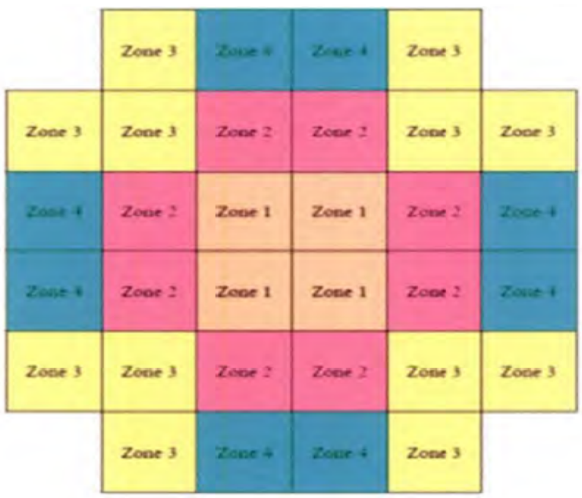
limit, the thermal design, and the heat removal mechanism for HSM. Therefore, the maximum fuel cladding and the component temperatures are not affected by expansion of the CC ISFSI capacity. The staff concludes that the proposed increase in ISFSI capacity from 120 HSMs to 132 HSMs is therefore acceptable because there is no significant impact to heat removal capability of the ISFSI.

6.3 Storage of 32PHB DSC in HSM-HB at CCNPP

6.3.1 Thermal Loads (revise TS 3.1.1(5))

The licensee stated in Section 3.0 of the USAR Attachment (1) in the amendment application that the current maximum heat generation rate limit is 0.66 kW per fuel assembly, and the proposed revision to TS 3.1.1(5) would add a new maximum heat generation rate of 0.8 kW per fuel assembly for NUHOMS®-32PHB DSC basket zones 1 and 4, and a maximum heat generation rate of 1.0 kW per fuel assembly for NUHOMS®-32PHB DSC basket zones 1 and 3, as shown in Figure 4 of the draft SAR or Figure 6-1 below in this SER. As indicated in Figure 6-1 of this SER, the maximum heat load for the 32PHB DSC is 29.6 kW.

Figure 6-1 - NUHOMS®-32PHB DSC maximum heat load zone configuration



Heat Zone	No. of FA	Configuration 1 (kW/FA)	Configuration 2 (kW/FA)	Configuration 3 (kW/FA)	Configuration 4 (kW/FA)
1	4	0.8	0.8	0.72	0.66
2	8	1.0	0.8	0.72	0.66
3	12	1.0	0.8	0.72	0.66
4	8	0.8	0.8	0.72	0.66
Total Heat Load, kW		29.6	25.6	23.04	21.12

The staff reviewed Section 3.0 of the draft SAR Attachment (1) and determined that information of the heat load zone configuration, provided in the amendment application, is consistent with the heat loads used in the thermal calculations.

<u>Environmental Conditions</u>
The ambient air temperatures used to evaluate the design of the 32PHB DSC, the DSC in the TC, and the DSC in the HSM-HB module are -8°F with no insolation to 104°F with full insolation. The design lifetime average ambient temperature identified in the USAR is 70°F.

6.3.2 Decay Heat Removal System

As described in draft SAR Attachment (1) for this amendment application, the HSM built at the CC ISFSI utilizes the high burnup horizontal HSM-HB design. The HSM-HB is similar to the horizontal storage module HSM-H with heat shields. A single HSM-HB is capable of storing a 32PHB DSC containing 32 PWR fuel assemblies. The HSM-HB is designed to have heat removal by natural convection to maintain acceptable temperatures.

In Section 2.0 of the draft SAR Attachment (1) the licensee stated that, for the HSM-HB at CC ISFSI, the air inlet vents extend through the front on both sides of the front wall and the air outlet vents are provided in the roof unit. The heat shields provide thermal protection for the HSM-HB concrete. Similar to the design of the HSM module, the HSM-HB further improves heat rejection by: (a) using slotted plates and holes in the DSC support rails to increase airflow at the bottom portion of canister, and (b) increasing the module cavity height to minimize air flow resistance in the module cavity.

The staff reviewed the thermal design of HSM-HB containing the 32PHB DSC, described in the draft SAR thermal chapter 4.0, and the design drawings attached to the amendment request. The staff found that the thermal design and heat removal capability of HSM-HB and 32PHB DSC are described in sufficient detail in the draft SAR (thermal chapter) and design drawings to enable an evaluation of their thermal effectiveness.

6.3.3 Temperature Limits and Material Properties

<u>Material Properties</u>

The licensee provided the thermal properties of homogenized fuel assembly, SA 240/SA-479 Type 304 stainless steel, aluminum alloys, helium, air, nitrogen and lead in Tables 4-2 through 4-8 of Trans Nuclear (TN) Calculation NUH32PHB-0402 (Thermal Evaluation of NUHOMS®-32PHB TC for Normal, Off-Normal, and Accident Conditions) and Tables 4-2 through 4-8 of TN Calculation NUH32PHB-0403 (Thermal Evaluation of NUHOMS®-32PHB DSC for Storage and Transfer Conditions).

The staff reviewed Tables 4-2 through 4-8 of TN Calculation NUH32PHB-0402 and Tables 4-2 through 4-8 of TN Calculation NUH32PHB-0403. The staff accepted the thermal properties used for the thermal calculations of the 32PHB DSC stored in the HSM-HB or transported by the TC because the thermal properties used in the licensees thermal analyses are consistent with those used in the previous amendments of the NUHOMS system (CoC No. 1004, Amendment No. 13, ADAMS Accession No. ML14153A573), which was approved by NRC on May 24, 2014.

6.3.4 Boundary Conditions

The licensee described the boundary conditions, in Section 5.1.2 of TN Calculation NUH32PHB-0403, for 32PHB DSC in the HSM-HB and the OS197TC.

The licensee stated in Section 5.1.2 of TN Calculation NUH32PHB-0403 that (a) even with greater heat load in 61BTH DSC, the 61BTH DSC heat load “density” can be lower than the heat load “density” of 32PHB DSC due to a smaller volume in 32PHB DSC, and (b) the lower

hydraulic resistance in 32PHB DSC may not be a significant factor for bounding relation because convection heat transfer is not a significant heat removal mechanism in DSC with a lower pressure, and (c) the configuration of HSM-H for the 61BTH DSC is different from that of HSM-HB for the 32PHB DSC. Therefore, the values derived for DSC shell temperatures from the HSM-H model with 61BTH DSC can be used for thermal analysis of 32PHB DSC under storage conditions.

The staff reviewed TN Calculation NUH32PHB-0403 and the request for additional information (RAI) response. Based on comparison of heat flux and heat generation, heat capacity and initial conditions for HSM-H/61BTH DSC and HSM-HB/32PHB DSC models, the staff finds that the DSC shell temperature profile and the maximum HSM-H component temperatures from the thermal evaluation of 61BTH DSC in HSM-H are bounding for the 32PHB DSC in HSM-HB and are therefore acceptable.

6.4 Thermal Evaluations of the 32PHB DSC

6.4.1 32PHB DSC in HSM-HB

The licensee performed the heat transfer analysis with the DSC inside the HSM for the ambient air temperatures defined in the draft SAR Section 13.8.1.3. The analytical model is described in TN Calculation NUH32PHB-0410 (Reconciliation of Thermal Analyses Results for 32PHB DSC Storage in HSM-HB Module). The maximum and the average 32PHB DSC component temperatures under normal, off-normal, and accident conditions are shown in Table 6-1 and Table 6-2, respectively, of TN Calculation NUH32PHB-0403. The maximum DSC component temperatures are used to derive the DSC internal pressures, as shown in TN Calculation NUH32PHB-0404 (Internal Pressure for NUHOMS®-32PHB DSC for Storage and Transfer Conditions).

The staff reviewed the model and methodology described in TN Calculation NUH32PHB-0410 and verified the peak cladding temperatures (PCTs) and the maximum 32PHB DSC component temperatures listed in Table 6-1 of TN Calculation NUH32PHB-0403. The staff found that the model and methodology used in the TN calculations are realistic with the thermal features, consistent with the guidance in NUREG 1567, and are also consistent with those used in NUHOMS® HSM/DSC systems which were evaluated and approved by NRC. Based on these conclusions and staff's confirmatory analyses, the staff finds that the PCTs and the maximum 32PHB DSC component temperatures are below the corresponding limits under normal, off-normal, and accident conditions for both storage and transfer operations and are therefore acceptable.

6.4.2 Blowdown and Vacuum Drying with Nitrogen (add TS 3.3.3.1 and SR 4.3.3.1)

As stated in TN Calculation NUH32PHB-0408 (Thermal Analysis of NUHOMS®-32PHB DSC for Vacuum Drying Operations), the licensee assumed an average ambient temperature of 100°F for vacuum drying using nitrogen for blowdown. The licensee performed the thermal transient analysis of the 32PHB DSC with heat loads of 29.6 kW, 25.6 kW and 23.04 kW, respectively, assuming a bounding DSC shell temperature of 212°F (boiling temperature of water) during the vacuum drying process.

The licensee listed the calculated PCT histories and the maximum 32PHB DSC component temperatures in Tables 6-1 and 6-2, respectively, of TN Calculation NUH32PHB-0408. The

licensee stated that the PCTs and the maximum cask component temperatures for the thermal loads of 29.6 kW, 25.6 kW and 23.04 kW, remain below the allowable temperature limits for the proposed time periods of vacuum drying using nitrogen blowdown, DSC/TC in vertical orientation, and with water in the DSC/TC annulus.

The licensee also stated in TN Calculation NUH32PHB-0408 that the thermal analyses demonstrate that when helium is used for blowdown, the PCTs remain well below the ISG-11 specification of 752°F for normal operation, with no time limitation on completion of the blowdown and vacuum drying process.

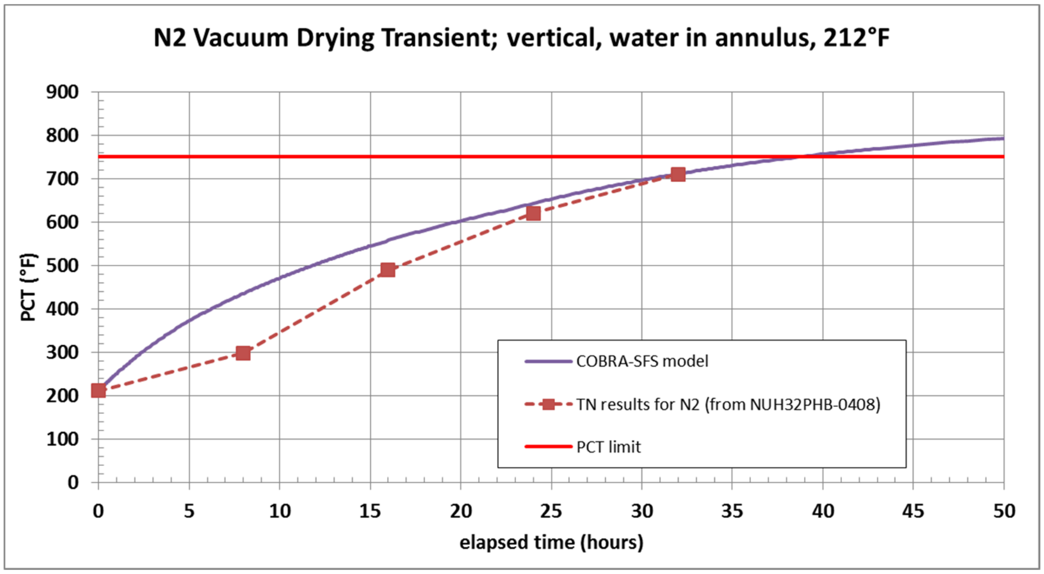
The staff reviewed TN Calculation NUH32PHB-0408 and performed the confirmatory thermal analyses for 32PHB DSC vacuum drying using nitrogen and helium, respectively, for blowdown. The comparisons are listed in Tables 6-1 and 6-2 and Figures 6-2 and 6-3 of this SER. The staff noted from Table 6-1 and Figure 6-2 of this SER that at 32 hours when using nitrogen for blowdown, the PCT of 711.5°F from the staff's confirmatory calculation is consistent with the PCT of 711°F from the licensee's model. For the post-vacuum drying steady-state after backfilling with helium (DSC/TC in vertical orientation and water at 212°F in TC/DSC annulus), the licensee assumed perfect contact in all locations and calculated a steady-state fuel cladding temperature of 592°F which is lower than the fuel cladding temperature of 604°F from the staff's confirmatory analysis (PNNL COBRA-SFS results). The staff also performed the confirmatory analysis by assuming a contact gap 0.01 inch in all locations where the aluminum basket plates are perpendicular to the steel basket plates, and calculated a steady-state fuel cladding temperature of 613°F. After reviewing the licensee's evaluation and performing the confirmatory analyses, the staff determined that the time limit of 32 hours for nitrogen blowdown is acceptable for 32PHB DSC, loaded with 29.6 kW, during vacuum drying.

Table 6-1 - PCT histories for 32PHB DSC vacuum drying using helium and nitrogen for blowdown (Comparison of TN results and confirmatory calculations)

<table>
<tr><th rowspan="2">Elapsed time (hrs)</th><th colspan="2">PCT (°F) using N_2 blowdown</th><th colspan="2">PCT (°F) using He blowdown</th></tr>
<tr><td>TN results (from Table 6-1 of NUH32PHB-0408)</td><td>PNNL COBRA-SFS results</td><td>TN results (from Table 6-1 of NUH32PHB-0408)</td><td>PNNL COBRA-SFS results</td></tr>
<tr><td>0</td><td>212</td><td>211.3</td><td>212</td><td>212</td></tr>
<tr><td>8</td><td>299</td><td>436.0</td><td>279</td><td>420.1</td></tr>
<tr><td>16</td><td>490</td><td>558.2</td><td>437</td><td>521.3</td></tr>
<tr><td>24</td><td>621</td><td>643.4</td><td>521</td><td>584.4</td></tr>
<tr><td>32</td><td>711</td><td>711.5</td><td>560</td><td>618.6</td></tr>
<tr><td colspan="5">Post-vacuum drying after backfilling with helium:
DSC/TC vertical, water (at 212°F) in DSC/TC annulus</td></tr>
<tr><td></td><td colspan="2">TN results (from Table 6-1 of NUH32PHB-0408)</td><td colspan="2">PNNL COBRA-SFS results</td></tr>
<tr><td rowspan="2">Steady State</td><td colspan="2">592[1]</td><td colspan="2">604[1]</td></tr>
<tr><td colspan="2">n/a</td><td colspan="2">613[2]</td></tr>
</table>

Notes 1: perfect contact and 2: contact gap of 0.01 inch at all locations where the aluminum basket plates are perpendicular to the steel basket plates.

