ATTACHMENT 1

Responses to RAI Questions Related to HBU Cask

Attachment 1 provides the consolidated responses to the NRC's RAI related to the High Burnup Cask Project at North Anna Power Station

North Anna Power Station ISFSI

Virginia Electric and Power Company

SAFETY REVIEW

Chapter 5 – Structural Evaluation

1. Provide AREVA TN Document [E-39973], "Documentation of Previously Analyzed Bounding Cask Outer Shell Analysis for TN-32 in Support of the TN-32B HBU Demonstration Project".

   As of date, the docketed materials relating to the proposed TN-32B HBU demonstration cask does not include any analysis that confirms the structural adequacy of the outer shell, incorporating all the modifications to TN-32 cask described in the application.

   This information is needed to determine compliance with 10 CFR 72.122.

   Response:

   AREVA TN Document E-39973, "Document of Previously Analyzed Bounding Cask Outer Shell Analysis for TN-32 in Support of the TN-32B HBU Demonstration Project," was provided to the NRC in Dominion Letter Serial Number 15-369H on January 14, 2016.

2. Provide AREVA TN Document [E-40199], "Reconciliation of TN 32B HBU Demonstration Cask Trunnions and the Gamma Shield Shell Evaluation".

   As of date, the docketed materials relating to the proposed TN-32B HBU demonstration cask does not include any analysis that confirms the structural adequacy of the cask trunnions, and the gamma shield shell, incorporating all the modifications to TN-32 cask described in the application.

   This information is needed to determine compliance with 10 CFR 72.122.

   Response:

   AREVA TN Document E-40199, "Reconciliation of TN 32B HBU Demonstration Cask Trunnions and the Gamma Shield Shell Evaluation," was provided to the NRC in Dominion Letter Serial Number 15-369H on January 14, 2016.

3. Provide AREVA TN Document [E-39552], "Documentation of Previously Analyzed Bounding Missiles for TN-32 in support of the TN-32B HBU Demonstration Package."

   As of date, the docketed materials relating to the proposed TN-32B HBU demonstration cask does not include any analysis that confirms the structural adequacy of the cask when subjected to the design basis missiles, incorporating all the modifications to TN-32 cask described in the application.

   This information is needed to determine compliance with 10 CFR 72.122.

   Response:

   AREVA TN Document E-39552, "Documentation of Previously Analyzed Bounding Missiles for TN-32 in support of the TN-32B HBU Demonstration Package," was provided to the NRC in Dominion Letter Serial Number 15-369H on January 14, 2016.

Chapter 6 – Thermal Evaluation

1. Clarify why the thermal evaluation performed for normal storage conditions thermally bounds the thermal evaluation during transfer operations.

   Page 17 of LAR with document identification number (IDN) 15-369 states that during transfer operations to the ISFSI pad, the TN-32B HBU cask is exposed to ambient conditions and is not surrounded by other casks. This ensures that there is no radiation heat transfer between the casks as there is during storage on the ISFSI pad. Therefore, the thermal evaluation performed for normal storage bounds the thermal performance of the TN-32B HBU cask during transfer to the North Anna Power Station (NAPS) ISFSI pad.

   However, it is not clear whether during transfer conditions, the cask is in the horizontal or vertical configuration. Depending on the configuration, different correlations are applied to model convective heat transfer to the environment. Correlations obtained for horizontal cylinders may be more limiting and may overcome the lack of radiation heat transfer from surrounding casks.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   The TN-32B HBU cask will always be in a vertical configuration from the beginning of loading operations through storage on the ISFSI pad. The vertical configuration is the same configuration the TN-32B HBU cask will be in while stored on the ISFSI pad. During transfer to the pad, there are no other casks around the TN-32B HBU cask that would emit heat. The thermal analysis performed for the TN-32B HBU Cask was performed for the bounding case where the cask is stored near other heat emitting TN-32 casks. This

thermal analysis bounds the transfer operation of the TN-32B HBU cask during this operation as it will be exposed to only ambient temperatures, and will not be located adjacent to any heat emitting TN-32 casks.

2. Explain how the 23-day thermal soak period was obtained for the TN-32B HBU cask.

   Page 18 of LAR IDN 15-369 states that to ensure the TN-32B HBU cask thermocouples are functioning correctly and that the cask and payload have reached a state of thermal equilibrium, the TN-32B HBU cask will remain in the NAPS loading bay for a maximum of 23 days from the time the cask is filled with helium.

   However, the licensee does not provide any details on how the 23-day period was obtained. Analysis that demonstrates the cask will reach thermal equilibrium during this period is needed in order to evaluate the adequacy of this assumption. Boundary conditions and cask configurations should also be properly justified. An adequate response is also necessary to justify Surveillance Requirement (SR) 3.1.3.1.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   The intent of the thermal soak period is to provide a period for data collection immediately after the cask has been vacuum dried and backfilled with helium. The 23 days is intended to allow for temperature measurements to be recorded from the thermocouples and gas samples to be taken from the cask cavity through the vent port. However, the analysis to demonstrate the cask has reached equilibrium is provided.

   Transnuclear commissioned two tests to verify the thermal conductance of TN-32 casks. The test results were provided to the NRC under Transnuclear Letter E-18578, December 1, 2000. Each test was performed using a TN-32 cask with an open cavity (i.e., the basket was not installed). Each test involved heating the cask interior to 300°F and holding until thermal equilibrium was achieved. The test reports indicated that thermal equilibrium (without a basket) occurred after approximately 4½ days.

   The basket will add additional mass (primarily stainless steel and aluminum) to the interior of the cask that will affect the time to reach thermal equilibrium. Results from separate fire accident transient thermal analyses conducted by Transnuclear (TN Calculation 19885-0403) show that the cask, loaded with fuel, requires approximately 140 hours (5.83 days) to reach steady state thermal equilibrium. The temperature delta between interior and exterior (ΔT) for the fire accident transient was approximately 900°F. This ΔT was scaled to normal operating conditions to extrapolate the time to reach steady state thermal equilibrium under normal conditions. The ΔT associated with normal conditions is approximately 560°F assuming the ambient temperature of the cask at loading is 90°F. Because conduction and convection heat transfer

mechanisms are directly related to the ΔT, the time to reach steady state conditions can be assumed to be approximately equal to the ratio of the ΔT. For this case, the ratio would be 900/560, or 1.61. Therefore, as expected with decreased ΔT, the analyzed time to reach steady state would be extended and would be the product of 1.61 and 5.83 days, or about 9.4 days. This compares favorably to the time for the cask body to reach steady state of 4½ days. That is, the added mass of the basket and fuel essentially extends the time to reach steady state by about 5 days.

Therefore, a thermal soak period of 23 days is considered to be sufficiently long in duration to assure thermal equilibrium is reached, and should provide a sufficient amount of time to complete testing of the cask before it is transported to the ISFSI pad. In addition the 23-day thermal soak period also provides time to complete cask thermal testing, cask cavity composition testing, and combined helium leak rate testing in accordance with TS LCO 3.1.3.

3. Clarify if any insert components are planned to be installed in the TN-32 HBU cask. Explain if these components are irradiated and how their decay heat is accounted for in the total heat load of the cask.

   Page 18 of LAR IDN 15-369 states that no irradiated inserts shall be inserted in the TN-32B HBU cask. However, page 13 of document number E-42038 (TN-32B HBU Demonstration Cask Design/Licensing Basis Document) states that any insert components which are planned to be installed in the HBU demonstration cask, such as poison rod assemblies, are installed in designated fuel assemblies during loading operations. It appears these two statements are not consistent. Also, the total decay heat seems to have been considered for the fuel assemblies only and not from any other irradiated components.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   There are no irradiated components being inserted into the fuel assemblies in the TN-32B HBU Cask. The poison rod assemblies (PRAs) that are to be inserted into the designated fuel assemblies are not radioactive, and have not been irradiated. The PRAs are being inserted to add sub-criticality margin. There is no decay heat associated with the inserted components.

4. Explain how the thermocouple lances installed though the cask lid will indirectly monitor the fuel assembly cladding temperature during the demonstration storage period.

   Page 8 of E-42038 states that the TN-32B HBU demonstration cask will have thermocouple lances installed to indirectly monitor the fuel assembly cladding temperature.

   However, the licensee does not provide any details on the location of the thermocouples and how these measurements will indirectly monitor the fuel cladding temperature.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   The purpose of the thermocouple lances is to obtain actual temperatures of the fuel cladding to better understand the behavior of high burnup fuel under typical dry storage conditions. It is impractical to instrument the cladding directly, since this would require attaching thermocouples directly to the cladding of irradiated fuel. Instead, the temperature inside one of the fuel guide tubes will be measured using thermocouple lances designed to be inserted during the loading evolution. The thermocouples will measure temperatures at several different local axial positions, i.e., inside the guide tube. Best-estimate computational models will be validated using the thermocouple lance information and will then be used to infer the cladding temperature distributions. A separate activity at Sandia National Laboratories is underway to correlate measured guide tube temperatures using the thermocouple lance design to the cladding temperature. The results will establish the bias and uncertainty of the best-estimate model to calculate the cladding temperature from the temperature inside the guide tube. This best-estimate model is separate from the model used in the thermal analysis for this LAR. Temperature measurements inside the cask cavity are not being used in the thermal analysis for this LAR, nor are they being used to demonstrate compliance with 10 CFR 72.122 and 72.128. The thermal analysis for this LAR remains as a stand-alone analysis to demonstrate compliance with 10 CFR 72.122 and 72.128, and will not be informed from data or subsequent evaluations derived from the program.

5. Clarify if the installed thermocouples will adequately capture the maximum fuel cladding temperature.

   Page 8 of E-42038 states that a number of thermocouple lances will be installed in specific assemblies. However, the licensee does not provide any details on the number of thermocouples per lance location.

   The staff needs details on the number of thermocouples used to obtain measurements. Also, the staff needs to know if the purpose of the temperature measurements is to capture both the axial profile and the maximum cladding temperature (See also RAI-6-4).

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

Response:

The purpose of the temperature measurements inside the cask cavity is to better understand the temperature distribution of high burnup fuel during cask loading, vacuum drying, and cool-down following drying. Therefore, it is important to have a good array of measurements to capture the full thermal distribution. There are seven radial and nine axial locations for a total of 63 thermocouple locations. The assembly predicted to have the highest fuel clad temperature is one of the instrumented locations.

For the seven radial locations, there are two in the center of the cask, two in the middle, and three on the periphery of the cask (see Figure 6.5-1). For each assembly with a thermocouple lance, the specific guide tube to insert the lance into was selected to provide data of the best value from a research perspective, and was chosen considering the burnup distribution within the assembly and the predicted rod location of the peak temperature. For ease of design and installation, guide tubes were selected from one of the eight inner guide tubes. The seven radial locations are shown in the figure below as "Option 1" (green locations).

The nine axial locations in each thermocouple lance were chosen to capture the axial profile. Since the expected temperature profile is a reasonably flat cosine shape typical of casks that rely primarily on conduction for heat removal, several locations were selected that are fairly evenly distributed in the center, and with more on the ends where the largest thermal gradient occurs. The thermocouples are located between the grids to avoid any local perturbation caused by the grid (see Figure 6.5-2).

Thus, the locations of the array of 63 thermocouples were selected to capture the full radial and axial temperature distribution. Although the assembly expected to have the highest clad temperature will be monitored with a thermocouple lance, the peak clad temperature will be inferred separately from the computational models based on data observed from the thermocouples. The measurements of the temperatures inside the cask cavity are not being

used in the thermal analysis for this LAR that demonstrates compliance with 10 CFR 72.122 and 72.128.

**Figure 6.5-1:
Radial Locations of the Thermocouple Lances in the TN-32B HBU Cask**

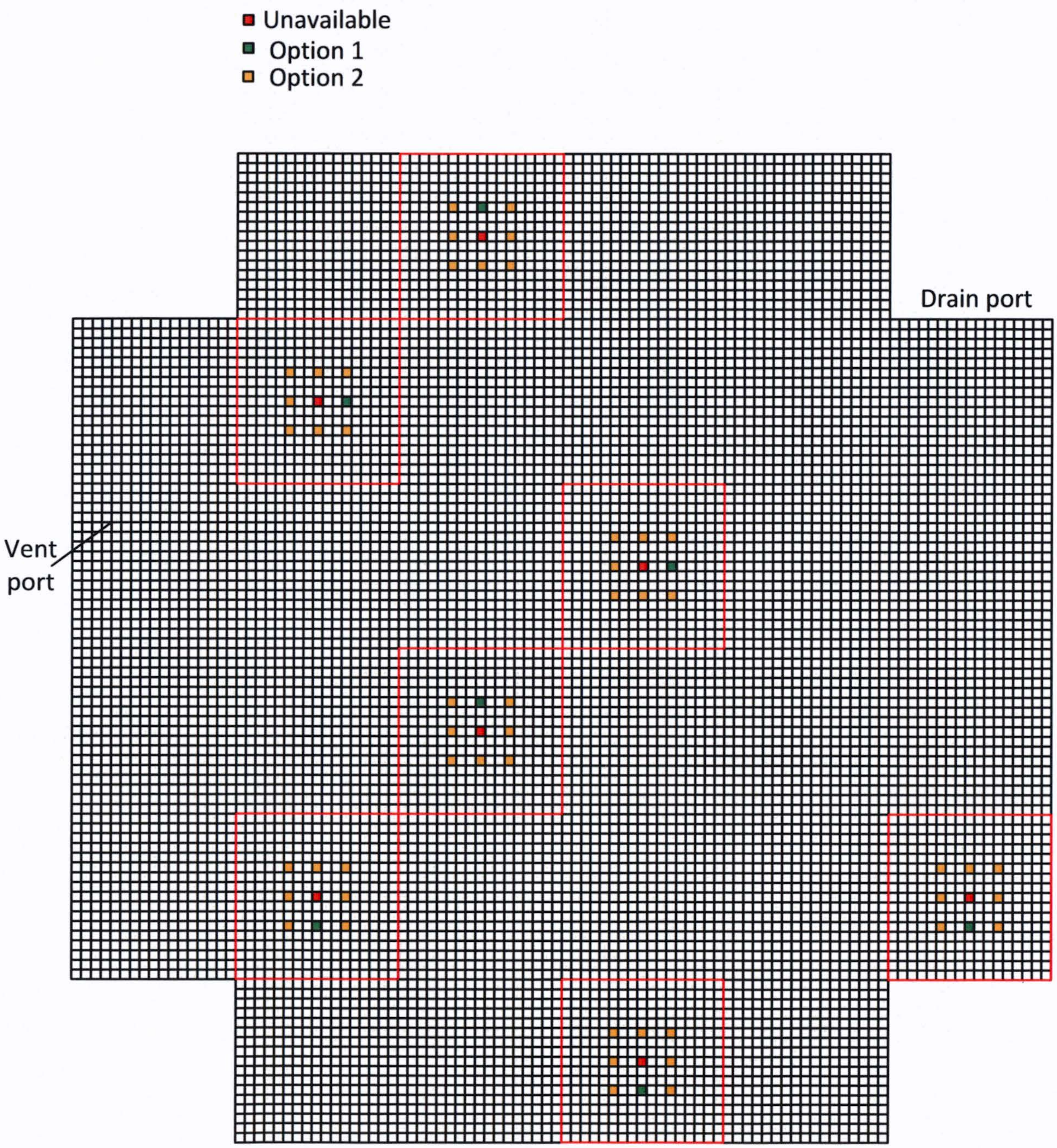
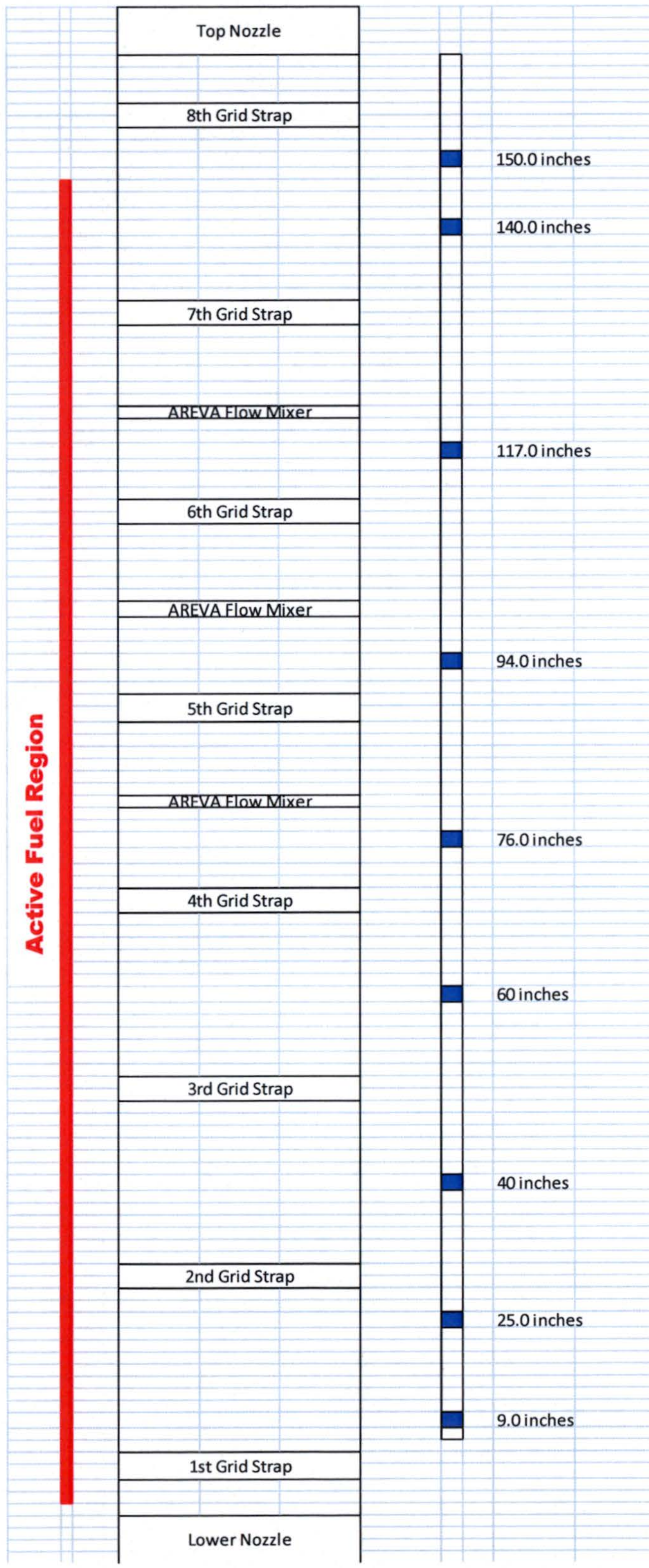


**Figure 6.5-2:
Axial Location of the Thermocouples for the TN-32B HBU Cask**



6. Clarify which thermal analysis will be benchmarked using the measured data obtained from the TN-32B HBU cask during the thermal soak period.

