SAFETY EVALUATION REPORT

DOCKET NO. 72-16
NORTH ANNA
INDEPENDENT SPENT FUEL STORAGE INSTALLATION
MATERIALS LICENSE NO. SNM-2507
AMENDMENT NO. 5

TABLE OF CONTENTS

SUMMARY

This safety evaluation report (SER) documents the review and evaluation of an amendment request to Special Nuclear Materials (SNM) License No. 2507 for the North Anna Power Station (NAPS) Independent Spent Fuel Storage Installation (ISFSI). By letter dated August 24, 2015, as supplemented October 8, November 18, November 19, December 1, and December 28, 2015; January 14, March 22, March 23, April 21, June 21, July 26, September 23, November 22, 2016; April 10, and June 14, 2017, Virginia Electric and Power Company (Dominion, Dominion Energy or the applicant) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) in accordance with Title 10 of the *Code of Federal Regulations* (10 CFR) 72.56, to amend the Technical Specifications (TS) to allow storage of spent fuel in a modified TN-32 bolted lid cask. This particular cask will be referred to herein as sealed surface storage cask (SSSC) model "TN-32B HBU." The existing TN-32 casks already licensed in SNM-2507 will be identified as SSSC model "TN-32."

The NRC staff (staff) has reviewed the application including the justifications for the requested TS changes. As discussed in further detail below, based on the statements and representations in the application, as supplemented, the NRC staff finds that the requested amendment of the NAPS ISFSI TS meets the regulatory requirements of 10 CFR 72.

Dominion requested the following TS revisions:

1. Functional and Operating Limits
    - Table 2.1-1, Fuel Assembly Limits
        - An additional page is added to Table 2.1-1 to reflect TN-32B HBU cask fuel assembly limits. All limits from the original Table 2.1-1 are defined for the TN-32B HBU cask with the exception of cooling time after shutdown for the Burnable Poison Rod Assemblies (BPRAs) and Thimble Plugging Devices (TPDs) identified for TN-32 casks. No BPRAs or TPDs are to be stored in the TN-32B HBU cask.
    - Table 2.2-1, Decay Heat Load Methodology for Fuel Stored in TN-32B HBU Cask
        - This table is added to prescribe the decay heat load calculation method for use in Figure 2.1-4.
    - Figure 2.1-1, Minimum Acceptable Cooling Time, in Years, As a Function of Burnup and Initial Enrichment
        - A parenthetical statement is added to the title of this figure to show that it only applies to the TN-32 casks, not the TN-32B HBU cask.
    - Figure 2.1-4, Zone Heat Load Limits for TN-32B HBU Cask
        - This figure is added to establish the zone heat load limits for fuel to be stored in the TN-32B HBU cask.

2. Limiting Conditions for Operation
    - Surveillance Requirement (SR) 3.1.2.1, Verify SSSC helium backfill pressure is within limit.
        - An "AND" logical connector is added to verify SSSC helium backfill pressure is within the limit every subsequent 96 hour interval after the initial 6-hour frequency is met. This is to ensure that the helium backfill pressure is maintained within the limit even during the extended period (sometimes referred to as the thermal soak period) of thermal testing and cavity gas testing that will be conducted after vacuum drying.

- o Surveillance Requirement (SR) 3.1.3.1, Verify SSSC combined helium leak rate is within limit.
  - ▪ The specification frequency for verifying the combined helium leak rate is within the limit is relocated to Table 3-1, under the applicable SSSC model. There is no change to this frequency for TN-32 casks. However, for the TN-32B HBU cask, the frequency requirement is increased to allow for thermal testing and cavity gas testing. The combined helium leak rate test for the TN-32B HBU cask will be completed within 23 days after satisfactorily completing the initial helium backfill pressure test (i.e., within 6 hours after completing the vacuum dryness test). Twenty-three days allows for 21 days of thermal soak, plus 48 hours to complete the combined helium leak test.
- o Specification 3.3.1, SSSC Average Surface Dose Rates
  - ▪ This specification is changed to read, "SSSC Average Surface Dose Rates for TN-32 Casks," to clarify that it pertains only to TN-32 casks.
- o Specification 3.3.2, SSSC Average Surface Dose Rates for TN-32B HBU Cask
  - ▪ LCO 3.3.2 is added to reflect a different dose rate limit pertaining to the top of the TN-32B HBU cask. The Required Actions and Surveillance Requirement are the same as those identified for Specification 3.3.1.
- o Specification 3.3.2, SSSC Surface Contamination
  - ▪ The SSSC Surface Contamination specification number is changed to 3.3.3, but is otherwise unchanged from the previously approved limits. This specification will apply to both the TN-32 casks and the TN-32B HBU cask.
- o Table 3-1, SSSC Model-Dependent Limits
  - ▪ An additional SSSC model, the TN-32B HBU cask, is added to the table. All limits from the original Table 3-1 are defined for the TN-32B HBU cask. In addition, the surveillance frequency for performance of SR 3.1.3.1 is added for each design (Item h). This parameter is defined as 48 hours for the TN-32 cask and 23 days for the TN-32B HBU cask.

3. Design Features
   - o Section 4.2.1, Storage Cask
     - ▪ The TN-32B HBU cask is added as an available design for spent fuel storage.

The proposed changes in this amendment request are intended to allow storage of high burn-up spent fuel in a modified TN-32B cask at the NAPS ISFSI.

1.0 BACKGROUND

The NRC authorizes construction and operation of both general and specifically licensed ISFSIs in accordance with the regulations in 10 CFR Part 72. A specifically-licensed ISFSI is licensed separately from the nuclear power plant license and requires an application to perform the licensed activities. On June 30, 1998, the NRC issued Dominion a 20-year license to receive, possess, store, and transfer the NAPS Units 1 and 2 spent nuclear fuel to an ISFSI located on the NAPS site. The NAPS site is located in the north-central portion of Virginia in Louisa County and is approximately 40 miles north-northwest of Richmond, 36 miles east of Charlottesville; 22 miles southwest of Fredericksburg; and 70 miles southwest of Washington, D.C. The site is on a peninsula on the southern shore of Lake Anna at the end of State Route 700.

The NAPS specific license, SNM-2507, allows for the storage of eighty-four (84) TN-32 SSSCs on three pads - 28 SSSCs per pad. Each TN-32 cask is designed to hold 32 pressurized water reactor (PWR) fuel assemblies. Currently, the specific license ISFSI consists of one pad with 27 loaded TN-32 SSSCs. Dominion plans to load a modified TN-32B cask with 32 high burnup fuel assemblies specifically chosen for a High Burn-up Dry Storage Cask Research and Development Project sponsored by the Department of Energy and the Electric Power Research Institute. The cask used in the research project was designed and fabricated per NRC Certificate of Compliance (CoC) No. 1021 and the TN-32 Final Safety Analysis Report (FSAR) (ADAMS Accession Nos. ML010460308 and ML16097A219 respectively) except for the cask lid and protective cover. Seven penetrations were incorporated into the lid to allow instrumentation to penetrate the cask cavity. Data gathered by the instrumentation will be used to confirm the effects of long-term dry storage on high burn-up fuel assemblies by monitoring fuel temperatures inside the cask during the storage period.

2.0 REVIEW CRITERIA

The staff's evaluation of the requested changes are based on ensuring NAPS continues to meet the applicable requirements of 10 CFR Part 72 for independent storage of spent fuel and of 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” (ADAMS Accession No. ML003686776) in evaluating the impact of using the TN-32B HBU cask at the NAPS ISFSI. The staff’s evaluation focused only on changes to the TN-32B cask, to License No. SNM-2507 and to the associated TS described in the Design Licensing Basis Document, proprietary calculations and other documents submitted in support of the application. Staff did not reassess previously approved portions of the license, TS, and those areas of either the TN-32 FSAR or the NAPS FSAR modified per 10 CFR 72.48. The objectives for the following review disciplines are as described below for each of the requested changes.

3.0 SSC AND DESIGN CRITERIA EVALUATION

The ISFSI structures, systems and components and ISFSI design criteria relevant to the staff review are discussed in the subsequent sections of this safety analysis report.

4.0 STRUCTURAL EVALUATION

4.1 Review Objective

Dominion requested to revise the license SNM-2507 TS for the NAPS ISFSI. This section summarizes the findings of the structural evaluation performed by the staff for use of the TN-32B HBU cask at the NAPS ISFSI. Staff reviewed the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) supplied by Dominion. The design criteria utilized for the structural evaluation for the TN-32B HBU cask modifications are identical to the criteria described in the original TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219). The staff also reviewed proprietary TN document 19885-0101, Rev. 6, “Design Criteria Document” (DCD) TN-32B High Burnup Demonstration Cask” (ADAMS Accession No. ML17109A456). The staff’s review objective was to verify that the application complies with the 10 CFR Part 72 regulations.

4.2 Areas of Review

The applicant incorporated the following structural changes for the TN-32B HBU cask into the calculations reviewed by staff:

1) Four-paired bolting bars, which are ¾ inch thick and 10 inches long, welded to each end of the ½ inch thick outer shell for attaching impact limiters for future off-site transportation,
2) The top neutron shield is elevated approximately 1 inch using four (4) 1 inch thick steel bars welded to the through bolt holes on the bottom of the steel plate,
3) Seven new penetrations are made to the lid's confinement boundary and shield plate, to provide access to the cask cavity,
4) A funnel guide assembly is installed into the top nozzle of each of the seven fuel assemblies that receive the thermocouple lance assemblies,
5) The protective cover is provided with an additional access cover above the vent port cover, and
6) Lid closure bolts are upgraded to an improved material with a reduced shank diameter, a captured hardened flat washer, and increased through-hole diameter for the lid bolts to facilitate the future transportation of the TN-32B HBU cask off site.

The applicant provided dimensions and weights for various structural components of the TN-32B HBU cask in Table 1.1-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), and identified the total cask weight, as loaded on the ISFSI pad, as 117.14 tons.

4.3 Structural Review

The staff reviewed the following SSCs related to the TN-32B HBU cask:

4.5.1 Cask Body

Staff reviewed proprietary AREVA TN calculation 19885-0212, Rev. 0 (ADAMS Accession No. ML16019A335) which the applicant provided to demonstrate the structural adequacy of the TN-32B HBU cask body and compliance with the 10 CFR Part 72 storage requirements.

For normal and off-normal conditions, the applicant evaluated the performance of the TN-32B HBU cask shell using the following forces in various combinations: 1g down, 3g vertical lift using upper trunnions, 100 psig internal pressure, 25 psig external pressure as well as thermal stresses due to a 100°F ambient hot environment and a decay heat load of 36.96 kW. The applicant determined that the maximum stress ratio was less than 1.0. In addition, the applicant specified a 266.2 kips design load, which included a dynamic factor of 1.1, for the upper trunnions in the DCD, Rev. 6 (ADAMS Accession No. ML17109A456). The original upper trunnions analysis in proprietary AREVA TN calculation 1086-02, Rev. 0 (ADAMS Accession No. ML16176A239) utilized a design load of 267.3 kips including a dynamic factor of 1.1. Therefore, the loads in calculation 1086-02 (ADAMS Accession No. ML16176A239) bounded the loads for the TN-32B HBU upper trunnions. Consequently, staff found the applicant's evaluation of the cask body under normal and off-normal conditions acceptable.

For the accident load conditions, the applicant evaluated the performance of the TN-32B HBU cask shell using the following forces in various combinations: 50g bottom end drop, 50g tip-over impact, 3g vertical lift plus 1g lateral, applicable tornado wind and tornado missile impacts as well as the seismic forces for both the NAPS ISFSI Design Basis earthquake, and the 2011 earthquake centered near Mineral, VA with the cask in a vertical storage position. The applicant determined that the maximum stress ratio, which was less than 1.0, occurred for the load case with lid bolt preload, lid sealing pressure, 50g tip-over impact, 25 psig external pressure and thermal stresses. In addition, the applicant identified in the DCD, Rev. 6 (ADAMS Accession No. ML17109A456), the tornado winds and tornado missiles applicable to the NAPS ISFSI. The applicant previously evaluated these tornado winds and tornado missiles in proprietary AREVA TN calculation 1066-33, Rev. 0 (ADAMS Accession No. ML16176A239), and documented the evaluation results in the ISFSI SAR. Proprietary AREVA TN calculation 1066-33, Rev. 0 determined the bounding missile (a 6” diameter schedule 40 pipe) will not challenge the TN-32B HBU cask shell (ADAMS Accession No. ML16176A239). Therefore, based upon a review of the above mentioned documents, staff found the applicant’s analyses of the cask body under accident conditions acceptable.

Staff also noted that the TN-32B HBU design incorporated four pairs of ¾ inch thick x 10 inches long bars welded to the ½ inch thick outer shell of the cask body to facilitate impact limiter attachment for future off-site transportation of the TN-32B HBU cask. The applicant asserted that, since the bars were for future off-site transportation of the TN-32B HBU cask, a structural evaluation associated with attaching the bars to the cask body was not necessary at this point in time. Since the overall weight of the cask includes these bars, staff found this change acceptable.

After reviewing the above mentioned cask body analyses, staff concluded that the cask body satisfies the required design criteria for normal, off-normal and accident conditions for the NAPS ISFSI.

4.5.2 Cask Lid

4.5.2.1 Lid Assembly

Staff reviewed the modified lid assembly analysis (with two existing penetrations and seven new penetrations) submitted by the applicant in proprietary AREVA TN calculation 19885-0207, Rev. 1 (ADAMS Accession No. ML15331A132). As the pattern of the penetrations was not symmetric, the applicant created a three dimensional (3-D) finite element (FE) model of the lid using the ANSYS program. The applicant used a uniform bounding temperature for determining stress in the lid assembly because the thermal gradients in the lid assembly are very small. The applicant compared the resulting stresses in the lid and its welds using the allowable stresses in ASME B&PV Code Section III Subsection NB for normal (level A) and appendix F, and for accident (level D) conditions. The staff determined that the lid assembly model and the acceptance criteria for the lid assembly analysis are reasonable.