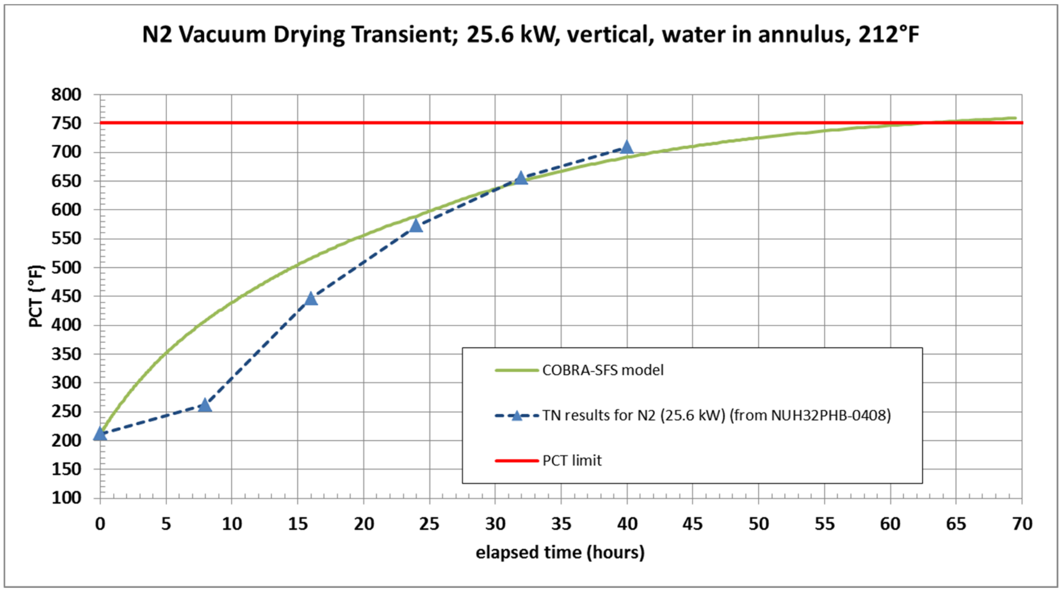
Figure 6-2 - TN results (NUH32PHB-0408) compared to staff's confirmatory calculations (COBRA-SFS model) for 32PHB DSC /TC in vacuum drying (N2 blowdown, 29.6 kW)



The staff also performed the confirmatory analyses for 32PHB DSC vacuum drying with nitrogen blowdown at the heat loads of 25.6 kW and 23.04 kW, respectively. The staff's confirmatory analyses calculated the PCTs of 692°F for 25.6 kW at 40 hours and 694°F for 23.04 kW at 56 hours, as shown in Table 6-2 below. The licensee's calculations (TN results) for vacuum drying (with N_2 blowdown and 25.6 kW), compared to the staff's confirmatory calculations with COBRA-SFS model is displayed in Figure 6-3 of this SER.

Compared to the PCTs of 709°F for 25.6 kW at 40 hours and 718°F for 23.04 kW at 56 hours from the licensee's calculations (NUH32PHB-0406), the staff concluded that the licensee's analyses are consistent with the staff's confirmatory analyses for heat loads of 25.6 kW and 23.04 kW, respectively. In addition, the staff also concludes that the heat loading configurations of 23.04~25.6 kW and ≤23.04 kW, as listed in TS 3.3.3.1, are acceptable when using nitrogen for blowdown operation. Therefore, the staff determined that the time limits proposed in TS 3.3.3.1 for the 32PHB DSC in the TC using N_2 blowdown in vacuum drying are acceptable.

Figure 6-3 - TN results (NUH32PHB-0408) compared to staff's confirmatory calculations



(COBRA-SFS model) for 32PHB DSC/TC in vacuum drying (N_2 blowdown, 25.6 kW)

The licensee performed the thermal analysis for vacuum drying with helium (He) blowdown following up with helium backfill and then calculated the steady-state PCTs of 592°F, 555°F, and 524°F, respectively, for heat loads of 29.6 kW, 25.6 kW and 23.04 kW. The staff's confirmatory analysis calculated a steady- state PCT of 604°F with helium blowdown and heat load of 29.6 kW. All calculated PCTs are below the limit of 752°F. As expected, the other heat loading configurations of 23.04~25.6 kW and ≤23.04 kW are bounded by the loading configuration of 25.6~29.6 kW. Therefore, the staff determined that there is no time limit required for all heat load configurations, as listed in TS 3.3.3.1, for vacuum drying with helium blowdown.

With the time limits proposed in TS 3.3.3.1 for 32PHB DSC in the TC using N_2 blowdown in vacuum drying, the staff also determined that the SR 4.3.3.1, added by the licensee, is required and appropriate to monitor time duration following initiation of draining of the TC/DSC annulus until completion of the insertion of the NUHOMS®-32PHB DSC into the HSM.

Table 6-2 - NUHOMS®-32PHB DSC vacuum drying time limits

Heat Load		25.6~29.6 kW	23.04~25.6 kW	≤23.04 kW
Vacuum drying time limit (hrs)		32	40	56
Peak Fuel Cladding Temperature (°F)	**TN results** N_2 blowdown w/time limit	711	709	718
	Confirmatory Analysis COBRA-SFS results N_2 blowdown w/time limit	712	692	694
	TN results H_e blowdown w/o time limit	592	555	524

	Confirmatory Analysis COBRA-SFS results H_e blowdown w/o time limit	604	NA	NA

6.4.3 Time Limit of Transfer Operations (add TS 3.3.2.1)

The licensee noted in the draft SAR that the time allowed for draining of the DSC/TC annulus has an administrative control time limit. For thermal analyses of transfer operations, however, the licensee's calculations treat the draining operation as essentially instantaneous. The licensee stated that this is a conservative assumption, since it reduces the total time that the DSC shell has the benefit of heat transfer to water in the annulus, as the water level drops.

The staff reviewed both draining operation and transfer operation and concludes that treating draining operation as an instantaneous action is conservative in the thermal analysis because the draining operation with water still in TC/DSC annulus will further reduce the fuel and canister temperatures.

As described in TN Calculation NUH32PHB-0402 and TN Calculation NUH32PHB-0403, the transient thermal analysis of DSC/TC transfer operation was initiated from assumed steady-state conditions, with helium backfill, the package vertical within the fuel handling building, and water in the DSC/TC annulus. The transient analysis was initiated at time zero assuming instantaneous draining of the DSC/TC annulus, replacing liquid water with air.

For this transient analysis, the licensee calculated a PCT of 733°F after 20 hours (Table 6-3), with the DSC/TC in vertical orientation, heat load 29.6 kW, ambient 100°F, and no FC. The licensee calculated a PCT of 728°F after 20 hours (Table 6-4), with the DSC/TC in horizontal orientation, heat load 29.6 kW, ambient 104°F, and no FC. The staff compared the results reported by the licensee in Tables 6-3 and 6-4 to confirmatory calculation results obtained by the staff using COBRA-SFS model. The confirmatory results are consistent with the temperatures reported by the licensee for these conditions.

The staff performed confirmatory transient analyses (using PNNL COBRA-SFS code) and predicted a PCT of 730.3°F for the DSC/TC in vertical orientation, and a PCT of 730.4°F for the DSC/TC in horizontal orientation, at 20 hours. The staff finds the licensee's thermal analyses acceptable based on (1) review of the licensee's model (including assumptions, initial conditions, boundary conditions, and methodology) which followed the guidance in NUREG-1567, (2) consistency with the staff's confirmatory analyses, and (3) the calculated PCTs being below the specification of 752°F per ISG-11 for both DSC in horizontal and vertical TCs at 20 hours. The staff also finds the time limits proposed in TS 3.3.2.1, for completion of NUHOMS®-32PHB DSC transfer operation acceptable because of the three aforementioned findings.

Table 6-3 - TN results and confirmatory calculations for 32PHB DSC in vertical TC, after draining DSC/TC annulus, for heat load of 29.6 kW

Elapsed time (hrs)	PCT (°F)	
	TN results (NUH32PHB-0403)	Confirmatory calculations (COBRA-SFS model)
0	592	604
18.8	Not reported	725.9

20.0	733	730.3

Table 6-4 TN results and confirmatory calculations for 32PHB DSC in horizontal TC: after draining DSC/TC annulus, for heat load of 29.6 kW

Elapsed time (hrs)	PCT (°F)	
	TN results (NUH32PHB-0403)	Confirmatory calculations (COBRA-SFS model)
0	592	604
18.67	Not reported	725.3
20.0	728	730.4

For the heat load of 25.6 kW, horizontal, air-in-annulus, with solar, and no FC transient, the staff's confirmatory calculations show a PCT of 720°F at 48 hours and a PCT of 718°F at 46 hours, as shown in Table 6-5. For the heat load of 23.04 kW, horizontal, air-in-annulus, with solar and no FC transient, the staff's confirmatory calculations show a PCT of 695°F at 72 hours and less than 695°F. The staff's confirmatory analyses predicted the PCTs lower than the PCTs calculated by the licensee and therefore the staff concludes that those PCTs from the licensee's analyses are conservative and below the limit of 752°F with good margin and are therefore acceptable.

Table 6-5 - TN results and confirmatory calculations for 32PHB DSC in horizontal TC: after draining DSC/TC annulus, for heat load of 25.6 kW and 23.04 kW

	TN results (NUH32PHB-0403)		Confirmatory calculations (COBRA-SFS model)			
Heat Load (kW)	25.6	23.04	25.6		23.04	
Transfer Time (hour)	48	72	46	48	70	72
Fuel Cladding Temperature (°F)	728	705	718	720	< 695	695

The licensee displayed the maximum temperatures of the fuel and the TC components in Table 6-6 for NUHOMS®-32PHB DSC located in horizontal TC without FC (Table 6-1 of TN Calculation NUH32PHB-0406 Thermal Evaluation of NUHOMS®-32PHB Transfer Cask for Normal, Off Normal and Accident Conditions with Heat Load < 29.6 kW). Based on calculations, the licensee concluded that the PCTs will be below the limit of 752°F if the transfer operations could be done within (a) 20 hours for a heat load greater than 25.6 kW and less than 29.6 kW, (b) 48 hours for a heat load greater than 23.04 kW and less than 25.6 kW, and (c) 72 hours for heat load greater than 21.12 kW and less than 23.04 kW. There is no time limit for a heat load of less than 21.12 kW.

The staff reviewed the licensee's calculations, shown in TN Calculation NUH32PHB-0406, of 32PHB transfer cask with heat load less than 29.6 kW and no FC. The staff verified that the licensee's methodology is appropriate and finds acceptable the licensee's thermal analyses and results (Table 6-1 of TN Calculation NUH32PHB-0406) because: (a) licensee's analyses are consistent with the staff's confirmatory calculations, and (b) the calculated PCTs from the licensee's analyses are below the limit of 752°F, consistent with ISG-11 specifications, for the heat load cases of 29.6, 25.6, and 23.04 kW (see Tables 6-3 ~6-5 of the SER). The staff also finds that there is no time limit for heat load less than 21.12 kW, based on the licensee's own

analyses with the same methodology and the results shown in Table 6-6 of the SER (or Table 6-1 of TN Calculation NUH32PHB-0406).

Following receipt of an RAI on the transfer time limits, the licensee submitted a revised proposed TS 3.3.2.1 that reduced the time limits for completion of transfer of a loaded and welded NUHOMS®-32PHB DSC from the cask handling area to the HSM-HB as follows:

1) No time limit for a DSC with heat load of ≤ 21.12 kW
2) 62 hours for a DSC with heat load > 21.12 kW and ≤ 23.04 kW
3) 38 hours for a DSC with heat load > 23.04 kW and ≤ 25.6 kW
4) 10 hours for a DSC with heat load > 25.6 kW and ≤ 29.6 kW

The staff compared the licensee's calculations with the staff's confirmatory analyses, and confirms that the above time limits in the transfer time are a 10-hour reduction from those calculated in TN Calculation NUH32PHB-0402 (Revision 1) and TN Calculation NUH32PHB-0406. Therefore, the remaining 10 hours of time to complete the transfer operation can be used to initiate one of the recovery actions listed in TS 3.3.2.1. Based on the licensee's model/methodology, the staff's confirmatory analyses, and the calculated PCTs (below the specification of 752°F with significant margins), the staff determined that (1) the proposed transfer time limits in TS 3.3.2.1 for the heat loads less than 29.6 kW for the NUHOMS®-32PHB DSCs located at the CC ISFSI are appropriate, and (2) the proposed transfer time limits allow more time (10 hours) to initiate the recovery actions for the heat load greater than 21.12 kW.

6.4.4 Forced Cooling (FC) during Transfer Operation (add TS 3.3.2.2)

The FC system proposed for the CC ISFSI TC would be used if the transfer operation cannot be completed within the time limits noted in TS 3.3.2.1 during the transfer of a 32PHB DSC with heat load greater than 21.12 kW. The FC system provides forced-air flow of the ambient air around a loaded 32PHB DSC, which is contained with TC, during movement from the fuel building to the onsite ISFSI.

The design load cases for the 32PHB DSC in CC TC with FC is shown in Table 4-1 of TN Calculation NUH32PHB-0401 (Thermal Evaluation of NUHOMS®-32PHB Transfer Cask for Normal, Off Normal, and Accident Conditions with Forced Cooling (Steady State)) or Table 6-7 in this SER. For the case that the transfer time limit is exceeded and FC is lost, the licensee selected the load case #3 (off-normal hot ambient condition) as the bounding case because of maximum insolation and maximum ambient temperature of 104°F, and performed a steady-state analysis for the 32PHB DSC with heat load of 29.6 kW and airflow of 450 cfm. As shown in Table 6-1 of TN Calculation NUH32PHB-0401, the load case #3, bounds the maximum temperatures for normal hot/cold and off-normal cold conditions (load cases #1, #2, and #4). The licensee calculated a bounding PCT of 689°F from the load case #3.