   Page 14 of E-42038 states that during the thermal soak period, measured data (temperatures, pressures, etc.) will be utilized to more fully understand the loading and drying temperature transients for benchmarking thermal analysis techniques, and to identify any rod failures, should they occur.

   However, the LAR does not provide any thermal analysis for loading operations (for example vacuum drying) because the licensee stated these operations are bounded by normal storage conditions (see also RAI 6-1).

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   The thermal analysis for this LAR does not depend upon the measured data obtained from the TN-32B HBU cask. The thermal analysis for normal storage conditions is bounding for the loading operations and demonstrates compliance with 10 CFR 72.122 and 72.128.

   The TN-32 HBU cask is being instrumented as part of the DOE/EPRI High Burnup Dry Storage Cask Research and Development Project to collect measured data for use in modeling the behavior of high burnup fuel during cask loading, vacuum drying, and cool-down following drying. It is anticipated that the scientific community, in particular, the national laboratories will utilize these data to validate computational models for cask content temperature predictions. The measured data obtained through this project will be made publicly available.

7. Justify the methodology used to evaluate the TN-32B HBU cask hypothetical fire accident. Provide reasons why the methodology adequately capture the maximum temperature of the fuel cladding, cask components, and seals.

   Page 15 of document number 19885-0403 (Thermal Evaluation of TN-32B HBU Cask for Normal and Accident Conditions) states that simplified models are used to model the conditions during the fire accident and to obtain the maximum temperature of the fuel cladding, cask components, and seals. However, the licensee does not provide adequate justification why these simplified models bound analyses based on a thermal model of the entire cask.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

Response:

The methodology used to evaluate the thermal performance of the TN-32B HBU cask during a hypothetical fire accident uses two sub models and is identical to the approach previously approved for the TN-32 cask, as described in Chapter 4, Section 4.5 of TN-32 UFSAR [6.7-1]. The same method is also the basis for Amendment 2 to North Anna site-specific license SNM-2507 [6.7-5] as documented in Chapter 3 of the Design Licensing Basis Document (DLBD). Therefore, the same methodology is used to evaluate the hypothetical fire accident in this LAR. The use of these models results in a conservative estimate of the maximum fuel cladding temperature as described below.

Justification for use of Cask Cross-Section Model

The slice of the cask cross-section used for the hypothetical fire accident evaluation is selected such that the decay heat generation rate and the resultant temperatures are highest for normal storage conditions, as described in Section 5.2.1 of document 19885-0403 [6.7-2]. Based on the thermal evaluation performed for normal storage conditions, the hottest cross-section of the cask is identified along the axial direction and is used to evaluate the hypothetical fire accident. The cask cross-section model and boundary conditions for the hypothetical fire accident are shown in Figure 6-4 (a) and Figure 6-6 of [6.7-2], respectively.

Due to the large thermal inertia of the cask (including the contents), and the short duration of the fire, the maximum fuel cladding temperature and other basket component temperatures occur during steady-state post-fire conditions, which occur long after the end of the 15-minute fire. Because the maximum temperatures occur during steady-state post-fire conditions, the use of a slice model is conservative as it ignores any axial heat transfer at both ends, as noted in Section 6.2 of [6.7-2]. The use of adiabatic boundary conditions in the axial directions ensures that all heat dissipation from the cask is in the radial direction, which maximizes the fuel cladding temperature.

Justification for use of Cask Top Model

The cask top model is used to evaluate maximum seal temperatures due to the hypothetical fire accident. This model is shown in Figure 6-4 (b) of [6.7-2], and includes the protective cover, the protective cover flange, the top neutron shield resin and box, the cask lid and flange, the top shield plate, and the top part of the carbon steel gamma shield.

During a hypothetical fire accident, the maximum temperature of the cask lid seal is influenced by the heat input into the seal area (contact area of cask lid and cask flange, as seen in Figure 6-4 (b)) from the fire and the heat input due to the decay heat from the fuel assemblies. Both of these heat inputs are captured in the cask top model.

As noted in Section 6.2 of [6.7-2], the heat input from the fire is modeled similar to the cask cross–section model. For the decay heat input from the fuel assemblies, the heat dissipated from the top of the cask is retrieved from the full-length model utilized for normal storage conditions, and is applied as a heat flux on the inner surfaces of the cask top model. As described in Section 6.2, approximately 2.6% of the decay heat generated from the fuel assemblies is dissipated through the top of the cask. Figure 6-7 of [6.7-2] illustrates the boundary conditions considered for the cask top model for the hypothetical fire accident evaluation.

Based on this discussion, the cask cross-section model and the cask top model capture the relevant heat transfer characteristics required to predict the maximum fuel cladding and seal temperatures.

In addition, a similar approach to evaluate the hypothetical fire accident using two sub models are described in Appendix A, Section A3.3.2.2.1.2 of [6.7-3] for the TN-40HT cask, and Chapter 4, Section 4.4 of [6.7-4] for the TN-68 cask to evaluate the hypothetical fire accident. Both of those cask designs have been approved by NRC.

References

6.7-1 AREVA TN, TN-32 Updated Final Safety Analysis Report, Revision 6, NRC Docket No. 72-1021.

6.7-2 AREVA TN Calculation, "Thermal Evaluation of TN-32B HBU Cask for Normal and Accident Conditions," 19885-0403, Rev. 0.

6.7-3 Prairie Island ISFSI Safety Analysis Report, Revision 16. (ADAMS Accession No. ML15355A438).

6.7-4 AREVA TN, TN-68 Final Safety Analysis Report, Revision 7, NRC Docket No. 72-1027.

6.7-5 USNRC, Safety Evaluation Report, Docket No: 72-16, North Anna Independent Spent Fuel Storage Installation, License No. SNM-2507, Amendment 2.

8. Explain why a very small thermal margin is acceptable for the radial neutron shield material. Provide the maximum predicted value of this material. Perform additional analysis to determine that the predicted temperatures in this region are mesh independent.

   Page 39 of document number 19885-0403 (Thermal Evaluation of TN-32B HBU Cask for Normal and Accident Conditions) states that the average resin temperature in the radial direction at the hottest cross section is only three degrees lower than the allowable limit. However, the LAR does not provide the maximum predicted value or an explanation why this very small margin is acceptable. Also, additional analyses should be performed to demonstrate the predicted results are mesh independent.

   This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

   Response:

   The temperature limit on the neutron shield resin is to prevent off-gassing of hydrogen and thereby maintain the shielding performance of the cask. Based on the discussion presented in Appendix 9A of the TN-32 UFSAR [6.8-1], test specimens of the neutron shield resin heated to 311 °F have shown that the amount of hydrogen off-gassed is negligible, i.e., less than 1%.

   A mesh sensitivity study to determine the discretization error is presented in response to Thermal (Chapter 6) RAI 10. The maximum predicted temperature, including the discretization error (±0.20 °F) for the average neutron shield resin, becomes 294.2 °F. This temperature is also below the resin service temperature limit of 300 °F, as further discussed in response to Thermal RAI 10.

   In addition, the resin temperature would be much lower than this predicted value due to the lack of solar insolation and radiation heat transfer from the surrounding casks during loading/transfer operations performed indoors. The maximum predicted temperature would only occur during storage operations on the ISFSI pad. A review of the maximum ambient temperatures in Section 2.3.1 of the North Anna ISFSI SAR [6.8-2] demonstrates that the maximum recorded ambient temperature in the area was 107 °F. However, a bounding temperature of 115 °F is considered as the maximum ambient temperature in determining the daily average ambient temperature utilized for the thermal evaluations. This assumption introduces additional conservatism to the thermal evaluation of the TN-32B HBU cask, and increases the thermal temperature margin for the resin.

   Based on the above discussion, the neutron shield resin does not exhibit any significant loss of shielding performance up to 311 °F, and the maximum predicted value for the average neutron shield resin remains below this limit. The small calculated thermal margin is due to significant conservatisms in the analysis as discussed above. Therefore, the small calculated thermal margin

is acceptable with no adverse impact on the performance of the radial neutron shield.

References

6.8-1 AREVA TN, TN-32 Updated Final Safety Analysis Report, Revision 6.

6.8-2 North Anna Power Station Units 1 & 2, Independent Spent Fuel Storage Installation (ISFSI), Safety Analysis Report, Revision 8.01.

9. Clarify how the correlations to calculate the convection heat transfer coefficients on the TN-32B HBU cask external surfaces are used. Justify the applicability of the selected correlations to the TN-32B HBU cask geometry to calculate these coefficients.

Page 41 of calculation number 19885-0403 states that correlations for vertical cylindrical surface and flat horizontal surfaces are used to obtain the average Nusselt numbers which are used to calculate the convection heat transfer coefficients.

However, it is not clear if the Nusselt numbers are obtained using the average temperature of the surface or the local face nodal or face temperature of a given cell or element. These correlations are usually obtained based on average surface temperatures. Therefore, they may not be applicable to a surface where the local temperature is varying with location and flow regime (laminar, transitional, or turbulent). Appropriate correlations may exist in the literature that depend on both the location and Rayleigh number but their application to the considered geometry must be fully justified. One approach to demonstrate the adequacy of the predicted heat transfer coefficients will be to model the ambient. If this approach is used, the location of the boundary should be sufficiently far from the external surfaces to avoid any nonphysical effect on the cask heat transfer characteristics. Also, the mesh close to the surface should be sufficiently fine to properly capture the heat transfer and to follow the specific guidelines for the selected turbulence model.

This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

Response:

The methodology used to evaluate the convection heat transfer from the outer surfaces of the TN-32B HBU cask is based on the benchmarking evaluations performed for the TN-24P cask.

As described in Part 3 (TN-24 Benchmarking Model) of [6.9-1], the temperatures determined using an ANSYS® model of the TN-24P cask were compared to the temperatures recorded during the TN-24P cask thermal test performed by Pacific Northwest National Laboratories to validate the methodology used in the thermal model.

The correlations used to determine the heat transfer coefficients for the ANSYS® model are listed in Part 3 (TN-24 Benchmarking Model), Section 3.4.1 of [6.9-1]. The ANSYS® macros used for applying the correlations to the thermal model are described in Part 3 (TN-24 Benchmarking Model), Appendix B of [6.9-1]. Using this methodology, the temperatures for the exterior surface of the cask are shown in Item "e" of Figure 5, Part 3 (TN-24 Benchmarking Model) of [6.9-1] for the vertical case. These results demonstrate that the temperatures predicted by the ANSYS® model are higher than the measured values for the vast majority of the cask outer surface. A similar behavior is also observed in Item "e" of Figure 6, Part 3 (TN-24 Benchmarking Model) of [6.9-1] for the horizontal case.

This thermal test demonstrates that the correlations and methodology used to determine the heat transfer coefficients in the ANSYS® model result in a conservative estimate of the temperatures on the outer surface of the TN-24 cask. Since the TN-32B HBU and the TN-24P casks are similar, and the methodology and correlations used for the TN-32B HBU cask are similar to those used in the benchmarking evaluation of the TN-24P cask, the temperatures predicted for the TN-32B HBU cask are conservative.

References

6.9-1 Transnuclear, Inc., Calculation, "TN-24P Benchmarking Analyses Using ANSYS®," Transnuclear Calculation No. NUH32PT.0408, Revision 0, provided to USNRC in TN Letter NUH03-03-04, dated January 24, 2003, "Response to Request for Additional Information (RAI) and Submittal of Revision 4 of Application for Amendment No. 5 to the NUHOMS® Certificate of Compliance No. 1004 (TAC NO. L23343)," Docket No. 72-1004.

10. Obtain the analysis discretization error for the normal conditions of storage by calculating the grid convergence index (GCI) following the procedure described in American Society of Mechanical Engineers Verification and Validation 20-2009 (ASME V&V 20-2009), "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer."

    The licensee presents the TN-32B HBU cask maximum component temperatures for normal storage conditions. However, the LAR does not provide the analysis discretization error or adequate validation for the analytical methods used in the evaluations. The licensee needs to obtain this error so the staff can verify the adequacy of the results. Also, due to the predicted small margin in the radial neutron shield, discretization error should also be obtained for this region.

    This information is needed to determine compliance with 10 CFR 72.122 and 72.128.

Response:

Using the procedure outlined in the ASME V&V 20-2009 [6.10-1], a grid convergence study has been performed for the TN-32B HBU cask ANSYS finite element model. Due to the small margin to the temperature limit for the radial neutron shield, the grid convergence index (GCI) and the discretization error for the normal conditions of storage are obtained for this component as described in [6.10-2]. Reference calculation [6.10-2] will be submitted to the NRC under a separate cover letter due to proprietary information concerns.

Based on the calculation in [6.10-2], the variation in the average temperature of the radial neutron shield is insignificant (less than 0.5°F) due to mesh refinement from the design basis cask model with 0.4 million elements to the fine mesh cask model with 3.5 million elements. As seen from Table 1 of [6.10-2], the GCI is 0.07% and the maximum discretization error is ±0.20°F. The maximum discretization error is smaller than the predicted margin of 6°F for the radial neutron shield. Therefore, the thermal evaluation presented in the LAR remains valid and the thermal performance of the radial neutron shield is acceptable.

<u>References</u>

6.10-1 American Society of Mechanical Engineers, "Standard for Verification and Validation in Computational Fluid Dynamics and Heat Transfer," ASME V&V 20-2009, November 30th, 2009.

6.10-2 AREVA TN Calculation, "Grid Convergence Study of TN-32B HBU Cask ANSYS Model for Normal Conditions of Storage," Calculation No. 19885-0409, Revision 0.

Chapter 7 – Shielding Evaluation

1. Provide the basis for choosing 6 hours per evolution, and how many staff hours is required (number of staff *time) for the cask loading.

   Table 4.4-1 of the DLBD (Design/ Licensing Basis Document, DOCUMENT NUMBER: E-42038) states that six hours is the time needed for cask loading from the pool. There is no documentation provided to justify the estimated time required for cask loading, particularly with consideration of the installation of the lances and poison rod assemblies.

   This information is needed to determine the TN-32B HBU cask design compliance with 10 CFR 72.126.

   Response:

   The six man-hours for loading a cask was determined by current scheduling and past experience for loading a 32 fuel assembly cask, two operators for a three-hour evolution. The cask loading evolution in Table 4.4-1 is limited to loading the cask with 32 fuel assemblies. The installation of PRAs into their host fuel assemblies is completed prior to the start of the loading campaign. The installation of the thermocouple lances is noted in Table 4.4-1 as a separate evolution. Additional clarification will be added to the revised DLBD to account for the installation of seven funnel guides into their host fuel assemblies. Nevertheless, since the installation of the funnel guides is expected to be a short duration evolution in a low dose-rate area, the dose impact is expected to be small.

2. Check and correct, if necessary, the dose rates reported in tables 4.4-2, 4.3-1, and 4.3-2 of the DLBD and revise the expected dose for occupational workers per the requirement of 10 CFR 72.126.

   Table 4.4-2 stated that the estimated dose rates for gamma is 0.5 mrem/hr, and for neutron is 0.5 mrem/hr during cask loading. However, the average dose rates for normal/off normal and accident conditions in tables 4.3.1 and 4.3.2 are much higher than that of table 4.4-2. The applicant needs to cross check the numbers in these tables and make corrections if necessary to the data and expected dose to the occupational workers.

   This information is needed to determine the TN-32B HBU cask design compliance with 10 CFR 72.126.

   Response:

   The first item in Table 4.4-2 of the DLBD labeled as "Cask Loading (pool) (low dose evaluation-dose rate over pool is about 1 mrem/hr)" applies to the operation of loading the fuel assemblies into the TN-32B HBU cask. The dose rate reported, about 1 mrem/hr, is an estimated "background" dose rate that would be over the pool, see Table 4.4-1. The estimated 1 mrem/hr

"background" dose rate over the pool is broken down equally to 0.5 mrem/hr due to gamma and 0.5 mrem/hr due to neutron in Table 4.4-2.