For normal and off-normal conditions, the applicant evaluated the performance of the TN-32B HBU cask lid using the following forces in various combinations under normal and off-normal conditions: 1g down, 3g vertical lift using upper trunnions, 100 psig internal pressure, 25 psig external pressure, and thermal stresses due to a 100°F ambient hot environment with a 36.96 kW decay heat load. The applicant determined the maximum stress ratio to be less than 1.0. Therefore, staff found the normal and off-normal analyses acceptable.

For accident load conditions, the applicant evaluated the performance of the TN-32B HBU cask lid using the following forces in various combinations under accident conditions: 100 psig internal pressure, 50g bottom end drop, 50g tip-over impact, 3g vertical lift plus 1g lateral, applicable tornado wind impacts, applicable tornado missile impacts, the NAPS ISFSI Design Basis Earthquake seismic event with the cask in a vertical storage position, and the 2011 earthquake centered near Mineral, VA with the cask in a vertical storage position. The applicant determined the maximum stress ratio to be less than 1.0. Also, although the size of the bounding tornado missile (a 6” diameter schedule 40 pipe) challenged the cask lid penetrations, the applicant determined in proprietary AREVA TN calculation 1066-33, Rev. 0 (ADAMS

Accession No. ML16176A239) that the missile is not a hazard to the lid penetrations because it travels in a horizontal direction. The applicant also demonstrated that both a 12” diameter, 40 foot long utility pole with a 50 lb/ft^3 density, and a 1” diameter, three foot long solid steel rod with a 490 lb/ft^3 density will not penetrate the combined thicknesses of the protective cover and neutron shield plates. Therefore, staff found the accident analyses acceptable.

4.5.2.2 Lid Closure Bolts

The applicant analyzed the lid bolts in accordance with NUREG/CR-6007, “Stress Analysis for Shipping Casks”, April 1992. Staff reviewed proprietary AREVA Document 19885-0203, Rev. 0 (ADAMS Accession No. ML15331A132) in which the applicant evaluated the following normal and off-normal load conditions: lid bolt tightening torque, bolt preload, lid sealing pressure, 100 psig internal pressure, 25 psig external pressure, and thermal stresses due to a 100°F ambient hot environment. The margin of safety (M.S.), defined as (allowable stress ÷ actual stress) -1, was greater than zero. Therefore, staff found the normal and off-normal analyses acceptable.

Staff reviewed proprietary AREVA Document 19885-0203, Rev. 0 (ADAMS Accession No. ML15331A132) and found that, for accident conditions, the applicant verified the adequacy of the lid bolts using the following loads: 100 psig internal pressure, 50g tip-over impact, 30 ft. end free drop, 30 ft. side free drop, 30 ft. center of gravity over-top corner free drop, and thermal stresses due to a 100°F ambient hot environment with a 36.96 kW decay heat load. The applicant subsequently reported that the maximum interaction ratio was less than 1.0. Therefore, staff found the accident analyses acceptable.

4.5.2.3 Fasteners for Miscellaneous Covers

The applicant analyzed fasteners used for the vent and drain port cover, access ports protective covers, and the thermocouple lance assemblies in accordance with NUREG/CR-6007, “Stress Analysis for Shipping Casks”, April 1992. Staff reviewed proprietary AREVA Documents: 19885-0206, Rev. 0, 19885-0205, Rev. 0, and 32-9235107-000, Rev. 0 (ADAMS Accession No. ML15331A132).

The applicant verified that the tightening torque for these fasteners would seat the double-metallic, silver-jacketed O-ring seal. In addition, the applicant also evaluated these fasteners for the following normal and off-normal loading conditions: fastener initial preload (installation torque), a 100 psig internal pressure, and thermal expansion from 100°F to 300°F for a 36.96 kW decay heat load. The applicant reported that the M.S. for all fasteners was greater than zero. Staff also noted that the applicant used the average tensile stress allowable values in NUREG/CR-6007 which employ conservative assumptions. Based upon the analytical results and the conservative approach employed by the applicant, staff found the normal and off-normal analyses acceptable.

The applicant also evaluated these fasteners for the following accident load conditions: fastener initial preload, a 100 psig internal pressure, 50g tip-over event, and thermal expansion from a 100°F ambient environment to a 400°F fire event. The applicant reported that the M.S. for all fasteners was greater than zero. Therefore, staff found the accident analyses acceptable.

4.5.3 Cask Basket and Basket Rails

Structurally, the basket and basket rails remained unchanged from a standard TN-32 cask. However, the operating temperatures for these components increased due to an increased fuel assembly decay-heat load. Therefore, staff reviewed the following proprietary AREVA TN calculations: 19885-0214, Rev. 1, 19885-0215, Rev. 0, 19885-0219, Rev. 0 (ADAMS Accession No. ML15331A132).

For normal and off-normal conditions, the applicant evaluated the performance of the TN-32B HBU basket using the following forces in various combinations: 3g vertical lift, 1g lateral, and thermal stresses due to a 100°F ambient hot environment with a 36.96 kW decay heat load. The M.S. reported by the applicant was greater than zero. Therefore, staff found the normal and off-normal analyses acceptable.

NAPS calculation CE-1339 dated April 1998 sated that "…the US NRC concluded that the cask tip-over cases could be characterized by an equivalent cask side drop with the following specifications: 55g peak amplitude, isosceles triangle pulse shape, pulse duration of 6 msec, upon reanalysis, Transnuclear, Inc. conservatively applied a 1.6 dynamic amplification factor to the results of this US NRC cask side drop criteria. Corresponding quasi-static force inputs of 88g and 52g were applied to the top of the basket and to the 90 degree orientation of the basket cross-section, respectively."

For the basket accident conditions, the applicant evaluated the performance of the TN-32B HBU basket using the following forces in various combinations: 50g bottom down drop, tip-over impact as described above, and thermal stresses due to a 100°F ambient environment with a 36.96 kW decay heat load. The applicant determined the M.S. was greater than zero for all load combinations. Therefore, staff found the accident analyses acceptable.

The applicant modeled the cask aluminum basket rails using the ANSYS computer program and analyzed their performance for a tip-over event accident condition as described above. As the primary membrane plus bending stress ($P_m + P_b$) governed, the applicant reported the ratio of actual maximum combined membrane and bending stress intensities over those allowable stress intensities for the basket rails. As this ratio was less than the allowable ratio of 1.0, staff found the basket rails accident analysis acceptable.

4.5.4 Fuel Assembly

The staff reviewed proprietary AREVA TN Calculation 19885-208, Rev. 0, "TN-32B HBU Fuel Structural Evaluation," (ADAMS Accession No. ML15331A132) to ensure that the applicant verified the adequacy of the three different types of fuel assemblies to be stored in the TN-32B HBU. The applicant used a FE model in the LS-DYNA program to evaluate the 18 inch end drop, and the ANSYS program for the 50g side drop analysis. As the AREVA-AMBW 17 x 17 fuel assembly has the thinnest cladding and the lowest yield strength among the three different types of fuels, the applicant appropriately used it as the bounding fuel assembly for this analysis.

The applicant reported in the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) that the maximum principal strain for the fuel cladding was well below the allowable strain limit of 0.485% at 750ºF. For the 50g side drop, the applicant also reported that the M.S. against cladding yielding was greater than zero. Therefore, staff concluded that the fuel assemblies will maintain their structural integrity under accident conditions during the storage period.

4.4 Evaluation Findings

Based on a review of the application, proposed design criteria, and confirmation that the applicant has made appropriate use of material properties and conducted an adequate structural analyses of the relevant structures, systems and components of the TN-32B HBU cask, the staff concludes that the SSCs are in conformance with the regulations. Specifically, the SSCs ITS pertaining to the TN-32B HBU cask, as described in the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) are in compliance with the applicable 10 CFR Part 72 regulations as determined by independent confirmatory calculations, comparison with the Regulatory Guides and staff judgement. In addition, the confinement systems have sufficient and adequate structural capability to withstand the worst-case design basis normal, off-normal and accident loading conditions.

F4.1 The SAR and docketed materials for the subject cask relating to the description of confinement SSCs meet the applicable sections of 10 CFR 72.11, and 10 CFR 72.24.

F4.2 The SAR and docketed materials relating to the TN-32B HBU cask design criteria, including applicable codes and standards, and the structural integrity under all required normal, off-normal and accident conditions 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(b)(1), (b)(2), (c), (h) and (l); and 10 CFR 72.128(a)(3).

F4.3 The SAR and docketed materials provide adequate analytical and/or test reports to ensure the structural integrity of the Cask SSCs, and meet the requirements of 10 CFR 72.24(c)(1) and (c)(2); and 10 CFR 72.122(b)(1), (b)(2), (c), (h) and (l).

5.0 THERMAL EVALUATION

5.1 Review Objective

The objective of the NAPS ISFSI license amendment request thermal evaluation is to confirm that the decay heat removal system remains capable of reliable operation given the proposed increased heat load and the addition of high burnup fuel for the TN-32B HBU storage cask. The review also evaluated whether the temperatures for SSCs ITS and fuel assembly cladding remain within the allowable limits under normal, off-normal, and accident conditions.

The following proposed NAPS ISFSI TS changes are applicable to the thermal evaluation:

- Table 2.1-1 “Fuel Assembly Limits”. An additional page is added to Table 2.1-1 to reflect TN-32B HBU cask fuel assembly limits. All limits from the original Table 2.1-1 are defined for the TN-32B HBU cask with the exception of cooling time after shutdown for the Burnable Poison Rod Assemblies (BPRAs) and Thimble Plugging Devices (TPDs) identified for TN-32 casks. No BPRAs or TPDs are to be stored in the TN-32B HBU cask.

- Table 2.2 “Decay Heat Load Methodology for Fuel Stored in TN-32B HBU Cask”. This table is added to prescribe the decay heat load calculation method for use in Figure 2.1-4.

- Figure 2.1-4 “Zone Heat Load Limits for TN-32B HBU Cask”. This figure is added to establish the zone heat load limits for fuel to be stored in the TN-32B HBU cask.

- Surveillance Requirement (SR) 3.1.2.1 “Verify SSSC helium backfill pressure is within limit”. An "AND" logical connector is added to verify SSSC helium backfill pressure is within the limit every subsequent 96 hour interval after the initial 6-hour frequency is met. This is to ensure that the helium backfill pressure is maintained within the limit even during the extended period (sometimes referred to as the thermal soak period) of thermal testing and cavity gas testing that will be conducted after vacuum drying.

- Surveillance Requirement (SR) 3.1.3.1 “Verify sealed surface storage cask (SSSC) combined helium leak rate is within limit.

- The specification frequency for verifying the combined helium leak rate is within the limit is relocated to Table 3-1, under the applicable SSSC model. There is no change to this frequency for TN-32 casks. However, for the TN-32B HBU cask, the frequency requirement is increased to allow for thermal testing and cavity gas testing. The combined helium leak rate test for the TN-32B HBU cask will be completed within 23 days after satisfactorily completing the initial helium backfill pressure test (i.e., within 6 hours after completing the vacuum dryness test). Twenty-three days allows for 21 days of thermal soak, plus 48 hours to complete the combined helium leak test.

- Table 3-1 “SSSC Model-Dependent Limits”. An additional SSSC model, the TN-32B HBU cask, is added to the table. All limits from the original Table 3-1 are defined for the TN-32B HBU cask. In addition, the surveillance frequency for performance of SR 3.1.3.1 is added for each design (Item h). This parameter is defined as 48 hours for the TN-32 cask and 23 days for the TN-32B HBU cask.

- Section 4.2.1 “Storage Cask”. The TN-32B HBU cask is added as an available design for spent fuel storage.

5.2 Material Temperature Limits

The applicant identified temperature limits for the fuel cladding and materials considered ITS for both normal and accident conditions. The applicant stated that, in order to maintain fuel cladding integrity, the maximum temperature must be kept below 752°F (400°C) for both normal conditions and all short-term loading operations as well as 1,058°F (570°C) for accident conditions. The applicant identified that, in order to assure confinement of radioactive materials, the seal temperatures must be maintained below 669°F (354°C). In addition, the applicant stated that, in order to maintain stability of the neutron shield resin during normal conditions of storage, the allowable temperatures should remain between -40 to 300°F (-40 to 149°C). After reviewing the temperature limits specified in the application, staff determined that the fuel cladding limits are consistent with the limits provided in the standard review plans and that the temperature limits for the other materials are reasonable for their particular application. Therefore, staff finds the material temperature limits acceptable.

5.3 Thermal Loads and Environmental Conditions

The applicant identified a total heat load of 32.934 kW based on the analyzed configuration described in the application for the TN-32B HBU cask, and used this heat load to perform both the normal and accident condition thermal evaluations. The applicant used the ORIGEN-ARP module in the SCALE sequence of computer codes to calculate the total heat load. Oak Ridge National Laboratory developed this computer code for the NRC for radioactive material licensing actions including spent nuclear fuel storage and transportation. Because this computer code has been extensively verified and validated for applications like the North Anna high burnup fuel dry storage system, staff finds it is adequate and acceptable for this application.

The proposed changes did not impact the original environmental conditions evaluation. Therefore, an evaluation was not required and the previous evaluation remains valid for this amendment.

5.4 Analytical Methods, Models, and Calculations

5.4.1 Analytical Methods

The applicant provided thermal analyses to demonstrate the ability of the TN-32B HBU cask to manage the total heat load provided in Section 5.4 and to demonstrate that predicted maximum temperatures remain within allowable limits under normal and accident conditions. The applicant stated that, because the average ambient temperature used in the thermal evaluation for normal conditions of storage is higher than the maximum ambient temperature observed in the last 50 years, it sufficiently bounds any off-normal temperature condition. Therefore, the applicant did not perform an off-normal condition thermal evaluation.