Table 6-7 - Design load cases for the 32PHB DSC in TC with FC

Case	Operation Condition	Description	Ambient Temperature (°F)	Insolation (Btu.hr-ft^2)	Airflow (cfm)
1	Normal	Normal Hot, FC	104	82	450
2	Normal	Normal Cold, FC	-8	0	450
3	Off-Normal	Off-Normal Hot, FC	104	127	450
4	Off-Normal	Off-Normal Cold, FC	-8	0	450
5	Off-Normal	Loss of FC, Transient	104	127	0

The licensee then started the transient analysis of the load case #5 (loss of FC and a bounding heat load of 29.6 kW) with the steady state temperatures from the load case #3 (PCT of 689°F, ambient 104°F, FC on, and bounding heat load of 29.6 kW), as shown in Table 6-1 of TN Calculation NUH32PHB-0401. At time = 0 from the steady state with FC on, the fan airflow is immediately lost and the system starts to heat up. The licensee calculated a PCT of 734°F and the key TC components below their corresponding limits at 2 hours after exceeding the 18-hour limit for transfer (Table 6-2 of TN Calculation NUH32PHB-0401, Rev. 2). The licensee stated that the PCT of 734°F is below the limit of 752°F at the end of 20 hours with heat load of 29.6 kW and no FC.

The staff did not start the confirmatory analysis of load case #5 (loss of FC and 29.6 kW) from the steady-state results of load case #3 (ambient 104°F, 29.6 kW, and PCT of 689°F) because it would not be a conservative assumption for the starting condition of the loss of FC transient. The staff initiated the transient for loss of FC by assuming that FC immediately fails when activated after 20 hour without FC with a PCT of 730°F. That is, the loss of FC transient is initiated from the transient state at 20 hours, after 18 hours of normal operation with no FC, plus the additional 2-hour time limit allowed to initiate corrective action, as initially proposed in TS 3.3.2.1. The staff calculated a PCT of ~752°F at 26.8 hours, which is 6.8 hours after the loss of FC postulated for this off-normal conditions. The staff's evaluation postulates that the normal operations (without FC) proceeds for 18 hours, the off-normal operations (also without FC) proceed for 2 hours before corrective action is initiated by attempting to activate FC, and the operations with failure of corrective actions proceed for another 6 hours before the PCT exceeds the limit of 752°F. The staff compared the time period of 26.8 hours to reach the limit of 752°F with the time limit of 10 hours specified in TS 3.3.2.1 for heat load > 25.6 kW and ≤ 29.6 kW, and finds that there is a time period of ~16.8 hours for recovery action. The staff concludes that this is well within the recovery action directives in the TS and therefore the added TS 3.3.2.1 for 32PHB DSC is acceptable.

The licensee added TS 3.3.2.2 for 32PHB DSC per the 2nd RAI response "Clarification to TS 3.3.2.1 and TS 3.3.2.2," to provide additional assurance that the PCT would not exceed the limit of 752°F during normal transfer operations:

1) Two blowers at CC form a redundant system (each blower is independently coupled to each respective motor, diesel generator, power cord). In addition to the redundant

diesel generators, the blowers can also be operated using the facility power by connecting them to a power receptacle.

2) Time for any recovery actions is increased to 10 hrs from the 2 hrs, proposed in the initial revisions of TS 3.3.2.1 and TS 3.3.2.2 for the bounding heat load of 29.6 kW. This ensures that there is sufficient time to return the DSC to the cask handling area when FC is not available.

3) New requirements are added to TS 3.3.2.2: "If the heat load of a NUHOMS® 32 PHB DSC is greater than 21.12 kW, the FC shall be installed on the transfer skid and verified operable within 7 days prior to commencing the transfer operations of a loaded NUHOMS® 32PHB DSC."

The staff reviewed the 2nd RAI's response "Clarification to TS 3.3.2.1 and TS 3.3.2.2" and finds the proposed TS 3.3.2.1 and TS 3.3.2.2 for 32PHB DSC acceptable because the time limit on the highest/bounding heat load condition (> 25.6 kW and ≤ 29.6 kW) is reduced from 20 hours to only 10 hours, and this gives the licensee about 17 hours (16.8 hours) to the PCT limit if FC fails at the most adverse condition. This is well within the recovery action directives in the revised TS.

6.4.5 Air Temperature Rise between HSM-HB Inlet and Outlet (revise TS 3.4.1.1)

The licensee performed the steady-state thermal analyses and had a bounding 80°F temperature rise from the HSM-HB inlet to the HSM-HB outlet, with the PCTs equal or less than 724°F under normal and off-normal hot conditions. The licensee's transient analysis shows a PCT of 867°F in the 40-hour blocked accident event, assuming a maximum air inlet temperature of 104°F (Table 7-1 of TN Calculation NUH32PHB-0403). The PCT of 867°F is below the limit of 1058°F for accident conditions.

Therefore, the licensee requested a new maximum allowable air temperature rise of 80°F from the HSM inlet to outlet, with a 32PHB DSC inserted (at maximum decay heat load of 29.6 kW). The licensee justified this allowable temperature rise based on thermal analysis results showing that the air temperature rise of 80°F determined for an HSM-H loaded with 61BTH DSC (with the maximum heat load of 31.2 kW) is conservative and bounding on the 32PHB DSC (with the maximum heat load of 29.5 kW) in a HSM-HB. The licensee's analysis shows that for this bounding assumption for 61BTH DSC on a 32PHB DSC: (1) the PCTs for normal and off-normal hot storage conditions are below the limit of 752°F, and (2) the maximum PCT for vent blockage storage accident conditions is below the limit of 1058°F.

The staff reviewed the RAI response and the methodology used for HSM-HB thermal evaluation (described in the draft SAR) for air temperature rise analysis, and verified that the exit air temperature is dependent on the heat load of the DSC, the ambient temperature of the inlet air, and the dimension of the HSM and DSC as described in the draft SAR.

Based on the factors above, the staff compared the maximum heat load, the maximum ambient temperature, the HSM dimensions, and the DSC outer diameters between the HSM-H with 61BTH DSC and the HSM-HB with 32PHB DSC and found: (a) the maximum heat load for 61BTH DSC is 31.2 kW and is higher than the maximum heat load of 29.6 kW for the 32PHB DSC; (b) a higher ambient temperature of 105°F is used for the 61BTH DSC in HSM-H to the maximum ambient temperature of 104°F for the 32PHB DSC in HSM-HB; (c) there are no

changes in the dimensions of the HSM-H compared to the HSM-HB; and (d) the outer diameter of the 61BTH DSC is identical to that of the 32PHB DSC whereas the length of the 61BTH DSC is longer than the length of the 32PHB DSC and therefore provides more flow resistance to the air flow.

Therefore, with the air temperature rise of 80°F approved by NRC for the HSM-H with the 61BTH DSC, the staff determined that the exit air temperature rise determined for the HSM-H with the 61BTH DSC is acceptable for the HSM-HB with the 32PHB DSC.

6.4.6 Fire Accidents

Forest fire accident in storage conditions

The licensee performed calculations and showed the effect of a forest fire at the CC ISFSI on the maximum concrete temperature of the HSM-HB end wall, the maximum fuel cladding temperature and the maximum internal DSC pressure in TN Calculation NUH32PHB-0409 (Forest Fire Thermal Evaluation for CC ISFSI). The licensee assumed a maximum fire temperature of 1832°F for one hour, an initial temperature of 215°F for the end wall of the HSM-HB, a steady state ambient temperature of 250°F during the forest fire and an ambient temperature of 104°F for 16 hours after the end of the forest fire.

As shown in Table 6-2 of TN Calculation NUH32PHB-0409, the licensee calculated a PCT of 829°F (1289°R) and a maximum pressure of less than 19.3 psig for the 32PHB DSC (with heat load of 29.6 kW) during a forest fire. Both PCT and maximum internal pressure of 32PHB DSC (29.6 kW) are below the limits of 1058°F as specified in ISG-11 and 100 psig per design criteria, respectively, for the fire accident conditions.

The staff reviewed the fire analysis described in TN Calculation NUH32PHB-0409 and finds that the results showing that the peak internal pressure and the PCT are below the specification of 100 psig of design pressure and 1058°F per ISG-11. Therefore, the staff finds that the temperature and pressure in the 32PHB DSC in HSM-HB remain below ISG-11 specifications during a forest fire event at CC ISFSI.

Fire accident in transfer conditions

As described in and NUH32PHB-0403, the licensee performed thermal analyses of the TC loaded with 32PHB DSC (heat load of 29.6 kW) under a 15-minute fire accident and calculated a PCT of 932°F which is below the limit of 1058°F, as shown in Tables 6-1 and 6-2 of TN Calculation NUH32PHB-0403. The maximum temperatures for the CC TC with the 32PHB DSC at 25.6 kW, 23.04 kW and 21.12 kW heat loads in the fire accident are bounded by the temperatures for the CCNPP-FC TC at 29.6 kW.

The staff reviewed the assumptions, methodology, and boundary conditions used for the fire accident analysis described in TN Calculation NUH32PHB-0402, and checked the PCT and the maximum component temperatures shown in Tables 6-1 and 6-2 of TN Calculation NUH32PHB-0403. The staff finds the licensee’s evaluations acceptable because the PCT and the maximum key component temperatures, calculated by the licensee, are far below the corresponding limits for the fire event.

6.4.7 Dry Shielded Canister Pressurization

The licensee calculated the maximum 32PHB DSC pressures in TN Calculation NUH32PHB-0404 by assuming release of the fission and fuel rod fill gasses to the DSC cavity. The 32PHB DSC is assumed to be initially backfilled with helium to a pressure of 3.5 psig after vacuum drying, by using a conservative helium temperature of 300°F.

The internal pressure calculation took into account the DSC free volume, the total quantities of DSC backfill gas, the gas mixture released from the fuel rods, and the average DSC cavity gas temperature. The fuel rod fission gas release fraction is assumed to be 30% and the fuel rod fill gas release fraction is assumed to be 1% for normal conditions, 10% for off-normal conditions, 10% for blocked vent accident, and 100% for transfer accidents.

The licensee noted in TN Calculation NUH32PHB-0404 that the maximum 32PHB DSC internal pressures calculated for storage and transfer conditions, as summarized in Tables 4-2 and 6-5 of TN Calculation NUH32PHB-0404, are below the limits of 15, 20, and 100 psig, for normal, off-normal, and accident conditions, respectively.

The staff reviewed the assumptions and methodology used for pressure calculations, as described in Section 3.0 of TN Calculation NUH32PHB-0404, and reviewed the calculations of the maximum internal pressures for normal, off-normal and accident conditions of storage and transfer (Table 7-1 of TN Calculation NUH32PHB-0404 or Table 4-8 of this SER). The staff evaluation confirmed that: (a) the methodology used for pressure calculations is based on the ideal gas equation which was approved by NRC in all NUHOMS® systems, and (b) the calculated pressures are correct. The staff finds that the maximum 32PHB DSC internal pressures do not exceed the design pressure limits, as shown in Table 6-8 of this SER.

6.4.8 Thermal Expansion

The licensee performed thermal expansion analyses for the 32PHB system, as reported in TN Calculation NUH32PHB-0405 (Thermal Expansion of NUHOMS®-32PHB System for Transfer and Storage Conditions). The analyses included the following evaluations: thermal expansion effects on the axial gap between a fuel assembly and the DSC cavity; the radial gap between basket and DSC cavity; the axial gap between basket and DSC cavity; the axial gap between basket support rails and DSC shell inner surface; the radial gap between DSC shell outer surface and inner liner of the TC cavity, and the axial gap between DSC and TC cavity.

Based on the results shown on Section 5 of TN Calculation NUIH32PHB-0405, the licensee concluded that the thermal expansion is acceptable for: (1) the axial hot gap between fuel assembly and 32PHB DSC cavity; (2) the radial hot gap between basket and 32PHB DSC cavity; (3) the axial hot gap between basket rail and 32PHB DSC cavity; (4) the axial hot gap between basket rail and 32PHB DSC cavity; (5) the radial hot gap between 32PHB DSC and CCNPP-FC TC cavity; and (6) the axial hot gap between 32PHB DSC and TC cavity between DSC and CC- TC cavity.

The staff conducted a comparison of the calculated results, as shown in TN Calculation NUH32PHB-0405. The staff found that: (a) the assumptions and methodology used for thermal expansion calculation, as described in TN Calculation NUH32PHB-0405, are conservative when compared to the staff's confirmatory analyses because staff's confirmatory analyses used assumptions that contain additional restrictions and the licensees model has a smaller safety margin and is still below ISG-11 specifications; and, (b) the calculated thermal

expansions are below the limits. The staff also confirmed that there are adequate gaps among basket, DSC, transfer cask and irradiated fuel assemblies to allow free thermal expansion growths during storage and transfer. Therefore the staff finds the licensee's calculations on thermal expansion acceptable.

6.5 Technical Specifications Evaluation

1) The staff approves the modified TS: 3.1.1(5) and 3.4.1.1 and the new TS 3.3.2.1, 3.3.2.2, and 3.3.3.1 which are applicable for the NUHOMS®-32PHB DSC, located at CC ISFSI.

2) The staff accepts the new SR 4.3.3.1 added in TS to monitor the time duration following initiation of NUHOMS®-32PHB DSC (located at CCNPP ISFSI) blowdown using nitrogen until the initiation of helium backfill.

3) Action 3 of TS 3/4.3.2 is revised and added with the statement (as follows) to assure that FC is operable when needed.

   "If the use of the forced-cooling blowers is the anticipated action in the case of approaching DSC transfer time limits, the FC system should be verified ready to install and operate if needed."

4) Action 4 under TS 3/4.3.2 (Time Limit for Completion of NUHOMS®-32PHB DSC Transfer Operation) is revised as follows to cover the possibility of FC failure:

   "If the transfer cask is in a horizontal orientation and air circulation is not available, return the transfer cask to the cask handling area, reposition in a vertical orientation, and fill the transfer cask/DSC annulus with clean water."

6.6 Evaluation Findings

F6.1 The licensee's thermal analysis provides reasonable assurance to verify the fuel cladding and cask component temperatures below the allowable temperature limits for the NUHOMS®-32PHB DSC under normal, off-normal, and accidental storage conditions and transfer operations.

F6.2 The staff has reasonable assurance that the HSM-HB storage system provides adequate heat removal capacity without active cooling systems for the NUHOMS®-32PHB DSC stored in HSM-HB at CC ISFSI.

