ATTACHMENT 1

DOMINION CALCULATION NE-1311, TECHNICAL REPORT, "EVALUATION OF THE TN-32 CASK WITH INCREASED ENRICHMENT AND BURNUP FUEL FOR USE AT THE NORTH ANNA POWER STATION INDEPENDENT SPENT FUEL STORAGE INSTALLATION," REV. 0

Virginia Electric and Power Company (Dominion)
North Anna Power Station
Independent Spent Fuel Storage Installation

TECHNICAL REPORT NE-1311, Revision 0

EVALUATION OF THE TN-32 CASK WITH INCREASED ENRICHMENT AND BURNUP FUEL FOR USE AT THE NORTH ANNA POWER STATION INDEPENDENT SPENT FUEL STORAGE INSTALLATION

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A. Introduction

This report evaluates the use of TN-32 casks for storage of spent fuel with higher initial enrichment and burnup than currently allowed by the North Anna ISFSI Technical Specifications. This evaluation will form the basis for a request to amend the North Anna ISFSI Technical Specifications to allow storage of this spent fuel.

The North Anna ISFSI is currently licensed to store spent fuel in the TN-32 spent fuel dry storage cask as evaluated in the TN-32 Topical Safety Analysis Report (TSAR), Revision 9A (Reference 1) and the North Anna ISFSI Safety Analysis Report. These evaluations and the North Anna ISFSI Technical Specifications limit the fuel to be stored in the TN-32 to that which meets the following criteria:

Initial Enrichment	≤ 3.85 weight percent U235
Assembly Average Burnup	≤ 40,000 E\IWD/MTU
Heat Generation	≤ 0.847 Kw/Assembly

These restrictions limit the spent fuel that can be placed in dry storage at the North Anna Power Station. Without the proposed change in these limits, North Anna will be unable to load TN-32 casks after December of 2003.

In January of 2000, the NRC issued a Certificate of Compliance and Safety Evaluation Report (SER) (Reference 2) for the TN-32 cask as described and evaluated in the TN-32 Final Safety Analysis Report (FSAR), Revision 0 (Reference 3). In the SER, the NRC evaluated and approved the use of the TN-32 cask for the following conditions:

Initial Enrichment	≤ 4.05 weight percent U235
Assembly Average Burnup	≤ 45,000 MWD/MTU
Heat Generation	≤ 1.02 Kw/Assembly

The TN-32 cask design evaluated in the TN-32 TSAR, Revision 9A is physically the same as the TN-32 cask design evaluated in the TN-32 FSAR, Revision 0. Therefore the evaluations performed in the TN-32 FSAR, Revision 0 with respect to the above parameters are applicable to the TN-32 casks used at North Anna.

Recently, Transnuclear performed criticality analyses (Reference 4) to determine what initial enrichment could be stored if the water used in loading and unloading had a soluble boron concentration of 2500 ppm. This is the current minimum limit specified in the North Anna Power Station Technical Specifications for the spent fuel pool soluble boron concentration. These analyses show that the TN-32 cask will remain subcritical and meet the necessary requirements if loaded with fuel of 4.30 weight percent U-235. Therefore it is proposed that the above criteria of 4.05 weight percent U-235 be increased to 4.30 weight percent U-235, which will allow a substantial increase in the number of candidate assemblies for dry storage.

This report will describe the applicable evaluations performed and address their impact on the site-specific evaluations performed for North Anna which show the TN-32 casks used at North Anna are capable of storing fuel meeting the proposed criteria.

These evaluations require certain operating conditions and limits different than those currently provided in the North Anna ISFSI Technical Specifications. Therefore an amendment to the Technical Specifications and NRC approval will be required prior to loading a TN-32 cask at North Anna with fuel unacceptable under the current limits but meeting the proposed limits.