To perform the thermal evaluation for normal conditions of storage, transfer operations, and accident (fire) conditions, the applicant used the general purpose ANSYS finite element computer code which can be used to perform both steady state and transient thermal analyses. For the normal storage thermal evaluation, the applicant developed a three-dimensional (3-D) ISFSI pad thermal model. The applicant's ISFSI pad thermal model included two cask models, which are both described in section 5.5.2.1 below: an explicit model of the TN-32B HBU cask and a model of the TN-32 cask currently used at the NAPS ISFSI composed of homogenized zones. The applicant used the ISFSI pad thermal model to evaluate radiation heat transfer between the TN-32B HBU cask and the surrounding TN-32 casks. The applicant subsequently used this information to model radiation heat transfer from the TN-32B HBU cask to the environment.

5.4.2 Description of Thermal Models

5.4.2.1 Normal Conditions

For the detailed TN-32B HBU 3-D thermal model, the applicant represented the fuel assemblies as a solid, homogenized fuel region, characterized by effective thermal properties, in which heat transfer only occurred by conduction. However, in developing the effective thermal conductivity for the homogenized fuel region, the applicant considered both conduction, and radiation heat transfer. Using an axial decay heat profile typical for spent fuel assemblies, the applicant modeled heat generation over the length of the active fuel region of the homogenized fuel assemblies by dividing the active fuel region along its length into ten segments and applying peaking factors to each segment to ensure the model accurately represented the decay heat profile for the fuel assemblies. The applicant assumed that heat transfer from the homogenized fuel assembly to the cask cavity occurred only by conduction and ignored radiation and convection heat transfer.

The applicant explicitly modeled the TN-32B HBU fuel basket which is fabricated from stainless steel boxes connected by fusion plug welds that pass through holes in aluminum plates sandwiched between the stainless steel boxes. In the model, the applicant ignored the fusion plug welds and modeled the aluminum plates without holes using both an effective conductivity and effective density for the aluminum plates. The applicant reduced the aluminum plate conductivity by 10% and used this reduced aluminum plate conductivity to calculate effective conductivities for the welded basket plates. The applicant determined the effective density of the welded basket plates with plug holes by a mass balance technique. Although the TN-32B HBU fuel basket aluminum plates contain holes through which the fusion weld plugs pass, the applicant assumed a reduced density for the TN-32B HBU fuel basket aluminum plates to determine the effective density of welded basket plates in this calculation. In addition, the applicant ignored the effect of the borated aluminum plates in the effective property calculation for the TN-32B HBU fuel welded basket plates. In computing the effective transverse conductivity of the homogenized basket region, the applicant assumed a uniform heat generation for the fuel assemblies. Since the surface area of the fuel assemblies at the basket cross section is much larger than those of the other components, assuming a uniform heat generation is a reasonable approximation to calculate the transverse effective conductivity. The applicant also neglected heat transfer through helium filled spaces around the basket rail edges. The 3-D, full length detailed model represented the entire TN-32B HBU cask. The model included the geometry and material properties of the basket, basket rails, cask shells, radial neutron shield, top neutron shield, cask lid as well as the top and bottom shield plates. The model employed the following gaps (actual values are omitted due to the proprietary nature of the model):

- Axial helium gap between the bottom ends of the basket assembly, including basket rails, and the cask cavity inner surface,
- Axial helium gap between the top ends of the basket assembly and the cask cavity inner surface,
- Axial air gap between the cask bottom shield and inner plates
- Radial helium gap between the outer basket plates and the basket rails,
- Radial edge helium gap at the cutout between inner/middle basket plates and outer basket plate periphery,
- Radial air gap between top resin and top neutron shield plate,
- Helium contact gap between any two adjacent basket plates to calculate effective conductivities of the basket plates,
- Helium contact gap between the basket rails and the inner shell,
- Air contact gap between any two adjacent cask body components, and
- Axial air gap between the lid outer plate and top neutron shield plate.

The applicant also developed a TN-32 cask model composed of various homogenized zones. For each homogenized zone, the applicant calculated effective transverse and axial thermal conductivities using ANSYS thermal slice models and classical equations. Since the purpose of the TN-32 cask model was only to provide external cask surface temperatures for thermal radiation exchange with the TN-32B HBU cask detailed model in normal storage operation thermal evaluations, the applicant only considered the major heat transfer paths in calculating the effective thermal conductivities for homogenized zones in the TN-32 cask model.

The applicant applied heat transfer by natural convection and radiation on all exterior surfaces exposed to the environment. The applicant used referenced correlations, which considered a combination of laminar and turbulent flow, to obtain the average Nusselt number in calculating the free convection coefficients for the cask's vertical cylindrical surfaces. The applicant also calculated the free convection coefficients for flat, horizontal cask surfaces facing upwards using referenced experimentally determined correlations which considered a combination of laminar and turbulent flow. The applicant applied a total heat transfer coefficient, which considered convection and radiation heat transfer, to all exterior surfaces exposed to the environment.

In response to staff's request for additional information, the applicant obtained the grid discretization error by calculating the grid convergence index. In the request for additional information, staff stated that solution verification was necessary due to the small margin in the radial neutron shield predicted temperature. To calculate the grid convergence index, the applicant used the procedures described in ASME Verification and Validation 20-2009 (ASME V&V 20-2009), "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer."

5.4.2.2 Accident Conditions

To analyze accident (fire) conditions, the applicant developed two simplified ANSYS thermal models. The first model consisted of a slice from the normal storage 3-D ANSYS model at which the decay heat generation and the resultant temperatures were highest for the normal storage conditions. Using initial conditions taken from the normal storage analysis in this sub-model, the applicant predicted maximum temperatures for fuel cladding, basket components and cask shell components during fire conditions.

The second model consisted of a quarter symmetric ANSYS model of the top portion of the TN-32B HBU demonstration cask which included the geometry and material properties of the cask flange, upper region of the cask body shells, cask top shield plate, cask lid, protective cover, and the overpressure (OP) tank. The applicant modeled radiation heat transfer among the top neutron shield, OP tank, and protective cover to determine the maximum O-ring metallic seal temperatures during the fire accident condition.

5.4.2.3 Model Evaluation

In evaluating the applicant's thermal models, staff reviewed input values used in both calculation packages and computer files along with design details the applicant used to develop computer model parameters. Staff determined that the appropriate material properties and boundary conditions were used, and that the applicant's models appropriately reflected design parameters. Staff reviewed not only the assumptions, but also the modeling parameters employed by the applicant and determined both were consistent with review guidelines in NUREG-1567 "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776). Staff also determined the assumptions and modeling parameters were adequate for the heat transfer characteristics associated with the TN-32B HBU cask storage geometry and storage conditions. In addition, staff reviewed the applicant's engineering drawings to ensure dimensions were adequately translated to the analytical models.

Based on the information provided describing the analytical methods and thermal models, staff determined that the application is consistent with guidance provided in NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General Licensee" (ADAMS Accession No. ML101040620) and NUREG-1567 "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776). The staff also determined that the licensee's sensitivity analysis calculations provided bounding predictions for all analyzed conditions during both normal storage and transfer operations as well as accident events. Consequently, the staff determined that the licensee's utilization of computer modeling software was consistent with the guidance of NUREG-1567 "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776) and ISG-21, "Use of Computational Modeling Software"

(ADAMS Accession No. ML061080667). Therefore, the staff concludes that the description of analytical methods and thermal models is acceptable and it satisfies the requirements in 10 CFR 72.122 and 72.128.

5.4.3 Calculations and Results

5.4.3.1 Normal Conditions

The applicant used the thermal model described in Section 5.5.2.1 to evaluate the thermal performance of the TN-32B HBU cask for normal storage conditions and to predict maximum temperatures for key components such as fuel cladding, seals, radial and axial neutron shield, basket components, and cask shell components. The applicant demonstrated the maximum predicted temperatures of the key components did not exceed the allowable limits specified in the application during normal storage conditions. In addition, using methods consistent with those described in NUREG-1567 “Standard Review Plan for Spent Fuel Dry Storage Facilities” (ADAMS Accession No. ML003686776), the applicant also calculated the maximum cavity pressure during normal storage conditions as 21.3 psig which is less than the maximum allowed internal pressure of 100 psig.

Staff reviewed both the thermal and pressure calculations to ensure the design criteria provided for key cask components were consistent with NUREG-1567 “Standard Review Plan for Spent Fuel Dry Storage Facilities” (ADAMS Accession No. ML003686776) and associated Interim Staff Guidance (ISG) documents. Also, staff reviewed these criteria to ensure the applicant provided adequate justification for critical components that assure both confinement of radioactive materials and heat removal capability. Staff reviewed the calculation results to ensure that the predicted values either demonstrated adequate margin below the allowable limits or that the applicant provided adequate justification for components with small margin. Based upon a review of the information presented, staff finds the calculation results demonstrate the TN-32B HBU cask performs adequately under normal storage conditions by maintaining thermal parameters (temperatures and pressures) below the allowable limits (provided in the application) for the entire licensed period.

5.4.3.2 Off-Normal Conditions

As stated in Section 5.5.1, normal storage conditions bounded off-normal conditions because the ambient temperature used in the normal storage condition thermal evaluation exceeded the maximum observed for the last 50 years for the storage site. Therefore, a thermal evaluation for off-normal conditions is not necessary.

5.4.3.3 Accident Conditions

The applicant used the thermal models described in Section 5.4.2.1 and 5.4.2.2 to evaluate the thermal performance of the TN-32B HBU cask for accident (fire) conditions. The applicant predicted maximum temperatures for key components such as fuel cladding, seals, radial and axial neutron shield, basket components, and cask shell components. The applicant demonstrated the maximum predicted temperatures of the key components did not exceed the allowable limits specified in the application during accident (fire) conditions. Using methods consistent with those described in NUREG-1567 “Standard Review Plan for Spent Fuel Dry Storage Facilities” ADAMS Accession No. ML003686776), the applicant also calculated the maximum cavity pressure during accident (fire) conditions as 95.5 psig which is less than the maximum allowed internal pressure of 100 psig.

Staff reviewed both the thermal and pressure calculations to ensure that the design criteria provided for key cask components were consistent NUREG-1567 “Standard Review Plan for Spent Fuel Dry Storage Facilities” (ADAMS Accession No. ML003686776) and associated ISG documents. Also, staff reviewed these criteria to ensure the applicant provided adequate justification for critical components that assure both confinement of radioactive materials and heat removal capability. Staff reviewed the calculation results to ensure that the predicted values either demonstrated adequate margin below the allowable limits or that the applicant provided adequate justification for components with small margin. Based upon a review of the information presented, staff finds the calculation results demonstrate the TN-32B HBU cask performs adequately under accident storage conditions by maintaining thermal parameters (temperatures and pressures) below the allowable limits (provided in the application).

5.5 Confirmatory Analysis

The staff performed confirmatory analyses using the ANSYS FLUENT finite volume computational fluid dynamics (CFD) code, as an independent evaluation of the thermal analysis and modeling options presented in the application. Specifically the staff developed a 3-D model of the TN-32B HBU storage cask. Using the staff’s confirmatory analysis, applicants predictions were confirmed because the staff’s calculated results were very similar to the results provided in the application.

Both the applicant’s thermal evaluation and staff’s confirmatory analysis demonstrate that the decay heat removal system for the TN-32B HBU storage cask is capable of reliable operation given the proposed increased heat load due to the addition of high burnup fuel. The staff finds the NAPS ISFSI thermal analysis and conclusions adequate. Therefore, the staff concludes that the description of analytical methods and thermal models is adequate and it satisfies the requirements in 10 CFR 72.122 and 72.128.

5.6 Evaluation Findings

F5.1 The DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) describes SSCs ITS to enable an evaluation of their thermal effectiveness. The staff determined that the SSCs ITS will remain within the operating temperature ranges specified in SER Section 5.2 as required by 10 CFR 72.122. This finding is supported by the applicant’s thermal evaluation and staff’s confirmatory analysis as described in SER Sections 5.4.3 and 5.5 respectively.

F5.2 The NAPS ISFSI will reliably maintain heat-removal capability consistent with its importance to safety with the proposed increased heat load due to the addition of high burnup fuel as confirmed by the applicant’s thermal evaluation and staff’s confirmatory analysis described in SER Sections 5.4.3 and 5.5 respectively.

F5.3 Given the increased heat load due to the addition of high burnup fuel, the TN-32B HBU cask will protect the spent fuel cladding against degradation leading to gross ruptures under long-term storage by maintaining cladding temperatures below 752°F (400°C) under normal conditions in a helium environment as required by 10 CFR 72.122. Protection of the cladding against degradation will allow ready retrieval of spent fuel for further processing or disposal.

F5.4 Given the increased head load due to the addition of high burnup fuel, the spent fuel cladding will be protected against degradation leading to gross ruptures under off-normal and accident conditions by maintaining cladding temperatures below the NUREG-1567 (ADAMS Accession No. ML003686776) guidance temperature of 1058°F (570°C) in a helium environment maintaining 10 CFR 72.122 requirements. Protection of the cladding against degradation continues to allow ready retrieval of spent fuel for further processing or disposal.

F5.5 Given the increased head load due to the addition of high burnup fuel, the staff finds that the thermal design of the NAPS ISFSI will comply with 10 CFR Part 72 and that the applicable design and acceptance criteria, as identified in NUREG-1567 (ADAMS Accession No. ML003686776) and the NAPS ISFSI FSAR, will be satisfied. The evaluation of the thermal design provides reasonable assurance that under the proposed amendment, the cask continues to allow safe storage of spent fuel. This finding is reached on the basis of a review that considered 10 CFR Part 72, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices as noted above.