F6.3 The staff has reasonable assurance that the transfer cask system provides adequate heat removal capacity without active cooling systems for configurations of NUHOMS®-32PHB stored in HSM-HB at CC ISFSI.

F6.4 The staff finds that the thermal design of NUHOMS®-32PHB DSC system at the CC ISFSI are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied.

F6.5 The staff finds that the expansion of the ISFSI total capacity from 120 HSMs to 132 HSMs at CC ISFSI is acceptable.

F6.6 The staff finds that the proposed changes in TS 3.1.1(5) and 3.4.1.1, and addition of TS 3.3.2.1, 3.3.2.2, 3.3.1.1 and SR 4.3.3.1 for the 32PHB DSC at CC ISFSI are acceptable and are in compliance with 10 CFR Part 72. The finding is reached on the basis of a review that considered the regulations in Part 72, appropriate RGs, applicable codes, model assumptions/methodology, and accepted engineering practices.

7 SHIELDING EVALUATION

7.1 Discussion

This section presents the results of the shielding evaluation review of the amendment request for the addition of the NUHOMS®-32PHB system to the CC ISFSI. The licensee submitted the request for approval of the storage of high burnup fuel (HBF) with a higher source term in the NUHOMS®-32PHB DSC. The 32PHB DSC is stored in the HSM-HB at the CCNPP ISFSI. The same transfer cask is used for 32PHB DSC as is used for the NUHOMS®-32P DSC and the NUHOMS®-24P DSC.

The proposed changes in this amendment regarding the shielding features must limit the dose to the operating staff and members of the public so that the dose remains within regulatory requirements during normal-operating, off-normal-operating, and design-basis accident conditions. The review seeks to ensure that the shielding design is sufficient and reasonably capable of meeting the operational dose requirements of 10 CFR 72.126(a)(6), 20.1201, 72.24(e), 72.104, and 72.128(a)(2).

The shielding review for this amendment is to evaluate the request as stated below.

- Modification to Technical Specification (TS) 2.1 to add a new neutron and gamma source for fuel assemblies stored in NUHOMS®-32PHB DSCs.

7.2 Proposed TS Changes

The licensee has proposed changes to TS 2.1. The proposed change would add a new neutron and gamma source for fuel assemblies stored in NUHOMS®-32PHB DSCs. New shielding calculations were performed by the licensee using the new gamma and neutron source term. TS 2.1 is currently met for the NUHOMS®-32P DSCs by requiring that fuel assemblies selected for loading must meet certain minimum required cooling times. The licensee maintained the current format for TS 2.1 to avoid altering the licensing basis of the previous NUHOMS®-24P and NUHOMS®-32P DSCs loaded at CC. Addition of Design Basis New Gamma Source-Term LCO 3.1.1 currently limits fuel assemblies to be loaded in the ISFSI to certain enrichments, fuel assembly average burnup, heat output, and a minimum cooling time.

TS 2.1 permits a fuel assembly not specifically meeting the requirements of TS 3.1.1 for maximum burnup and post-irradiation time to be stored if it meets the minimum cooling time

listed in USAR Table 9.4-1 and the neutron and gamma source requirements of this specification. An evaluation was performed by the licensee using a new gamma source for fuel assemblies stored in NUHOMS®-32PHB DSCs.

7.3 Source Term Evaluation

The licensee stated that the evaluation for the new gamma and neutron source term was done similar to the way they did in the previous amendment for the NUHOMS®-32P DSC by ranking all the fuel in the pool at the time it reached the target decay heat. For the NUHOMS®-32P DSC they ranked by assembly gamma MeV/sec and neutron source strength. For the NUHOMS®-32PHB DSC, the licensee developed a gamma dose response function using a simplified HSMHB and Transfer Cask MCNP model and did the ranking based on gamma dose and neutron source strength.

The process for this evaluation is described as follows:

- The first step to determining the bounding source terms was to determine the cooling time when the decay heat limits of 1000 watts and 800 watts for each SAS2H case for AREVA fuel (this step was taken in Amendment 9 for standard and VAP fuel). Once the cooling time for each SAS2H case to reach 1000 watts and 800 watts has been determined, the gamma and neutron energy spectra were taken. The gamma energy spectrum was multiplied by the HSM-HB response function (Table 50 of Calculation Package CA-07255-0000) and the TC response function (Table 51 of Calculation Package CA-07255-0000) to determine HSM-HB and TC dose rates.

- The bounding HSM-HB and TC gamma source terms were taken as the gamma energy spectra and source strengths which result in the highest dose rates for the HSM-HB and TC. The bounding neutron source term was based on the SAS2H case which results in the highest total neutron source strength in terms of neutrons/sec since the majority of the neutron source term was based on the spontaneous fission of curium-244.

From this evaluation the licensee determined that a fuel assembly gamma source strength of 2.56 E+15 MeV/sec bounds fuel assemblies in the spent fuel pool for the cooling time required to reach a heat output of 1.0 kW. This gamma source term calculation was based on a fuel assembly with an enrichment of 4.25 weight percent U-235, a fuel assembly average burnup of 42,000 MWd/MTU, a cooling time of 4.2 years and a heat output of 1.0 kW.

The new neutron source term is 6.66E+08 neutrons/sec which will bound the fuel assemblies in the spent fuel pool for the cooling time required to reach 1.0 kW. The bounding neutron source was based on a fuel assembly with a maximum initial enrichment of 4.0 weight percent U-235, a

maximum fuel assembly average discharge burnup of 58,000 MWd/MTU, a cooling time of 9.4 years and a heat output of 1.00 kW.

The licensee requested changes to TS 2.1 to establish new neutron and gamma source term limits allowed in each fuel assembly using the same methodology as previously approved for this design. Although Interim Staff Guidance (SFST-ISG)- 6*, "Establishing Minimum Initial Enrichment for the Bounding Design Basis Fuel Assembly(s)",* states that the SAR should not attempt to establish specific source terms as operating controls and limits for cask use, the staff finds the licensee's approach in this instance acceptable in order to avoid altering the licensing basis of loaded NUHOMS®-32PHB.

In order to provide additional justification to supplement the changes to TS 2.1, a specific fuel qualification table for the NUHOMS®-32PHB DSC was added to proposed USAR Table 9.4.1 using information provided by Calvert Cliffs Calculations to indicate cooling times for the CE14x14 fuel. The staff performed confirmatory analyses based on the information provided in Table 9.4.1 for fuel assemblies with burnup up to 62 GWD/MTU. Staff calculations of the decay heat for burnup, enrichment and cooling times on Table 9.4.1 has confirmed that the new neutron and gamma source terms are adequate for the requested amendment.

7.4 Shielding Evaluation

The staff reviewed the information provided by the licensee to support this amendment, including the following documents:

- Transnuclear Calculation No. NUH32PHB-0502, CALVERT CLIFFS NUHOMS 32PHB RADIATION DOSE RATES FOR LOADING AND TRANSFER DESIGN CALCULATION
- Transnuclear Calculation No. NUH32PHB-0503, HSM-H SHIELDING ANALYSIS FOR 32PHB SYSTEM DESIGN CALCULATION
- Transnuclear Calculation No. NUH32PHB-0505, SITE DOSE ANALYSIS FOR NUHOMS 32PHB SYSTEM DESIGN CALCULATION

The staff determined that the amendment is in compliance with the requirements of 10 CFR 72.126(a)(6), 72.126(a)(3), 20.1201, 72.24(e), 72.104, and 72.128(a)(2). The staff also determined that the calculated dose rates at the CC ISFSI using the gamma and neutron source terms for high burnup fuel mentioned in the previous section satisfy the regulations for the HSM-HBs. Based on the information provided in the amendment, staff concludes that the CC ISFSI TS 2.1 continues to meet the acceptance criteria specified in NUREG-1567 and the dose rates will continue to remain under the regulatory limits and provide reasonable assurance for safe storage of spent fuel. This finding considered applicable regulations as 10 CFR 72.104, and 72.106 as appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

7.5 Dose Rate Determinations

The NUHOMS®-32PHB DSC and the HSM-HB provides enhanced shielding which includes (1) a thicker roof (3 feet 8 inches vs. 3 feet), (2) the door is inset in DSC opening, with increased thickness, (3) inlet vents used to attenuation pipes attached to the inside of the bird screen (the attenuation pipes are included for ALARA dose reduction). These physical improvement helps the shielding capacity to compensate for the higher source term of spent fuel elements compared to the NUHOMS®-24P and NUHOMS®-32P DSCs. The licensee performed dose rates calculations for the design basis conditions for the added neutron and gamma source terms using the same methods approved in Reference 4. Table 4 of the proposed SAR shows that ISFSI dose limits remain satisfied for the HSM-HBs and there are no TS changes required for a change in dose rates. Dose rates at the ISFSI site fence remain within the limits of 10 CFR 20.1301 for an individual during loading operations. The effects of both neutron and gamma radiation on the HSM-HB concrete were determined to be negligible for the NUHOMS®-32PHB DSC.

Table 4. Radiation Dose Rates

Location	HSM with NUHOMS-32P DSC	HSM-HB with NUHOMS-32PH DSC	Technical Specification Limit
HSM wall or roof	13.5 mrem/hr	6.27 mrem/hr	20 mrem/hr
HSM air outlet	75.4 mrem/hr	47.1 mrem/hr	--
HSM door center	13.9 mrem/hr	0.98 mrem/hr	100 mrem/hr
HSM open door (1 ft inside)	4.66E+03 mrem/hr	1.76E+04 mrem/hr	--
HSM air inlet	61.0 mrem/hr	121 mrem/hr (w/o insert)	--
HSM (1 m from the closed door)	8.9 mrem/hr	13.5 mrem/hr	--

7.6 Staff Confirmatory Analysis

The staff evaluated the proposed changes described in Section 7.1 of this SER. Confirmatory analysis were performed by the staff on source term evaluations using the SCALE 6.1 computer code with the ORIGEN/ARP isotopic depletion and decay sequence with the 238-group ENDF/VII cross section library. Using irradiation parameter assumptions similar to the licensee's, the staff obtained bounding source terms that were similar to, or bounded by, those determined by the licensee and therefore finds the licensee's result acceptable. The staff determined that the licensee's evaluation was performed in accordance with the guidelines of NUREG-1567, and accepted industry practices. The staff therefore finds that the exterior dose rates continue to be acceptably controlled by limits in the license for cooling time, and enrichment.

7.7 Evaluation Findings

The proposed TS change is in compliance with the requirements of 10 CFR 20.1201, 10 CFR 72.126(a)(3), 72.126(a)(6), 72.24(e), 72.104, and 72.128(a)(2). The staff also determined that the calculated dose rates at the CC ISFSI using the gamma and neutron source terms for high burnup fuel mentioned in the previous section satisfy 10 CFR 20.1201, 10 CFR 72.126(a)(3), 72.126(a)(6), 72.24(e), 72.104, and 72.128(a)(2) for the 32PHB DSC and HSM-HBs. Based on the information provided in the amendment, staff concludes that the requested TS 2.1 meets the acceptance criteria specified in NUREG-1567, and the CC ISFSI dose rates will continue to remain under the regulatory limits and provide reasonable assurance for safe storage of spent fuel.

F7.1 The staff has reasonable assurance that the changes to TS 2.1 to add a new neutron and gamma source for fuel assemblies stored in NUHOMS®-32PHB DSCs are acceptable. The staff also has reasonable assurance that the NUHOMS®-32PHB system to the CC ISFSI will continue to meet the dose requirements of 10 CFR 20.1201, 72.126(a)(3), 72.126(a)(6), 20.1201, 72.24(e), 72.104, and 72.128(a)(2), 72.106.

8 CRITICALITY EVALUATION

This section presents the results of the criticality evaluation review of the amendment request for the addition of the NUHOMS®-32PHB system to the CC ISFSI. According to the licensee, the current maximum initial fuel assembly enrichment limit is 4.5 weight percent ^{235}U. The proposed change to TS 3.1.1(2) would add a new maximum initial fuel assembly enrichment limit of 4.75 weight percent ^{235}U for a NUHOMS®-32PHB DSC basket type A and 5.0 weight percent ^{235}U for a NUHOMS®-32PHB basket type B. The current maximum initial fuel assembly enrichment limit of 4.5 weight percent ^{235}U for the NUHOMS®-24PHB and NUHOMS®-32PHB DSCs remains the same.

In addition, the fact that these proposed fuel assemblies have a high burnup exceeding 45 GWD/MTU, needs to be evaluated with respect to the assumptions of fixed fuel geometry for criticality safety purposes.

8.1 Discussion

The NUHOMS®-32PHB DSC is designed to accommodate 32 high burn-up PWR fuel assemblies with Zircaloy-4 and AREVA M-5 cladding. The NUHOMS®-32PHB system consists of the 32PHB DSC, basket and shell assemblies, the HSM-HB and the TC. The licensee noted that the 32 PHB system shares many similarities with the 24P and 32P systems currently approved and in operation at the CC ISFSI. As such, the staff considered previous criticality evaluations of the NUHOMS®-32P DSC and the TC as part of this criticality evaluation.

8.2 Licensee TS Evaluation

The requested Revision to TS 3.1.1(2) required staff evaluation, as described in sections 8.3 and 8.4.

The licensee performed the criticality analysis to determine the bounding k_{eff} value for the

NUHOMS®-32PHB system loaded with fuel assemblies containing uranium dioxide fuel enriched up to 5.0 weight percent ^{235}U. According to the licensee, criticality is controlled by taking credit for 2,450 ppm soluble boron present in the spent fuel pool (TS 3.2.1.1) and fixed neutron absorbers present in the NUHOMS®-32PHB DSC baskets. The fixed poison inside the basket is based on an aluminum boron carbide metal matrix composite design. Credit for 90% of the absorber material (^{10}B) is assumed in the analysis. This results in conservatism in the calculated k_{eff}.

To support a demonstration of compliance, the licensee performed parametric studies to maximize reactivity for the normal and off-normal storage conditions. These conditions include fuel geometry based on the arrangement of fuel assemblies (centered or inward) relative to the center of the basket, geometrical tolerances, variation in guide sleeve inner width, variation in borated water density, insert plate height, poison plate slot length, poison plate slot width, poison plate height, poison plate thickness, and temperature. The licensee considered three fuel assembly types, the CE 14x14 standard fuel assembly, the Westinghouse VAP 14x14 fuel assembly and the AREVA 14x14 fuel assembly. As a result of the parametric studies, the Westinghouse VAP fuel lattice was determined, by the licensee, to be the most reactive fuel lattice and it was used in the criticality analysis with a maximum enrichment of 5.0 weight percent ^{235}U.