The hourly average of the rad monitor on the bridge crane over the spent fuel pool at North Anna Nuclear Generating Station indicates a reading that is typically below 0.5 mrem/hr (gamma-only).

3. Explain why the dose rates under normal/off normal conditions are higher than the dose rates under accident conditions.

   Referring to tables 4.3-1 and 4.3-2 of the DLBD for normal/ off normal and accident conditions respectively, the dose rates for the side surface above the shield seem to be higher under normal conditions than the cask under accident conditions. This seems to be inconsistent with the assumptions made in the safety analyses that the cask will lose the neutron shield under accident conditions. However, there is no explanation for this unusual result.

   This information is needed to determine ISFSI design with the addition of the TN-32B HBU cask compliance with 10 CFR 72.104 (a), 10 CFR 72.106 (b), and 72.126.

Response:

Table 4.3-1 and Table 4.3-2 of the DLBD provide the dose rates at different locations during normal/off normal conditions and during accident conditions, respectively.

For accident conditions, the protective cover, top neutron shield and the radial neutron shield are not credited in the analysis. The dose rates at the protective cover, the top neutron shield, and the radial neutron shield are expected to be substantially higher in accident conditions compared to those in normal/off normal conditions; this conclusion is shown in Table 4.3-1 and Table 4.3-2 for:

- **Side Surface along shield,**
- **Top Surface (protective cover)**
- **Side Surface including above and below radial neutron shield,**
- **1-meter from Side,**
- **2-meter from Side.**

The average dose rates at the Side Surface above the shield, below the shield and at the Bottom Surface are expected to be similar between normal/off normal conditions and accident conditions since these locations are not affected by the accident conditions. The differences in dose rates from the two tables are due to the MCNP computational convergence of the two cases.

Table 4.3-2 of the DLBD will be revised to remove the average dose rates at the Side Surface above the shield, below the shield and at the Bottom Surface in accident conditions since they appear to be redundant and confusing with

those in Table 4.3-1. The DLBD will be sent to the NRC under a separate cover letter due to proprietary information concerns.

4. Provide a justification for using the annual dose at 500 meters from the cask pad as the annual dose rate at the site boundary. In addition, provide the actual distance between ISFSI and the site controlled area boundary and an explanation for not estimating the dose rates at the actual boundary of the ISFSI or the annual dose at 500 meters bounds the controlled area boundary.

   In the radiological protection section and the Far Field section of the DLBD, dose rate estimation at a distance of 500 meters is selected for dose rate at the boundary. But, the applicant provided no information on bases for this determination. The applicant needs to provide information on the estimated annual dose at the controlled area boundary resulting from the addition of the TN-32B HBU cask.

   This information is needed to determine ISFSI design with the addition of the TN-32B HBU cask compliance with 10 CFR 72.104 and 10 CFR 72.106.

   Response:

   As described in the North Anna ISFSI SAR, the minimum distance to the controlled area boundary from the ISFSI is approximately 2500 feet (762 meters) and occurs in the southwest sector relative to the ISFSI. The 500 meter distance used in the dose analysis is conservative relative to the controlled area boundary.

   Dominion Calculation PA-0243, Revision 0, Addendum C, analyzes the impact to the ISFSI dose rate as a result of emplacing the TN-32B HBU cask on the North Anna ISFSI pad. This calculation concludes that for dose rates beyond 300 meters the TN-32B HBU cask is bounded by the current analysis of a TN-32 cask at North Anna. Therefore, no changes need to be made to the site boundary dose rate as a result of the TN-32B HBU cask.

   Dominion Calculation, PA-0243, Revision 0, Addendum C is provided in Attachment 2.

5. Provide documentation or a reference for the site boundary dose rates.

   In the conclusion of the radiological protection section of the application document 15-369, the applicant states that "an evaluation performed by Dominion that demonstrated the site boundary annual dose is not increased with the TN 32B HBU cask installed at the NAPS ISFSI". The applicant needs to provide the documentation or a reference to the document that provides information for the calculations of the site boundary dose.

   This information is needed to determine ISFSI design with the addition of the TN-32B HBU cask compliance with 10 CFR 72.104.and 10 CFR 72.106.

   Response: See response to Question #4.

6. Provide the locations at which high dose rates are expected with the corresponding dose rate values and revise, if necessary, the calculated values of the expected doses under radiation protection chapter.

   On page 11 of document Serial No. 15-369, the applicant provides the calculated average dose rates at the side and top of the TN-32B HBU cask and used that for calculations of the expected dose for occupational workers performing the cask loading and installation operations. To get a reliable estimate of the expected dose for these operations, it is imperative to clearly understand the actual dose rates at various locations of the cask and identify hot spots rather than only an average dose rate. For example, based on the information in the document number E-42038, the applicant did not model the penetration explicitly. Given that the cask has two thick steel layers for shielding gammas and one thick borated resin layer for shielding neutrons, it is conceivable that these penetrations will significantly alter the gamma and particularly the neutron shielding at the cask top. In addition, considering the fact that the cask will be loaded with much hotter fuel (high burnup and shorter cooling time), the staff is concerned if these through-cuts of the neutron and gamma shields will provide streaming paths and create hot spots at the top of the cask lid, especially for neutron radiation. The applicant needs to provide a calculation for the dose rate at the top of the cask or a justification that the through-cuts of the neutron shields and gamma shield will not significantly impact the dose rates at the top of the cask where a significant amount of operations will be performed by the workers.

   This information is needed to determine the TN-32B HBU cask design compliance with 10 CFR 72.126.

   Response:

   The locations at which the highest dose rates are expected to occur are centered directly above the seven penetrations of the TN-32B HBU cask lid. The maximum dose rates above the seven penetrations are discussed below. All penetrations were modeled without the steel shield plugs installed and without the top lid borated resin neutron shield installed. The thermocouple

closure assembly, wires, and funnel were explicitly modeled. The water level was modeled as being equal to the top of the top nozzle.

The maximum total dose rate at 10 inches above the surface of the lid and centered above the penetrations is 4.14 Rem/hr with a top lid surface averaged total dose rate of 0.455 Rem/hr.

Since the penetrations are located only on the top lid of the TN-32B HBU cask and not on other surfaces of the cask, notable hot spots are isolated to the top lid only.

During installation of the thermocouple lances, the borated resin neutron shield is not present and the cask is considered 'wet' with water fully covering the fuel assemblies. The 'wet' condition of the cask provides adequate neutron shielding even with the borated neutron shield not installed. However, for the 'wet' configuration, the dose rate on the top lid is dominated by gamma radiation. Therefore, the top lid penetrations have no major impact on neutron dose rates but have a noticeable impact on the gamma dose rates since the lid penetrations provide a streaming path for gamma radiation. This impact on gamma dose rates is isolated to directly above the lid penetrations since the geometry of the lid penetrations create a columniation effect for gamma radiation. Workers are likely to place their hands near the penetrations while placing their torso on the non-penetrated portions of the lid. Therefore, the most likely full body dose rate to the worker is the top lid surface averaged dose rate of 0.455 Rem/hr, with exposure to the hands of 4.14 Rem/hr.

Operational techniques will be implemented to reduce the exposure time and increase the distance from these lid penetrations in order to maintain As Low As Reasonably Achievable (ALARA).

7. Provide justification for not evaluating potential operational difficulties during cask loading in estimation of dose rates received by the occupational workers.

   On page 12 of document Serial No. 15-369, the applicant discusses radiation protection during cask loading operation. However, the applicant did not provide evaluation for the cases in which potential operational difficulties may occur or proper justifications for not considering any potential operational difficulties given that this is a very unique cask design with the installation of the instrumentation and lances.

   This information is needed to determine the TN-32B HBU cask design compliance with 10 CFR 72.126.

   Response:

   The operations associated with the TN-32B HBU cask that are atypical will be addressed during pre-operational fit up testing conducted offsite prior to the

TN-32B cask arriving at North Anna. The use of fit-up testing provides a non-radiological environment to determine the best methods and practices for conducting atypical operations and significantly reduces the potential for operational difficulties when loading the TN-32B HBU cask at North Anna. Contingency measures will be developed during the fit-up testing and hands-on activities and will be included into the specific site loading procedure that will be developed for the TN-32B HBU cask.

Chapter 8 –Criticality Evaluation

1. Provide the name or material composition, the material density of the cladding material of poison rods, the material density of the B4C, and revise Table 5.1-1 of the DLBD to include this information.

   The applicant states in the safety analysis report (SAR) for the North Anna ISFSI amendment request dated August 24, 2015, that poison rod assemblies are used in the TN- 32B HBU cask for criticality safety control. Table 5.1-1 of the DLBD provides information on the poison rods, material composition of the poison, and geometric dimensions of the rods. However, the SAR does not include information on the material composition and density for the poison rod assembly cladding material and the B4C material density.

   This information is needed to determine compliance with 10 CFR 72.126.

   Response:

   Dominion Letter Serial Number 15-369F dated November 19, 2015 provides the material composition and material density of the poison pellet material density. The material composition is B_4C with a theoretical material density of 2.52 g/cc (0.08816 g/cm B-10) as provided in AREVA TN document E-43839, Rev. 0. The analyzed B_4C content is 1.26 g/cc (50% credit of B_4C theoretical density).

   The material of the poison rod cladding is M5® with a density of 6.5 g/cm^3. The analyzed PRA cladding material is stainless steel with a density of 7.94 g/cm^3. Experience in modeling these cladding material types has shown that the difference in the results between using stainless steel and M5® cladding is small. When developing the criticality model, undocumented sensitivity studies showed that cases using stainless steel cladding are slightly more reactive than cases using zirconium based cladding, such as M5® cladding. Thus, stainless steel cladding was selected for the criticality analysis for conservatism. The small differences between these two cladding types are well within the 50% credit allowance used in the analysis.

   Table 5.1-1 of the DLBD is updated below. A revision to the DLBD will be sent to the NRC under a separate cover letter due to proprietary information.

DLBD Table 5.1-1 and Note

Table 5.1-1 - PRA Design Values for Criticality Control

Design Parameter	Design Value
Number of PRAs	6
PRA Locations	See Figure 5.1-1
Number of Poison Rods per PRA	24
Poison Pellet Diameter	0.295 inch
Poison Pellet Material	B_4C
Poison Pellet Material Theoretical Density	2.52 g/cm^3
Credit Taken per PRA	50% (1)
Poison Rod Clad Material	M5® (2)
Poison Rod Diameter	0.374 inch
Poison Rod Clad Thickness	0.0225 inch
Poison Rod Clad Density	6.5 g/cm^3 (2)

Note: 1. Analyzed B_4C with 1.26 g/cm^3 density
2. Analyzed as stainless steel with a density of 7.94 g/cm^3

Chapter 9 – Confinement Evaluation

1. Provide updated figures and drawings for the thermocouple lance assembly and penetrations in the modified TN-32B lid.

   The figures and drawings presented in the LAR as not of sufficient quality and detail needed for evaluation. The requested drawings and figures update should include clear details of the sealing location, bolting patterns, and any welds that are necessary to make the lid modification. Preferable figures would include 3D renderings of the assembly and seal region; however, 2D drawings and figures are acceptable provided they include the level of detail requested and are of sufficient quality. The 2D drawings and figures should include a side or elevation view, a top view, as well as detail callouts for areas such as the seal location.

   This information is needed to determine compliance with 10 CFR 72.24(c)(3) and 10 CFR 72.122(h)(1).

   Response:

   The additional drawings for the thermocouple lance assembly and penetrations were provided to the NRC in Dominion Letter Serial No. 15-369H on January 14, 2016. The drawing numbers for this information are 02-8076669D-001 and 02-8076670D-000.

2. Justify the difference in the durations reported in Table 6.3-3 of the DLBD for the estimated time to exceed dose limits of 10 CFR 72.106 and those reported in the TN-32 UFSAR.

   Inspection of the latent seal leak calculations provided in the TN-32 UFSAR and supporting documents for this LAR illustrate that durations for time to alarm and time to loss of Over Pressuring system pressures are similar for both the TN-32 and TN-32B, as expected. In the accident conditions scenario, the time to exceed dose limits of 10 CFR 72.106, was significantly longer for the TN-32B[s] than for the TN-32 for each of the representative leak rates provided. Staff is unclear as to why this would be the case given the similarities of the two casks.

   This information is necessary to demonstrate compliance with 10 CFR 72.24(c)(3) and 10 CFR 72.122(h)(1).

   Response:

   The accident conditions analysis for the TN-32B cask is performed at a bounding distance to the controlled area boundary from the ISFSI. Section 2.1.2 of North Anna ISFSI SAR indicates the minimum distance to the controlled area boundary from the ISFSI is approximately 2500 feet, which is 762m. The accident conditions analysis for the TN-32B HBU cask is performed at 500m which is bounding compared to 762m at North Anna.

   The times to exceed dose limits of 10 CFR 72.106 in Table 6.3-3 of the DLBD are calculated using the total effective dose under hypothetical accident condition at 500m.

   The times to exceed dose limits of 10 CFR 72.106 in Section 7.3.3 of TN-32 UFSAR are calculated using the total effective dose under hypothetical accident condition at 100m.

   The existing TN-32 casks were evaluated with a more limiting nuclide inventory than that evaluated for the TN-32B HBU cask. Therefore, the 100m accident dose analysis will bound that for the TN-32B HBU cask at 100m. See Question 3 response for additional details.

3. Provide a verification that the radionuclide release concentrations in Table 6.2-3 are bounding.

   It is not clear to the NRC staff how the multiple fuel assemblies with various burnup and cooling time in Table 6.2-1 were translated into the single set isotope inventory. The supporting documentation does not indicate whether a bounding assembly was used to generate the data in Table 6.2-3.

   This information is necessary to demonstrate compliance with 10 CFR 72.24(c)(3) and 10 CFR 72.122(h)(1).

Response:

The radionuclide release concentrations for Off-Normal and Accident Conditions presented in Table 6.2-3 of the DLBD are the combined release concentrations from all the fuel assemblies shown in Table 6.2-1. As described in Section 6.2 of the DLBD, the radionuclide inventory contained within the TN-32B HBU cask was modeled with the depletion-decay module, ORIGEN-ARP, in the SCALE Computer Code sequence. The radionuclide inventories were developed using the realistic parameters for the fuel assemblies that will be stored in the TN-32B HBU cask. Utilizing these realistic parameters, the fuel inventory off-normal and accident releases were all calculated with release fractions specified in Table 5-2 of the Standard Review Plan, and are reiterated in Table 6.2-2 of the DLBD. The radionuclide inventory in an existing TN-32 cask bounds the nuclide inventory in the TN-32B HBU cask.

Note that fuel assembly F52 in Table 6.2-1 has been replaced by fuel assembly F40 in the fuel selection for loading in TN-32B HBU cask. However, the analysis performed which included fuel assembly F52 remains valid since the radionuclide inventory for assembly F52 bounds that for assembly F40.

Chapter 10 – Materials Evaluation

1. Provide a revised SAR for the North Anna ISFSI accounting for the proposed amendment, which defines and includes all applicable revisions of the drawings to the TN-32B demonstration cask. Provide a list of drawings changes from those previously approved for the TN-32 cask in the TN-32 FSAR, Rev. 2 (with clear mapping to where the changes were made from the approved TN-32 drawings, e.g. Change XXX in Section A-8 of Drawing YYY). Provide a copy of the TN-32 FSAR, Rev. 2, which should include the approved drawings for the TN-32 cask to which changes were made.

   Drawings in the LAR (Document No. E-42038) are not legible. In addition, all drawings pertinent to the revised TN-32 design were not submitted in the LAR. For example, Drawing 19885-30-1, Rev. 0, "TN-32 HBU Demonstration Cask Assembly and Parts List" (dated 5-29-15) was unofficially submitted to the staff in an external shared site but was not included in the LAR. This appears to be an alternate version of Drawing 19885-70-1, "TN-32B HBU Demonstration Cask General Arrangement" (dated 6/8/15), which was submitted in the LAR but is not legible. As another example, there appears to be two different drawings for the cask lid: Drawing 19885-70-3, Sheets 1-3, Rev. 0, "TN-32B HBU Demonstration Cask Lid Assembly and Details" (dated 6/8/15, submitted in the LAR) and Drawing 19885-30-4, Rev. 0, Sheets 1-4, "TN-32B HBU Demonstration Cask Lid Assembly and Parts List" (dated 5/31/15 and unofficially submitted to the staff in an external shared site). It appears that there are two sets of applicable drawings for the amendment, namely 19885-70-X series and 19885-30-X series. The staff is unclear what set of drawings is applicable to the amendment. The staff cannot complete the review until all drawings pertinent to the amendment are clearly submitted and properly referenced (and included) in the revised North Anna ISFSI SAR. The drawings must be clear and legible.

The staff further notes that it cannot complete the review of the modifications to the cask protective cover until it receives applicable legible drawings (identified as Drawing 19885-30-07, Sheets 1-3 in the LAR).

In addition, Drawing 02-8076670D, referenced in Drawing No. 19885-30-4 was not submitted in the LAR, which is needed to verify the material composition of the thermocouple lance assembly, weld requirements for the two seals welds at the closure flange and the metallic seals used in the lance assembly.