6.0 SHIELDING EVALUATION

6.1 Review Objective

The objective of this review is to determine if the storage of high burnup fuel loaded in a modified TN-32B bolted lid dry storage cask at the NAPS ISFSI site meets the regulatory requirements of 10 CFR Part 72 and 10 CFR Part 20 for radiological protection during normal, operations as well as off-normal, and accident conditions. The requested amendment applied only to the initial cask loading. The applicant indicated additional amendment requests for operations associated with experiments will be submitted in the future.

6.2 Shielding Design

The applicant designed the TN-32B HBU cask to store three types of high burnup 17x17 PWR spent fuel assemblies (AMBW, LOPAR, and NAIF) with nominal initial enrichments of 4.55 wt%, 3.59 wt%, and 4.45 wt% uranium-235, respectively. Although the NAPS ISFSI TS currently limit the spent fuel decay heat to 1.02 kW/assembly, the applicant designed the TN-32B HBU cask to hold 32 assemblies with a combined maximum decay heat of 32.934 kW. The applicant indicated that irradiated non-fuel hardware (e.g., thimble plugging devices) would not be stored in the TN-32B HBU cask. Tables 1.1-1 and 1.2-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) identified the TN-32B HBU cask design characteristics and fuel data respectively. Chapter 4.0 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) described the bounding radiation source terms for the fuel assemblies to be stored in the TN-32B HBU cask.

Although the TN-32B HBU cask design is similar to the TN-32 casks currently used at the NAPS ISFSI, the TN-32B HBU cask included larger, single-failure proof trunnions for cask handling, and seven new cask lid penetrations. The applicant stated that these cask lid penetrations will allow seven thermocouple lance assemblies to be inserted into seven different fuel assemblies – one thermocouple lance per assembly.

6.3 Source Terms

To determine the bounding radiation source terms for the fuel assemblies to be loaded in the TN-32B HBU cask, the applicant modeled spent fuel assemblies using a uranium loading of 476 kg, nominal initial enrichments ranging from 3.59 wt% U-235 to 4.55 wt% U-235, and burn-ups ranging from 50.0 to 58.1 GWd/MTU per assembly. The applicant used the actual number of irradiation cycles for each assembly and a specific power of 21.015 MW per fuel assembly in the model. Except for fuel assembly OA4, which has two irradiation cycles, the applicant used three irradiation cycles in the model for all assemblies. The applicant used the assembly which produced the largest total source term as the bounding assembly and conservatively assumed all assemblies had this source term for the dose rate calculations.

The applicant used the ORIGEN-ARP/ORIGEN-S modules of the SCALE 6.0 code to generate radiation source terms. Using a Babcock and Wilcox high burn-up cross section library, instead of the Westinghouse 17x17 cross section library built into the ORIGEN-ARP code, as well as material compositions required by the ORIGEN-ARP code from proprietary AREVA TN Calculation 19885-0502, Rev. 1 (ADAMS Accession No. ML16118A206), the applicant identified that fuel assembly 54B produced the largest neutron and gamma source terms. Fuel assembly 54B had the following design characteristics: 4.55 wt% nominal initial enrichment, 51.340 GWd/MTU burnup, and 4.81 years cooling time. The applicant used the neutron and gamma source terms for this assembly to calculate the dose rates for the TN-32B HBU cask. The applicant also determined gamma sources from activated hardware in the plenum, top and bottom end fitting regions for fuel assembly 54B using ORIGEN-ARP/ORIGEN-S.

The applicant presented the primary gamma source terms from the bottom nozzle, the active fuel region, the plenum, and the top nozzle, as well as the neutron source term, in Table 4.1-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457). The applicant increased the bounding neutron source for fuel assembly 54B using both an axial peaking factor, and a subcritical multiplication factor.

Staff reviewed the applicant's source term calculation methodology and the calculation results. Staff found the methodology acceptable. Staff also performed confirmatory source term analyses using the same fuel depletion parameters provided in the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) with the 238-group ENDF/B-VII cross section library of the ORIGEN-ARP isotopic depletion and decay sequence in the SCALE 6.1 computer code. Staff's confirmatory calculations generated results which were similar to the applicant's results; therefore, staff found the applicant's results acceptable.

6.4 Shielding Analysis Models

6.4.1 Normal and Off-Normal Shielding Configuration

The applicant developed a 3-D MCNP5 model of an intact TN-32B HBU cask, and used this model to evaluate dose rates for both normal and off-normal conditions. The applicant modeled the fuel as a cuboid, with a homogenized top zone, a homogenized plenum, a homogenized active fuel region, and a homogenized bottom zone. The applicant assumed all 32 fuel assemblies in the TN-32B HBU cask had the same source term strength as fuel assembly 54B, and used an axial profile which divided the active fuel regions of the fuel assemblies into 18 axial zones. Each zone contained between 5% and 6% of the total fuel region. The applicant applied peaking factors, ranging from 0.5 at the bottom and top of the active fuel region to 1.11

just below the middle of the active fuel region, to ensure that MCNP5 accurately modeled the fuel assembly source strength. The applicant also appropriately modeled the gamma source as proportional to burnup and the neutron source as proportional to the fourth power of burnup.

The applicant discretely modeled the stainless steel and aluminum plates of the TN-32B HBU cask basket as well as both cask trunnions, the neutron resin shields and the cask protective cover. The applicant also explicitly modeled a small portion of the bottom of the seven thermocouple penetrations in the cask lid as small diameter tubes in response to an information request by staff. In the TN-32B HBU MCNP5 model, the applicant modeled the hardware in the top of these thermocouples as homogenized stainless steel.

To determine dose rates on the radial, top and bottom surfaces of the TN-32B HBU cask, as well as 1 and 2 meters from the cask radial and top surfaces, the applicant used MCNP5 mesh tallies. These MCNP5 tallies determined the number of particles per unit area; i.e., the particle flux. To convert the particle flux into dose rates, the applicant used the flux to dose conversion factors in ANSI/ANS 6.1.1, 1977.

6.4.2 Accident Condition Shielding Configuration

Based on the results of cask drop accident analyses, the applicant revised the MCNP5 model described in section 6.4.1 of this SER for accident condition evaluations by modeling the following cask components as void: both the radial and top cover neutron shielding, the outer steel shell, the polypropylene disk at the top of the cask and the protective cover at the top of the cask.

6.4.3 Far Field Shielding Configuration

The applicant utilized the MCNP5 model described in section 6.4.1 to calculate both the direct radial dose rate and the skyshine dose rate (i.e., the dose rate from radiation reflected by the air above the cask, to evaluate the far field dose rates). The applicant used MCNP5 point detector tallies in the model to calculate the particle flux at 2 meters, 5 meters, 50 meters, 100 meters, 150 meters, 200 meters, 300 meters, 400 meters, and 500 meters from the cask surface. To convert the particle flux into dose rates, the applicant used the flux to dose conversion factors in ANSI/ANS-6.1.1, 1977.

The applicant first adjusted the model described in section 6.4.1 by assuming a void existed above the top of the cask and calculated the direct radial dose rate. Next, the applicant used the model as described in section 6.4.1 with air above the cask to calculate the total dose rate. Using the difference between the direct radial dose rate and the total dose rate, the applicant evaluated the skyshine dose rate contribution to an individual from one storage cask which is shielded by a second storage cask.

6.4.4 Shielding Configuration Evaluation

Staff evaluated the applicant’s assumptions and approximations used for modeling the cask and the source term distributions. Staff finds the applicant’s approach to modeling the TN-32B HBU cask reasonable. Staff also finds the applicant’s use of an average burnup profile, 18 discrete fuel regions and discrete hardware regions represent both the gamma and neutron source terms with reasonable accuracy. Staff determined the use of MCNP5 mesh tallies in calculating particle fluxes on cask surfaces, at one meter from the cask surfaces and two meters from the cask surfaces appropriate. Staff finds the use of MCNP5 point detector tallies at distances between 2 meters and 500 meters from the radial cask surfaces appropriate as well. Staff also finds the flux to dose rate conversion factors used by the applicant acceptable because they are recommended by NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776). Therefore, staff finds the applicant's models acceptable.

6.5 Dose Rates

6.5.1 Normal and Off-Normal Dose Rates

The applicant calculated dose rates on the TN-32B HBU cask surfaces, as well as 1 meter and 2 meters from the radial cask surfaces, using the model described in section 6.4.1 of this SER and the bounding fuel source terms associated with fuel assembly 54B for all 32 assemblies in the TN-32B HBU cask under normal and off-normal conditions of storage. In Table 4.3-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant summarized both the normal and the off-normal condition dose rates. The applicant calculated average surface dose rates (neutron plus gamma) of 96.1 mrem/hour at the top and 91.1 mrem/hour on the side of the TN-32B HBU cask, and modified the NAPS ISFSI SAR to reference these dose rates.

Although the dose rate at the top of the TN-32B HBU exceeded the dose rates at the top of the TN-32 casks currently on the ISFSI pad, the side dose rates for the TN-32 casks currently on the ISFSI pad bounded the side dose rates of the TN-32B HBU cask. Therefore, the applicant developed TS 3.3 for the TN-32B HBU dose rates. This TS utilized the higher side dose rate for the TN-32 casks currently on the ISFSI pad and the higher top dose rate for the TN-32B HBU cask.

6.5.2 Accident Dose Rates

The applicant calculated dose rates on the TN-32B HBU cask surfaces, as well as 1 meter and 2 meters from the radial cask surfaces, using the model described in section 6.4.2 of this SER and the bounding fuel source terms associated with fuel assembly 54B for all 32 assemblies in the TN-32B HBU cask under accident conditions of storage. In Table 4.3-2 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant summarized the accident condition dose rates.

6.5.3 Far Field Dose Rates

The applicant used the MCNP5 model described in section 6.4.3 of this SER to estimate dose rates at distances from 2 meters to 500 meters from the TN-32B HBU cask. The applicant performed two calculations as described in 6.4.3 above, and listed the direct dose rates, as well as the skyshine dose rates, at distances of 2 meters, 5 meters, 50 meters, I00 meters, 150 meters, 200 meters, 300 meters, 400 meters, and 500 meters from the cask in Tables 4.5-1 and 4.5-2 respectively of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457).

6.5.4 Dose Rate Evaluation

The staff performed independent MCNP5 shielding analyses of the TN-32B HBU cask. The results of these independent calculations were in good agreement with the applicant's results. Therefore, the staff finds the applicant's shielding analysis results acceptable.

6.6 Evaluation Findings

Based on its review of the information provided by the applicant, as well as the staff's independent confirmatory analytical results, the staff finds that the applicant made conservative assumptions in their shielding analyses. The staff finds that NAPS ISFSI, with the TN-32B HBU cask, meets the regulatory requirement of 10 CFR 72 and the acceptance criteria specified in NUREG-1567 (ADAMS Accession No. ML003686776) for radiation protection with the following conditions:

1. The maximum average burnup of the spent fuel shall not exceed 60 GWD/MTU,

2. The nominal initial U-235 enrichments are 4.55%, 3.59%, and 4.45% for the AMBW, LOPAR, and NAIF fuel respectively. The maximum allowable U-235 fuel initial enrichments for these fuel types, which include a five percent (0.05%) manufacture tolerance on enrichment, are 4.60%, 3.64%, and 4.50% respectively, and

3. The maximum cask heat load shall not exceed 32.934 kW.

In addition, the staff finds the following:

F6.1 Chapters 1 and 4 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) sufficiently describe the shielding design bases and design criteria for the structures, systems, and components ITS.

F6.2 The TN-32B HBU cask system radiation shielding and confinement features are sufficient to meet the radiation protection requirements of, 10 CFR 72.104, 10 CFR 72.106, and 10 CFR 72.126.

F6.3 The staff concludes that the shielding and radiation protection design features of the TN-32B HBU system are in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria have been satisfied. The evaluation of the shielding and radiation protection design features provides reasonable assurance that the TN-32B HBU cask will provide safe storage of spent fuel. This finding is based on a review that considered the regulation itself, the appropriate regulatory guides, applicable codes and standards, the applicant's analyses, the staff's confirmatory analyses, engineering drawings and acceptable engineering practices.

F6.4 Structures, systems, and components of the TN-32B HBU system are adequate to prevent accidents and to mitigate the consequences of accidents and natural phenomena events that do occur.

7.0 CRITICALITY EVALUATION

7.1 Review Objective

The objective of this review is to determine if the TN-32B HBU dry storage cask loaded with specific high burnup fuel at the NAPS ISFSI site remains subcritical under normal, off-normal, and accident conditions during all operations, including transfers and storage as required by 10 CFR 72.124(a).

7.2 Criticality Safety Evaluation

7.2.1 Criticality Design Features

The TN-32B HBU dry storage cask was designed specifically to hold a maximum of thirty-two (32) high burnup 17x17 spent PWR fuel assemblies. The applicant stated that Areva Advanced BW (AMBW), Westinghouse LOPAR, and NAIF 17x17 fuel assembly types, with nominal enrichments of 4.55 wt%, 3.59 wt%, and 4.45 wt% uranium-235 respectively, will be loaded into the TN-32B HBU cask. The applicant identified the maximum theoretical densities for the AMBW, LOPAR, and NAIF fuel assembles as 96%, 95%, and 96% respectively, and indicated that the active fuel region for all three assembly types was 144 inches. The applicant provided detailed specifications for these three fuel types in Table 1.2-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457). In addition, the applicant stated that the TN-32B HBU dry storage cask design was identical to the TN-32 dry storage cask except that the TN-32B HBU cask closure lid was equipped with penetrations to allow instruments to be installed to monitor internal environmental parameters during storage.

The applicant used a combination of neutron poison plates, poison rod assemblies (PRAs), and soluble boron to ensure criticality safety for the TN-32B HBU cask under normal, off-normal, and accident conditions of operation. The applicant designed the cask fuel basket with neutron poison plates, and identified the location and geometric dimensions of the poison plates in licensing drawings within the TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219). The applicant also used six (6) PRAs in the cask with each PRA containing 24 poison rods filled with B_4C. The applicant identified the PRA cladding material as M5. Figure 5.1-2 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) identified the PRA locations inside the cask and Table 5.1-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) provided the PRA material composition. Staff determined the applicant provided an adequate description of the criticality parameters associated with the TN-32B HBU cask.