8.3 Cladding Evaluation

Since the burnup exceeds 45 GWD/MTU, it is important to analyze the cladding for criticality safety purposes. The licensee stated that two cladding materials, Zircaloy-4 and AREVA M-5, are used for the fuel assemblies in the NUHOMS®-32PHB DSC. The parameters used for the Zircaloy-4 clad fuel assemblies in the NUHOMS®-32P DSC are the same as those used for the Zircaloy-4 clad fuel assemblies in the NUHOMS®32PHB DSC, therefore, the staff concludes that the analysis of the fuel assemblies, with Zircaloy-4 cladding, from the NUHOMS®-32P DSC bounds that of the NUHOMS®-32PHB. For the M-5 cladding, the licensee scaled the maximum principle strain by the ratio of Young's Modulus between M-5 and Zircaloy-4 at 750°F, assuming the fuel assembly deforms elastically.

The staff requested the licensee provide calculation NUH32PHB, Rev 1, "PWR Fuel Rod Accident Side Drop Loading Stress Analysis for NUHOMS®-32PHB System," to verify the scaling factor used by the licensee. The licensee provided the document which contains the material properties of Zircaloy-4 and M-5 cladding at 750°F and establishes the scaling factor that the licensee used to calculate the maximum principle strain in the M-5 cladding as a result of the 80 inch end drop. For both the Zircaloy-4 and the M-5 cladding, the licensee determined the maximum principle strain is well below the yield strain.

The staff reviewed the calculation and found that it was performed in accordance with NUREG 1567 guidance and standard industry practices, and confirmed the licensee's determinations. As a result, the staff finds that the performance of the M5 cladding under the 80 inch drop scenario is acceptable.

8.4 Benchmark Evaluation

The licensee performed a series of 102 benchmark criticality calculations. These calculations assumed un-irradiated fuel in the criticality analysis and used the SCALE 6 computer code package. The upper subcritical limit (USL) as described in Section 4 of NUREG/CR-6361,

"Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages," was determined using the results of these 102 benchmark calculations. The benchmark problems used to perform this verification are representative of benchmark arrays of commercial light water reactor fuels with the following characteristics: water moderation, boron neutron absorbers, un-irradiated light water reactor type fuel, close reflection, and uranium oxide fuel. The licensee chose 102 uranium oxide experiments to model a wide range of uranium enrichments, fuel pin pitches, fuel assembly separation, concentration of soluble boron, and control elements in order to test the code's ability to accurately calculate k_{eff}. The staff reviewed the series of 102 benchmark criticality calculations and finds the licensees approach to be acceptable as it is consistent with NUREG/CR-6361.

The minimum value of the upper subcritical limit for the NUHOMS®-32PH-IB system over the parameter range (in this case, the fuel assembly separation distance) was 0.9410. The limiting separation distance was determined using the inward fuel lattice position as a conservative approach. According to the licensee, the upper subcritical limit value of 0.9410 was based on a methodology bias and an administrative 5% margin on criticality. Section 6.5.2 of Reference 12 provided the basis for selecting 0.9410 as the limiting value. Enclosure 5 provided the detailed basis for the USL functions used in Table 6.5-1 of Enclosure 4, with one of the functions specifically addressing rod pitch. The criticality analysis for the NUHOMS®-32PHB DSC system demonstrates that the maximum k_{eff} value is below the upper subcritical limit of 0.9410 for a variety of loading configurations under normal and off-normal conditions. The maximum k_{eff} value based on an "inward" loading of the Westinghouse VAP fuel assemblies is 0.9363 for basket type A (with a maximum enrichment of 4.75 weight percent ^{235}U) and 0.9358 for basket type B (with a maximum enrichment of 5.0 weight percent ^{235}U). This configuration includes the minimum fuel compartment dimension of 8.47 inch, an internal moderator (soluble boron at 2,450 ppm) density of 75%, poison plate height of 8.01 inch, and poison plate slot width of 0.75 inch with a ^{10}B areal density of 0.0171 g/cm^2 for basket type A and 0.0243 g/cm^2 for basket type B.

The licensee stated that the criticality analysis takes credit for only 90% of the minimum physically available ^{10}B areal density in the poison plates. Therefore, the basket type A is manufactured with 0.019 g/cm2 of ^{10}B and the basket type B is manufactured with 0.027 g/cm^2 of ^{10}B.

According to the licensee, reconstituted fuel assemblies, where the fuel pins were replaced by lower enriched fuel pins or non-fuel pins that displace the same amount of borated water, were considered intact fuel assemblies. The reactivity of the fuel assemblies with reconstituted fuel pins were bounded by those without reconstituted fuel pins because fuel pins were modeled with the highest allowable enrichment while those with the reconstituted fuel pins will contain lower enriched $U0_2$ or other non-fuel material.

Finally, the licensee evaluated the impact of transfer cask drop accidents on the potential for a criticality event in a NUHOMS® -32PHB DSC. The rod pitch of some fuel rods may be reduced to the fuel clad outside diameter during a drop accident. The upper subcritical limit as a function of the rod pitch decreases from 0.9424 to 0.9422 under these conditions. Reduced rod pitch also leads to less neutron moderation and, subsequently, k_{eff} decreases.

The staff reviewed the licensee's criticality evaluation, performed a confirmatory analysis which demonstrated that using the minimum fuel parameters previously mentioned resulted in a K_{eff} very comparable with the licensee's determinations. Therefore the staff concludes the

representations in the SAR concerning criticality and offsite dose exposure are reasonable. The staff thus finds the changes to TS 3.1.1(2) acceptable and has reasonable assurance that the NUHOMS system to the CC ISFSI will continue to meet the offsite dose requirements of 10 CFR 72.124(b).

8.5 EVALUATION FINDINGS

F8.1 The licensee's criticality analysis provides reasonable assurance to verify the fuel M5 cladding under the 80 inch drop scenario is acceptable for the NUHOMS®-32PHB DSC under normal, off-normal, and accidental storage conditions and transfer operations.

F8.2 The staff has reasonable assurance that the changes to 3.1.1(2) to add a new maximum initial fuel assembly enrichment limit of 4.75 weight percent U-235 for a NUHOMS®-32PHB DSC basket type A and 5.0 weight percent U-235 for a NUHOMS®-32PHB DSC basket type B are acceptable. The staff also has reasonable assurance that the NUHOMS®-32PHB system to the CC ISFSI will continue to meet the offsite dose requirements of 10 CFR 72.124(b) and provides adequate heat removal capacity without active cooling systems for the NUHOMS®-32PHB DSC stored in HSM-HB at CC ISFSI.

9 CONFINEMENT EVALUATION

The requested addition of the NUHOMS®-32PHB DSC system required a confinement evaluation. The objective of the confinement review of the NUHOMS®-32PHB DSC system was to verify that potential radiological releases to the environment would be within the limits established by the regulations and that the spent fuel cladding and fuel assemblies would be sufficiently protected during storage against degradation that might otherwise lead to gross ruptures. The staff reviewed the information provided in the licensee's submittals, which included the draft SAR and calculation packages included in supplemental correspondence, and determines that the system fulfills the applicable regulatory requirements in Part 72 and the acceptance criteria listed in Section 5 of NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities", as described in SER Sections 9.1, 9.2, and 9.3.

9.1 Review of Confinement Design Features and Confinement Design Characteristics

A description of the confinement boundary for the NUHOMS®-32PHB system was provided in Section 13.3.3.2 of the draft SAR. This description identifies the confinement boundary as: the DSC shell; the bottom casing plate; alignment block; the siphon/vent block; siphon/vent covers; lifting lug round bars; and the associated shop and field welds. The confinement boundary was pictorially represented in the "Confinement Boundary Sketch for 32PHB DSC". Draft SAR section 3.3.1 stated that there are double closure seal welds on both ends of the DSC; there are no bolted closures or mechanical seals providing closure of the confinement boundary. As denoted in drawing NUH32PHB-30-10, all confinement boundary components are listed as important to safety (ITS) category A in accordance with NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety".

Draft SAR Section 13.3.2.6 stated that the DSC shell assembly welded joint details are the same as the NUHOMS-32P. In addition, draft SAR Section 13.3.2.6 and drawing NUH32PHB-30-1 indicate that the NUHOMS®-32PHB canister components and associated welds are evaluated, designed, and inspected to meet ASME Code, Section III, Subsection NB.

According to draft SAR Section 13.3.3.2, the top cover plate, which serves as the redundant closure, is welded to satisfy the large weld exception criteria of ISG-18. Drawing NUH32PHB-30-20 indicates that the top cover plate contains a test port that is used to helium leak test the top shield plug assembly and siphon/vent cover welds. Per drawing NUH32PHB-30-20, the test port penetration is subsequently welded closed to maintain a redundant closure. Draft SAR Section 3.3.2 indicates that the DSC shell, inner bottom plate and associated welds are pressure tested in accordance with the ASME Code, Section III, NB-6000 and, according to SAR Section 13.3.3.2, leak tested to meet the American National Standards Institute (ANSI) N14.5 leaktight criteria during fabrication. Likewise, the TS state that the top shield plug closure weld, siphon and vent port cover welds, and the top cover plate weld shall satisfy the liquid penetrant acceptance standards of ASME Code, Division I, Section III, Subsection NB. Further details on the Codes and Standards pertaining to the DSC are presented in the SER's structural evaluation. The staff finds that the welds would behave similarly to the adjacent parent material of the cask because the shell, baseplate, and DSC lid closure welds are designed, tested, and inspected in accordance with the applicable requirements of the ASME Code, Division 1, Section III, Subsection NB.

Draft SAR Section 13.3.3.2 stated that the 32PHB DSC and inner bottom cover plate, including all circumferential, longitudinal, and cover plate welds, are to be helium leak tested in the fabrication shop to meet the helium leaktight criterion per ANSI N14.5. The staff edited license condition 15 to clarify these licensee requirements that were described in the draft SAR. According to draft SAR Section 13.3.3.2, after fuel loading the closure lid weld associated with the top shield plug assembly, which includes the top casing plate shown in the pictorial and denoted in drawing NUH32PHB-30-10, is helium leak tested to 1E-7 atm cc/sec, helium, and bounded by the leaktight criterion (1E-7 ref cc/sec, air) per ANSI N14.5-1997. The staff added TS 3.2.2.2(b), and SR 4.2.2.2 to clarify these licensee requirements that were described in the draft SAR. Draft SAR Section 3.3.2 and 13.3.3.2 indicated that the NUHOMS®-32PHB DSC, including base metal and welds, is leaktight, as defined by ANSI N14.5-1997, with a maximum acceptable leakage of 1E-7 atm cc/sec of helium. The licensee stated in draft SAR Section 13.3.3.2 that the fabricator would perform a helium leak test on the 32PHB DSC cavity following the welding of all circumferential and longitudinal welds of the shell and bottom plate and another helium leak test on the top shield plug cavity. The top shield plug would be helium leak tested after welding the top casing plate, side casing plate, alignment block, siphon and vent block, and top shield plug lifting plug round bars. In addition, draft SAR Section 13.3.3.2 stated that a final helium leak test would be performed after fuel loading and welding of the top shield plug to the DSC shell. Draft SAR Section 13.3.3.2 also stated that a nondestructive testing Level III individual, qualified according to the training requirements of American Society for Non-Destructive Testing (ASNT)-TC-1A, would develop the helium leak test procedures in the fabrication shop and field and perform helium leak testing.

The staff finds that Sections 3.3.2, 13.3.2, 13.3.3.2 of the draft SAR describe confinement SSCs ITS in sufficient detail to permit evaluation of their effectiveness.

9.2 Radionuclide Confinement Analysis

NUREG-1567 indicates that the extent of a confinement analysis is dependent on the DSC design and its performance under potential events. Draft SAR section 13 discussed the performance of the NUHOMS®-32PHB DSC during various normal, off-normal, and accident scenarios. According to draft SAR Section 13.3.2, the NUHOMS®-32PHB DSC is handled, loaded, and sealed in the same manner as the previously approved NUHOMS®-32P DSC. The

loading process is described in draft SAR Sections 5 and 7.2.2 and transfer operations are described in Section 4.7.4.1. Draft SAR Section 3.3.2 stated there are multiple confinement barriers and systems, including the cladding that contains the fuel, the confinement provided by the stainless steel DSC, and the double seal welded bottom plate and lid closures and therefore, there were no credible events that would breach a DSC that would result in a leakage path to the environment.

9.2.1 Consideration of operations and accident scenarios

Section 13.8 of the draft SAR discussed the structural and thermal analyses that were performed to show the integrity of the confinement boundary would be maintained during normal and off-normal operations and accident scenarios.

Normal Conditions

According to draft SAR Section 13.8.1, the licensee performed ANSYS evaluations on the DSC to address dead weight, pressure, thermal, and handling loads. In addition, the licensee performed a structural evaluation assuming an external hydrostatic load on the DSC when it is placed within the transfer cask and filled with water. The licensee's results indicated the DSC stresses were within the ASME Code allowable stresses. For normal conditions of storage and transfer, and assuming 1% fuel rod rupture (per the licensee's calculation package NUH32PHB-0404), the maximum internal pressure for the NUHOMS®-32PHB would be 9.3 psig, as reported in Table 7-1 on page 13.1-63 of the draft SAR, and would be below the normal maximum allowable pressure of 15 psig. The staff accepts the 1% rod rupture assumption in the licensee's calculation because it matched the rod breakage fraction provided in Section 9.5.2.2 of NUREG-1567.

Off-Normal Conditions

Off-normal conditions were analyzed and discussed in draft SAR Section 8.1.2 and supporting calculation packages. According to the licensee's calculation package NUH32PHB-0404, the maximum internal pressure of the NUHOMS®-32PHB DSC at off-normal conditions assumed 10% of fuel rod rupture. For off-normal conditions of storage the maximum internal pressure for the NUHOMS®-32PHB DSC would be 15 psig, as reported in Table 7-1 on page 13.1-63 of the draft SAR and would be below the licensee's off-normal maximum allowable pressure of 20 psig. The staff accepts the 10% rod rupture assumption in the licensee's calculation because it matched the rod breakage fraction provided in Section 9.5.2.2 of NUREG-1567.