The rest of this report deals with the affected analyses. As the higherburnup results in a different source term for the fuel, radiological impacts must be addressed. Section B evaluates this impact on dose analyses, accident analyses and occupational dose. The higher enrichment impact on the criticality analysis is described in Section C. Section D provides a thermal analysis which accounts for the higher allowed heat load of the fuel. Section E provides an environmental assessment. Conclusions are documented in Section F and references are listed in Section G.

B. Radiological Evaluation

Shielding Calculation

The TN-32 cask loaded with fuel of 3.85 weight percent U-235 initial enrichment and burnup of 40,000 MWD/MTU was evaluated in the TN-32 TSAR Rev. 9A and considered the base case in the North Anna 1SFSI SAR for determining cask surface dose rates. To provide for variations in cask designs or vendors, enveloping factors of 1.5 for the side and 2.5 for the top were used as dose rate multipliers to calculate a bounding licensing basis value that would still allow regulatory limits for on-site and off-site dose to be met. This resulted in bounding surface dose rates of 129 mrem/hr for the side and 55 mrem/hr for the top which were used for the North Anna 1SFSI Technical Specifications limits.

New shielding and dose analyses have been performed based on spent fuel with 3.5 weight percent U-235 initial enrichment, 45,000 MWD/MTU average fuel assembly burnup, a minimum cooling time after reactor discharge of seven years, and containing burnable poison rods.

Transnuclear, using the above parameters, calculated combined neutron and gamma surface dose rates for the TN-32 cask of 410 mrem/hr, 183 mrem/hr, and 304 mrem/hr for the cask radial surfaces above the neutron shield, along the neutron shield, and below the neutron shield respectively. For the top of the cask a dose rate of 68 mrem/hr was determined. These values are given in Table 5.1-2 of the TN-32 FSAR Rev. 0.

In order to generate site specific dose rates for evaluation of on-site and off-site dose limits, Dominion developed a cask and ISFSI model using the MCNP4C code (Reference 5) to perform dose rate calculations using monte carlo techniques for solving the radiation transport equations. Details of this model and the calculations performed may be found in Calculation PA-0181 Revision 0 (Reference 6). The results of the surface dose rates are provided in the following table.

Dominion's surface dose rate evaluation is consistent with the results reported in the TN-32 SAR, Revision 0, January 2000 with the slight differences being attributed primarily to code and modeling techniques. Dominion's top surface dose rate result is approximately 17% less. Dominion's lower dose rate results will be used in the development of Technical Specifications limits for surface dose rates as the Dominion model forms the basis for the ISFSI on-site and off-site dose rate calculations

The side surface dose rate limit is determined by weighting the calculated dose rate above the radial neutron shield, along the radial neutron shield, and below the neutron shield according to the surface area of the region. Area weighting will be applied in the proportions of 10% both above and below the neutron shield, and 80% along the neutron shield in order to determine a side surface dose rate limit. The side surface and top surface combined neutron and gamma dose rate limits are calculated below from the individual gamma and neutron calculated dose rates.

Location	Gamma (mrem/hr)	Neutron (mrem/hr)	Total (mrem/hr)	Weight Factor	Total*Weight (mrem/hr)
Top of Cask	54	4	58	1	58
Location	**Gamma (mrem/hr)**	**Neutron (mrem/hr)**	**Total (mrem/hr)**	**Weight Factor**	**Total*Weight (mrem/hr)**
Radial Surface Above Neutron Shield	287	115	402	0.1	40
Radial Surface Along Neutron shield	165	23	188	0.8	150
Radial Surface Below Neutron Shield	99	183	282	0.1	28
				Total	218

Surface gamma and neutron dose rates will be measured separately, but the results will be combined to yield the total dose rate for comparison against the Technical Specifications limits. That is, it is not intended to have separate limits for the gamma and neutron dose rates. The method for calculating the surface dose rates will be delineated in the North Anna ISFSI SAR.

When the above method of surface dose rate determination is applied to the Transnuclear dose rate values reported in Section 5.2.3.3 of the TN-32 Generic Technical Specifications, the resulting side surface dose rate is 225 mrem/hr. The side surface dose rate limit of 218 mrem/hr proposed for use at North Anna is consistent with the analysis results provided in the TN-32 FSAR.