7.2.2 Model Configuration

The applicant explicitly modeled the fuel assemblies, the fuel basket with poison plates, the neutron PRAs, and other structures and components of the cask. The applicant introduced a significant conservatism by assuming a fresh fuel composition for the high burnup spent fuel assemblies and taking no credit for either the loss of fissile materials, the accumulation of non-fissile transuranic materials, or the accumulation of fission products, i.e., no burnup credit is taken for the cask criticality safety analysis. Staff concluded this was a significant conservatism based on data in Figure 35 of NUREG/CR-6800 [Ref. 6] (ADAMS Accession No. ML031110280). In NUREG/CR-6800 (ADAMS Accession No. ML031110280), the estimated difference in the effective neutron multiplication factor (Δk_{eff}) for the generic high-capacity burnup-credit-style cask, which is very similar to the TN-32B HBU cask, loaded with fuel at 4.0 wt% enrichment and 50 GWd/MTU burnup is about 0.3. Using engineering judgement, staff determined this value is sufficient to compensate for uncertainties in the criticality calculation parameters.

The applicant utilized only 50% of the PRA boron content in their criticality analyses which is another significant conservatism. The applicant also modeled the PRA cladding material as stainless steel in the criticality safety analyses versus M5. Because stainless steel has a higher neutron absorption capability compared to M5, staff determined this is a non-conservative assumption. However, staff found it insignificant because, in comparison to taking credit for only 50% of the B_4C load in the PRA, the difference between stainless steel and M5 in neutron absorption is negligible. Besides only utilizing 50% of the PRA boron content in their criticality analyses, the applicant only modeled 90% of the boron in the neutron poison plates in the criticality analyses consistent with the guidance provided in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" [Ref. 1] (ADAMS Accession No. ML003686776) and industrial practice endorsed in ANSI/ANS 8.21-1995 [Ref. 5]. Also, in accordance with a cask loading and unloading operations TS requirement, the applicant assumed a minimum soluble boron concentration of 2500 ppm in the spent fuel pool water in their criticality analyses. Finally, the applicant modeled the instrumentation lances which will be inserted into the cask cavity as solid aluminum. Staff compared the cross sections of aluminum with water and found that aluminum has a lower absorption cross section compared to water, i.e., neutrons go through aluminum easier than borated water. Staff determined these modeling parameters are acceptable.

Using the model configuration described above, the applicant calculated a k_{eff} of 0.9058 for the TN-32B HBU cask. This is below the upper subcriticality limit (USL) of 0.9388 for this cask design. The USL is determined through computer code benchmarking analyses. The staff finds that this is consistent with the recommendation of NUREG/CR-6361 [Ref. 2] and the guidance provided in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776) for code benchmarking and therefore acceptable. Detailed evaluation of the applicant's code benchmarking analyses are discussed in Section 7.3.3 of this SER.

7.2.3 Material Properties

The applicant used material properties based on the fuel specifications presented in Table 5.1-3 and PRA material compositions in Table 5.1-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457). The applicant used material properties for the remaining structures and components from the standard material composition library of SCALE 6.0 in the SCALE computer code package which has been adequately verified and validated for this type of application. Therefore, staff finds the material properties of the cask structure and components used in the criticality safety analysis models appropriate and acceptable.

7.3 Applicant Criticality Analysis

7.3.1 Computer Program

The applicant used the CSAS5 module of the SCALE 6.0 version computer code with the 44-group ENDF/B-V cross section library in the criticality safety analyses. Oak Ridge National Laboratory developed this computer code for the NRC for radioactive material licensing actions including spent nuclear fuel storage and transportation. Because this computer code has been extensively verified and validated for applications like the North Anna high burnup fuel dry storage system, staff finds it is adequate and acceptable for this application.

7.3.2 Multiplication Factor

The applicant identified the maximum k_{eff} (calculated k_{eff} + 2σ) for the TN-32B HBU cask with the fuel specified in Table 1.2-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) by varying moderator density and rod pitch which are the only parameters that may change under normal, off-normal, and accident conditions, to determine the maximum k_{eff}. The applicant calculated a maximum k_{eff} of 0.9058. This is below the USL value of 0.9338 which is determined by code benchmarking studies as discussed in the next section of this SER. The staff finds this acceptable because the applicant's calculated k_{eff} value demonstrates that the system will remain subcritical with adequate safety margin under normal operations as well as off-normal and accident conditions and meets the regulatory requirements of 10 CFR 72.124(a).

7.3.3 Benchmark Comparisons

The applicant performed code benchmarking analyses for the SCALE 6.0 computer code together with the selected cross section library (44-group ENDF/B-V). The applicant selected ninety-two (92) critical experiments from the International Handbook of Evaluated Criticality Safety Benchmark Experiments. The selected critical experiments encompassed the range of enrichments, rod pitches, and soluble boron associated with this application. Table 5.2-1 in the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) identified the selected critical experiments.

The applicant performed trending analyses of the k_{eff} calculated for these critical experiments using the SCALE 6.0 code for six parameters: enrichment, fuel rod pitch, fuel assembly separation distance, soluble boron concentration, moderator to fuel volume ratio, and energy of average lethargy causing fission using the USLSTATS computer code, which is published in NUREG/CR-6361 [Ref. 2] and endorsed by the staff in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776). Based upon its code benchmarking and trending analyses, the applicant determined that the USL for the TN-32B HBU cask is 0.9338.

Staff reviewed the applicant's selection of critical experiments, trending analyses (including the selected trending parameters), and USL calculation. Based on its review, staff determined that the applicant correctly performed code benchmarking analyses and that the USL is conservative.

7.4 NRC Independent Criticality Analyses

Staff performed independent criticality safety analyses for the TN-32B HBU cask using the fuel and loading patterns specified by the applicant in the SAR. Staff independently developed a criticality analysis model using the same assumptions as used in the applicant's criticality safety analysis model. However, the staff used the SCALE 6.1 version of the SCALE computer code with the ENDF/B-VII continuous energy cross section library in its independent analysis [Ref. 7]. Staff's analysis showed that the k_{eff} value calculated by the applicant is conservative. Therefore, staff finds that the k_{eff} value calculated by the applicant for the TN-32B HBU cask is acceptable.

7.5 Evaluation Findings

The staff reviewed the information provided by the applicant. Based on its review, the staff finds that the applicant made conservative assumptions in the criticality safety analyses, including maximum allowable quantity of fissile materials (i.e.; assuming fresh fuel), used conservative cask geometry tolerances, and assumed that only 90% of the neutron poison in the poison plates was present, as well as only 50% of the neutron poison in the PRAs. In addition, the calculated maximum neutron multiplication factor, k_{eff}, of the cask is less than the USL. Based on its review of the information provided by the applicant, as well as its independent confirmatory analyses, the staff determined that the TN-32B HBU cask meets the regulatory requirement of 10 CFR 72.124(a) and 72.124(b) and the acceptance criteria specified in

NUREG-1567 (ADAMS Accession No. ML003686776) on criticality safety with the following conditions:

1. The minimal boron concentration in the spent fuel pool during cask loading and unloading operations shall be 2500 ppm, and
2. The nominal U-235 initial enrichments are 4.55%, 3.59%, and 4.45% for the AMBW, LOPAR, and NAIF fuel respectively. The maximum allowable U-235 fuel initial enrichments for these fuel types, which include a five percent (0.05%) manufacturing tolerance on enrichment, are 4.60%, 3.64%, and 4.50% respectively.

In addition, the staff finds the following:

F7.1 Structures, systems, and components important to criticality safety are described in sufficient detail in Sections 1, 2, and 5 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) to enable an evaluation of their effectiveness.

F7.2 The TN-32B HBU cask is designed to be subcritical under all credible conditions.

F7.3 The criticality design is based on favorable geometry, soluble boron, and fixed neutron poisons. Previously, evaluation of fixed neutron poisons has shown that they will remain effective for the 20-year storage period. In addition, there is no credible way to lose the fixed neutron poisons; therefore, there is no need to provide any further means to verifying their continued efficacy as required by 10 CFR 72.124(b).

F7.4 The analysis and evaluation of the criticality design and performance demonstrate that the cask will provide for the safe storage of spent fuel for 20 years with an adequate margin of safety.

7.6 References

1. NUREG-1567, “Standard Review Plan for Spent Fuel Dry Storage Facilities,” United States Nuclear Regulatory Commission, March 2000.

2. NUREG/CR-6361, “Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages,” Oak Ridge National Laboratory, March 1997.

3. ANSI/ANS 8.1-1983, “Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors,” American National Standards Institute, American Nuclear Society, 1983.

4. ANSI/ANS 8.17-1984, “Criticality Safety Criteria for the Handling, Storage, and Transportation of LWR Fuel Outside Reactors,” American National Standards Institute, American Nuclear Society, 1984.

5. ANSI/ANS 8.21-1995, “Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors,” American National Standards Institute, American Nuclear Society, 1995.

6. NUREG/CR-6800, “Assessment of Reactivity Margins and Loading Curves for PWR Burnup-Credit Cask Designs,” Oak Ridge National Laboratory, March 2003.

7. Criticality Safety Validation of SCALE 6.1, Oak Ridge National Laboratory, http://info.ornl.gov/sites/publications/Files/Pub40500.pdf

8.0 CONFINEMENT EVALUATION

8.1 Review Objective

The objective of the confinement review was to determine if the confinement systems ensure that the annual dose equivalent, from normal operations, anticipated occurrences, and design basis accidents to individuals either at or beyond the controlled area is less than the limits set forth in the regulations as well as ensure that the cask design protects the spent fuel cladding against degradation that might lead to gross ruptures.

8.2 Confinement Design Characteristic Changes

The applicant described the TN-32B HBU cask as a modified TN-32B cask that accommodates thirty-two (32) intact spent fuel assemblies, with or without PRAs. The applicant certified that the TN-32B HBU cask was manufactured as a standard TN-32B cask in accordance with the TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219) and complied with NRC CoC No. 72-1021 (ADAMS Accession No. ML010460308). The modifications identified by the applicant to the standard TN-32B cask design which are relevant to this evaluation consist of the following:

- Seven new penetrations were made to the lid confinement boundary and shield plate. Thermocouple lance assemblies were mounted and secured in each of the seven penetrations and each lance mounting assembly was designed with its own double-metallic, silver-jacketed O-ring seals and comprises part of the confinement boundary.

- A funnel guide assembly was installed into the top nozzle of each of the seven fuel assemblies that receive the thermocouple lance assemblies to guide the lance into the fuel assembly guide tube during installation.

- The overpressure (OP) monitoring system was modified to provide leakage monitoring of the inner seal space of each double-metallic, silver-jacketed O-ring seal for the thermocouple lance assemblies.

- The protective cover was provided with an additional access cover above the vent port cover for maintenance purposes and an instrumentation junction box closure is located on the protective cover to permit worker access to the thermocouple connections.

8.1.1 Confinement Vessel

As described by the applicant, the confinement boundary for the TN-32B HBU cask consisted of the inner shell, the bottom plate, the welded flange forging, the lid outer plate, lid bolts, the seven thermocouple penetration sleeve inserts, the thermocouple instrument head and lance, the jacking plates and retainer ring, the vent and drain cover plates and fasteners, the inner double-metallic, silver-jacketed O-ring seals of the lid, vent and drain covers, and the thermocouple instruments. Staff reviewed the information provided by the applicant and finds the description acceptable.

8.1.2 Confinement Penetrations

As described previously, the applicant modified the TN-32B lid to include seven penetration sleeves. The applicant stated the penetration sleeves form part of the confinement boundary, and fabricated the penetration sleeves from SA-350 Grade LF3 forging material which is the same material specification as the lid. The applicant fabricated the lid from SA-203 Grade D. The applicant designed a retaining ring, fabricated from either Type 302 or Type 316 stainless steel, to secure the thermocouple lance assembly to the lid and to provide support for jacking plate assemblies which consist of two plates fabricated from SA-387 Type 91 Class 2 material. The applicant fabricated the jacking plate screws from SA-193 Grade B7 material. Staff reviewed the information provided by the applicant and finds the description acceptable.

8.1.3 Seals and Welds

The applicant identified that the only difference to the confinement boundary welds and seals for the TN-32B HBU cask from a standard TN-32 dry storage cask is the addition of the seven thermocouple lance assemblies including the penetration sleeves. The applicant used partial penetration groove welds, which are classified as a Category C weld under Section NB of the ASME B&PV Code, to secure the penetration sleeves to the lid. Partial penetration groove welds also secured the penetration sleeves to the shield plate. To examine the welds, the applicant employed visual examination, as well as either MT or PT NDE, techniques in accordance with the requirements of Chapter 9 of the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025).

The applicant performed multi-layer PT examinations of these multi-layer closure welds as an alternative to the NDE requirements of Subsection NB-5230 for Category C welds. The applicant asserted that the multi-layer PT examination provided reasonable assurance that flaws of interest will be identified. Staff accepted this position because it is consistent with the guidance in Section 8.4.7.4 of NUREG 1536 (ADAMS Accession No. ML101040620) and Section 5.4.1.2 of NUREG 1567 (ADAMS Accession No. ML003686776). The applicant indicated qualified personnel performed the PT examination in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000 of the ASME B&PV Code.

The applicant utilized a double metallic, silver-jacketed O-ring seal for the thermocouple closure assembly which is identical to the seal for the vent and drain closures previously approved for CoC No. 72-1021 (ADAMS Accession No. ML010460308). Because this design feature was previously approved for use as part of the TN-32 cask design, staff finds this design feature acceptable for the TN-32B HBU cask.