The LAR further identified changes to the top neutron shield elevation and the external shell of the cask bod[y]; changes that are unclear in which specific drawings are located.

This information is needed to determine compliance with 10 CFR 72.11(a) and 72.24.

Response:

The response to this question is broken up into several parts to fully answer all facets of the question.

<u>Changes to the North Anna ISFSI Safety Analysis Report</u>

The preliminary changes to the North Anna ISFSI Safety Analysis Report for the TN-32B HBU cask are provided in draft form in Attachment 3. The draft changes to the SAR may be altered in the future to comply with any new NRC requirements or conditions and limitations.

<u>List of drawing changes from TN-32 UFSAR, Rev. 2</u>

All drawings specific to the TN-32B HBU Cask were issued <u>after</u> Revision 2 of the TN-32 UFSAR was issued in April 2002. Revision 2 of the TN-32 UFSAR was in effect when the TN-32B cask was built in 2003. Drawings that have a prefix of "19885" were specifically issued for the TN32B HBU cask. All other drawings for the TN-32B cask would have been governed by Revision 2 of the TN-32 UFSAR.

The following drawings have been issued since the initial LAR was submitted on August 24, 2015. These drawings will be sent to the NRC under a separate cover letter as they are proprietary:

- **19885-30-4, Rev. 1, "Downgraded Safety Class of OP Tubing Quick Connects," issued on January 5, 2016.**
- **19885-70-4, Rev.0B, "Welding Details for Protective Cover Access Port," issued on January 7, 2016.**

Copy of TN-32 UFSAR, Rev. 2

The TN-32 UFSAR, Revision 6 was provided to the NRC on April 16, 2014 in AREVA letter E-37965 (Adams Accession No. ML14108AD25). The TN-32 UFSAR, Revision 2 was provided to the NRC on April 19, 2002 via letter E-19479. The TN-32 UFSAR is provided to the NRC for their use on the Dominion SharePoint site and in Attachment 4 of this RAI response.

Drawings in the License Amendment Request (Document No. E-42038)

The highest quality drawings used in support of the TN-32B HBU cask have been loaded onto the Dominion SharePoint site. Printing and scanning of these documents reduces the quality of the paper submittals submitted to the NRC document control desk. The image quality may be further diminished with additional scanning or copying. Use of the SharePoint site is recommended for images that may have been unclear in the paper copy.

The following drawings have been uploaded to the Dominion SharePoint site and submitted to the NRC:

Drawing #	Drawing Title	Dominion S/N Letter	Date Sent to NRC
19885-70-1	TN-32B HBU Demonstration Cask General Arrangement	15-369	August 24, 2015
19885-70-2	TN-32B HBU Demonstration Cask General Arrangement Cross Section and Details	15-369	August 24, 2015
19885-70-3	TN-32B HBU Demonstration Cask Lid Assembly and Details	15-369	August 24, 2015
19885-70-4	TN-32B HBU Demonstration Cask Protective Cover	15-369	August 24, 2015
19885-70-7	TN-32B HBU Demonstration Cask Overpressure System Arrangement	15-369	August 24, 2015
19885-70-8	TN-32B HBU Demonstration Cask Top Neutron Shield	15-369	August 24, 2015
19885-70-9	TN-32B HBU Demonstration Cask Loading Pattern and Details	15-369	August 24, 2015
19885-30-1	TN-32B HBU Demonstration Cask Assembly & Parts List	15-369G	Dec. 28, 2015
19885-30-2	TN-32B HBU Demonstration Cask Shell Assembly	15-369G	Dec. 28, 2015
19885-30-3	TN-32B HBU Demonstration Cask Shell Details and Parts List	15-369G	Dec. 28, 2015
19885-30-4	TN-32B HBU Demonstration Cask Lid Assembly and Parts List	15-369G	Dec. 28, 2015

Drawing #	Drawing Title	Dominion S/N Letter	Date Sent to NRC
19885-30-8	TN-32B HBU Demonstration Cask Lid Bolt and Washer	15-369G	Dec. 28, 2015
02-8076669D-001	HBU Storage Cask Closure	15-369H	Jan. 14, 2016
02-8076670D-000	HBU Cask Lance Assembly	15-369H	Jan. 14, 2016

Regarding the difference between the 19885-70-X series drawings and the 19885-30-X series drawings, the 19885-70-X series drawings are designed for licensing applications and generally provide more of an outline or summaries as necessary to obtain regulatory design approval. The 19885-30-X series drawings are AREVA-TN internal design drawings that are used to provide more specific dimensional and detail information that would be needed for fabrication and manufacturing. Thus, the 70-X series drawings provide a high level overview, and the 30-X series drawings provide more detailed information.

Drawing 19885-30-7 will be submitted to the NRC under a separate letter as it is proprietary.

Drawing 02-8076670D was provided to the NRC in Dominion Letter S/N 15-369H, dated January 14, 2016.

Drawings 19885-30-4, Rev. 1 and 19885-70-4, Rev. 0B will be submitted to the NRC under a separate letter as these drawings are proprietary.

All other pertinent licensing drawings for the TN-32B HBU Cask Demonstration project have been submitted to the NRC and uploaded to the Dominion SharePoint site.

<u>Changes to the top neutron shield elevation and the external shell of the cask body</u>

The changes to the top neutron shield are provided on drawing 19885-70-8, which are as follows:

- The addition of (4) 1-inch thick, 3" OD × 1.38" ID steel plates welded over the (4) 1¼ Schedule 40 pipes on the inside surface (detail 3), and (4) 1" × 1" × 1" bars welded below the OP tank supports on the inside surface (Section A-A). These items raise the top neutron shield 1 inch to allow space for the routing of cables and OP tubing from the thermocouple lance assemblies.
- The addition of a removable 10.0" diameter access plug (Section C-C) that allows access to the vent port on the lid after assembly.

The changes to the external shell of the cask body are identified on drawing 19885-30-2, Item 32. Details of Item 32 may be found on drawing 19885-30-3. The changes are attachments for the impact limiters that will be used for future transportation.

2. Revise the LAR to justify that Section 3.3.4 of the TN-32 SAR, Rev. 2 remains valid for the revised HBU fuel content.

   Section 3.3.4 of the TN-32 SAR, Rev. 6 states that gamma radiation has no significant effect on metals, and the effect of fast neutron irradiation is insignificant below 10^{17} n/cm^2. The design-bases fuel for the TN-32 SAR, Rev. 2 resulted in an integrated fast neutron flux in the range of 10^{17} n/cm^2. The LAR should adequately justify that the integrated fast neutron flux for the TN-32B is bounded by the analysis in Section 3.3.4 of the TN-32 SAR, Rev. 2. The justification should be included in the revised SAR for the North Anna ISFSI requested in RAI 1.

   This information is needed to determine compliance with 10 CFR 72.24.

   Response:

   A material time-limited aging analysis performed using a neutron source term over three times stronger than the highest neutron source in the TN-32B HBU cask confirms that the TN-32 SAR, Rev. 2 statement that the integrated fast neutron flux is in the range of 10^{17} n/cm^2 is bounding.

   The analysis is performed with a source term corresponding to 62 GWd/MTU, 3.4 wt% initial enrichment, and 3 year cooling time for a design basis fuel loading of 490 kgU. The calculated maximum neutron fluence integrated over 100 years in the compartment stainless steel is 7.59×10^{15} n/cm^2; therefore, the analysis in Section 3.3.4 of the TN-32 SAR, Rev. 2 is still valid.

   Note that the 100-year neutron fluence on the compartment stainless steel, using conservative source term, is well below the threshold level of neutron fluence of 1×10^{18} n/cm^2 cited for alteration of reinforcing steel mechanical properties, as indicated in Section 4.3.2.3 of NUREG/CR-6927, "Primer on Durability of Nuclear Power Plant Reinforced Concrete Structures – A review of Pertinent Factors."

   Gamma radiation has no significant effect on metals.

   The DLBD will be revised to incorporate the material time-limited aging analysis and state the neutron fluence for the TN-32B HBU cask is bounded by the analysis in Section 3.3.4 of the TN-32 SAR, Rev. 2. The revised DLBD will be sent to the NRC under separate cover letter due to proprietary information concerns.

3. Regarding progressive liquid penetrant (PT) or magnetic particle non-destructive examination, revise the LAR to justify that as low as reasonably achievable (ALARA) principles will be followed and clarify provisions for correcting weld defects or any additional drying and purging that may be necessary.

   The application requested the alternative use of progressive PT examination for the partial penetration welds attaching the thermocouple lance penetration sleeves to the lid. The guidance in NUREG-1536, Rev. 1, states that the alternative may be accepted if a stress-reduction-factor of 0.8 is imposed on the weld strength. The staff verified that the applicant properly identified the reduction factor in the Design Requirements in Section 4.0 of Specification 19885-0101. However, NUREG-1536, Rev. 1 further states that the SAR should also ensure ALARA principles are followed and include acceptable provisions for correcting weld defects and any additional drying and purging that may be necessary. The application should be revised to clarify if these considerations are applicable to the lid fabrication, and if so, properly address them in the LAR and the revised North Anna ISFSI SAR.

   This information is needed to determine compliance with 10 CFR 72.24.

   Response:

   Progressive liquid penetrant (PT) and magnetic particle (MT) non-destructive examinations (NDE) will not be performed on site at North Anna. The majority of the work on the TN-32B HBU cask will be performed offsite at the fabricator's facility in a non-radioactive area. At North Anna, ALARA principles will be utilized in accordance with all applicable station health physics procedures in order to minimize dose exposure.

Chapter 11 – Conduct of Operations Evaluation

1. Clarify why an evaluation for conduct of operation is not provided in the NAPS ISFSI LAR.

   Document with identification number E-42038 includes the evaluation for different areas or disciplines. However, the licensee did not provide an evaluation for Conduct of Operations. The licensee needs to provide adequate justification why this evaluation was not provided as part of the LAR.

   This information is needed to determine compliance with 10 CFR 72.24.

   Response:

   The TN-32B HBU cask is similar to the existing TN-32 casks stored on Pad 1 of the North Anna ISFSI. It was determined that there are no impacts to the existing conduct of operations as a result of the TN-32B HBU cask license amendment request (LAR) due to the similarities of the TN-32B and TN-32 casks. For this reason, an evaluation on the conduct of operations was not provided.

Chapter 9 of the North Anna ISFSI Safety Analysis Report (SAR) discusses the conduct of operation. This includes discussion on the organizational structure, startup testing and operation, training program, normal operations, emergency planning, and the physical security plan. The small differences between the TN-32B HBU cask and the TN-32 casks already loaded and stored on Pad 1 at the North Anna ISFSI do not impact the conduct of operations as described in Chapter 9 of the North Anna ISFSI SAR.

ENVIRONMENTAL REVIEW

1. Dominion is requesting an amendment to materials license number SNM-2507 for the NAPS ISFSI. The amendment requests changes to the Technical Specification to use a modified TN-32B cask (TN-32B HBU cask) to store high burnup spent fuel from North Anna Units 1 and 2. The TN-32B HBU cask will be modified to insert thermocouples through the cask lid and into the fuel assemblies to monitor fuel temperatures in the cask. Please provide information regarding additional changes to (i) routine operations or maintenance activities and (ii) land-disturbance as a result of this license amendment request, if any are anticipated.

   This information is needed to determine compliance with 10 CFR 51.30.

   Response:

   The only change to routine operations or maintenance activities is downloading data from the data logger on a quarterly basis. Otherwise there are no changes to routine operations or maintenance activities. Operations staff will download data from the data logger on a quarterly basis as indicated in Section 4.4 of the DLBD (E-42038). It is anticipated that data retrieval will be performed during the quarterly ISFSI inspection, so additional unscheduled entries into the ISFSI area are not planned as a result of adding the TN-32 HBU cask to the pad.

   When loading the TN-32B HBU cask in the decontamination bay at North Anna, there will be two new activities for the TN-32B HBU Cask. These activities are the installation of the seven thermocouple lances and obtaining a cavity gas sample as described on page 13 of the LAR and Section 4.4 of the DLBD (E-42038).

   There are no changes to land-disturbance as a result of this license amendment request. Currently, NAPS has twenty-seven TN-32 casks on Pad 1 at the North Anna ISFSI. The TN-32B HBU Cask will be emplaced at the NAPS specifically licensed ISFSI on the single remaining vacant Pad 1 location. All previous analyses for Pad 1 of the North Anna ISFSI assumed 28 TN-32 casks were already present.

2. Identify applicable regulatory requirements and permits (federal, state, or local) necessary to carry out the proposed action. The information provided should identity the issuing agency, describe the type of license, permit or approval needed, and provide the status of securing the license, permit or approval.

   This information is needed to determine compliance with 10 CFR 51.30.

   Response:

   No additional regulatory requirements or permits are necessary to carry out the proposed action other than what has been submitted in the license amendment request.

   The North Anna ISFSI is subject to periodic renewal of a Louisa County Conditional Use Permit (CUP). Adding the TN-32 HBU cask to the ISFSI does not affect the CUP.

3. In the environmental report that Dominion submitted on October 8, 2015, Dominion explains that "AREVA, Inc. performed a complete cask analysis, including thermal and criticality assessments," "cask/fuel components analyzed included: outer surface, radial neutron shield (resin/aluminum), seal/lid, fuel compartment, and fuel cladding," and concluded that the "material limits for the TN-32B HBU cask are not exceeded." It is not clear that the AREVA, Inc. analysis referenced in the environmental report is the same analysis discussed in the license amendment request dated August 24, 2015, which includes a criticality evaluation, radiological protection, accident evaluation, occupational exposures, thermal evaluation, and structural evaluation. Please confirm that this is the same analysis or provide the AREVA, Inc. analyses referenced in the environmental report.

   In the environmental report Dominion also explains that storage of high burnup fuel assemblies in the TN-32B HBU cask "has no effect on the analysis of record for offsite dose at the site boundaries" and that the "the analysis of record assumed the presence of 28 casks." In addition, Dominion states that "an analysis of dose at the site boundary that modeled the TN-32B HBU cask on Pad 1 with the resident casks" was re-performed and the analysis showed no changes to the analysis of record. Please, provide the analysis of record that is referenced in the environmental report and the analysis of dose that Dominion re-performed.

   This information is needed to determine compliance with 10 CFR 51.30.

   Response:

   The complete cask analysis referenced in both the original submittal (Dominion Letter Serial No. 15-369) and the environmental supplemental letter (Dominion Letter Serial No. 15-369A) is the same analysis. The complete cask analysis is provided in the Design and Licensing Basis Document (Attachment 4 of Dominion Letter Serial No. 15-369).

The current analysis of record for the offsite dose at the site boundary for Pad 1 of the North Anna ISFSI is Dominion Calculation PA-0243, Revision 0, including Addendum A and Addendum B. The offsite dose at the site boundary assumed the presence of 28 TN-32 casks.

Dominion Calculation PA-0243, Revision 0, Addendum C, assessed the impact of the TN-32B HBU Cask with the existing 27 TN-32 casks currently on Pad 1 of the North Anna ISFSI. This calculation determined that there is no change to the site boundary dose when the TN-32B HBU Cask replaces an assumed 28th TN-32 cask in the current analysis of record.

Dominion Calculation PA-0243, Revision 0 and all of its addenda are provided in Attachment 2 of this RAI response.

4. In the license amendment request Dominion submitted on August 24, 2015, Dominion explains that the current plan is to load the cask with high burnup spent fuel in July 2017 and place it on Pad 1 of the specifically-licensed ISFSI before the end of August 2017. Dominion further explains that the cask will remain at the site for approximately ten years and then will be shipped to a fuel examination facility for characterization of the fuel. Please, provide additional information about the transportation impacts (including, but not limited to, transportation mode, routes, destination, transportation cask, doses) of shipping the cask to an examination facility.

   This information is needed to determine compliance with 10 CFR 51.30.

   Response:

   Although the objective is to transport this cask to an examination facility in approximately 10 years, at this time, it is unknown exactly when or where the TN-32B HBU cask will be transported. In order to meet this latter objective, which is not being licensed with this particular amendment, coordination with the Department of Energy (DOE), the Electric Power Research Institute (EPRI), Dominion, and additional stakeholders will be needed to establish the licensed (or otherwise approved) examination facility and then seek NRC approval to make the shipment. Dominion will ensure that all necessary approvals are obtained, all necessary analyses performed (e.g. NEPA), and all permits acquired prior to transporting the cask offsite.

   To summarize, the overall purpose of this LAR is to request NRC approval for the storage of the TN-32B HBU cask on Pad 1 of the North Anna ISFSI. Transportation impacts will be fully addressed in accordance with the applicable sections of 10 CFR 71 prior to shipment.

5. Discuss any past, present, or reasonably foreseeable future actions which could result in cumulative impacts when combined with the proposed action. These future actions may be occurring on or near the NAPS specifically-licensed ISFSI.

Finally, the information the NRC uses to conduct and inform its NEPA environmental reviews, including the information in the environmental report, must be publicly available, as appropriate. Therefore, please ensure that the information included in response to these requests for additional information can be made publicly available.

This information is needed to determine compliance with 10 CFR 51.30.