The top surface dose rate reported in the TN-32 FSAR, Revision 0, is greater than the current TS limit allowable top surface dose rate or the value calculated and proposed for the Technical Specifications amendment. To remain consistent with the models used for on-site and off-site dose, the Dominion calculated value rather than the TN-32 FSAR Rev. 0 value is proposed for the limit.

Dominion presently calculates the top surface dose rate in the manner described in Section 5.2.3.7.D of the Generic TN-32 Technical Specifications. Dominion has considered the use of an area-weighted average for the top surface dose rate similar to that described above for the radial surface. However, an area-weighted average for the top surface dose rate has not been adopted to date. If such a method is developed in the future, the method will be described in the ISFSI SAR.

As the calculated side surface dose rate for the TN-32 exceeds the current Technical Specification limits, analyses were performed to determine the new dose rates at the ISFSI perimeter fence, site boundary, and nearest permanent resident consistent with the side surface dose rates. These analyses also used Version 4C of the MCNP Monte Carlo transport code and the following conservative inputs:

1. The neutron and gamma source spectra were obtained from the TN-32 Final Safety Analysis Report, Revision 0. The neutron and gamma source emission rates, as indicated

in the TN-32 FSAR, Rev. 0, are 1.699E+17 Photons/sec/cask, and 1.049E+10 Neutrons/sec/cask.

2. The three storage pads are filled with 84 TN-32 casks, each pad having 28 casks. Assuming 84 TN-32 casks results in an amount of fuel stored on the pads which exceeds the current licensed limit of 839.04 TeU (approximately 57 TN-32 casks), providing additional conservatism to the analysis.

3. The inventory of casks stored in the ISFSI will increase by four casks 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.

To determine the dose rate to the nearest permanent resident (2860 feet) calculations were performed using MCNP. These calculations were made using a single cask model requiring that the resulting dose rates be scaled to reflect a full ISFSI (84 casks) accounting for decay due to elapsed time since discharge. This is a conservative approach as it minimizes the variation in distance between the casks and the nearest permanent resident. These calculations resulted in a total dose rate to the nearest permanent resident of 2.10 mrem/yr (0.40 mrem/yr neutron plus 1.70 mrem/yr gamma).

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

Using the same method the nearest site boundary (2500 feet) dose rate was calculated. The MCNP analysis for the nearest site boundary indicates that the maximum dose rate at this location will be 6.45E-4 mrem/hr or 5.65 mrem/yr assuming full-time residence at the boundary, which meets the requirements of 10 CFR 20.1301 of 100 mrem/yr.

The MCNP analysis of the dose rate at the ISFSI perimeter fence using TN-32 casks with the proposed fuel limits resulted in peak dose rates that range from 0.302 to 1.933mrem/hr when all three pads are full. This analysis was based on the above assumptions with the addition of accounting for cask and ISFSI pad location as well as the effect of earthberms on the east and north side of the ISFSI. Experience at the North Anna ISFSI indicates that actual dose rates at the ISFSI perimeter fence are significantly less than the predicted values. The lower actual values result from the conservatism in the predicted values and the loading of storage casks with neutron and gamma source emission rates less than that assumed for design basis analyses.

The current North Anna ISFSI Technical Specifications contain ISFSI perimeter fence dose rate limits which correspond to the maximum predicted dose rates at the ISFSI perimeter fence when the ISFSI is loaded to the limit of 839.04TeU (57 TN-32 casks). These limits were placed in the Technical Specifications to require that measurements be taken to validate the off-site dose rate predictions and ensure the requirements of 10 CFR 20 are met. The measurement of the fence perimeter dose rates for validation of the predicted off-site dose rates is no longer necessary as the off-site dose rates are based on the same assumptions as the surface dose rates. As discussed above the predictions for off-site dose rates due to the ISFSI are based on assumptions made for a single cask that are scaled to represent the entire ISFSI as a source. By measuring the surface dose rates when the cask is loaded, the underlying assumptions for the off-site predictions are verified to be conservative. The fence line dose rates, although based on the surface sources generated for a cask, also account for decay of the fuel at the pad as well as the cask location on the pad, which is slightly different than the assumptions for the off-site dose rates. As the surface dose rates continue to be required at the time of loading the cask and are appropriate for validation of the off-site dose rates, it is proposed that the ISFSI perimeter dose predictions be removed from the Technical Specifications and provided in the ISFSI SAR.