8.1.4 Closure

For confinement vessel closure, the lid bolts are tightened to 1,085 ±145 lb-ft torque. For the TN-32B HBU cask compared to the TN-32 casks currently in place at the NAPS ISFSI. However, for closure of the seven thermocouple penetrations, the applicant designed a jacking plate assembly to compress the metallic confinement seal for these instruments. The applicant designed the fasteners for these penetrations to be tightened to 65 ± 5 lb-ft torque. Staff reviewed calculations provided by the applicant which demonstrated that this closure configuration is consistent with those of the vent and drain ports. Therefore, staff found this approach acceptable.

8.3 Confinement Monitoring

The applicant designed the TN-32B HBU cask to utilize the same OP monitoring system as employed on the TN-32 cask in place at the NAPS ISFSI. However, because the TN-32B HBU cask lid was modified such that the thermocouple lance assemblies are now classified as part of the confinement boundary, the applicant also connected the OP monitoring system to the interseal space of the lance assemblies as well as the vent and drain interseal spaces. Since the OP monitoring system specifications remained unchanged from the TN-32 cask, the applicant modified TS Table 3-1 to incorporate the OP monitoring system appropriate design pressures. Staff found these changes acceptable.

The applicant designed the OP monitoring system to provide defense in depth by measuring the interseal space helium pressure between the inner and outer seals of the confinement boundary components, and to signal an alarm if the pressure falls below a given value. The applicant described the following two conditions that could cause the OP monitoring system to alarm:

Case 1: The inner seal is intact and either the outer seal or the OP monitoring system is leaking to the atmosphere.

Case 2: The outer seal is intact and either the inner seal or the OP monitoring system is leaking into the cask cavity.

For both cases, the applicant considered two points in time to determine if sufficient notification of a leaking seal would be given to allow corrective actions:

Time 1. The time before the OP monitoring system alarms, and
Time 2. The time before the OP monitoring system equalizes with the cavity pressure allowing the cask cavity contents to reach the environment.

Based upon the design of the seals and the use of the OP monitoring system, the applicant asserted that neither case resulted in a release of the cask cavity contents to the atmosphere. Nevertheless, the applicant provided calculations assuming leak rates between 1×10^{-3} std. cm^3/sec and 1×10^{-5} std. cm^3/sec. These calculations showed that, even with a leak rate of 1×10^{-3} std. cm^3/sec, the OP monitoring system would alarm after approximately 15 days while the 10 CFR 72.106 dose limits would not be exceeded until approximately 143 days. Staff reviewed the applicant's results and finds the applicant's conclusions reasonable.

The applicant modified surveillance requirement, SR 3.1.3.1 "Verify SSSC Combined Helium Leak Rate is Within Limit," only for the TN-32B HBU cask. This TS modification allowed the combined helium leak test to occur after a 23 day period referred to as the thermal soak period. The applicant also modified surveillance requirement SR 3.1.2.1 to provide assurance that the helium backfill pressure will be maintained during this period. Based upon a review of the confinement design and the leak rate calculations provided by the applicant, staff has reasonable assurance that confinement will be maintained during the time period between cask loading and testing of the combined helium leak rate.

8.4 Confinement Analysis

8.3.1 Radionuclide Contents

The applicant performed calculations to determine the composition of a bounding release during off-normal or accident conditions using the radionuclide inventory contained within the TN-32B HBU cask as determined by the depletion-decay module, ORIGEN-ARP, in the SCALE sequence of computer codes. The applicant asserted, and staff confirmed, that the radiological inventories were developed utilizing realistic parameters for the fuel assemblies identified to be stored in the TN-32B HBU cask. The fuel inventory off-normal and accident releases were all calculated with release fractions consistent with Table 5-2 of NUREG 1536 (ADAMS Accession No. ML101040620) and Section 9.5.2.2 of NUREG 1567 (ADAMS Accession No. ML003686776). The applicant illustrated the released radionuclide concentration for each operating condition in Table 6.2-3 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457). Staff reviewed the radionuclide inventories provided in the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) and found them to be numerically consistent with the previously reviewed and approved values reported in the TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219); therefore, staff found them acceptable.

8.1.2 Leakage Rate

The applicant calculated TN-32B HBU cask leakage rates under off-normal and accident conditions according to the methodologies presented in ANSI N14.5 which assume a normal leakage rate of 1×10^{-5} std. cm^3/sec which corresponds to the sensitivity of the leakage rate testing equipment. The applicant presented the assumed conditions within the TN-32B HBU cask for off-normal and accident scenarios in Table 6.2-4 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), and provided the resulting leakage rates for both off-normal and accident conditions in Table 6.2-5 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457).

Staff reviewed the calculation results and compared them to the previously approved off-normal and accident condition leakage rates for the TN-32 casks currently stored at the NAPS ISFSI. Staff noted that, for off-normal calculations, the applicant utilized similar input parameters, e.g.; pressure and temperature, for the TN-32 and TN-32B HBU casks which resulted in similar leakage rates. For accident conditions, the applicant calculated a significantly higher leakage rate for the TN-32B HBU cask compared to the existing TN-32 cask due to the fact that the input temperature and pressure was significantly higher. Staff found these results reasonable and acceptable.

8.5 Offsite Dose Estimate

The applicant asserted that the dose assessments were made following the methods set out in Regulatory Guide 1.109 and used the dose conversion factors from Environmental Protection Agency guidance reports. To evaluate inhalation and immersion dose assessments at 100 and 500 meters for both off-normal and accident conditions, the applicant used the source terms contained in Table 6.2-3 and the release fractions presented in Table 6.2-2. Staff evaluated these parameters and found them acceptable. For these calculations, the applicant also used meteorological dispersion parameters in Table 6.2-6 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) which were calculated in the exact same method as in the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025). Staff previously evaluated these dispersion parameters in the TN-32 SER (ADAMS Accession No. ML003696918) and found them acceptable.

Given the postulated conditions for off-normal and accident scenarios discussed in the preceding paragraph, the applicant asserted that the amount of radionuclides released from the TN-32B HBU cask would not result in an absorbed dose approaching the limits specified in either 10 CFR 72.104(a) or 10 CFR 72.106(b). Staff compared the absorbed dose reported in the TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219) with the absorbed dose reported in the DLBD Rev. 8 (ADAMS Accession No. ML17109A457), and although staff found them numerically consistent in terms of magnitude, staff also found the TN-32B HBU cask absorbed dose higher due to a higher leakage rate for both off-normal and accident conditions. However, staff evaluated the higher absorbed dose for the TN-32B HBU cask and determined it was orders of magnitude below the regulatory limits in 10 CFR 72.104(a) and 10 CFR 72.106(b). Therefore, staff found both the reported dose calculations and conclusions by the applicant acceptable.

8.6 Protection of Stored Material from Degradation

The applicant not only limited the TN-32B HBU cask design changes to the thermocouple lance assembly penetrations, but also designed and evaluated those penetrations to the same standards as the previously approved vent and drain ports. Therefore, as indicated above in the confinement evaluation, staff found that the applicant sufficiently evaluated the lance assemblies, lance assembly seals, the lance assembly bolting, and lance assembly bolt torques to demonstrate that they will not adversely affect the ability of the TN-32B HBU cask to protect the stored material from degradation.

8.7 Summary Conclusion

The staff concludes that the TN-32B HBU cask confinement system design 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 TN-32B HBU cask will allow safe storage of spent fuel by preventing radiological releases above regulatory limits. This conclusion is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, the applicant's analysis, the staff's review and evaluation, and accepted engineering practices.

8.8 Findings

F8.1 Sections 1 and 6 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) describe confinement SSCs important to safety for the TN-32B HBU cask in sufficient detail to permit evaluation of their effectiveness in compliance with 10 CFR 72.24(d).

F8.2 The TN-32B HBU cask design provides redundant sealing of the confinement system closure joints by dual metallic seals.

F8.3 The confinement system is monitored with an OP Monitoring System which satisfies the requirements of 10 CFR 72.122(h)(4) and 10 CFR 72.128(a)(1).

F8.4 The design of the TN-32B HBU cask provides 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).

F8.5 The North Anna ISFSI UFSAR and the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) demonstrates that releases to the general environment during normal operations and anticipated occurrences will be within the exposure limit given in 10 CFR 72.104, and that releases to the general environment resulting from design-basis accidents and accident level events and conditions will be within the exposure limits given in 10 CFR 72.106, thus satisfying the requirements for accident conditions as specified by 10 CFR 72.126(d) and 72.128(a)(3).

F8.6 The TN-32B HBU cask confinement system has been evaluated by appropriate tests and analysis to demonstrate that it will reasonably maintain confinement of radioactive material under normal, off-normal, and credible accident conditions.

F8.7 The staff concludes that the TN-32B HBU cask confinement system design 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 TN-32B HBU cask will allow safe storage of spent fuel by preventing radiological releases above regulatory limits. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, the applicant's analysis and the staff's confirmatory analysis, and accepted engineering practices.

9.0 MATERIALS EVALUATION

9.1 Review Objective

Staff only reviewed changes pertaining to the proposed amendment, i.e. the modifications to the standard TN-32 cask, as described in Section 4.2 of the license amendment request (ADAMS Accession No. ML15239B251). The staff also consulted previously-reviewed references during the review when determining applicable precedent from previous approvals, namely the TN-32 TSAR, Rev. 9A (ADAMS Accession No. ML15331A132), TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025) and the NAPS ISFSI SAR, Rev. 8.02 (ADAMS Accession No. ML16022A073).

9.2 Mechanical Properties

The applicant provided the mechanical properties for both the cask and the basket materials, which were referenced in several calculations, in Tables 6-1 and 6-2 of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456), respectively. Staff confirmed these properties are acceptable by reviewing the TN-32 TSAR, Rev. 9A (ADAMS Accession No. ML15331A132); TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025), the ASME B&PV Code, Section II, Parts A, B and D, 2013, and Properties of Aluminum Alloys, Tensile, Creep, and Fatigue Data at High and Low Temperatures (1999). Staff also confirmed that the material densities used in the structural evaluations are consistent with values in Table 5.1-1 of the previously-approved TN-32 TSAR, Rev. 9A (ADAMS Accession No. ML15331A132).

The applicant referenced Section 3.3.4 of the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025) in Section 4.7 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) to demonstrate that neither gamma radiation nor an integrated fast neutron irradiation below 10^{17} n/cm^2 significantly affects metals. Using a neutron source term 3.7 times stronger than the bounding neutron source term calculated for fuel assembly 54B, the applicant determined the integrated fast neutron flux over a 100 year time period was on the order of 10^{16} n/cm^2. Staff reviewed the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), and determined that the applicant adequately justified that the integrated fast neutron flux from fuel stored in the TN-32B HBU cask will not have a significant adverse impact on the metals used to fabricate the TN-32B HBU cask.

9.3 Thermal Properties

Staff determined that the thermal material properties used in the evaluation of the TN-32B HBU cask are identical to the thermal material properties for the TN-32 casks currently utilized at the NAPS ISFSI. Staff also determined that the values listed in Tables 4-2 thru 4-7 of Calculation No. 19885-0402, Rev. 1 (ADAMS Accession No. ML17109A456) are consistent with the TN-32 TSAR, Rev. 9A (ADAMS Accession No. ML15331A132) and other relevant references, including NUREG CR-6150, Vol. 4, Rev. 2 (ADAMS Accession No. ML081960033) and NUREG CR-7024 (ADAMS Accession No. ML14296A063). In addition, staff independently confirmed that the thermal material properties used in Calculation No. 19885-0401, Rev. 0 (Section 4.2, Tables 1 thru 3) (ADAMS Accession No. ML15331A132) are consistent with the previously-approved TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025), and other references, including NUREG CR-6150, Vol. 4, Rev. 2 (ADAMS Accession No. ML081960033) and NUREG CR-7024 (ADAMS Accession No. ML14296A063). The neutron shielding material, which has a maximum allowable temperature of 300°F (149 °C) as specified in Section 4.1 of the TN-32 FSAR, Rev. 6 (ADAMS Accession No. ML14108A025) used in the TN-32B HBU cask remained unchanged. Therefore, staff determined the thermal properties of the materials defined in the aforementioned tables and calculations to be acceptable since these are consistent and bounded by the temperature range presented in the prior approved design bases for the TN-32 cask.

9.4 Cask Lid Modifications

The applicant stated the TN-32B HBU cask was fabricated in 2003 in accordance with the previously reviewed TN-32 FSAR, Rev. 2 (ADAMS Accession No. ML16097A219), and complied with NRC CoC No. 72-1021. As described in the TN-32 SER (ADAMS Accession No. ML003696918), staff previously approved the use of both SA-350 Grade LF3 and SA-203 Grade D, which are listed in Tables 3.3-1 and 3.3-6 of the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025), for fabrication of confinement components; therefore, staff found these materials acceptable for this amendment.

In section 1.1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant stated the only modification in this amendment to the previously-approved carbon steel lid was the incorporation of seven (7) penetration sleeves to accommodate thermocouple lance assemblies. In proprietary Drawing No. 19885-30-04, Rev. 2 (ADAMS Accession No. ML16211A077), the applicant identified that these penetration sleeves, which form part of the confinement boundary, can be fabricated from either SA-350 Grade LF3 or SA-203 Grade D material with a minimum yield strength of 42 ksi. The applicant also identified on proprietary Drawing No. 19885-30-04, Rev. 2 (ADAMS Accession No. ML16211A077), that the welds connecting the penetration sleeves to the lid are Category C partial penetration groove welds per ASME B&PV Code, Subsection NB and that the penetration sleeve sealing weld overlay material is stainless steel which is identical to the material identified for the vent and drain sealing surfaces in TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025). In Table 7-1 of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456), the applicant proposed performing a multi-layer PT examination of these multi-layer closure welds as an alternative to the NDE requirements of Subsection NB-5230 for Category C welds. The applicant indicated qualified personnel would perform the PT examination in accordance with Section V and the acceptance standards of Section III, Subsection NB-5000 of the ASME B&PV Code.