Response:

The placement of the TN-32B HBU cask has no adverse impact on past or present activities at the North Anna ISFSI. As described in the environmental assessment provided in Dominion Letter Serial No. 15-369A, the North Anna ISFSI has been analyzed for storage of 28 TN-32 casks, but currently only contains 27 TN-32 casks. The metric tons of uranium (MTU) loading of the TN-32B HBU cask is within the currently approved ISFSI license limit, and the heat load has a negligible impact on other TN-32 casks currently located on Pad 1 of the North Anna ISFSI.

Activities for the foreseeable future at the North Anna ISFSI are renewal of the site-specific North Anna ISFSI license (SNM-2507), and a potential licensing action for gas sampling of the TN-32B HBU cask during the licensed storage period. The cumulative effect of these actions will be considered as necessary, during the licensing process, and will include consideration of the TN-32B HBU cask.

The TN-32B HBU Cask submittal will be in review by the NRC when the North Anna ISFSI license renewal application is submitted. Following approval of the TN-32B HBU Cask submittal, a separate supplemental letter will be submitted to the NRC to document the cumulative effects impact of the TN-32B HBU Cask to support the North Anna ISFSI license renewal application.

Serial No. 16-055
Docket No. 72-16

Attachment 3

Preliminary Changes to the North Anna ISFSI Safety Analysis Report

Attachment 3 provides the preliminary changes to the North Anna ISFSI Safety Analysis Report for the TN-32 HBU Cask Project in support of the response for RAI Chapter 10, Question 1. The preliminary changes to the SAR may be altered in the future to comply with NRC requirements or conditions and limitations.

North Anna Power Station ISFSI

Virginia Electric and Power Company

Change Number	Section Number/Page Number	Basis for Change
1	Section 3.1.1 / Page 3-1	Include a description of the fuel to be stored in the TN-32B HBU cask.
2	Section 3.1.1.1.2 / Page 3-2	Describe the method of calculating decay heat that will be used for the TN-32B HBU cask.
3	Section 3.3.3.2 / Page 3-6	Identify the thermocouple lances to be used on the TN-32B HBU cask as being a safety related instrumentation component.
4	Table 3-1 / Page 3-9	Table 3-1 was modified to reflect two SSSC's at the ISFSI and the characteristics of the fuel that may be loaded into each.
5	Table 3-3	This is a new table to identify the decay heat calculation to be used for the TN-32B HBU cask
6	Section 4.2.4 / Page 4-12	Identify the thermocouple lances to be used on the TN-32B HBU cask as being a safety related instrumentation component.
7	Section 5.1.1.1 / Page 5-2	Provide a brief descriptions on TN-32B HBU cask loading process changes which differ from the standard SSSC.
8	Section 5.1.3.2 / Page 5-3	Identify the thermocouple lances to be used on the TN-32B HBU cask as being a safety related instrumentation component.
9	Table 5-1 /Page 5-6	Footnote added to direct to Appendix A.2 for applicable TN-32B HBU cask information.
10	Table 5-2 /Page 5-7	Footnote added to direct to Appendix A.2 for applicable TN-32B HBU cask information.
11	Section 7.3.2.1 / Page 7-8	Provide reference for TN-32B HBU cask dose information.
12	Section 7.3.2.2 / Page 7-8	Provide reference for TN-32B HBU cask dose information.
13	Section 7.5 / Page 7-10	Insert information indicating no change to offsite dose as a result of the TN-32B HBU cask.
14	Table 7-2 / Page 7-13	Footnote added to direct to Appendix A.2 for applicable TN-32B HBU cask information.
15	Appendix A.2	Section of Appendix A to incorporate the TN-32B HBU cask as a SSSC

INSERTS

A.

The TN-32B HBU cask has been licensed to include fuel with an initial enrichment of 4.55 weight percent U235, burnup of 60,000 MWD/MTU, and a cooling time of 5 years.

B.

The TN-32B HBU cask has no impact on the dose estimates at distances greater than the site boundary.

C.

The TN-32B HBU cask has a modified loading process compared to the standard SSSC loadings. After the TN-32B HBU cask is moved into the north bay, thermocouples are installed into the lid of the TN-32B HBU cask. The thermocouples are then attached to a data logger to record the internal temperature of the cask. Following vacuum drying the TN-32B HBU cask will remain in the north bay for two weeks while temperature readings are taken from the thermocouples and gas samples are obtained from the cask cavity.

At the time the pressure monitor is connected to the TN-32B HBU cask at the ISFSI, the thermocouples will be connected to the data logging device and set to record data from the TN-32B HBU cask.

D.

Thermocouples used on the TN-32B HBU cask establish part of the confinement boundary and are therefore safety related components.

Chapter 3 PRINCIPAL SSSC DESIGN CRITERIA

This chapter describes the design criteria to be met by the SSSCs to be used in the North Anna ISFSI. Compliance with these criteria ensures that the North Anna ISFSI complies with the requirements of 10 CFR 72.

3.1 PURPOSES OF SSSC

A summary description of each SSSC approved for use at the North Anna ISFSI is provided in Appendix A. A detailed description of the approved SSSCs is provided in the Topical Safety Analysis Reports (TSAR) listed in Table A-1 of Appendix A.

3.1.1 Spent Fuel to Be Stored

The ISFSI is designed to accommodate a total of 84 SSSCs. However, the licensed spent fuel storage design capacity of the facility is 839.04 MTU. At approximately 0.46 metric tons of uranium (MTU) per fuel assembly, the facility can accommodate 1824 fuel assemblies under the current license.

The physical characteristics of the fuel to be stored in the ISFSI are described in detail in Section 4.2 of the North Anna Power Station UFSAR and are summarized in Table 3-1. An evaluation of the storage of burnable poison rod assemblies (BPRAs) and/or thimble plug devices (TPDs) with the fuel assemblies placed in SSSCs is provided in Appendix A for each cask design.

The fuel used during the first years of North Anna Power Station Units 1 and 2 operation had initial enrichments not exceeding 3.5 weight percent U^{235} and discharge burnup not exceeding 35,800 MWD/MTU. The North Anna Power Station has been authorized to operate with fuel with higher initial enrichment and higher burnup. The design basis fuel characteristics used in the analyses included in Chapters 7 and 8 include initial enrichment of 4.3 weight percent U^{235}, burnup of 45,000 MWD/MTU and a cooling time of 7 years. The radioactive characteristics of the design basis fuel are discussed in Section 7.2.

Insert A

3.1.1.1 Spent Fuel Characteristics

The following fuel assembly characteristics constitute limiting parameters for storage of fuel assemblies at the ISFSI:

- Initial Fuel Enrichment
- Fuel Burnup
- Heat Generation
- Decay time
- Spent Fuel Physical Configuration/Condition

3.1.1.1.1 Allowable Limits

The allowable limits for each of these characteristics are discussed below.

1. Initial Fuel Enrichment

   The initial fuel enrichment of any fuel that is stored in a SSSC will be limited to the maximum enrichment specified in the ISFSI Technical Specifications.

2. Fuel Burnup

   The burnup of any fuel that is stored in a SSSC will be limited to that specified in the ISFSI Technical Specifications.

3. Heat Generation

   The heat generation rate by an individual fuel assembly is dependent on three factors: the initial fuel enrichment, the fuel burnup, and the amount of decay time after discharge. The maximum allowable heat generation rate for a particular SSSC is specified in the ISFSI Technical Specifications.

4. Decay Time

   The decay time of any fuel that is stored in a SSSC will be at least greater than that specified in the ISFSI Technical Specifications.

5. Spent Fuel Physical Configuration/Condition

   Only spent fuel irradiated at North Anna Power Station Units 1 and 2 with the physical configuration as listed in items 1, 2, and 3 of Table 3-1 will be stored in the ISFSI. The fuel stored shall be intact, shall not have gross cladding defects, and shall not have visible physical damage which would inhibit insertion or removal from the SSSC basket.

3.1.1.1.2 Verification

The method of verification for each of these characteristics is discussed below:

1. Initial Fuel Enrichment, Fuel Burnup and Decay Time

   Fuel management records shall be utilized to verify that the initial fuel enrichment, fuel burnup and decay time meet the specified limits. Each fuel assembly is engraved with a unique identification number (based on ANSI/ANS 57.8) and a vendor identification, which is unique to the site for which the fuel assemblies were fabricated. This will allow visual confirmation of the identity of the fuel assemblies placed in the SSSC.

2. Heat Generation

   The heat generation rate of a fuel assembly is based primarily on the fuel enrichment, burnup, operating history, and cooling time after discharge. Fuel management records will be used to obtain the parameters. A decay heat analysis using a computer code such as ORIGEN or the method described in NUREG/CR-5625 will be used to ensure that the heat generation per fuel assembly is less than that specified in the ISFSI Technical Specifications.

Decay Heat Analysis for the TN-32B HBU cask will be conducted using the algorithm provided in Table 3-3

Because of the passive nature of the North Anna ISFSI and the absence of support systems, no other items requiring special design consideration have been identified.

3.3.2 Protection By Multiple Confinement Barriers and Systems

3.3.2.1 Confinement Barriers and Systems

Confinement of radioactivity during the storage of spent fuel is achieved by (1) the uranium dioxide fuel pellet matrix, (2) the metallic tubes (cladding) in which the pellets are contained, and (3) the SSSC in which the assemblies are stored.

The confinement function of the SSSCs is achieved by totally enclosing the spent fuel assemblies within a double-seal rigid metal vessel. The SSSCs are fabricated, delivered to the North Anna site, loaded, sealed, and emplaced at the ISFSI in a manner that ensures their integrity, the capability to perform their safety functions, and compliance with all applicable rules and regulations.

Once the SSSCs are sealed, there are no credible events which could result in a release of radioactive material to the environment. Similarly, there are no credible scenarios which could result in contamination of the outside surface of the SSSCs or in the generation of radioactive waste products.

More detailed information on SSSC confinement barriers is provided in the SSSC Topical Safety Analysis Reports.

3.3.2.2 SSSC Cooling

Natural air flow around the SSSCs provides sufficient cooling. No forced ventilation is required.

3.3.3 Protection By Equipment and Instrumentation Selection

3.3.3.1 Equipment

As discussed in Section 3.2, the SSSCs represent the only components of the ISFSI which are important to safety. Design criteria for the SSSCs are described in this section and summarized in Table 3-2.

3.3.3.2 Instrumentation

Due to the totally passive and inherently safe nature of the SSSCs, safety-related instrumentation is not necessary.

High quality commercial grade instrumentation will be provided to monitor the SSSC's functional performance. Instrumentation to monitor SSSC parameters such as pressure will be furnished as recommended by the specific SSSC designs. The appropriate capabilities to check these monitors will also be provided. The SSSCs are provided with pressure monitoring systems as described in the SSSC Topical Safety Analysis Reports.

Insert D

1. SSSC TN-32

Table 3-1 (Page 1 of 2)

CHARACTERISTICS OF FUEL USED AT THE NORTH ANNA POWER STATION[a]

a. ~~1.~~ Fuel Assemblies	
i. ~~a.~~ Manufacturer	Westinghouse
ii. ~~b.~~ Type	PWR
iii. ~~c.~~ Rod array	17 x 17
iv. ~~d.~~ Rods per assembly	264 (25 fuel rods are omitted to provide passage for control rods and in-core instrumentation)
v. ~~e.~~ Assembly length	161.80 in.
vi. ~~f.~~ Rod pitch	0.496 in.
vii. ~~g.~~ Overall assembly dimensions	8.426 in. x 8.426 in.
viii. ~~h.~~ Total assembly weight	1533 lb (with heaviest insert component)
ix. ~~i.~~ Active fuel length	144 in.
b. ~~2.~~ Fuel Rods	
i. ~~a.~~ Outside diameter	0.374 in.
ii. ~~b.~~ Clad thickness	0.0225 in.
iii. ~~c.~~ Clad material	Zircaloy-4 and Zirlo
c. ~~3.~~ Fuel Pellets	
i. ~~a.~~ Material	UO_2 Sintered
ii ~~b.~~ Length	0.530 or 0.387 in. [c]
d. ~~4.~~ Fuel Condition for Storage in SSSCs	
i. ~~a.~~ Maximum initial enrichment	b
ii. ~~b.~~ Maximum burnup	b
iii. ~~c.~~ Maximum heat generation for each fuel assembly at the time of storage	b
iv. ~~d.~~ Minimum decay time	b

a. From North Anna Power Station UFSAR. All dimensions are for cold conditions.
b. Specified in the North Anna ISFSI Technical Specifications.
c. Reload batches starting with North Anna Unit 1, Batch 9 and North Anna 2, Batch 8 changed fuel pellet length from 0.530 in. to 0.387 in.

Insert Table 3-1
(Page 2 of 2)

Table 3-1 (page 2 of 2)
Characteristics of Fuel Used at the North Anna Power Station

2. SSSC		TN-32B HBU
a.	Initial Enrichment	< 4.60 wt. % (Areva Mark BW) ≤ 3.64 wt. % (Westinghouse Standard) ≤ 4.50 wt. % (Westinghouse Vantage 5H)
b.	Average Burnup	≤ 60 GWD/MTU
c.	Decay Heat	≤ 36.96 kW
d.	Fuel Assembly Design	Areva Mark BW (AMBW) Westinghouse Standard Westinghouse Vantage 5H
e.	Fuel Assembly Inserts	Poison Rod Assemblies (unirradiated)
f.	Fuel Assembly Weight, Including PRA	≤ 1551 pounds
g.	Fuel Assembly Initial Uranium Content	≤ 469.0 KgU/assembly

Table 3-2

DESIGN CRITERIA FOR DRY SEALED SURFACE STORAGE CASKS

The SSSCs must meet the following criteria, assuming that they are loaded with the fuel described in Table 3-1.

1.	Maximum weight with yoke	125 tons
2.	Criticality with single active or credible passive failure	$k_{eff} < 0.95$
3.	Ambient temperature	-20°F to 115°F
4.	Direct exposure to sunlight	800 gm-cal/cm^2 for flat surfaces[a] 400 gm-cal/cm^2 for curved surfaces[a]
5.	Tornado winds	300 mph rotational velocity, 60 mph translational velocity
6.	Tornado pressure drop	3 psi in 3 seconds
7.	Maximum winds (V)	80 mph
8.	Explosive peak overpressure	1 psi
9.	Design Earthquake peak acceleration	0.18g horizontal 0.12g vertical

10. Adequate provisions to monitor performance of SSSC leak tightness
11. 15-inch drop onto concrete pad without compromising SSSC integrity and without physical damage to fuel or loss of subcriticality
12. Capable of tipping over and rolling without compromising SSSC integrity and without physical damage to fuel or loss of subcriticality
13. Leak tightness to be maintained under all operating conditions and credible events

a. These values are adapted from 10 CFR 71.71(c) and apply to a 12-hour daylight period. These values may be averaged over a 24-hour period for long-term thermal analyses.

Insert Table 3-3

Table 3-3

Decay Heat Load Methodology for Fuel Stored in TN-32B HBU Cask

The following algorithm is to be used to determine the individual fuel assembly decay heat load for the zone loading represented in Technical Specifications Figure 2.1-4

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

$$F1 = A + B*X1 + C*X2 + D*X1^2 + E*X1*X2 + F*X2^2$$

$$DH = F1*Exp(\{[1-(5/X3)]*G\}*[(X3/X1)^H]*[(X2/X1)^I]),$$ where

F1 is the Intermediate Function, basically the thermal source at five year cooling,
X1 is the assembly average burnup in GWd/MtU,
X2 is the assembly average initial enrichment in wt. % U-235, minimum of 1.5 percent and maximum of 5 percent.
X3 is the cooling time of the assembly in years

Constants:

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

4.2.3.2 **Description**

A description of the SSSC components is provided in the SSSC Topical Safety Analysis Reports.

4.2.3.3 **Design Bases and Safety Assurance**

The ability of the SSSCs to perform their design function is demonstrated in the SSSC Topical Safety Analysis Reports and in Appendix A.

Loading and handling of the SSSCs will be done according to the applicable procedures.

As described in Chapter 8, the design and operation of the North Anna ISFSI ensures that a single failure does not result in the release of significant radioactive material.

The only interactions between the ISFSI and the North Anna Power Station are those concerning the loading and handling of the SSSCs in the Fuel and Decontamination Buildings. These are discussed in Chapter 5.

Radiation protection of operating personnel is addressed in Chapter 7.

Nuclear criticality safety for the SSSCs is addressed in the SSSC Topical Safety Analysis Reports or Appendix A.

4.2.4 Instrumentation System Description

Due to the passive nature of the SSSCs, no safety-related instrumentation is required. A description of the nonsafety-related SSSC pressure monitoring system is provided in Section 4.4.5.3.

Insert D

4.2.5 References

1. BOCA Basic Building Code, Building Officials and Code Administrations International, Inc., 1993.
2. American Concrete Institute, ACI 301, *Specifications for Structural Concrete for Buildings,* 1989.
3. American Nuclear Society, ANSI/ANS 57.9, *Design Criteria for an Independent Spent Fuel Storage Installation (Dry Storage Type),* 1984.
4. American Concrete Institute, ACI 349, *Code Requirements for Nuclear Safety Related Concrete Structures,* 1985.
5. American Nuclear Society, ANSI/ANS 2.19, *Guidelines for Establishing Site-Related Parameters for Site Selection and Design of an Independent Spent Fuel Storage Installation (Water Pool Type),* 1981.

Additional lids, if any, are installed and the pressure monitoring system is installed and tested. If appropriate, the weather cover is installed. Surface radiation dose measurements are then completed. When all preparations have been completed, the SSSC is lifted from the north bay and placed on the concrete surface outside of the Decontamination Building.