The North Anna ISFSI SAR provides for a design criteria for the cask restricting the surface dose rate to less than 200 mrem/hr anywhere on the cask surface. This dose rate of 200 mrem/hr was an initial design parameter used when providing limits to cask vendors and originated from transportation regulations. The overall design criteria for the dry storage cask are the regulatory dose limits and requirements in 10 CFR 20, 10 CFR 72.104(a) and 10 CFR 72.106(b). Using these dose limits, Virginia Power has determined that limiting the average surface dose rates for the TN-32 cask will ensure that the regulatory requirements are met. Therefore, as part of this change, the 200 mrem/hr surface dose rate limit will be removed from the ISFSI SAR. Additionally, it has been determined by Transnuclear and evaluated by the NRC that peak dose rates due to streaming effects above or below the neutron shield may exceed the 200 mrem/hr value. However, this has no impact on meeting the regulatory requirements for dose. Meeting the regulatory dose requirements is based on the surface dose rate limits specified in the Technical Specifications.

Conclusions For Radiological Protection

The radiation shielding features of the TN-32 cask with higher burnup fuel are sufficient to meet the radiation protection requirements of 10 CFR 20 and 10 CFR72.104 when storing fuel with the proposed fuel limits.

The proposed changes include modifying the limit for the side surface dose rate for a cask at the North Anna ISFSI from 129 mrem/hr to 218 mrem/hr and the top surface dose rate from 55 to 58 mrem/hr. Inclusion in the Technical Specifications of a table providing required cooling time versus burnup and enrichment will ensure the dose rates for the fuel stored will meet the proposed limits.

Occupational Exposures

The TN-32 side surface dose rate is 218 mrem/hour for fuel with the proposed enrichment and burnup. This is greater than the current licensing basis dose rate limit of 129 mrem/hour for the side by approximately 70%. Occupational exposures for cask loading, transport, and emplacement were recalculated using a side dose rate of 218 mrem/hr. In the calculation of these exposures, the time and number of persons required to perform several tasks have been updated to reflect our experience with loading 11 TN-32 storage casks at North Anna and 14 at Surry.

The ISFSI maintenance operations annual exposures were recalculated using a cask surface dose rate of 218 mrem/hr and a cask alarm panel dose rate of 2 mrem/hr. Annual maintenance operations exposures will increase by approximately 73% (from 0.299 person-rem to 0.515

person-rem) when using 84 TN-32 casks as the design basis.

Exposures to workers at the North Anna Power Station decrease slightly because the MCNP analysis of 84 TN-32 casks indicates that the dose rate at approximately 2000 feet is less than the current licensing basis by approximately 9%.

The above exposures were used to calculate total annual doses from ISFSI operations, as shown in the table below. These changes resulted in the annual doses from ISFSI operations increasing by approximately 100%. However the majority of this increase results from increasing the number of SSSCs loaded and stored at the ISFSI from 8 SSSCs every 3 years to 4 SSSCs every year.

Activity	Occupational Exposure Licensing Basis (man-rem)	Revised Occupational Exposures (man-rem)	Percent Change
Cask Loading	3.89[a]	11.12[b]	+186%
Maintenance	0.299	0.515	+73%
NAPS Personnel	3.0	2.75	-9%
Total	**7.19**	**14.39**	**+100%**

a. Cask loading annual exposure based on loading 8 casks every 3 years
b. Cask loading annual exposure based on loading 4 casks every year.