Staff reviewed proprietary Drawing No. 19885-30-04, Rev. 2 (ADAMS Accession No. ML16211A077), and determined it adequately identified the requirements for welding the penetration sleeves to both the lid and the shield plate. In addition, staff confirmed the visual inspection and NDE requirements in Section 9.1.1 and Section 9.1.2 respectively of the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025) stated that confinement welds are designed, fabricated, tested and inspected in accordance with ASME B&PV Code Subsection NB. In determining the adequacy of this NDE alternative, staff followed the guidance in ISG-15, "Materials Evaluation" (ADAMS Accession No. ML010100170) which states that this alternative approach may be accepted if a stress-reduction-factor of 0.8 is imposed on the weld strength. Staff confirmed that the applicant properly identified the reduction factor in Section 4.0 of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456). Therefore, staff finds the NDE alternative for examination of the welds securing the thermocouple lances to the cask lid to be acceptable.

In reviewing proprietary Drawing No. 19885-30-04, Rev. 2 (ADAMS Accession No. ML16211A077), staff also identified that the retaining ring, which secures the thermocouple lance assembly to the lid, is fabricated from either Type 316 or Type 302 stainless steel material while the penetration sleeve is fabricated from carbon steel. Although the retaining ring material differs from the penetration sleeve material, staff ruled out galvanic corrosion as a potential degradation mode. Staff made this determination because the contact area ratio of the stainless steel cathode to the carbon steel anode is small and polarization of the resulting galvanic current will be minimal.

The applicant identified that the retaining ring supports the jacking plate assemblies which consist of two plates fabricated from SA-387 Type 91 Class 2 material. Staff reviewed the material properties for the jacking plates, listed in Table 6-1 of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456), and compared them to ASME B&PV Code, Section II, Parts A and D, 2013. Staff determined that the jacking plate material properties are appropriate for this application upon review against the properties in ASME B&PV Code, Section II, Parts A and D, 2013.

The applicant identified that the thermocouple closure is fabricated from Type 304 stainless steel, and that the thermocouple lance is fabricated from SB-163 UNS N06600 (Alloy 600) material. Since the lance is inserted into the cask cavity, the outer lance sheath formed part of the confinement boundary. Staff confirmed that there is no structural weld between the lance and the closure flange. The thermocouple lance utilized one seal weld at the bottom of the closure flange and one seal weld at the upper end of the thermocouple lance if the bottom seal weld failed.

For the thermocouple lance assembly, the applicant utilized a double-metallic, silver-jacketed O-ring seal which is identical to the seal used for the previously-reviewed vent and drain closures. Similar to the vent and drain seals, the thermocouple closure seals are connected to the overpressure monitoring system for continuous verification of performance. Staff confirmed that these double-metallic, silver-jacketed O-ring seals are part of the approved design bases, as discussed in Appendix A.1 of the NAPS ISFSI SAR, Rev. 8.02 (ADAMS Accession No. ML16022A073). In addition, staff confirmed that the maximum service temperature for continued seal function is 669°F (354°C) per the Helicoflex® vendor guide (Technetics Group Catalog). Staff found the materials for these seals acceptable because the maximum seal temperature specified by the manufacturer exceeds the normal, off-normal and accident condition temperatures calculated by the applicant.

9.5 Lid Bolts

Because the applicant modified the lid closure bolts in consideration of future off-site transportation of the TN-32B HBU cask, staff reviewed the lid bolt material properties listed in Table 4.3 of proprietary TN document 19885-0203, Rev. 0 (ADAMS Accession No. ML15331A132) against the properties in the ASME B&PV Code, Section II, Part D, 2013, and determined that they were appropriate. The applicant also employed SA-193 Grade B7 bolts to attach the retaining ring to the lid. Although SA-193 Grade B7 differed from the previously-approved SA-193, Grade B8 bolts in Table 1.2-2 of the TN-32 TSAR, Rev. 9A (ADAMS Accession No. ML15331A132) for the protective cover bolts, top neutron shield bolts, drain and vent port cover bolts, and overpressure port bolts, staff confirmed the material properties for the SA-193 Grade B7 bolts, listed in Table 6-1 of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456), are acceptable by reviewing ASME B&PV Code, Section II, Parts A and D, 2013. Therefore, staff finds the material properties for the lid bolts to be acceptable.

9.6 High Burnup Fuel

In Table 1.2-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant defined the fuel to be stored in the TN-32B HBU cask as intact Westinghouse LOPAR, NAIF 17 x 17, and AREVA Advanced MK-BW (AMBW) 17 x 17 fuel assemblies. In addition, the applicant defined the burnup, enrichment, and zone heat load limits for these fuel assemblies in the TS. In the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant also stated the maximum fuel cladding temperatures for the TN-32B HBU cask were 605°F (318°C) and 708°F (376°C) for normal and fire accident conditions respectively which are well below the temperature limits of 752°F (400°C) and 1,058°F (570°C) for normal and accident conditions of storage respectively as defined in ISG-11, Rev. 3 (ADAMS Accession No. ML033230281). The applicant stated in section 5.1.1.1 of the NAPS ISFSI SAR, Rev. 8.02 (ADAMS Accession No. ML16022A073) that both moisture and oxygen would be removed from the cask before moving the cask to the storage pad by vacuum-drying and backfilling the cask with helium to its design pressure, and the applicant also stated that the cask drying and back-filling requirements remained unchanged by this amendment. The applicant identified the appropriate design pressures for the vacuum drying and helium backfill operations in TS Table 3-1. After reviewing this information, staff determined that the fuel will remain in the analyzed configuration during the licensed period, spent fuel cladding degradation will be prevented, and the occurrence of chemical or galvanic reactions will be prevented.

9.7 Evaluation Findings

Staff concludes that the materials used for fabrication of the TN-32B HBU cask will adequately perform per the Section 4.0 Design Requirements of proprietary TN document 19885-0101, Rev. 6 (ADAMS Accession No. ML17109A456) used in calculations to show compliance with the regulations in 10 CFR Part 72.

F9.1 The staff concludes the material properties of the SSCs of the TN-32B HBU cask for use as the NAPS ISFSI comply 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 SSC designs in this amendment will allow for safe storage of spent nuclear fuel.

F9.2 The licensee has met the requirements of 10 CFR 72.122(a). The material properties of TN-32B HBU cask SSCs ITS conform to quality standards commensurate with their safety function.

F9.3 The materials of SSC ITS in the design bases of the TN-32B HBU cask comply with the design criteria in 10 CFR 72.122 for all conditions of operation allowing safe storage of the spent nuclear fuel for the minimum required years and cask maintenance to 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.

10.0 CONDUCT OF OPERATIONS

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

11.0 RADIATION PROTECTION EVALUATION

11.1 Review Objective

The purpose of this section is to evaluate the radiation protection aspects of this amendment request. The primary objectives of this evaluation are to determine whether the design features and proposed operations provide sufficient assurance that: 1) the proposed TN-32 HBU cask meets the U.S. NRC design criteria for direct radiation; 2) the licensee has proposed engineering features and operating procedures that will ensure occupational exposures remain ALARA; and 3) radiation doses to the general public will meet regulatory standards during both normal and anticipated occurrences.

11.2 Occupational Exposure

To estimate occupational exposure, the applicant used the MCNP5 normal and off-normal shielding model described in section 6.4.1 of this SER. In Table 4.4-1 of the TN-32B HBU DLBD, Rev. 8 (ADAMS Accession No. ML17109A457), the applicant showed the estimated person-hours, working distances, and cask configuration for both wet and dry activities from cask loading through placing the cask on the storage pad as well as instrument monitoring activities after the cask is in storage. The applicant estimated the occupational exposure for each task associated with these activities using the dose rates generated by the MCNP5 model, the cask configuration, the work location as well as personnel working distance and provided the results in Table 4.4-2 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457).

The applicant’s analysis indicated that thermocouple installation would produce the highest occupational exposure. In response to an information request from staff, the applicant revised the MCNP5 cask model to explicitly model the seven new TN-32B HBU cask lid penetrations and determined the dose rates directly above the new lid penetrations, as well as an average dose rate for the entire lid, using mesh tallies 10 inches above the lid. The applicant calculated a maximum dose rate of 4.14 rem/hr directly above the thermocouple penetrations and an average dose rate of 0.455 rem/hr. The applicant anticipated that workers' hands would be exposed to the 4.14 rem/hr dose rate and their torso would be exposed to a dose rate of 0.455 rem/hr (ADAMS Accession No. ML16097A213). Combining these dose rates with the person-hour estimates in Table 4.4-1 of the DLBD, Rev. 8 (ADAMS Accession No. ML17109A457) resulted in an extremity dose of 16.56 person-rem and a whole body dose of 1.82 person-rem for thermocouple installation. After performing independent calculations, staff confirmed that the occupational exposures are within the regulatory limits of 10 CFR 20.1201.

In response to another information request from staff, the applicant identified the methods they would implement to reduce worker exposure. First, the applicant committed to performing fit up testing in a non-radiological environment prior to performing thermocouple installation. Second, since the borated top neutron shield will not be installed during thermocouple installation, the applicant planned to reduce the neutron dose by leaving the fuel assemblies covered with water. Finally, to reduce the gamma dose, the applicant indicated that temporary shielding would be employed during thermocouple installation (ADAMS Accession No. ML16097A213). In addition, the applicant indicated that NDE operations at the NAPS ISFSI would be minimal since the majority of the TN-32B HBU cask modifications will be performed offsite at the fabricator's facility in a non-radioactive area. However, in response to an additional information request by staff, the applicant clarified that ALARA principles will be utilized in accordance with applicable NAPS health physics procedures in order to minimize dose exposure should NDE operations be necessary (ADAMS Accession No. ML16097A213). Staff determined that performing these activities will either reduce the dose rates above the cask lid, or limit the time workers spend in higher radiation fields in order to maintain worker exposure As Low As Reasonably Achievable.

11.3 Public Exposure

The applicant determined the dose rate 500 meters (approximately 1640 feet) from the TN-32B HBU cask was 0.937 mrem/year. Although the nearest resident to the ISFSI is approximately 872 meters (2860 feet), as identified in the NAPS ISFSI SAR, Rev. 8.02 (ADAMS Accession No. ML16022A073), the applicant conservatively used the 500 meter calculation results as the dose rate to the nearest resident. The applicant previously estimated the annual dose to the nearest resident from ISFSI operations as 2.10 mrem/year, and when combined with operation of both NAPS units, as 5.10 mrem/year (ADAMS Accession No. ML16022A073). Therefore, the applicant conservatively assumed storage of the TN-32B HBU cask at the NAPS ISFSI will increase the annual dose to the nearest resident to 6.037 mrem/year. After performing independent calculations, staff confirmed the dose rate to the public is much less than the 25 mrem/year limit imposed by 10 CFR 72.104(a).

11.4 Evaluation Findings

Based on its review of the applicant's information and representations, as well as independent confirmatory analyses, staff determined that the applicant made conservative assumptions in the shielding analyses. Staff also determined that the applicant will implement appropriate measures to limit worker exposure to levels As Low As Reasonably Achievable. Consequently, staff finds that the TN-32B HBU demonstration cask meets the regulatory requirements of 10 CFR 20.1201, 10 CFR 72.24(e) and 10 CFR 72.104(a).

F11.1 The ISFSI design and operating procedures provide acceptable means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR 20 and for meeting the objective of maintaining exposures ALARA, in compliance with 10 CFR 72.24(e).

F11.2 The cumulative dose to the public from the combined operations of the NAPS and the NAPS ISFSI will not constitute an unreasonable risk to public health and safety in compliance with 10 CFR 72.104(a).

12.0 QUALITY ASSURANCE EVALUATION

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

13.0 DECOMMISSIONING EVALUATION

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

14.0 WASTE CONFINEMENT AND MANAGEMENT EVALUATION

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

15.0 ACCIDENT ANALYSIS

15.1 Review Objective

The purpose of the staff's accident analysis review is to evaluate the applicant's identification of hazards, and the summary analyses of the TN-32B HBU cask system's response to off-normal and accident or design-basis events. This review ensures that the applicant has conducted thorough accident analyses that identify all credible accidents, correctly assessed the safety performance of the cask system with respect to the various safety functions, and satisfied all applicable regulatory requirements.

15.2 Off-Normal Conditions

Off-normal events are those designated as Design Event II, as defined by ANSI/ANS 57.9-1992. These events can be described as infrequent, but can be expected to occur on the order of once per year. The applicant evaluated the TN-32B HBU cask against off-normal events relevant to the NAPS ISFSI. Based upon a review of the documents provided, staff finds the applicant adequately identified the off-normal events applicable to the NAPS ISFSI.

15.2.1 Electrical Power Loss

The NAPS ISFSI SAR identified loss of electric power as the only off-normal event. Because the TN-32B HBU cask does not utilize electric power, the staff finding associated with the original issuance of the license remained unchanged.

15.2.2 Cask Leakage

The applicant considered the following scenario for off-normal conditions: the cask leaked over a one year period at the off-normal leak rate of 1 x 10^{-5} std. cm^3/sec, 10% of the fuel assembly rods failed, and Stability Category D meteorological conditions with a 5 meter/sec wind speed existed. Under these conditions, the applicant calculated a Total Effective Dose Equivalent of 0.192 mrem/year at a point 500 meters from the TN-32B HBU cask. Not only is this value well below the regulatory limits specified in 10 CFR 72.104(a) and 10 CFR 20.1201(a)(1)(i), but also the distance at which this value was calculated is less than the distance to the site boundary; therefore, the value is an even more conservative estimate of the dose to the public. Consequently, staff finds these results acceptable. The applicant also asserted that the dispersion parameter used for off-normal conditions was calculated in the exact same method as in the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025). Staff reviewed the inputs and assumptions provided by the applicant and concluded they were appropriate. Staff also confirmed, as documented in the staff SER (ADAMS Accession No. ML003696918), the assertion that the methodology had been previously approved by the NRC. Consequently, staff finds the applicant’s off-normal analysis results acceptable.