The SSSC is lifted by the transporter for transfer to the ISFSI. The routes followed by the transporter from the Decontamination Building to the ISFSI are shown on Figure 4-4. This figure also shows the location of all nearby systems and structures needed for the safe shutdown of Units 1 and 2. Drop of an SSSC while in transit to the ISFSI will not result in damage to any of these systems and structures, nor in radioactive releases in excess of the guidelines in 10 CFR 100. As indicated in Section 3.3.1, the design criteria require that the SSSC maintain its integrity, preclude physical damage to the fuel, and ensure sub-criticality following a 15-inch drop. Operating procedures will limit the lifting heights to less than 15 inches once the SSSC is lifted by the transporter.

The pressure monitoring device on the SSSC must be connected to the monitoring panel after the SSSC is placed on the ISFSI pad.

Insert C

5.1.1.2 **Unloading Operations**

Unloading of an SSSC begins with disconnecting the pressure monitoring device on the SSSC from the monitoring panel and transporting the SSSC along the same route used for its placement at the ISFSI. Once the transporter and SSSC are outside the Decontamination Building, the SSSC is lowered to the concrete surface beneath the 125-ton crane. The SSSC is lifted using the lift beam and moved to the north bay of the Decontamination Building. A sample of the helium in the fuel cavity is tested for indications of fuel failure (Kr^{85}). If this test indicates that failed fuel is present in the SSSC, the fuel cavity is evacuated to the Decontamination Building ventilation system described in Chapter 6, and refilled with helium. This process of sampling, evacuating and refilling is continued until helium sample tests are acceptable.

The lid bolts are then loosened and the SSSC is lifted from the north bay and moved to the cask loading area. The SSSC is lowered into the deep end of the cask loading area until the top of the cask is level with the spent fuel bridge crane platform. A water supply, with flow indicator, is attached to the SSSC reflood valve and water is slowly added to the fuel cavity. Flooding of the cask cavity takes at least 3 hours. When the cavity is full, the lid bolts are removed, the SSSC is lowered to the bottom of the cask loading area, and the lift beam is detached. The lid is slowly removed from the SSSC, lifted from the pool and placed at its designated laydown area. Fuel assemblies are then removed from the SSSC using a long handling tool suspended from the spent fuel bridge crane hoist. After the SSSC is unloaded, the lid is placed back on the SSSC with the aid of guide pins. The SSSC is lifted to the pool surface and water is pumped from the fuel cavity. The SSSC is then returned to the north bay for decontamination of the inner and outer surfaces.

None of the operations needed to load or unload the SSSCs at the North Anna ISFSI will result in unacceptable damage to the North Anna Power Station Units 1 and 2, or to the stored spent fuel.

5.1.2 Flowsheets

Table 5-1 shows a general sequence of operations to load and transport an SSSC to the ISFSI. Table 5-2 shows the general sequence of operations for unloading an SSSC. Operations more specific to a particular vendor's SSSCs are outlined in the vendor's SSSC Topical Safety Analysis Report.

These operations are performed in accordance with procedures addressing health physics and handling of the SSSCs. They also fulfill the surveillance requirements specified in Chapter 10.

5.1.3 Identification of Subjects for Safety and Reliability Analysis

5.1.3.1 Criticality Prevention

The design criteria specified in Section 3.3.4 require that spent fuel stored at the North Anna ISFSI be maintained subcritical at all times. The specific means by which the SSSCs comply with this criterion are described in the SSSC Topical Safety Analysis Reports or Appendix A.

5.1.3.2 Instrumentation

Due to the totally passive and inherently safe nature of the SSSCs, there is no need for any instrumentation to perform safety functions. It is desirable, however, to monitor the performance of some or all of the SSSCs. Accordingly, the design criteria described in Section 3.3.3 require that the SSSCs have adequate provisions for the installation and testing of monitors.

The parameters to be monitored will be selected based on recommendations made by the SSSC manufacturers, experience gained with specific SSSC designs, and other engineering and health physics considerations. Instrumentation provisions for the SSSCs are described in the SSSC Topical Safety Analysis Reports.

Although these instruments are not safety related, commitments for their installation, inspection, and replacement (if needed) are proposed in Section 10.2.

Actions to be taken when monitored parameters exceed preset levels are described in Section 4.4.5.3. Insert D

5.1.3.3 Maintenance Techniques

Because of their passive nature, the SSSCs require little, if any, maintenance over the lifetime of the ISFSI. No major maintenance tasks are required. Typical maintenance tasks would involve occasional replacement of monitoring instrumentation, recoating of some SSSCs with

Table 5-1

GENERAL SEQUENCE OF LOADING OPERATIONS[a]

1. Unload empty SSSC from rail car.
2. Move SSSC inside Decontamination Building.
3. Remove weather cover and inspect for shipping damage.
4. Remove lid(s) and inspect the following for damage: exterior surfaces, sealing surfaces, trunnions, accessible interior surfaces and basket assembly, bolts, and bolt holes and threads.
5. Replace lid seals.
6. Move SSSC to cask loading area.
7. Lower SSSC into cask loading area.
8. Load SSSC with preselected spent fuel assemblies using spent fuel handling crane.
9. Verify inventory of fuel assemblies loaded into SSSC.
10. Place lid on SSSC.
11. Lift SSSC to surface and install lid bolts.
12. Pump water from the SSSC fuel cavity into cask loading area.
13. Raise SSSC from cask loading area and spray exterior with water.
14. Return SSSC to Decontamination Building.
15. Begin to decontaminate exterior surfaces of SSSC.
16. Secure lid with bolts.
17. Vacuum dry SSSC cavity and test.
18. Fill SSSC cavity with helium and test seals.
19. Install pressure monitoring device and test.
20. Perform SSSC surface radiation measurements.
21. Lift SSSC from Decontamination Building and place on concrete surface.
22. Lift SSSC with transporter.
23. Transport SSSC to ISFSI.
24. Connect pressure monitoring device to monitoring panel.

---

a. Some steps indicated on this flowsheet may be performed in parallel with other steps.

See Appendix A.2 Section A.2.1.2.1 for the loading sequence description of the TN-32B HBU cask.

Table 5-2

GENERAL SEQUENCE OF UNLOADING OPERATIONS[a]

1. Disconnect pressure monitoring device.
2. Transport SSSC to Decontamination Building.
3. Release SSSC from transporter.
4. Lift SSSC to Decontamination Building.
5. Sample and test helium in fuel cavity.
6. Purge helium in fuel cavity, if necessary.
7. Loosen lid bolts.
8. Lift SSSC from north bay and move to fuel loading area in Fuel Building.
9. Lower SSSC into cask loading area and install reflood water supply.
10. Reflood fuel cavity with water and remove lid bolts.
11. Lower SSSC into cask loading area.
12. Remove lid from SSSC and store.
13. Remove fuel assemblies from SSSC.
14. Place lid on SSSC.
15. Lift SSSC to surface of cask loading area.
16. Pump water from the SSSC fuel cavity into the cask loading area.
17. Raise SSSC from cask loading area and spray exterior with water.
18. Return SSSC to Decontamination Building.
19. Decontaminate interior and exterior surfaces of SSSC.

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a. Some steps indicated on this flowsheet may be performed in parallel with other steps.

See Appendix A.2 Section A.2.1.2.1 for the unloading sequence description of the TN-32B HBU cask.

average cask surface dose rate limit in the ISFSI Technical Specifications. The average surface dose rates calculated for the TN-32 base case SSSC were 218 mrem/hr (neutron and gamma) for the side surface and 58 mrem/hr (neutron and gamma) for the top surface.

Refer to Appendix A.2 Section A.2.4 for TN-32B HBU cask surface dose rates.

7.3.2.2 **Dose Rate Versus Distance**

Analyses have been completed to determine dose rates at the ISFSI perimeter fence, the site boundary and the nearest permanent resident. These analyses were performed using the MCNP Monte Carlo transport code (Reference 2) and the following conservative inputs.

1. Isotope inventories were based on 32 fuel assemblies with enrichment of 3.5 weight percent U-235 and burnup of 45,000 MWD/MTU.
2. The three storage pads are filled with 84 TN-32 SSSCs, each pad having 28 SSSCs. Assuming 84 TN-32 SSSCs results in an amount of fuel stored on the pads which exceeds the current licensed limit of 839.04 TeU (approximately 57 TN-32 SSSCs), providing additional conservatism to the analysis.
3. The inventory of SSSCs stored in the ISFSI will increase by four SSSCs per year. This average rate of inventory change was used to determine the age of the spent fuel (years after discharge) and the subsequent reduction in dose rates.
4. The effects of irradiated insert components are included in the MCNP analyses.

Figure 7-1 shows the layout of the ISFSI. The MCNP analysis of the dose rate at the ISFSI perimeter fence using base case TN-32 SSSCs resulted in peak dose rates that range from 0.3 to 1.9 mrem/hr when all three pads were full. The specific dose rates for the various points on Figure 7-1 are provided in Table 7-1. Dose rate measurements at the ISFSI perimeter fence will be used to ensure that the requirements of 10 CFR 20 are met.

The MCNP analysis for the nearest site boundary indicated that the maximum dose rate at this location was less than 100 mrem/yr, which meets the requirements of 10 CFR 20.1301.

The MCNP analysis for the nearest permanent resident indicated that the contribution to the maximum dose rate from the operation of the ISFSI was 2.1 mrem/yr. When combined with the contributions from the operations of North Anna Power Station Units 1 and 2, the result is well below the 25 mrem/yr imposed by 10 CFR 72.104(a).

Refer to Appendix A.2 Section A.2.4 for TN-32B HBU cask surface dose rates.

7.3.3 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

As indicated in Section 3.3.5, area radiation and airborne radioactivity monitors are not needed at the North Anna ISFSI. However, thermoluminescent devices will be used to record gamma radiation doses at appropriate intervals along the ISFSI perimeter fence. Neutron radiation detection devices may also be used on the ISFSI perimeter fence if they are available and reliable.

The total annual occupational exposure during ISFSI loading operations is 14.39 person-rem (see Table 7-4), and represents the maximum expected. As indicated previously, the actual occupational exposures for loading, transport, and emplacement of an SSSC are approximately 0.25 to 0.5 person-rem per loading. This combined with the North Anna Power Station annual occupational exposure during ISFSI loading operations (Table 7-4) results in a total annual occupational exposure during ISFSI operations of approximately 4 person-rem. This exposure represents approximately 5% of the average annual occupational exposure from all operations at the North Anna Power Station.

7.4.1 References

1. C. J. Hostick, J. C. Lavender and B. H. Wakeman, *Time and Dose Assessment of Barge Shipment and At-Reactor Handling of a CASTOR V/21 Spent Fuel Storage Cask,* Pacific Northwest Laboratory, PNL-7205, April 1992.

7.5 OFFSITE COLLECTIVE DOSE ASSESSMENT

The site plan for the North Anna ISFSI and its relative location to the North Anna Power Station are provided in Figure 2-3. The North Anna site within the boundary is the controlled area as defined in 10 CFR 72.

Based on projections for year 2000, 354 permanent residents are located within a 2-mile radius of the North Anna site boundary. The nearest permanent resident is located at 2860 feet from the ISFSI. The maximum annual dose to the nearest resident is 2.10 mrem. Using the conservative assumption that all of the residents within two miles are located at the same distance from the ISFSI as the nearest resident, their maximum annual collective dose from the ISFSI would be:

$$0.00210 \text{ rem/year} \times 354 \text{ persons} = 0.74 \text{ person-rem/year}$$

The annual dose to the maximally exposed individual from all significant sources at the North Anna Power Station has been estimated in Appendix 11B of the North Anna Power Station Updated Final Safety Analysis Report (UFSAR) as 3 mrem/yr. Therefore, the maximum combined radiation contribution to the nearest permanent resident from the operation of the ISFSI (2.10 mrem/yr) and North Anna Power Station Units 1 and 2 (3.00 mrem/yr) is 5.10 mrem/yr. This is well below the 25 mrem/yr limit imposed by 10 CFR 72.104(a).

The North Anna ISFSI has no gaseous or liquid effluents, therefore, these do not contribute to the dose of nearby residents.

Considering the conservatisms in the above calculation and the rapid attenuation of neutron and gamma dose rates with distance, the dose for the more distant population is negligible.

Insert B

Table 7-2

ESTIMATED OCCUPATIONAL EXPOSURES FOR CASK LOADING, TRANSPORT, AND EMPLACEMENT[a] (ONE TIME EXPOSURE)

Task	Time Required (hr)	No. of Persons	Dose Rate (rem/hr)	Person-Rem
1. Unload empty SSSC from rail car	2.00	5	0.00E+00	0.00E+00
2. Move SSSC inside Decon Bldg	0.25	2	0.00E+00	0.00E+00
3. Remove cover; inspect	2.00	2	0.00E+00	0.00E+00
4. Remove lid(s); inspect	2.00	2	0.00E+00	0.00E+00
5. Replace lid seals	0.50	2	0.00E+00	0.00E+00
6. Move SSSC to loading area	1.00	3	1.70E-03	5.10E-03
7. Lower SSSC into loading area	0.25	3	1.70E-03	1.28E-03
8. Load SSSC with spent fuel	3.00	3	1.70E-03	1.53E-02
9. Verify fuel inventory	0.50	1	1.70E-03	8.50E-04
10. Place lid on SSSC	1.00	2	1.70E-03	3.40E-03
11. Lift SSSC; install lid bolts	0.50	2	2.86E-02	2.86E-02
12. Remove water in fuel cavity	1.00	2	2.86E-02	5.72E-02
13. Raise SSSC from loading area	0.25	2	8.39E-02	4.20E-02
14. Return SSSC to Decon Building	0.33	2	8.39E-02	5.54E-02
15. Decontaminate SSSC	2.00	2	8.39E-02	3.36E-01
16. Secure Lid	1.00	2	8.39E-02	1.68E-02
17. Vacuum dry cavity and test	4.00	2	8.39E-02	6.71E-01
18. Fill cavity with helium and test	3.00	2	8.39E-02	5.04E-01
19. Install pressure device and test	3.00	2	8.39E-02	5.04E-01
20. Perform radiation measurements	0.50	1	8.39E-02	4.20E-02
21. Lift SSSC; place outside of Decon Building	0.50	2	5.88E-02	5.88E-02
22. Lift SSSC with transporter	1.00	2	3.36E-02	6.72E-02
23. Transport SSSC to ISFSI	0.50	3	3.36E-02	5.20E-02
24. Connect pressure monitoring device; install weather cover	1.00	2	8.39E-02	1.68E-01
			Total	2.78E+00

a. Dose rates are from the base TN-32 cask.

See Appendix A.2 Section A.2.4.2 for occupational dose evaluation for the TN-32B HBU cask.

Table A-1
TOPICAL SAFETY ANALYSIS REPORTS FOR SSSCs APPROVED FOR USE AT THE NORTH ANNA ISFSI

A.1. *TN-32 Dry Storage Cask Topical Safety Analysis Report,* Revision 9A, Transnuclear, Inc., December 1996.

A.2. E-42038 "TN-32B HBU Demonstration Cask Design/Licensing Basis Document", Revision 3, AREVA-TN

Appendix A.2

TN-32B HBU Dry Storage Cask

A.2.1 TN-32B HBU Cask Physical Description

The standard TN-32B cask design only differs from the TN-32 cask design approved and in use at the North Anna Power Station (NAPS) ISFSI in that the TN-32B has larger, single-failure proof trunnions for handling of the cask. The cask body and basket for the standard TN-32B are the same as in a standard TN-32.

The TN-32B HBU cask is a modified TN-32B cask that accommodates thirty-two (32) intact spent fuel assemblies, with or without poison rod assemblies (PRAs). The TN-32B HBU cask was manufactured as a standard TN-32B cask in accordance with the TN-32 Safety Analysis Report and certified to comply with the NRC Certificate of Compliance No. 72-1021. The modifications to the standard TN-32B cask design for the demonstration cask consist of the following:

1. The lid is modified with seven (7) new penetrations installed in the lid's confinement boundary and shield plate, providing access into the cask cavity.

2. Thermocouple lance assemblies are mounted and secured in each of the penetrations, as noted above. Each lance, which contains nine (9) Type K thermocouples, is inserted into a designated guide tube in selected fuel assemblies. The penetration, thermocouple lance assembly, and associated confinement boundary is illustrated in Figure 1.1-1 and Figure 1.1-2 of Reference 1. Additional discussion of the confinement boundary is provided in Section 6.1 of Reference 1, Confinement Boundary.

3. A funnel guide assembly is installed into the upper end fitting of each of the seven (7) fuel assemblies that receive the thermocouple lance assemblies. The funnel assembly guides the lance into the fuel assembly guide tube during installation. Refer to Figure 1.1-3 of Reference 1.

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

5. The protective cover is provided with an additional access cover above the lid vent port cover for maintenance purposes. An instrumentation junction box closure is located on the outer surface of the lid to permit worker access to the thermocouple conductors in accordance with ALARA principles.

6. Lid closure bolts are upgraded with a reduced diameter shank and a captured hardened flat washer. The hole diameter for the lid bolts is increased. These changes are implemented for consideration of future transportation of the HBU cask. Details of the lid bolt changes can be found in Section 2.2 of Reference 1.