Design-Basis Accident Condition

Draft SAR Section 7.2.2 indicates that there is no design basis accident which could result in a breach of the DSC. A list of accident scenarios considered in the application is presented in draft SAR Section 8.2. According to the licensee's calculation package NUH32PHB-0404, 100% fuel clad rupture was assumed when analyzing the internal DSC pressure during accident transfer and storage. For this condition, the cavity gas temperature was bounding for all of the conditions considered. The 100% fuel clad rupture assumption resulted in the bounding quantity of gas within the DSC. This, coupled with the bounding temperature, resulted in the bounding pressure within the DSC. Table 7-1 on page 13.1-63 of the draft SAR reported a maximum internal pressure for the NUHOMS®-32PHB DSC of 91.4 psig, which was below the licensee's maximum allowable pressure of 100 psig. The staff accepts the 100% rod rupture

assumption in the licensee's calculation because it matched the rod breakage fraction provided in Section 9.5.2.2 of NUREG-1567.

As noted in the SER's structural evaluation, the stresses in the NUHOMS®-32PHB DSC components for normal, off-normal, and accident loads, which were analyzed by the licensee, had margin of safety greater than zero, which the staff finds acceptable. Therefore, the staff concludes that the analyses presented in Section 13 of the draft SAR demonstrate that the pressure/confinement boundary would not be compromised following the evaluated normal, off-normal, and credible accident conditions. The staff also concludes that no evaluation of release estimates is necessary because the confinement boundary would not be compromised and because it would be helium leak tested to a leaktight criterion, per ANSI N14.5. The staff finds the NUHOMS®-32PHB confinement system has been evaluated by licensee analyses to demonstrate that it will maintain confinement of radioactive material under normal, off-normal, and credible accident conditions in accordance with NUREG-1567.

9.3 Confinement Monitoring

With regards to confinement monitoring, Section 9.5.3.1 of NUREG-1567 states that canisters closed entirely by welding, such as the NUHOMS®-32PHB DSC, do not require seal monitoring. Likewise, Section 9.4.3.1 of NUREG-1567 indicates that routine surveillance programs can meet the continuous monitoring requirements of 10 CFR 72.122(h)(4). Section 3.3.2 of the draft SAR stated there are double closure seal welds at both ends of the NUHOMS®-32PHB DSC; there is no bolted closure. Section 4.3.9 and Section 5.1.1.7 of the draft SAR and current TS indicate that the NUHOMS®-32PHB system will be visually inspected every 24 hours to ensure that there is no blockage of the air inlets and outlet vents. Likewise, Section 7.3.4 of the draft SAR indicated that the CC ISFSI environmental monitoring program includes dosimeters, air samplers, and vegetation and soil samples at the ISFSI. These inspections and monitoring activities are part of a routine surveillance program. In addition, according to the draft SAR, monitoring of the NUHOMS®-32PHB DSCs will be performed as part of the periodic inspections associated with the ISFSI's aging management plan (AMP).

Based on the welded canister design of the NUHOMS®-32PHB and the routine surveillance programs described above (e.g., AMP inspections- see SER Sections 5 and 17), the staff finds that the NUHOMS®-32PHB welded closure design and the proposed routine surveillance programs adequate to satisfy 10 CFR 72.122(h)(4) requirements.

9.4 Protection of Stored Materials from Degradation

Section 1.3.1.7 and Section 4.3.1 of the draft SAR indicated that the vacuum drying system removes water and air from the DSC and backfills it with helium, as detailed in Figure 5.1-1 "ISFSI Loading Operations Flowchart." Draft SAR Section 4.3.1 states that the vacuum drying process consists of liquid removal by pumping and using pressurized gas, vacuum drying, and helium backfill; the DSC is evacuated a second time after the first helium backfill to further reduce the partial pressure of any remaining water vapor. In addition, TS state that as part of the vacuum drying procedure, the DSC cavity would undergo a stepped evacuation to below 3 torr and be maintained at that pressure (i.e., does not rise in pressure) for not less than 30 minutes, such that oxidation gases would be less than 0.25%. The DSC cavity would be subsequently backfilled with helium to a minimum of 2.5 psig pressure. TS state that the top shield plug closure weld, vent port cover weld, and siphon port cover weld are helium leak tested after loading, and draft SAR Section 13.3.3.2 stated that the base metal of the

confinement boundary and its welds would be helium leak tested to be leaktight, per ANSI N14.5. Section 1.3.1.1.3 of the draft SAR further stated that the major steps of loading, including vacuum drying, and unloading of the NUHOMS®-32PHB DSC are the same as the previously approved NUHOMS®-24P DSC and NUHOMS®-32P DSC. The staff has found that these procedures would provide a benign environment within the confinement boundary by limiting the oxidizing gas concentration within the DSC, thus satisfying the regulatory requirements of 10 CFR 72.122(h)(1). The staff concludes the inert helium gas within the DSC should not leak or diffuse through the weld and cask material because the welds and base metal are tested to the leaktight criterion according to ANSI N14.5. In addition, the staff concludes that helium backfilling to a 2.5 psig pressure is sufficient to support heat transfer and to have a non-reactive environment within the DSC because the 2.5 psig pressure satisfies the guidance in NUREG-1567, the entire confinement boundary would be tested to a leaktight criterion such that, in a practical sense, there would be no leakage of the backfilled helium, and the integrity of the DSC will undergo monitoring as part of the DSC AMP. The staff finds that the design and proposed operations of the ISFSI provide adequate measures for protecting the spent fuel cladding against degradation that might otherwise lead to gross ruptures of the material to be stored, in compliance with 10 CFR 72.122(h)(1).

9.5 Supporting Information

Supporting information or documentation for the NUHOMS®-32-PHB and HSM-HB can be found in the application, as supplemented, and referenced in the SER introduction.

9.6 TS Evaluation

The staff reviewed revised TS 3.2.2.2 (a) and (b), and provided new SR 4.2.2.2 to clarify the licensee requirements that were in the draft SAR. Specifically, these TS changes clarify the NUHOMS®-32PHB DSC field closure helium leakage rate tests, which are in accordance with ANSI N14.5-1997, are to ensure the measured leakage rate is less than 1E-7 atm cc/s helium and staff concludes that the leakage rates are acceptable.

9.7 Evaluation Findings

F9.1 Section(s) 3, 4, 5, 7, 8, and 13 of the draft SAR describe(s) confinement SSCs ITS in sufficient detail in to permit evaluation of their effectiveness.

F9.2 The design and proposed operations of the ISFSI continues to provide adequate measures for protecting the spent fuel cladding against degradation that might otherwise lead to gross ruptures of the material to be stored, in compliance with 10 CFR 72.122(h)(1).

F9.3 The NUHOMS®-32PHB confinement system has been evaluated by analyses to demonstrate that it will maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F9.4 The staff concludes that the design of the confinement system of the NUHOMS®-32PHB 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®-32PHB will allow safe storage of spent fuel. This finding is reached on the basis of a review that considered 10 CFR 72.104, 72.106, 72.122(h)(1), 72.122(h)(4), 72.126(d), and 72.128(a)(3), appropriate RGs, applicable codes and standards,

the licensee's analysis, and accepted engineering practices.

10 CONDUCT OF OPERATIONS

The requested changes do not impact the original conduct of operations evaluation. Therefore an evaluation was not required.

11 RADIATION PROTECTION EVALUATION

The purpose of this section is to evaluate the radiation protection program proposed for this amendment request. The primary objectives of this evaluation are to determine whether the design features and proposed operations provide sufficient assurance that:

- The proposed NUHOMS®-32PHB and the HSM-HB meet the U.S. NRC design criteria for direct radiation;
- The licensee has proposed engineering features and operating procedures that will ensure occupational exposures will remain ALARA; and
- The radiation doses to the general public will meet regulatory standards during both normal and anticipated occurrences.

11.1 Radiation Protection Design Criteria and Features

11.1.1 Design Criteria

The NUHOMS®-32PHB DSC and the HSM-HB provide enhanced shielding which helps to compensate for the higher source term of spent fuel elements compared to the NUHOMS®-24P and NUHOMS® -32P DSCs. The licensee has stated that there are some differences between the HSM-HB and the HSM that affect shielding and radiation protection:

- Use of a 3-foot 8-inch thick roof on HSM-HB versus 3-foot thick roof on the HSM,
- HSM-HB door is inset in the doorway, with increased thickness,
- Outlet vents repositioned from top front and back of module to top sides (opening shared by adjacent modules), Inlet vents repositioned from front bottom center to front bottom sides (opening shared by adjacent modules), and
- Optional inlet vent attenuation pipes improves shielding (pipes are not credited for normal, off-normal or accident conditions).

Regarding the NUHOMS®-32PHB DSC and the NUHOMS®-32P DSC, the licensee has stated that there are some differences that affect shielding and radiation protection. These are:

- increasing the maximum fuel assembly neutron source term from 4.175E+08 n/sec/assy to 6.664E+08 n/sec/assy,
- increasing the maximum fuel assembly gamma source term from 1.61 E+1 5 MeV/sec/assy to 2.56E+1 5 MeV/sec/assy,
- full-length solid aluminum rail inserts between the DSC stainless steel cylindrical shell and the outside guide sleeves, and
- A redesign of the top shield plug (including vent and siphon ports).

11.1.2 Operational procedures

As part of the operational procedure for this amendment, the licensee has proposed three changes to the previous amendment: (1) the NUHOMS®-32PHB DSC is expected to be submerged in the pool for more than 12 hours which is more time than for the NUHOMS® -24P DSC, this additional submersion time does not affect the performance of the austenitic stainless steel as discussed in Section 7.1.2 of the USAR); (2) the contact dose goal for a transfer cask with a NUHOMS®-32PHB DSC is 250 mrem/hr, and (3) the NUHOMS®-32PHB DSC is going to be loaded into the transfer cask in the forced-cooling configuration for DSC heat loads exceeding 21.12 kW.

11.1.3 Dose Rates

Proposed SAR Table 13.7-1 of the amendment request reports the NUHOMS® -32PHB DSC shielding analysis results at maximum dose rates in mrem/hr.

Dose rates for the NUHOMS®-32PHB DSC in HSM-HB are provided in SER Section 7. Based on the new gamma and neutrons source terms mentioned in Section 11.1.1, the maximum dose rates are as follow:

Locations	Neutron (mrem/hr)	Gamma (mrem/hr)	Total (mrem/hr)	Technical Specification Limits (mrem/hr)
HSM-HB Wall of Roof	1.34	4.93	6.27	20
HSM-HB Air Outlet	11.9	35.2	47.1	
Center of Door	0.38	0.60	0.98	100
Doorway (Max. 1 ft into opening)	1.27×10^3	1.64×10^4	1.76×10^4	
Air Inlet Vent*	10.3	110	121	
1 m from HSM-HB Door	0.38	0.63	1.01	

(With attenuation pipes installed in the inlet vent, the gamma dose rate reduced by 43%, resulting in a total dose rates of 73 mrem/hr).

Dose rates for the NUHOMS®-32PHB DSC in cask were taken by the licensee from the Shielding Section. Based on the new gamma and neutrons source terms discussed in Section 11.1.1, the maximum dose rates are as follow:

	Neutrons	Gammas	Total
Centerline DSC Shield Plug (Flooded DSC)	2	242	244
DSC Cover Plate (Dry DSC)			
Center	549	150	695
Edge (Wet Gap)	317	314	631
Edge (Dry Gap)	378	407	785
Transfer Cask			
Side	138	112	217
Top	12	14	26
Bottom	100	108	208

The licensee determined the dose rates for normal transfer cask configuration meet the design

goal of less than 5 rem at the site boundary.

The staff reviewed the radiation protection design features, design criteria, and supporting operating procedures and concludes that, because the dose rates remain below regulatory limits, they meet the requirements of 10 CFR Part 20.1201, 20.1301, 20.1302, 10 CFR 72.104, 10 CFR 72.106, and 10 CFR 72.126.

11.2 Occupational Exposures

The staff performed confirmatory analyses to determine the result from the proposed increase in the allowable enrichment. Staff's confirmatory analyses demonstrate a minor change in dose rates for some loading and transfer activities and horizontal storage module dose locations. The analysis of the increases also shows that dose rates and accumulated dose remain below limits. As a result, the staff finds that there is no significant increase in individual or cumulative occupational radiation exposure from the proposed changes included in the amendment request to the ISFSI License.

11.3 Accident Dose Consequences

The licensee states that the same methodology and modeling used for the NUHOMS®-24P DSC transfer cask drop accident scenario were used to analyze the NUHOMS®-32PHB DSC and the analysis continues to assume that the neutron shielding is lost. The doses for the NUHOMS® -32PHB DSC, with the increased neutron source term, are 3521 mrem/hr on contact, and 152.2 mrem/hr at 15 feet. The contact dose rate remains below the limit of 5 rem/hr for this accident. The recovery dose to an on-site worker, at an average distance of 15 feet, increases from 1164 mrem for a NUHOMS® -32P DSC to 1218 mrem during the 8 hour time required to mitigate the accident. The recovery dose remains below the limit of 5 rem at the site boundary since the total dose at 15 feet is much less than 5 rem, as provided in Section 7.

The staff reviewed the dose rate calculations for accident dose consequences submitted by the licensee to support the new neutron and gamma source terms. The staff performed confirmatory calculations using ORIGEN-ARP and verified the acceptability of the new source terms. Therefore, staff has reasonable assurance that the NUHOMS®-32PHB will maintain doses less than those specified in 10 CFR 72.104 and 72.106.

11.4 Exposures at or Beyond the Control Area Boundary

Dose locations and distances were specified in Section 3.2 of NUH32PHB-0505, Site Dose Analysis for NUHOMS-32PHB System. The results show that the difference between the front, corner and side dose values reduces with increase in distance resulting in similar doses at far distances (about 400 meters from the ISFSI). At these distances, a majority of the dose is due to sky shine; and therefore, the licensee expects doses to be nearly symmetric around the ISFSI at distances greater than 400 meters or the same order of magnitude.

The staff reviewed the dose rate calculations for accident dose consequences submitted by the licensee to support the new neutron and gamma source terms. The staff performed confirmatory calculations using ORIGEN-ARP and verified the acceptability of the new source terms. Therefore, staff has reasonable assurance that the NUHOMS®-32PHB will maintain doses less than those specified in 10 CFR 20.1301.