15.3 Accident Events and Natural Phenomena

Accident events and conditions are those designated as Design Events III and IV, as defined by ANSI/ANS 57.9-1992. These events are very low probability events that might occur once during the lifetime of the ISFSI, or hypothetical events that are postulated because their consequences may result in the maximum potential impact on the surrounding environment. The effects of natural phenomena, such as earthquakes, tornadoes, hurricanes, floods, and tsunami, are considered to be accident events.

The applicant evaluated the operations at the NAPS ISFSI with the TN-32B HBU cask under accident conditions per the guidance in NUREG-1567 (ADAMS accession number ML003686776), and identified the following accident conditions: earthquake, tornado winds, tornado missiles, cask tip-over, cask drops, fires, fuel assembly misload, loss of neutron shield, and cask seal leakage. The staff reviewed the information and representations provided by the applicant. Based on its review, the staff determined that the applicant has adequately identified potential scenarios that could adversely impact the shielding safety of the cask.

15.3.1 Earthquake

The applicant analyzed the response of the TN-32B HBU cask both to the NAPS ISFSI Design Basis Earthquake seismic event, and the 2011 earthquake centered near Mineral, VA with the cask in a vertical storage position. As discussed in Sections 4.5.1 and 4.5.2.1 of this SER, the applicant demonstrated that the cask maintains its structural integrity. Therefore, staff determined with reasonable assurance that the confinement boundary integrity is maintained under accident conditions.

15.3.2 Tornado Winds and Tornado Missiles

The applicant evaluated the response of the TN-32B HBU cask to tornado winds and tornado missiles applicable to the NAPS ISFSI. As discussed in Sections 4.5.1 and 4.5.2.1 of this SER, the applicant demonstrated that the cask maintains its structural integrity. Therefore, staff determined with reasonable assurance that the confinement boundary integrity is maintained under accident conditions.

15.3.3 Cask Tip-Over

The applicant evaluated the response of the TN-32B HBU cask to a tip-over event at the NAPS ISFSI. The applicant demonstrated that the cask maintains its structural integrity in Section 4.5.1 of this SER. The applicant also demonstrated in Sections 4.5.2.1, 4.5.2.2 and 4.5.2.3 of this SER that the cask lid maintains its structural integrity, that the cask lid remains secured and that the cask lid port covers remain secured. In addition, the applicant showed in Section 4.5.3 of this SER that both the cask basket and the basket rails retain their structural integrity. Therefore, under accident conditions, staff determined with reasonable assurance that the confinement boundary integrity is maintained and that the fuel remains in an analyzed condition.

15.3.4 Cask Drops

The applicant evaluated the response of the TN-32B HBU cask to a 50g drop event at the NAPS ISFSI. The applicant demonstrated that the cask maintains its structural integrity in Section 4.5.1 of this SER. The applicant also demonstrated in Sections 4.5.2.1, 4.5.2.2 and 4.5.2.3 of this SER that the cask lid maintains its structural integrity, that the cask lid remains secured and that the cask lid port covers remain secured. In addition, the applicant showed in Section 4.5.3 of this SER that both the cask basket and the basket rails retain their structural integrity. Therefore, under accident conditions, staff determined with reasonable assurance that the confinement boundary integrity is maintained and that the fuel remains in an analyzed condition.

15.3.5 Fire

The applicant evaluated the performance of the TN-32B HBU cask during a hypothetical fire accident. As described in Section 5.5.3.3, both the fuel cladding temperatures and the seal temperatures remain below their respective allowable temperature limits. Therefore, staff determined with reasonable assurance that both the spent fuel cladding integrity and the confinement boundary integrity is maintained under accident conditions.

15.3.6 Fuel Assembly Misload

The applicant performed misload analyses using multiple 5% enrichment fresh fuel assemblies, the maximum allowable enrichment for power reactors per 10 CFR 50.68(b)(7), and demonstrated that the cask remains subcritical with sufficient safety margin when it is in the spent fuel pool. The applicant also determined that the cask will remain subcritical during a tip-over accident.

The applicant performed criticality safety analyses for the TN-32B HBU cask under accident conditions per the guidance of NUREG-1567 (ADAMS Accession No. ML003686776). Based on its review of the information and representations provided by the applicant, the staff determined that the applicant has adequately identified potential scenarios that could adversely impact the criticality safety of the cask. The scenarios identified and evaluated are consistent with those identified in NUREG-1567 (ADAMS Accession No. ML003686776). The applicant's criticality safety evaluations demonstrated that the cask remains subcritical under these accident conditions. On these bases, the staff determined with reasonable assurance that the applicant's criticality safety evaluations for the cask under accident conditions are acceptable.

15.3.7 Loss of Neutron Shield

Although total loss of the neutron shielding is not considered credible, the applicant evaluated the dose rates from the TN-32B HBU cask assuming that all neutron shielding as well as the radial outer shell are removed. Under these conditions, the applicant calculated a dose rate of 347 mrem/hr at one meter from the outer radial surface of the cask. This value is less than the 400 mrem/hr dose rate at one meter from the outer radial surface of the cask evaluated by the staff for original issuance of the license (ADAMS Accession No. ML060760416). Therefore, staff determined with reasonable assurance that the applicant is in compliance with 10 CFR 72.106(b) for a loss of neutron shield accident condition.

15.3.8 Cask Seal Leakage

The applicant considered the following scenario for accident conditions: the cask leaked over a 30 day period at the accident leak rate of 1 x 10^{-5} std. cm^3/sec, 100% of the rods failed, the temperatures and pressures inside the cask due to the fire accident conditions are 570^{o}F and 7.8 atmospheres, and Stability Category F meteorological conditions with a 1 meter/sec wind speed existed. Under these conditions, the applicant calculated a Total Effective Dose Equivalent of 9.71 mrem over a 30 day period at a point 500 meters from the TN-32B HBU cask. Staff identified that this value is well below the regulatory limits specified in both 10 CFR 72.106(b) and 10 CFR 20.1201(a)(1)(i), and that the distance at which this value was calculated is less than the distance to the site boundary; therefore, the value is an even more conservative estimate of the dose to the public. The applicant also asserted that the accident condition dispersion parameter was calculated using the exact same method as in the TN-32 UFSAR, Rev. 6 (ADAMS Accession No. ML14108A025). Staff reviewed the inputs and assumptions provided by the applicant and concluded they were appropriate. Staff also confirmed, as documented in the staff SER (ADAMS Accession No. ML003696918), the assertion that the methodology had been previously approved by the NRC. Consequently, staff finds the applicant’s accident analysis results acceptable.

15.4 Evaluation Findings

F15.1 Structures, systems, and components of the TN-32B HBU system are adequate to prevent accidents and to mitigate the consequences of accidents and natural phenomena events that do occur.

F15.2 The applicant’s evaluation demonstrates that the TN-32B HBU cask will reasonably maintain confinement of radioactive material under credible accident conditions.

F15.3 Neither off-normal nor accident conditions will result in a dose to an individual outside the controlled area that exceeds the limits of 10 CFR 72.104(a) or 72.106(b), respectively.

F15.4 The staff concludes that the accident design criteria for the TN-32B HBU cask is in compliance with 10 CFR Part 72 and the accident design and acceptance criteria have been satisfied. The applicant's accident evaluation of the cask adequately demonstrates that it will provide for safe storage of spent fuel during credible accident situations.

F15.5 The analyses of off-normal and accident events and conditions and reasonable combinations of these and normal conditions show that the design of the TH-32B HBU cask and the ISFSI loaded with this cask will acceptably meet the requirements of 10 CFR 72.124 regarding the maintenance of the spent fuel in a subcritical condition.

16.0 TECHNICAL SPECIFICATIONS

16.1 Review Objective

In this section, the staff evaluated the proposed changes to the operating controls and limits, or TS, including their bases and the applicant's justification that the conditions of use for the TN-32B HBU cask at the NAPS ISFSI meet the requirements of 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste and Reactor-Related Greater Than Class C Waste". The TS define the conditions that are deemed necessary for safe use of the TN-32B HBU cask at the NAPS ISFSI. Specifically, they define operating limits and controls, surveillance requirements, design features, and administrative controls considered necessary to ensure safe use of the TN-32B HBU cask at the NAPS ISFSI. These TS are included as an attachment to the NAPS ISFSI license.

16.2 Review Criteria

Staff reviewed the TS for use of the TN-32B HBU cask at the NAPS ISFSI in accordance with guidance provided in NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities" (ADAMS Accession No. ML003686776). The conditions were derived from analyses and evaluations provided in the application and pertain to the design, and operation of the ISFSI.

16.3 Technical Specifications

16.3.1 Functional and Operating Limits

Functional and operating limits are those limits on fuel handling and storage conditions necessary to protect the integrity of the stored fuel, to protect employees against occupational exposure and to guard against the uncontrolled release of radioactive materials. Functional and operating limits impacted by this amendment include Tables 2.1-1 and 2.2-1 as well as Figure 2.1-4. The staff concluded that the functional and operating limits listed in Tables 2.1-1 and 2.2-1 as well as Figure 2.1-4 are those necessary to protect the integrity of the stored fuel and to guard against the uncontrolled release of radioactive materials by maintaining the fuel cladding temperatures below the limits in ISG-11, Rev. 3 (ADAMS Accession No. ML033230281) as shown in sections 5.5.3 and 9.5 as well as to protect employees against occupational exposure as shown in section 11.1. The applicant also modified Figure 2.2-1. However, staff determined this change was editorial in nature and did not address it in the SER. The staff therefore concludes that the NAPS ISFSI TS are in compliance with 10 CFR 72.44(c)(1)(i).

16.3.2 Limiting Conditions/Surveillance Requirements

Limiting conditions for operation are the lowest equipment functional capability or performance levels required for safe ISFSI operation. Surveillance requirements provide for inspection and test activities to ensure that the necessary integrity of required systems is maintained, confirmation that operation of the ISFSI is within the required functional and operating limits, and confirmation that the limiting conditions required for safe storage are met.

The table below lists the NAPS ISFSI TS Limiting Conditions and Surveillance Requirements and the SER section(s) which documents the acceptability for each limiting condition or surveillance requirement. In addition to the TS Limiting Conditions and Surveillance Requirements listed in the table below, the applicant modified the TS 3.3.1 title to identify the surface dose rates in this TS were associated with the TN-32 casks and not the TN-32B HBU cask. The applicant also revised the number for the cask surface contamination TS from 3.3.2 to 3.3.3. Staff determined these changes were editorial in nature and did not address them in the SER.

TS	Limiting Condition	Surveillance Requirement	SER Section(s)
3.1.2	Verify SSSC helium backfill pressure is within limit	3.1.2.1	8.2, 9.5
3.1.3	Verify SSSC combined helium leak rate is within limit	3.1.3.1	8.2
3.3.2	SSSC Average Surface Dose Rates for TN-32B HBU Cask	3.3.2.1	6.5
Table 3-1	SSSC Model-Dependent Limits	3.1.3.1	4.5.4, 7.2.2, 8.2, 8.3.1, 9.5

The staff concluded that the limiting conditions discussed in this section specify the lowest functional capability for safe operation of the TN-32B HBU cask. In addition, the staff concluded that the surveillance requirements listed in the table provide for necessary inspection and testing, confirm operation within appropriate functional and operating limits and confirm that limiting conditions for safe storage are met. The staff therefore concludes that the North Anna ISFSI TS are in compliance with 10 CFR 72.44(c)(2) and (c)(3).

16.3.3 Design Features

The TS Design Features include items that would have a significant effect on safety if altered or modified. The applicant modified the TS to identify the TN-32B HBU cask as a necessary design feature of the NAPS ISFSI. The staff concluded, based upon a review of the information provided by the applicant, that the TN-32B HBU cask is a design feature, which if altered, would have a significant effect on safety. The staff therefore concludes that the North Anna ISFSI TS are in compliance with 10 CFR 72.44(c)(4) because they identify the necessary design features of the NAPS ISFSI.

16.3.4 Administrative Controls

The requested changes do not alter the original TS administrative controls evaluation. Therefore, staff determined that an evaluation was not required.

16.4 License Conditions

Although the requested changes did not affect the license conditions, staff made editorial changes to License Conditions 6A, and 9 and provided a draft of the revised license to the applicant for review (ML17158B189). The applicant communicated approval of the changes by phone on June 12, 2017 (ML17164A233).

16.5 Evaluation Findings

The staff reviewed the information provided by the applicant in the SAR, the analytical methods, the data used in the analyses, the analytical results and the applicant's conclusions. The staff also performed independent analyses as necessary. The staff evaluated the proposed technical specification changes including their bases and the applicant's justification for the use of the TN-32B HBU cask. Based on this review, staff makes the following finding:

F16.1 The staff concludes that the conditions for at the NAPS ISFSI identify necessary TS to satisfy 10 CFR Part 72, and that the applicable acceptance criteria have been satisfied. The TS provide reasonable assurance that the ISFSI will allow safe storage of spent fuel. This finding is based on the regulation itself, appropriate regulatory guides, applicable codes and standards and accepted practices.

ENVIRONMENTAL REVIEW

Pursuant to 10 CFR Part 51, an Environmental Assessment (EA, ML16168A104) has been prepared for this action and a Finding of No Significant Impact (FONSI) was issued. The EA and FONSI were published in the Federal Register on June 30, 2016 (81 FR 42743).

CONCLUSION

The staff reviewed the license amendment request for SNM-2507, as supplemented, including the engineering analyses, proposed FSAR revisions, and other supporting documents submitted with the application. Based on the information provided in the application, as supplemented, the staff concludes that SNM-2507, as amended, meets the requirements of 10 CFR Part 72.
Issued with Materials License No. 2507, Amendment No. 5, on September 13, 2017.