7. Four-paired bolting bars are attached to each end of the outer shell for attaching impact limiters to the HBU cask for future transportation.

8. The top neutron shield is elevated approximately one (1) inch by four (4) 1-inch thick steel bars that are welded to the through bolt holes on the bottom steel plate. This elevation is to provide space for the thermocouple wiring, and for the OP system tubing routed to the instrument seals.

As with the vent and drain port covers, each thermocouple lance penetration is provided with a double-seal, mechanical closure. Aside from the modifications, the cask body and basket for the HBU cask are the same as in a standard TN-32 configuration. Pertinent dimensions and weights for the TN-32B HBU cask are provided in Table 1.1-1. The drawings for the TN-32B HBU cask are provided in Section 8.1 of Reference 1, Licensing Drawings.

A.2.1.1 TN-32B HBU Cask Contents Description

The TN-32B HBU cask is designed to store thirty-two (32) intact HBU PWR fuel assemblies with or without PRAs. The maximum nominal enrichment of the HBU fuel to be stored is 4.55 wt. % U-235 with a maximum assembly-average burn-up of 60,000 MWd/MTU. The HBU fuel assemblies must be cooled a minimum of 5.31 years prior to storage in the HBU cask. The HBU cask has been evaluated for a maximum total decay heat load of 36.96 kW. The HBU fuel that will be stored in the TN-32B HBU cask are Westinghouse LOPAR, NAIF 17 x 17, and AREVA Advanced MK-BW (AMBW) 17x17 fuel assemblies, provided that they satisfy the burn-up, enrichment, and minimum required cooling time. The data for the HBU fuel that will be stored within the TN-32B HBU cask is presented in Table 1.2-1 of Reference 1.

The quantity and type of radionuclides in the HBU fuel assemblies are described and tabulated in Chapter 4.0, Shielding Evaluation. Chapter 5.0, Criticality Evaluation of Reference 1, discusses the criticality safety of the TN-32B HBU cask and its HBU contents, listing material densities, moderator ratios, and geometric configurations.

A.2.1.2 Operations and Auxiliary Equipment

A.2.1.2.1 Operations

A typical sequence of operations to be performed in loading HBU fuel into the TN-32B HBU cask is summarized below.

Upon receipt at North Anna, the HBU cask will be up-righted and transferred into the North Anna crane enclosure in accordance with existing procedures and practices. The overhead cask crane provides lifting and placement of the cask in the north bay of the station's Decontamination Building. The protective cover, overpressure tank and associated tubing connections, top neutron shield, and lid are removed and inspected. The HBU cask, basket and cavity are visually inspected.

Fuel assemblies scheduled to be loaded into the cask will be inspected and prepared for loading prior to cask loading operations. Inspection and preparation would include visual examinations, and as necessary, verification of guide tube free-path travel to ensure that no obstructions exist in the fuel assemblies designated for thermocouple monitoring. Any insert components which are planned to be installed in the HBU cask, such as PRAs, are installed in designated fuel assemblies.

When the HBU cask is ready for final loading, a new silver metallic O-ring seal will be installed on the lid assembly. The lid is then prepared and staged for submerged installation on the cask body. The cask is transferred to the cask loading area in the North Anna spent fuel pool in accordance with existing site procedures. The (32) HBU fuel assemblies that are designated for loading are moved from their respective spent fuel storage rack locations and emplaced into their designated basket location, in accordance with fuel move sheets developed from the spent fuel storage certification documents and applicable fuel handling procedures.

After the cask is fully loaded, funnel guides, for installation of the thermocouple lances are installed in seven (7) designated fuel assemblies guide tubes that are to be monitored during storage. Once all loading and pre-assembly is complete, which includes verification of loaded fuel identification, the lid is lowered into position using special long handling tools and guide pins for true alignment to preclude damage to the silver metallic O-ring and mating surfaces. The lifting yoke is installed on the overhead cask crane 125 ton hook and then moved to engage the cask trunnions. The cask is then lifted to the pool surface, where the lid is accessible for workers to prepare the cask for safe movement to the north bay of the Decontamination Building. The lid bolt holes are dewatered, as required, and a minimum of six lid bolts are installed and tightened to 100 ft.-lbs. torque, per site procedures. Additional preparation consisting of dewatering the cask to approximately seven (7) inches below the flange surface, to support ALARA activities associated with lance installation, and decontamination of the exposed cask surfaces are performed. The lid guide pins may be removed. The HBU cask is then transferred to the north bay of the Decontamination Building. Remaining lid bolts are installed, and all bolts tightened, per procedure, to required torque values.

The thermocouple lance assemblies are installed in their designated penetrations, each with a double metallic silver seal, a jacking plate assembly and a retaining ring, and the fasteners are tightened, per procedure, to required torque values. Thermocouple leads are temporarily connected to a data logger to collect temperatures during the dewatering, vacuum drying, and helium back-fill processes. The water is removed from the cask cavity, and it is simultaneously back filled with helium gas to maintain the temperature of the fuel assemblies below 752 °F (400 °C) during drying and to prevent air infiltration during water removal. The vacuum drying process is performed to ensure the HBU cask meets Technical Specifications requirements. Once the Technical Specifications requirement is met for drying, the cask is again backfilled with helium gas to the Technical Specifications backfill pressure requirement.

The cask will remain in the north bay of the Decontamination Building, with a pressure gauge attached to the vent port to allow direct monitoring of cask cavity pressure during the thermal stabilization period. The purpose of the thermal stabilization period is to collect temperature measurements as the cask and contents approach thermal equilibrium, monitor cavity pressure, and collect cask cavity gas samples for fission gas, composition, and moisture analysis. These data will be utilized to more fully understand the loading and drying temperature transients for benchmarking thermal analysis techniques, and to identify any rod failures, should they occur.

After completion of thermal stabilization, the temporary thermocouple leads will be disconnected from the data logger and cask seal leak testing is performed. Once the leak testing is verified to meet the Technical Specification requirements, the top neutron shield, overpressure system (that part existing beneath the protective cover assembly), and protective cover assembly package are installed. External surface radiation readings are collected and verified to ensure that they are within Technical Specifications limits.

The HBU cask is transferred to the ISFSI pad using the cask transporter and prime mover. The cask is emplaced in the designated storage location, and the cask's external OP system components are installed and connected to the site storage cask monitoring and alarm system. The thermocouple lance conductors, conduit and associated supporting hardware are assembled on the ISFSI pad, to support long-term data collection.

To unload the HBU cask, the above steps may be performed in reverse. The thermocouple lance conductors and associated external hardware are removed. The HBU cask is returned to the north bay of the Decontamination Building using the cask transporter and prime mover. The protective cover, pressure monitoring system, overpressure tank, and top neutron shield will be removed. Prior to opening the HBU cask, the cavity gas will be sampled through the vent port, and analyzed for potential nuclear and moisture composition. The cavity is depressurized to atmospheric pressure, and all but six of the lid bolts would be removed. The six lid bolts will then be tightened to 100 ft.-lb. torque in according with site procedures. The cask is transferred to the cask loading area of the North Anna spent fuel pool. Water is introduced into the cask through the drain port. Off-gas hosing is connected to the vent port, with its effluent discharging directly into the pool water. The water/steam effluent from the vent line may contain radioactive gas. ALARA practices and engineering controls are planned and in place to support these activities. The exit pressure and temperature are typically monitored during this operation. Once the HBU cask is filled with water, the remaining six lid bolts are removed, and the cask is lowered into the place for completion of disassembly, access to fuel and unloading, as necessary.

A.2.1.2.2 Auxiliary Equipment

The objective of the HBU cask is to monitor the fuel cladding temperatures of HBU fuel during storage. To support this objective, auxiliary equipment for the TN-32B dry storage cask is provided, as required. Specifically, the seven (7) thermocouple lances are connected to a junction box on the protective cover, and conductors routed through conduit to a data logger, which measures and records the thermocouple output. A solar cell is attached to the HBU cask to supply power to the data logger battery system. No additional supplemental site power is required for the auxiliary equipment.

A.2.1.3 Design Criteria

The design criteria that are utilized for the TN-32B HBU cask modifications are identical to the criteria delineated in the TN-32 Dry Storage Cask Safety Analysis Report, Revision 2 (TN-32 SAR). Properties for materials that were unavailable in the 1992 ASME Boiler and Pressure Vessel (B&PV) Code utilized for the TN-32 SAR are extracted from the 2013 ASME B&PV Code. Additionally, applicable NUREG/CR and/or Regulatory Guide documents that were not used in or issued subsequently to the design and licensing of the TN-32 dry storage cask were utilized, e.g., NUREG/CR-6007, for evaluation of the lid, vent, drain, thermocouple lance bolted assemblies, and penetration welds. These added documents are incorporated into the design criteria for this cask.

A.2.2 Structural Evaluation

The structural evaluation from Section 2.0 of the TN-32B Demonstration Cask Design/Licensing Basis Document (Reference 1) includes the structural evaluation for the TN-32B HBU cask. This evaluation is summarized below.

A.2.2.1 TN-32B HBU Cask Body

The TN-32B HBU cask body was analyzed to meet the design criteria of the NAPS ISFSI with the addition of the analysis for the August 23, 2011 earthquake centered near Mineral, VA. The TN-32B HBU cask fuel assembly payload results in increased temperatures in the basket/rail structure from the increased decay heat load. For this payload, the applicable normal, off-normal, and accident load conditions of the NAPS ISFSI license were analyzed based on the temperatures discussed in the Section A.2.3, Thermal Evaluations. Note that only accident load conditions apply for analysis of the basket rails.

The TN-32B HBU cask body with fuel payload has been analyzed to demonstrate structural integrity with no loss of confinement for the following normal and off-normal load conditions:

1. 1g down, cask vertical supported on bottom
2. 100 psig internal pressure;
3. 25 psig external pressure;
4. Thermal stress due to 100 °F (38 °C) ambient hot environment with maximum decay heat load; and
5. 3g vertical lift using upper trunnions.

Results of the Structural Evaluation for the TN-32B HBU cask body with fuel payload under normal and off-normal load conditions can be found in Table 2.1-1 of Reference 1.

The TN-32B HBU cask body with fuel payload has been analyzed to demonstrate structural integrity with no loss of confinement for the following accident load conditions as described in:

1. Seismic event in vertical storage position (includes the NAPS ISFSI design basis earthquake and the 2011 earthquake centered near Mineral, VA);
2. 50g bottom end drop;
3. 50g tip-over impact;
4. Tornado, wind, and missile impacts; and
5. 3g vertical lift plus 1g lateral.

Results of the Structural Evaluation for the TN-32B HBU cask body with fuel payload under accident load conditions can be found in Table 2.1-1 of Reference 1.

A.2.2.2 TN-32B HBU Cask Lid Assembly

For the modified lid assembly as discussed in Section A.2.1, TN-32B HBU Cask Physical Description, the cask was analyzed for normal, off-normal, and accident load conditions.

The TN-32B HBU cask lid has been analyzed to demonstrate structural integrity with no loss of confinement for the following normal and off-normal load conditions:

1. 1g down, cask vertical supported on bottom
2. 100 psig internal pressure;
3. 25 psig external pressure;
4. Thermal stress due to 100 °F (38 °C) ambient hot environment with maximum decay heat load; and
5. 3g vertical lift using upper trunnions.

The TN-32B HBU cask lid has been analyzed to demonstrate structural integrity with no loss of confinement for the following accident load conditions:

1. 100 psig internal pressure
2. Seismic event in vertical storage position (includes the NAPS ISFSI design basis earthquake and the 2011 earthquake centered near Mineral, VA);
3. 50g bottom end drop;
4. 50g tip-over impact;
5. Tornado, wind, and missile impacts; and
6. 3g vertical lift plus 1g lateral.

The TN-32B HBU cask lid bolts have been analyzed in accordance with NUREG/CR-6007, "Stress Analysis of Closure Bolts for Shipping Casks," to demonstrate structural integrity with no loss of confinement for the following normal and off-normal load conditions:

1. Lid bolt tightening torque;
2. Lid bolt preload, lid sealing pressure;
3. 100 psig internal pressure;
4. 25 psig external pressure; and
5. Thermal stress due to 100 °F (38 °C) ambient hot environment.

The TN-32B HBU cask lid bolts have been analyzed in accordance with NUREG/CR-6007 to demonstrate structural integrity with no loss of confinement for the following accident load conditions:

1. 100 psig internal pressure
2. Thermal expansion due to 100 °F (38 °C) ambient to 400 °F (204 °C) fire event;
3. 50g tip-over impact;
4. 30-ft side free drop;
5. 30-ft end free drop; and
6. 30-ft CG-over-top corner free drop.

The TN-32B HBU cask fasteners for the vent port cover, drain port cover, and the lance assemblies have been analyzed in accordance with NUREG/CR-6007 to verify that the tightening torque would seat the metallic O-ring seal. Additionally, the fasteners were evaluated for the following normal and off-normal load conditions:

1. 100 psig internal pressure (vent, drain, and lance assemblies only);
2. Thermal expansion due to 100 °F (38 °C) ambient to 300 °F (149 °C) for the maximum decay heat load; and
3. Fastener initial preload.

The TN-32B HBU cask fasteners for the vent port cover, drain port cover, and the lance assemblies have been analyzed in accordance with NUREG/CR-6007 to demonstrate structural integrity with no loss of confinement for the following accident load conditions:

1. 100 psig internal pressure
2. Thermal expansion due to 100 °F (38 °C) ambient to 400 °F (204 °C) fire event;
3. 50g tip-over impact; and
4. Fastener preload.

A.2.2.3 Cask Basket and Rails Assembly

The TN-32B HBU cask basket and rails are unchanged from the standard TN-32B design. The TN-32B HBU cask basket with fuel payload has been analyzed to demonstrate structural integrity for the following normal and off-normal load conditions:

1. 3g vertical lift plus 1g lateral; and
2. Thermal stress due to 100 °F (38 °C) ambient hot environment with maximum decay heat load.

The TN-32B HBU cask basket with fuel payload has been analyzed to demonstrate structural integrity for the following accident load conditions:

1. Thermal stress due to 100 °F (38 °C) ambient hot environment with maximum decay heat load;
2. 50g bottom down drop; and
3. 55g tip-over impact (treated as a side drop for basket).

A.2.2.4 Conclusions for Structural Evaluation

The structural evaluation of the TN-32B HBU cask body, lid, basket, and rails has demonstrated that all components satisfy the required design criteria for all of the normal, off-normal and accident conditions for the NAPS ISFSI including criteria of the 2011 earthquake centered near Mineral, VA. Cask internal pressures under normal conditions are acceptable.

During the side drop accident event, the basket/fuel assemblies are laterally displaced relative to the thermocouple lances, which are inserted into guide tubes in the fuel assemblies. The thermocouple lance has been analyzed and it has been demonstrated that the lance sheath confinement boundary satisfies the required design criteria for this lateral displacement.

The fuel assemblies used as payload in the TN-32B HBU cask have been analyzed to demonstrate structural integrity with no loss of confinement for a postulated 18-inch end drop and a 50g side drop. The AREVA Advanced Mark BW assembly design is used in the analyses as a bounding assembly for all potential fuel assembly design loadings because it has the lowest yield strength. The analyses demonstrated that the payload fuel assemblies will maintain their structural integrity for all accident conditions during the storage period on the NAPS ISFSI.

A.2.3 Thermal Evaluation

The thermal evaluation from Section 3.0 of the TN-32B Demonstration Cask Design/Licensing Basis Document (Reference 1) includes the thermal evaluation for the TN-32B HBU cask. This evaluation is summarized below.

The TN-32B HBU cask is designed to passively reject decay heat under normal, accident and loading/unloading conditions while maintaining appropriate cask temperatures and pressures within the specified temperature limits. To establish the confinement and heat removal capability, several thermal design criteria are established for the TN-32B HBU cask. These are:

1. Seal temperatures must be maintained within specified limits. The silver-jacketed metallic O-ring seals that form part of the TN-32B HBU cask confinement boundary have a maximum temperature limit of 669 °F (354 °C).

2. An allowable temperature range of -40 to 300 °F (-40 to 149 °C) is set for the neutron shield to maintain resin stability.
3. Maximum and minimum temperatures of the confinement structural components must not adversely affect the confinement function.
4. For normal conditions and all short term loading operations (including vacuum drying and backfilling of the cask cavity with helium), a fuel cladding temperature limit of 752 °F (400 °C) is established in accordance with NUREG-1536, "Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility – Final Report." For accident conditions, the fuel cladding temperature limit is 1,058 °F (570 °C) per NUREG-1536.

A.2.3.1 Normal Conditions

The thermal evaluation for normal conditions was based on the following inputs:

1. A maximum total decay heat load of 36.96 kW from all 32 fuel assemblies;
2. An ambient temperature range of -20 °F to 100 °F. The temperature range is averaged over 24 hours and a maximum daily averaged ambient temperature of 100 °F is used for the maximum cask temperature evaluation;
3. 10 CFR 71.71(c) insolation averaged over 24 hours.
4. Inclusion of the effect of storing the TN-32B HBU cask in a 2 by infinite array with a 16 ft pitch from the existing TN-32 casks at the NAPS ISFSI.

Using these inputs, the thermal analysis for normal storage concluded that the TN-32B HBU cask met all applicable requirements.