11.5 ALARA

The licensee is committed to a strong ALARA program in the design and operation of its nuclear facilities. The staff concludes the CC ISFSI ALARA program follows the general guidelines of Regulatory Guides 8.8, 8.10 and CFR Part 20. Plant and design personnel are trained and updated on ALARA practices and dose reduction techniques. Design and implementation of systems and equipment are reviewed to ensure ALARA exposure on all new and modification projects. The basic ALARA program consists of:

A. The Calvert Cliffs Radiation Safety Manual, ALARA Program, and Radiation Safety (Implementation) Procedures.
B. Continued surveillance and evaluation of in-plant radiation and contamination conditions, as well as the monitoring and control of the exposure of personnel by radiation safety professionals and technical personnel.
C. The Radiation Safety-ALARA Unit comprised of radiation safety technical personnel, whose primary function is to perform ALARA reviews of operations, maintenance, and modifications.
D. Responsible Engineers who are responsible to assure ALARA considerations are accounted for in the design process.

11.6 Evaluation Finding

The staff finds with reasonable assurance that the design of the radiation protection system of the NUHOMS® 32PHB System has been demonstrated to be in compliance with 10 CFR Part 72 and that the licensee design and acceptance criteria have been satisfied. The evaluation of the radiation protection system design provides reasonable assurance that the NUHOMS® 32PHB System will allow safe storage of spent fuel. This conclusion is reached on the basis of a review of the licensee’s submittals that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted health physics practices.

Based on the staff’s review of the information provided in the application, the staff concludes the following:

F11.1 The NUHOMS® 32HB System provides radiation shielding and confinement features that are sufficient to meet the requirements of 10 CFR 72.104 and 72.106.

F11.2 The design and operating procedures of the NUHOMS® 32HB System provide acceptable means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR Part 20 and for meeting the objective of maintaining exposures ALARA.

12 QUALITY ASSURANCE EVALUATION

The requested changes do not impact the original quality assurance evaluation. Therefore an evaluation was not required.

13 DECOMMISSIONING EVALUATION

The requested changes do not impact the original decommissioning evaluation. Therefore an evaluation was not required.

14 WASTE CONFINEMENT AND MANAGEMENT EVALUATION

The requested changes do not impact the original waste confinement and management evaluation. Therefore an evaluation was not required.

15 ACCIDENT ANALYSIS

The specific accident evaluations required due to the changes requested in Amendment 11 are provided in SER Sections 5, 6, 8, 9, 11 and 17. The evaluations were performed in accordance with NUREG 1567, Chapter 15.

16 TECHNICAL SPECIFICATIONS

The objective of this review is to determine whether the changes to the operating controls and limits or the TS for the CC ISFSI would meet the requirements of 10 CFR Part 72 under the proposed amendment. Specifically, the proposed changes were reviewed to ensure that they support the fuel loading changes requested by the licensee. The technical and safety aspects of these changes were evaluated by the staff in Sections 5, 6, 7, and 8, of this SER and were found to be acceptable.

The amendment authorizes the following:

a. Maximum fuel assembly average initial enrichment of 5 weight percent U-235.

b. Expansion of the ISFSI total capacity from 120 horizontal storage modules (HSMs) to 132 HSMs on the existing site.

c. A new 32PHB DSC design and a new HSM-HB for use at the CC ISFSI.

d. Storage of Westinghouse / AREVA / Combustion Engineering 14X14 fuel in the NUHOMS®-32PHB DSC system.

Proposed changes to the CC ISFSI license and TS needed to accommodate the above changes are described below and shown on the amended license and TS pages.

a. Renewed Material License No. SNM-2505 Section 6, Byproduct, Source, and/or Special Nuclear Material. The proposed amendment would increase the maximum allowable enrichment from 4.5 percent U-235 to 5.0 percent U-235 to allow for storage of higher enriched fuel assemblies.

b. Renewed Material License No. SNM-2505 Section 8, Maximum Amount That Licensee May Possess at Any One Time Under This License. The proposed amendment would increase this amount from the current 1,111.68 TeU to 1,558.27 TeU to allow for storage of fuel generated over the 60 year licensed lifetime of the Calvert Cliffs Units 1 and 2.

c. Renewed Material License No, SNM-2505 Section 15. The proposed amendment would add acceptance standards for liquid penetrant tests of the double closure seal welds at the bottom end of the DSC for the NUHOMS®-32PHB DSC.

The acceptance standards for the NUHOMS®-24P DSC and the NUHOMS®-32P DSC remain the same.

d. TS 2.1, Fuel to be Stored at ISFSI. This TS ensures that the fuel assembly radiation source is below design values. To accomplish this, the TS provides limits on the neutron and gamma sources allowed in each fuel assembly. The proposed change would add a new neutron and gamma source for fuel assemblies stored in NUHOMS®-32PHB DSCs. The new neutron and gamma sources for the NUHOMS®-32PHB DSC were selected to bound fuel assemblies that reach the TS Limiting Condition for Operation 3.1.1(5) thermal limit to be loaded.

e. TS 3.1.1, Fuel to be Stored at ISFSI. This TS ensures that the fuel assemblies stored in the DSCs meet the design requirements of the DSCs. This proposed amendment makes the following changes:

- TS 3.1.1(2) – The current maximum initial enrichment limit is 4.5 weight percent U-235. The proposed amendment would add new maximum initial enrichment limits of 4.75 and 5.0 weight percent U-235 for a NUHOMS®-32PHB DSC, based on internal DSC basket design. The current maximum initial enrichment limit of 4.5 weight percent U-235 for the NUHOMS®-24P and NUHOMS®-32P DSCs remains the same.

- TS 3.1.1(3) – The current maximum fuel assembly average bumup limit is 47,000 MWd/MTU) for the NUHOMS®-24P DSCs and 52,000 MWd/MTU for the NUHOMS®-32P DSCs. The proposed amendment would add a new maximum fuel assembly average bumup limit of 62,000 MWd/MTU for fuel stored in NUHOMS®-32PHB DSCs. The current bumup limits for the NUHOMS®-24P and NUHOMS®-32P DSCs remain the same.

- TS 3.1.1(5) – The current maximum heat generation rate limit is 0.66 kilowatt per fuel assembly. The proposed amendment would add a new maximum heat generation rate of 0.8 kilowatt per fuel assembly for NUHOMS®-32PHB DSC basket zones 1 and 4, and a maximum heat generation rate of 1.0 kilowatt per fuel assembly for NUHOMS®-32PHB DSC basket zones 2 and 3. The current maximum heat generation rate for the NUHOMS®-24P and NUHOMS®-32P DSCs remain the same.

- TS 3.1.1(7) – Currently, the maximum fuel assembly mass to be placed in the NUHOMS®-24P and NUHOMS®-32P DSCs, including control components, shall not exceed 1450 lbs (658 kg). This proposed amendment adds a new requirement that the maximum fuel assembly mass to be placed in the NUHOMS®-32PHB DSC shall not exceed 1375 lbs (625 kg) excluding control components. The current maximum fuel assembly mass limit remains the same for the NUHOMS®24P and NUHOMS®-32P DSCs.

f. TS 3/4 2.2, DSC CLOSURE WELDS. – Requested to revise Limiting Condition for Operations (LCOs) 3.2.2.1 and 3.2.2.2 to clarify the 24P and 32P DSC top shield plug closure weld testing requirements. In addition, added testing requirements for the new 32 PHB DSC top shield plug. Added SR 4.2.2.2 for the 32PHB DSC post installation test.

g. New LCO 3.3.2.1, Time Limit for Completion of NUHOMS®-32PHB Transfer Operations -The proposed amendment would establish a new LCO for the time to complete the

transfer of the NUHOMS®-32PHB DSC from the cask handling area to the HSM. This new LCO does not apply to the NUHOMS®-24P or NUHOMS®-32P due to their lower heat load. There is no time limit for completion of the transfer for a DSC with a total heat load of 21.12 kW or less,

- 62 hours for a DSC with a total heat load greater than 21.12 kW but less than or equal to 23.04 kW,
- 38 hours for a DSC with a total heat load greater than 23.04 kW but less than or equal to 25.6 kW,
- 10 hours for a DSC with a total heat load greater than 25.6 kW but less than or equal to 29.6 kW
- SR 4.3.2.1 was added to monitor the time limit.

h. New LCO 3.3.3.1, Time Limit for Completion of NUHOMS®-32PHB DSC Vacuum Drying Operation - The proposed amendment would establish a new LCO for the NUHOMS®-32PHB DSC blowdown and vacuum drying process if nitrogen is used for blowdown. The time limit for completion of vacuum drying of a loaded NUHOMS®-32PHB DSC following blowdown with nitrogen is as follows:
   - 56 hours for a DSC with a total heat load of 23.04 kW or less,
   - 40 hours for a DSC with a total heat load greater than 23.04 kW but less than or equal to 25.6 kW,
   - 32 hours for a DSC with a total heat load greater than 25.6 kW but less than or equal to 29.6 kW.
   - SR 4.3.3.1 was added to monitor the time limit.

i. LCO 3.4.1.1, Maximum Air Temperature Rise – This TS limits the temperature rise from the HSM inlet to the outlet. This provides assurance that the fuel is being adequately air cooled while in the HSM. The current limit is a maximum 64°F temperature rise. The proposed amendment would add a new maximum allowable temperature rise for HSM-HBs with NUHOMS®-32PHB DSCs loaded of 80°F. The TS “Action” and Surveillance are also changed to address the additional temperature limit and the verification of the appropriate heat load for the fuel assemblies. The maximum temperature rise limit will remain 64°F for the existing NUHOMS®-24P and NUHOMS®-32P DSCs.

j. TS, Design Feature 5.2, NUHOMS®-32P DSC -The proposed amendment would add the required minimum areal density for the NUHOMS®-32PHB DSC poison plates. The NUHOMS®-32PHB DSC poison plates shall have a minimum ^{10}B areal density of 0.019 g/cm^2 for basket type A and 0.0270 g/cm^2 for basket type B. The minimum areal density for the NUHOMS®-32P DSC poison plates remains the same.

16.1 Findings

F16.1 The staff finds that the conditions for use at the CC ISFSI identify necessary TS to satisfy 10 CFR Part 72 and that the applicable acceptance criteria have been satisfied.

The proposed TS changes provide revised conditions that provide reasonable assurance that the CC ISFSI (as operated within the conditions) will continue to allow safe storage of spent nuclear fuel (SNF).

17 MATERIALS EVALUATION

The following changes requested by the licensee required a staff materials evaluation.

a. A new 32PHB DSC design and a new HSM-HB for use at the CC ISFSI.
b. Storage of Westinghouse and AREVA Combustion Engineering 14X14 fuel in the NUHOMS®-32PHB DSC system.

17.1 Westinghouse and AREVA CE 14x14 Fuel Assembly Design

The licensee stated that these fuel designs are not suitable for the existing approved DSC and HSM designs. Therefore, NUHOMS®-32PHB DSC has been selected to allow storage of this fuel in modified HSM-HB. A number of changes in the CE 14x14 fuel design used at the CC ISFSI have occurred since originally licensed. Most recently the change to AREVA fuel with M5® cladding, gadolinia (GD_2O_3) burnable absorber, and high thermal performance grids. In addition, 24-month cycle operation and the high CC capacity factors for more than the past decade have resulted in a continuing trend towards higher fuel assembly discharge burnups.

Zirconium alloys (cladding), in general, are highly resistant to corrosion, though susceptible to oxidation during operation inside the reactor vessel. PWR fuel previously used Zircaloy-4 and have been transitioning to Zirconium-Niobium (Zr-Nb) alloy cladding, for example, Zirlo™ and the latest M5® alloys. During the oxidation process, the cladding also absorbs hydrogen, which may remain dissolved or precipitate as hydrides.

Hydrogen pick-up is the absorption into zirconium-based alloys of hydrogen generated during the low rate surface corrosion process on the zirconium. The oxidation of zirconium by water generates free hydrogen ions which may permeate into the zirconium metal.

Dimensional instability in zirconium alloys is due to hydride volume changes, irradiation growth, and irradiation creep (thermal creep is slight at operating temperatures). Irradiation creep is critical to the interaction of the cladding with the fuel pellets. Initially a gap exists between the fuel pellet and cladding; the cladding then creeps down to close this gap. At higher burn-ups (i.e., greater than 50 GWd/tHM) the gap begins to reopen due to fission gas-generated pressure. Zirlo™ and M5® cladding possess improved irradiation and thermal creep properties.

The licensee used various methodologies and assumptions to calculate and provide both high burn up fuel (HBU) cladding mechanical properties and M5® cladding mechanical properties. Methodologies, assumptions and these mechanical properties are part of proprietary information and will not be specified in this discussion. Regarding the mechanical properties of M5®, the staff performed independent validations of proprietary data provided in the application with data from the NRC-approved M5® topical report (ADAMS Accession No. ML003681490). Regarding the mechanical properties of zircaloy-4 and ZIRLO™, the licensee relied on the use stress/strain models developed by Pacific Northwest National Laboratory (PNNL-17700, 2008) (ADAMS Accession No. ML13098A021) that the staff has previously accepted for the proposed burnups in this amendment application.

Mathematical expressions were derived from correlations of experimental results and various investigations over a range of temperatures, an important factor in the derivation of Zircaloy properties. For example, PNNL developed a model for stress/strain behavior in Zircaloy predicting yield stress and ultimate tensile strength under uniaxial conditions for un-irradiated and irradiated Zircaloy. The model was created using axial tension tests and biaxial burst tests, confirmed using ring stretch tests. PNNL models account for yield and ultimate tensile strengths, uniform and total strain, local fast fluence, local burnup, corrosion level, hydrogen concentrations, test temperature, strain rate, and cold work ratios.

The staff finds the methods, assumptions, and material properties of the cladding materials acceptable and consistent with data in previous NRC-approved applications and topical reports. (CoC. No. 1004, Amendment No. 13) (ADAMS Accession No. ML14153A573)

17.2 NUHOMS®-32PHB DSC Design Evaluation

The licensee states that the NUHOMS®-32PHB DSC design is similar to previously NRC approved design of the NUHOMS®-32P DSC with the exceptions noted as follows:

- The fixed neutron absorber plate material contains a higher concentration of Boron-10.