1. The predicted maximum fuel cladding temperature is less than the design criterion of 752 °F (400 °C).
2. The maximum seal temperature is less than the long-term limit of 669 °F (354 °C) for continued seal function.
3. Under the minimum daily average temperature condition of -20 °F (-29 °C) ambient, the resulting cask component temperatures will approach -20 °F (-29 °C) if no credit is taken for decay heat load. The cask materials including confinement structures and the seals continue to function at the temperature range between -40 °F (-40 °C) and 669 °F (354°C).
4. The average bulk resin temperature in the radial neutron shield at the hottest cross section for normal conditions and the temperature of the resin in the top neutron shield are below the allowable limit of 300 °F (149 °C). Therefore, no degradation of the neutron shielding is expected for the storage period.

A sensitivity study was performed assuming storage in a 2 by infinite array with a 14 ft pitch between the existing TN-32 casks. The decrease in pitch between the TN-32 casks was shown to have no effect on the maximum temperatures of the TN-32B HBU cask.

A.2.3.2 Accident Conditions

The thermal evaluation for accident conditions was based on the following:

1. 15 minute fire accident with the following conditions:

   1.1 Average flame temperature of 1,550 °F (843 °C)
   1.2 Average convective heat transfer of 4.5 Btu/hr-ft2-°F

Using these inputs for the fire accident, the thermal analysis concluded that the TN-32B HBU cask design met all applicable requirements.

1. The predicted maximum fuel cladding temperature is less than the design criteria of 1,058 °F (570 °C) for accident conditions.
2. The maximum seal temperature is less than the long-term limit of 669 °F (354 °C) for continued seal function.

A.2.3.3 Transfer Conditions

During transfer operations to the ISFSI pad, the TN-32B HBU cask is exposed to the ambient conditions and is not surrounded by other casks. This ensures that there is no radiation heat transfer between the casks as there is during storage on the ISFSI pad. Therefore, the thermal evaluation performed for normal storage bounds the thermal performance of the TN-32B HBU cask during transfer to the NAPS ISFSI pad.

A.2.3.4 Loading/Unloading Conditions

All fuel transfer operations occur when the cask is in the spent fuel pool with the cask lid removed. The fuel is always submerged in free-flowing water, permitting heat dissipation. After fuel loading is complete, the cask is removed from the pool, drained, and the cavity is dried. Helium is used for the cask blowdown operation and, therefore, its presence is credited during the vacuum drying operation. With helium being present during vacuum drying operations, the maximum temperatures, including those of the fuel cladding and cask components, are bounded by those calculated for transfer operation. Since the thermal evaluation for normal storage conditions bounds the transfer operations as discussed above, no further evaluation for loading/unloading conditions is performed.

A.2.3.5 Thermal Expansion Evaluation

Thermal expansion analysis of the TN-32B HBU cask evaluates the fuel assemblies and cask components clearances for thermal expansion including:

1. The gap between an irradiated fuel assembly and the TN-32B HBU cask lid;
2. The gap between the basket and basket rails of the TN-32B HBU cask body.

The maximum allowable gap between the fuel assemblies and the cask lid is 1.45 inches. The analytically demonstrated gap between the fuel assemblies and the cask lid is less than 1.45 inches. The minimum required gap between the fuel assemblies and the lid is 0.25 inches. The analytically demonstrated gap between the fuel assemblies and the cask lid is greater than 0.25 inches.

The evaluation demonstrates that there will be an adequate hot radial gap between the basket assemblies and basket rails. The minimum gap between the basket assembly and the basket rails is adequate to provide sufficient clearance for thermal expansion. The basket plates are free to expand in the axial direction, since sufficient clearance is provided between the lid and the top of the basket for the maximum evaluated decay heat load.

A.2.3.6 Thermal Soak Period

To ensure the TN-32B HBU cask thermocouples are functioning correctly and that the cask and payload have reached a state of thermal equilibrium, the TN-32B HBU cask will remain in the North Anna Power Station north bay. The TN-32B HBU cask will be completely sealed within 23 days from the time the cask is filled with helium. During this time period, temperatures within the cask will be monitored, gas samples will be taken from the cask cavity, and external temperature readings will be taken. These initial data will confirm when the cask and cask contents have reached thermal equilibrium and will provide a baseline for comparison with future measurements. After the TN-32B HBU cask has reached thermal equilibrium, and prior to exceeding the 23 day limit, the cask will be sealed and the final leak rate test will be performed.

A.2.3.7 Cask Pressure Evaluation

Using the ideal gas law, the design pressures in the TN-32B HBU cask cavity are calculated based on the amount of cavity gas with the average gas temperatures for normal, off-normal, and accident conditions.

Fuel rod fill and fission gases released into the cavity are calculated based on an assumed percentage of ruptured fuel rods: 1% for normal conditions, 10% for off-normal conditions, and 100% for accident conditions. In addition to the release of 100% of the fill gas, 30% of the fission gas generated within the fuel rods during operation is also considered.
The maximum calculated internal pressures for normal, off-normal, and accident conditions in the TN-32B HBU cask cavity are 21.3 psig, 26.9 psig, and 95.5 psig, respectively. Therefore, the maximum internal pressure of 100 psig utilized in the evaluation of the TN-32B HBU cask and basket is a bounding pressure.

A.2.3.8 Conclusions for Thermal Evaluations

The thermal design of the TN-32B HBU cask is in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied.

The temperatures determined by the evaluation of the cask systems, structures, and components important to safety were found to remain within their operating temperature ranges for the design heat load. The TN-32B HBU cask provides adequate heat removal capacity at the ISFSI pad without active cooling systems. Spent fuel cladding will be protected against degradation that leads to significant fuel failures by maintaining the cladding temperature below maximum allowable limits and by providing an inert environment in the cask cavity.

The NAPS ISFSI TS will be revised to specify the maximum total decay heat load of 36.96 kW for the TN-32B HBU cask only.

A.2.4 Shielding Evaluation

The shielding evaluation from Section 4.0 of the TN-32B Demonstration Cask Design/Licensing Basis Document (Reference 1) includes the shielding evaluation for the TN-32B HBU cask. This evaluation is summarized below.

For the purposes of the analyses provided in Section 4.1 of Reference 1, a limiting fuel assembly with regards to source term was identified and all thirty-two assemblies were modeled as having the same initial conditions as the bounding assembly. The use of these fuel parameters in the TN-32B HBU cask analyses, under normal and off-normal conditions, resulted in average surface dose rates of 91.1 mrem/hour for the side and 96.1 mrem/hour for the top (neutron plus gamma). The weighted side dose rate limit of 218 mrem/hr (neutron plus gamma) is currently listed in the Technical Specifications for the TN-32 casks and exceeds that of the TN-32B HBU cask. The shielding analysis details are provided in Section 4.2 of Reference 1 and results for normal, off normal and accident conditions are provided in Section 4.3 of Reference 1.

The total contributions to dose rates around the NAPS ISFSI due to the TN-32B HBU cask being located on the storage pad were determined using the MCNP Monte Carlo transport code. To determine a conservative dose rate at the nearest site boundary, which is also conservative with respect to the nearest permanent resident, due to the TN-32B HBU cask, calculations were performed at a distance of 500 meters from the cask. At this distance, the total dose rate from the cask is 0.0937 rem/year (0.937 mrem/year). Details and results of far field dose rate analysis are provided in Section 4.5 of Reference 1.

A.2.4.1 Conclusions for Shielding Evaluation

The radiation shielding features of the TN-32B HBU cask with fuel having the proposed limits is sufficient to meet the radiation protection requirements of 10 CFR 20 and 10 CFR 72.104.

As described in the site specific NAPS ISFSI Safety Analysis Report (SAR) Section 7.5, the maximum combined radiation contribution to the nearest permanent resident from the operation of the ISFSI (2.10 mrem/year) and the North Anna Power Station Units 1 and 2 (assuming 3.00 mrem/year) is 5.10 mrem/year. Conservatively adding the total dose rate at 500 meters for the TN-32B HBU cask (0.937 mrem/year) results in a total combined dose rate of 6.037 mrem/year. This is well below the 25 mrem/year limit imposed by 10 CFR 72.104(a). In addition, an evaluation was performed by Dominion that demonstrated the site boundary annual dose does not increase with the TN-32B HBU cask installed at the NAPS ISFSI.

A.2.4.2 Occupational Exposures

AREVA TN analyzed dose rates from the loading, emplacement, and maintenance of the TN-32B HBU cask with a fuel payload with the proposed limits in Section 4.4 of Reference 1. Exposures were calculated using these calculated dose rates and conservative estimations of person-hours associated with cask activities.

Relative to existing TN-32 analyses, estimated personnel doses increase for the TN-32B HBU cask due to the following:

- The fuel payload allowed for the TN-32B HBU cask includes assemblies with higher enrichments, higher burn-up, and higher initial uranium weight;
- Cask loading includes two new activities, which require operation in close proximity to the cask:
- Thermocouple lance installation, and
- Obtaining a cavity gas sample; and
- Cask emplacement includes a new activity, assembly and installation of a data package mounted on the cask at the ISFSI, which requires operation in close proximity to the cask.

A.2.4.3 Conclusions for Operational Exposures

Occupational exposures from the TN-32B HBU cask loaded with fuel having the proposed limits are expected to be higher than the current ISFSI licensing basis. A detailed table of Occupational dose to personnel per evolution is provided in Table 4.4-2 of Reference 1. Occupational exposure for loading and placement of the TN-32B HBU cask at the ISFSI is estimated to be 3.65 rem.

A.2.5 Confinement Evaluation

The confinement evaluation from Section 6.0 of the TN-32B Demonstration Cask Design/Licensing Basis Document (Reference 1) includes the confinement evaluation for the TN-32B HBU cask. This evaluation is summarized below.

A.2.5.1 Confinement Boundary

The confinement boundary for the TN-32B HBU cask consists 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, and the inner metallic O-ring seals of the lid, vent and drain covers, and the thermocouple instruments.

When the thermocouple lance is inserted into the cask cavity, the outer lance sheath becomes part of the confinement boundary. To accommodate the thermocouple lance assemblies, the lid is modified to include seven penetration sleeves, which form part of the confinement boundary. The seal utilized for the thermocouple closure assembly is a double metallic, silver-jacketed O-ring seal, which is identical to the seal used for the vent and drain closures. As with the vent and drain seals, the thermocouple closure seals are connected to the OP monitoring system.

Details of the confinement boundary for the TN-32B HBU cask can be found in Section 6.1.1 for Confinement Vessel, Section 6.1.2 for Confinement Penetrations, Section 6.1.3 for Seals and Welds, and Section 6.1.4 for Closer of Reference 1.

A.2.5.2 Accident Evaluation

Confinement of radioactivity during the storage of spent fuel is achieved by (1) the uranium dioxide fuel pellet matrix, (2) the metallic tubes (cladding) in which the pellets are contained, and (3) the SSSC in which the assemblies are stored.

The confinement function of the SSSC is achieved by totally enclosing the spent fuel assemblies within a double-seal rigid metal vessel. The SSSC is fabricated, delivered to the NORTH ANNA POWER STATION site, loaded, sealed, and emplaced at the ISFSI in a manner that ensures its integrity, the capability to perform its safety functions, and compliance with all applicable rules and regulations.

Once the SSSC is sealed, there are no credible events which could result in a release of radioactive material to the environment. Similarly, there are no credible scenarios which could result in contamination of the outside surface of the SSSCs or in the generation of radioactive waste products.

Despite the lack of credible scenarios which could result in a release of radioactive material to the environment, the loss of confinement barrier is evaluated for compliance with the requirements in the ANSI N14.5 Standard for Radioactive Materials – Leakage Tests on Packages for Shipments. The leakage rate for off-normal and accident conditions was assumed to be $1x10^{-5}$ std. cm^3/sec.

In the off-normal analysis, 10% of the rods are assumed to be failed and the condition exists over a one year period. In the accident analysis, 100% of the rods are assumed to be failed, temperatures inside the cask are consistent with the fire accident conditions, and the leaking condition exists over a thirty day period. Dispersion factors used in the analyses are consistent with the existing TN-32 site specific SAR.

A.2.5.3 Conclusions for Accident Evaluation

The Total Effective Dose Equivalent (TEDE) for the off-normal conditions at a point 500 meters from the TN-32B HBU cask is 0.192E(-1) mrem/year. The TEDE for the accident conditions at a point 500 meters from the TN-32B HBU cask is 9.71 mrem/30 days. Under off-normal and accident conditions, no amount of radioactive nuclides was found to be released that would result in doses approaching the limits specified in 10 CFR 72.104(a) or 10 CFR 72.106(b).

A.2.6 Criticality Evaluation

The criticality evaluation from Section 5.0 of the TN-32B Demonstration Cask Design/Licensing Basis Document (Reference 1) includes the criticality evaluation for the TN-32B HBU cask. This evaluation is summarized below.

The criticality evaluations provided in Section 5.0 of Reference 1 demonstrate that the TN-32B HBU cask with the planned high burnup spent fuel assemblies complies with the requirements of 10 CFR 72 for normal, off-normal, and accident conditions defined by the NAPS ISFSI SAR. Criticality control in the TN-32B HBU cask is provided by the basket structural components, which maintain the relative position of the spent fuel assemblies under normal and accident conditions, by the neutron absorbing plates between the basket compartments, by the poison rod assemblies (PRAs) inserted in six of the fuel assemblies stored in the cask, and by dissolved boron in the spent fuel pool water.

The standard TN-32B cask was previously analyzed by AREVA TN with older versions of the SCALE computer software. The TN-32B HBU cask is analyzed with the same SCALE control sequence, cross-section data, modeling methods, and code options as the standard TN-32B cask, but uses Version 6.0 of the SCALE computer code. The SCALE models for both casks are essentially identical, except that the TN-32B HBU cask is instrumented with thermocouple lances and uses PRAs in addition to borated water and poison plates for criticality control. Neither the thermocouple lance nor the PRAs affect the most reactive configuration. Therefore, the most reactive configuration of the standard TN-32B dry storage cask is also the most reactive configuration for the TN-32B HBU cask.

The TN-32B HBU cask stores thirty-two, high burn-up, 17 × 17 spent fuel assemblies of three fuel types: AREVA Mark BW, Westinghouse Standard, and Westinghouse Vantage 5H. The criticality analysis of the TN-32B HBU cask is performed by AREVA TN using the following conservative assumptions:

1. The fuel assemblies are assumed to be fresh (i.e., no burnup credit);
2. All 32 fuel assemblies are modeled as the most reactive fuel type based on initial enrichment, AREVA Mark BW;
3. Thermocouple lances are modeled as solid aluminum cylinders;
4. Poison rod assemblies (PRAs) are modeled as containing 50% of the as-designed B4C material;
5. All fuel cladding is modeled as Zircaloy-4.

The criticality analysis is performed for the TN-32B HBU cask using the above assumptions in the most reactive configuration under normal, off-normal, and accident conditions with various moderations details of the analysis performed. The limiting case identified for the normal and off-normal conditions is 90% moderation. The criticality analysis considers two accident conditions; the single fuel misplacement accident and the cask tip-over accident.

The single fuel misplacement accident is analyzed based on the limiting case identified for the normal and off-normal condition. The initial enrichment of the misplaced fuel is assumed to be 5.00 weight percent U-235. Five misplacement locations are analyzed.

The cask tip-over accident is represented by the side drop accidents described in Section A.2.2, Structural Evaluation. The criticality modeling of the cask tip-over accident analysis focuses on the integrity of the fuel rod location, fuel cladding, the grid spacers and the fuel compartment. Based on the results from the TN-32B HBU cask fuel structural evaluation, the cladding integrity is maintained. Based on the results from the TN-32B HBU cask basket accident analysis, the maximum transverse deformation of the fuel compartments is zero. Based on the results from the TN-32 Final Safety Analysis Report (FSAR) Revision 6, the grid spacers are assumed to crush and the fuel rod slides axially. The fuel rod axial sliding relative to the poison plate is modeled in the intact fuel analysis. Thus, only the fuel rod pitch reduction is modeled to account for the grid spacer collapse. The limiting case identified for the normal and off-normal conditions is modified with four fuel rod pitch reductions.

A.2.6.1 Conclusions for Criticality Evaluation

The TN-32B HBU cask is designed to be substantially subcritical under all credible conditions. The criticality design is based on favorable geometry, fixed neutron poisons, neutron poison inserts, and soluble poisons in the spent fuel pool. The criticality design features of the TN-32B HBU cask are in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied.
The acceptance criterion for the criticality analysis is defined by an Upper Subcriticality Limit (USL) that is set based on a 95% confidence band per NUREG/CR-6361, "Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages," with a correlation parameter of assembly separation distance. For all cases, normal, off-normal, and accident, an USL of 0.9388 was determined to be acceptable.

The results for the normal and off-normal conditions determined the limiting case is the 90% moderation case and the k_{eff} for this case is below 0.9388.

The results of the single fuel misplacement accident determined the limiting misplacement case has a k_{eff} below 0.9388.

For the cask tip-over accident, the reactivity effect of the fuel rod pitch reduction is negative, thus, the criticality safety margin is not impacted.

A.2.7 References

1. E-42038, "TN-32B HBU Demonstration Cask Design/Licensing Basis Document"

2. CALC-PA-0243, Revision 0, Addendum C "Impact on the ISFSI dose rates of placing a TN-32B HBU Demonstration Cask on Pad 1" June 30, 2015.