- Solid aluminum rails are used to support the fuel basket. The rails in previously-approved DSCs are also aluminum (not solid) and were previously evaluated for aging management activities as part of ISFSI license renewal. That evaluation determined that there were no aging management effects that required aging management activities to address. Given the materials and service are the same, this conclusion reasonably applies to the solid rails in the NUHOMS®-32PHB DSC.

- In addition to fuel with Zircaloy-4 and Zirlo cladding, the NUHOMS®-32PHB DSC may also contain fuel with M5 cladding. This cladding alloy exhibits superior performance compared to Zircaloy-4 and Zirlo in the areas of waterside corrosion and hydrogen pick-up during operation. Therefore, it is expected to perform as well or better than Zircaloy-4 or Zirlo clad fuel in the inert storage environment inside the NUHOMS®-32PHB DSC.

The NUHOMS®-32PHB DSC is designed for a maximum heat load of 29.6 kW and are designed together with the corresponding HSM-HB for high burnup fuel assemblies up to 62 GWd/MTU with a maximum fuel assembly average initial enrichment of 5 weight percent U-235.

The staff finds that the amendment provides no material that has not been previously evaluated by the staff in this application. The amendment adds only a minor increase to the previously evaluated materials, therefore material evaluation considerations come from their possible degradation due to increased heat load and/or radiation exposure (PNNL-17700, 2008) (ADAMS Accession No. ML13098A021). The staff finds the results of the thermal plus radiation demonstrate overall consistency with in-service experience for stainless steel canister. Therefore, no unanticipated response to service conditions (heat plus radiation) would result. The staff further notes that the radiation fluence levels for a storage cask are a number of orders of magnitude lower than the accumulated dose in reactor operation.

17.3 Modification of HSM to Accommodate HBU Fuel Evaluation

The licensee stated that the HSM-HB module design is similar to the design of the previously-approved HSM modules (CoC No.1004, Amendment No.13) (ADAMS Accession No. ML14153A573) and the differences are noted as follows:

- The HSM-HB has a thicker roof (3 feet 8 inches versus 3 feet), but is made of the same material as the previously-approved HSM design.

- Slotted plates and holes in the DSC support rails are used, and are made of the same material as the support rails in previously-approved DSC designs.

- Inlet vents use attenuation pipes attached to the inside of the bird screen which are the same material as the HSM ventilation air openings. While the attenuation pipes are included for ALARA dose reduction, their presence is not credited in the analyses for the HSM-HB, and therefore, they do not add a new intended function for the ventilation air openings. The existing ventilation air openings have been evaluated for aging management effects. That evaluation determined that there were no aging management effects that required aging management activities to address. Given the materials and service are the same, this conclusion reasonably applies to the attenuation pipes in the HSM-HB.

The amendment adds only a minor increase to the previously evaluated materials, therefore material evaluation considerations come from their possible degradation due to increased heat load and/or radiation exposure. Time-limited aging analysis (TLAA) data supports the licensee's statement that thermal aging is not a significant factor at the design temperature. Thus, no long term, thermally induced, degradation would be expected in service. The staff finds the results of the thermal plus radiation demonstrate overall consistency with in-service experience for stainless steel canister. Therefore, no unanticipated response to service conditions (heat plus radiation) would result.

17.4 Scoping Evaluation and Aging Management Review

The following discussion is a result of the staff's request for additional information concerning the scoping evaluation and aging management review to establish that the NRC-approved aging management programs (AMPs) remain adequate for all new and revised subcomponents part of this amendment. Aging effects could adversely affect the ability of the SSCs and related subcomponents from performing their intended functions during the period of extended operation. The scoping evaluation and aging management review involve identification of subcomponents within the scope of renewal, corresponding materials and environments, and potential aging effects. Consistent with 10 CFR 72.42a, the licensee addressed aging effects for the new SSCs and related subcomponents through either revised time-limited aging analyses (TLAAs) or revised AMPs. Consistent with 10 CFR 72.13, if the TLAA does not conclude that the aging effect does not result in a loss of intended function, the licensee must rely on an AMP to ensure timely detection of the aging effect and appropriate corrective action prior to a loss of intended function.

The staff requested a scoping evaluation and aging management review for the transfer cask with forced-air cooling modifications, and all applicable drawings, bill of materials and safety classifications of the related subcomponents. As a result, the licensee revised the renewal-

related sections of the USAR (Section 9.6.3.2; Table 9.6-4) to address new passive components related to the modified transfer cask, HSM-HB and the 32PHB DSC. These sections clarify

that the NRC-approved aging management programs apply to all the new SSCs and related subcomponents.

The licensee revised proprietary TLAAs and other time-limited calculations to address the new SSC designs (Proprietary TN Calculations 10955-0201, Rev. 1; 10955-0202, Rev. 1; 10955-0203, Rev. 3; Proprietary TN Technical Report 10955-0101, Rev. 1). The staff reviewed the analyses and conclusions in these documents to ensure compliance with 10 CFR 72.42(a), and the TLAA conditions set forth in the definition of TLAA found in 10 CFR 72.3. More specifically, the staff reviewed conclusions related to corrosion of the DSC internals and lead shield plugs, neutron damage of DSC materials, thermal expansion of the DSC internals, neutron absorber poison plate performance, peak fuel cladding temperature, neutron and gamma radiation damage of the HSM-HB concrete, thermal cycling fatigue of the HSM-HB concrete, fatigue evaluations for the transfer cask and lifting yoke, and NS-3 neutron shield performance. The staff finds the conclusions acceptable and consistent with previously-approved analyses during the review of Renewed Materials License No. SNM-2505 (ADAMS Accession No. ML14274A022).

The staff also requested additional details to ensure the NRC-approved AMPs adequately address the new HSM-HB and 32PHB DSC designs, and details on how data from the "High Burnup Dry Storage Cask Research and Development Project" would be adequate for ensuring safe storage of high burnup fuel up to 62 GWd/MTU, as requested in the amendment.

With respect to the transfer cask, the application describes the industrial grade blowers associated with the forced cooling option as redundant. These systems are active and therefore subject to maintenance activities per the licensee's NRC-approved quality assurance program and therefore do not require an aging management activity, consistent with NUREG-1927, Rev. 1 (ADAMS Accession No. ML15180A011). Therefore, the staff considers that the NRC-approved AMP for the transfer cask continues to be adequate for the revisions in this amendment.

With respect to cladding performance, the licensee provided supplemental details to support safe storage of high burnup fuel up to 62 GWd/MTU. The licensee clarified that the fuel fabricator's rod design method is only licensed to a peak fuel rod average burnup of 62 GWd/MTU, and based on the loading history at the Calvert Cliffs ISFSI, the assembly average burnup for zircaloy-4 and ZIRLO™ are both less than 55 GWd/MTU and less than 58 GWd/MTU for M5®. The staff reviewed the NRC-approved AMP for high burnup fuel and considers that the acceptance criteria remains adequate for these burnups (as supported by the technical references on separate effects testing of creep, listed in ISG-11, Rev. 3), and that non-destructive and destructive examination data from the demonstration program can be used in support of safe storage of all M5®, ZIRLO™ and zircaloy-4 at the increased burnups. The licensee stated that they currently store a few lead test assemblies with higher burnup than those discussed above, which have alternate cladding materials. However, the licensee clarified these assemblies will not be loaded in a 32PHB canister.

The new 32PHB DSC design does not include any revisions to the materials of construction and dimensions of the canister. The staff requested additional details on the inspection schedule for the 32PHB canisters per the current NRC-approved AMP for the DSC. The licensee clarified that the basis for inspection under the NRC-approved AMP is to inspect canisters suspect of chloride-induced stress corrosion cracking (CISCC), and that this degradation mode

is not expected to occur until the 32PHB DSC canisters reach temperatures around or below 80 °C. The licensee referenced a calculation that evaluated the required time for a fully-loaded 32P DSC to cool down to 80 °C to exceed 35 years, using a source content with a lower heat load that than of the 32PHB. Since the 32PHB has a higher heat load than that assumed in this calculation, it would therefore require a longer storage time to reach 80 °C. The licensee stated that a re-inspection of the baseline 24P canister (i.e. same canister inspected in support of the license renewal application) is scheduled for 2019, and that information from this inspection will be used to assess timely inspection of the 32PHB DSC under the licensee's corrective action program (CAP). Further, the licensee clarified that, under the CAP, the inspection dates and parameters will be modified, as needed, to support future DSC inspections for the potential effects of CISCC. The licensee stated that these parameters will include: (1) surface sampling of the 32PHB DSC for chloride deposits, (2) visual inspections of the HSM-HB and 32PHB DSC utilizing remote visual cameras, and (3) remote temperature readings of the 32PHB DSC. The staff concludes that the licensee has adequately justified not including a 32PHB in the sample size for inspection under the NRC-approved AMP for previously-licensed AMPs. The staff also finds that the corrective action provisions in the NRC-approved AMP for the DSCs in the ISFSI provide that the 32PHB DSC (just as other similar DSCs not currently part of the AMP sample size) will be timely addressed under the licensee's CAP in the event that CISCC effects are suspected of potential loss of intended function.

The new 32PHB DSC design also includes revisions to the internal basket and absorber plate, as discussed in Section 17.2. The materials and the environment for the revised component remain unchanged from those reviewed in the aging management review for the license renewal application. Therefore, no new or revised aging management activities are required to address these changes, consistent with the approved design bases.

The new HSM-HB design includes revisions to the roof thickness, support rails design and incorporation of attenuation pipes to the bird screen, as discussed in Section 17.2. The materials and the environment for these revised subcomponents remain unchanged from those reviewed in the aging management review for the license renewal application. Therefore, no new or revised aging management activities are required to address these changes and staff concludes the NRC-approved AMP for previously-licensed HSMs adequate for the new HSM-HB design.

17.5 Staff Material Evaluation Summary

The staff considered information from technical references pertinent to age related degradation of materials, applicable consensus codes and standards, NRC reports, and NUREG-1927, Rev. 1. Based upon this review, the staff concludes that, with the specific SSC and SSC subcomponents and aging effects/mechanisms identified in the AMPs, the licensee has demonstrated with reasonable assurance that the SSC or SSC subcomponents will maintain their intended function through the renewal period. The staff has determined that the SSC and SSC subcomponents are appropriately identified, and the identified aging effects/mechanisms are consistent with the technical references pertinent to age related degradation of materials. Therefore, with the inclusion of the specific SSC and SSC subcomponents and aging effects/mechanisms in the AMPs, the staff concludes that signs of deterioration will be adequately detected and addressed before degradation reaches a level where the SSC or SSC subcomponent would be challenged in performing its intended function.

17.6 Evaluation Findings

F17.1 The staff concludes the material properties of the structures, systems, and components of the CC ISFSI remain in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the material properties provides reasonable assurance the revised SSC designs in this amendment will allow for safe storage of SNF.

F17.2 The licensee has met the requirements of 10 CFR 72.122(a). The material properties of SSCs important to safety conform to quality standards commensurate with their safety function.

F17.3 The licensee has met the requirement of 10 CFR 72.122(h)(1). The design of the dry cask storage system and the selection of materials adequately protects the SNF cladding against degradation that might otherwise lead to damaged fuel.

F17.4 The material properties of SSC ITS will be maintained during all conditions of operation so the SNF can be safely stored for the minimum required years and maintenance can be conducted as required. These findings are reached on the basis of a review of the licensee's submitted documents and calculations, and evaluated under the applicable regulations, appropriate RGs, applicable codes and standards, and accepted engineering practices.

F17.5 The licensee has met the requirements of 10 CFR 72.42(a). The NRC-approved TLAAs were revised and adequately conclude that the relevant SSCs will continue to perform their intended function during the period of extended operation and that the NRC-approved AMPs remain adequate for the revised SSC designs.

18 ENVIRONMENTAL CONSIDERATION

The staff performed an environmental evaluation of Amendment Request No. 11 to Renewed Materials License No. SNM 2505 along with the categorical exclusion requirements of 10 CFR 51.22(c)(11), which provides for a categorical exclusion for:

> Issuance of amendments to licenses for fuel cycle plants and radioactive waste disposal sites and amendments to materials licenses identified in § 51.60(b)(1) which are administrative, organizational, or procedural in nature, or which result in a change in process operations or equipment, provided that (i) there is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite, (ii) there is no significant increase in individual or cumulative occupational radiation exposure, (iii) there is no significant construction impact, and (iv) there is no significant increase in the potential for or consequences from radiological accidents.

The staff evaluations in SER sections 5,6,7,8,11 and 17 find that the requested changes are changes in process equipment where:

(i) there is no significant change in the types or significant increase in the amounts of any effluents that may be released offsite. The 32PHB DSC and HSM-HB are similar in design as that approved in Renewed Materials License SNM – 2505. The 32PHB DSC is designed , fabricated and tested to remain hermetically sealed for the

duration of the renewed license; therefore, there is no increase in the amounts of effluents that may be released offsite,

(ii) there is no significant increase in individual or cumulative occupational radiation exposure. The shielding design of the 32PHB DSC and HSM-HB is similar to the DSCs and HSMs that currently approved in Renewed Materials License SNM – 2505. The staff has found that the exterior dose rates continue to be acceptably controlled by limits in the license for cooling time, and enrichment; therefore, there is no increase in individual or cumulative occupational radiation exposure,

(iii) there is no significant construction impact. There is no construction impact at the CC ISFSI as the additional 12 HSMs requested will fit on the existing ISFSI site approved in Renewed Materials License SNM - 2505 and

(iv) there is no significant increase in the potential for or consequences from radiological accidents. The SNF and 32PHB DSC and HSM-HB requested to be added is similar to that already approved in Renewed Materials License SNM – 2505. The staff's radiological protection evaluation had determined there is no increase in the potential for or consequences from radiological accidents.

The staff finds that Amendment Request No. 11 to Renewed Materials License No. SNM 2505 meets the requirements for a categorical exclusion per 10 CFR 51.22(c)(11), and therefore, pursuant to § 51.22(b), an environmental assessment or environmental impact statement is not required.

19 CONCLUSION

Based on its review of Amendment request No. 11 to Renewed Materials License No. SNM 2505, as revised and supplemented, the staff has determined that there is reasonable assurance that: (i) the activities proposed by the amendment can be conducted without endangering the health and safety of the public and (ii) these activities would be conducted in compliance with the applicable regulations of 10 CFR Part 72. Therefore, the staff concludes that the amendment should be approved.

Issued with Renewed Materials License No. SNM-2505, Amendment No. 11

Dated: April 26, 2016