Conclusions For Occupational Exposures

Occupational exposures from TN-32 casks loaded with fuel having the proposed limits are expected to increase from the current licensing basis, however ISFSI related exposures will remain a small percentage of the total exposure expected from operations at the North Anna Power Station.

Accident Evaluation

Current accident analyses for extreme wind, fire, and loss of neutron shield, are not affected by this change because none of these accidents result in a release of radioactive materials. The loss of confinement barrier is of concern and is evaluated for compliance with the requirements in 10 CFR 72.106.

The current accident analysis for loss of confinement barriers is based on the instantaneous release of all Kr-85, I-129, and tritium (H-3), from all the fuel assemblies in a TN-32 cask.

The accident analysis using the TN-32 casks with the proposed fuel limits is based on the requirements of NUREG-1 536 (Reference 7), Interim Staff Guidance-5, (ISG-5) Revision 1 from the US NRC Spent Fuel Project Office (Reference 8), and the following inputs:

1. Isotope inventories are based on 32 fuel assemblies with an enrichment of 3.30 weight percent U-235, burnup of 45,000 MWD/MTU and seven years decay. This enrichment was selected after reviewing the enrichment and burnup of all North Anna spent fuel to ensure

that this enrichment is "bounding". Although this amendment request proposes the use of 4.30 weight percent U-235 fuel, using a lower enrichment yields a bounding isotope inventory, and is in accordance with ISG-6 from the US NRC Spent Fuel Project Office (Reference 9).

2. The Co-60 source is calculated based on the surface area of a 17x17 fuel assembly and a seven year decay time from discharge.

3. A cask seal leak rate was calculated in the TN-32 FSAR Rev. 0. However, a leak rate 1.5 times greater than the rate calculated in the FSAR is used in the analysis to provide additional conservatism.

4. A bounding dispersion factor (X/Q) for accident conditions from the ISFSI SAR is used in the analysis.

5. The breathing rate identified in Revision 0 of the TN-32 FSAR is used in the analysis.

6. The bounding dose conversion factors in EPA Guidance Report No. 11 (Reference 10) are used to calculate the whole body, critical organ, and thyroid dose from inhalation.

7. The bounding dose conversion factors in EPA Guidance Report No. 12 (Reference 11) are used to calculate the whole body, critical organ, thyroid, and skin dose from immersion.

The isotopes used in the analysis are based on the selection criteria in ISG-5, Revision 1, including Co-60 in the fuel rod crud, iodine-129, tritium, metastable tellurium-125, fission products that contribute greater than 0.1% of activity, and actinides that contribute greater than 0.01% of activity. The isotope concentrations are used with the release fractions, the free volume in the cavity of the TN-32 cask (5.39 cubic meters), and the cask seal leak rate to calculate the isotope release rate (μCi/sec) from the cask. The isotope release rate is used over a 30-day period to calculate a release inventory in curies.

The site boundary inhalation dose for each isotope was calculated using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 11, a bounding dispersion factor (X/Q), and the breathing rate. Similarly, using this release inventory, the bounding dose conversion factors from EPA Guidance Report No. 12, and a bounding dispersion factor (X/Q), the site boundary immersion dose for each isotope was calculated.

This accident evaluation (Reference 12) resulted in a deep dose plus committed dose equivalent to the worst organ of 76 mrem that is well within the criteria of 10 CFR 72.106.

Conclusions For Accident Evaluation

The accident evaluation for a loss of confinement accident with fuel with the proposed limits results in an offsite dose less than the current licensing basis and is in compliance with 10 CFR 72.106. The design of the confinement system of the TN-32 is in compliance with 10 CFR 72.106 and satisfies the applicable design and acceptance criteria.

C. Environmental Assessment

The use of TN-32 casks having fuel with the proposed limits will not require any changes in the design of the North Anna ISFSI, and therefore their use will have no effect on the construction or operations impacts previously reviewed.

The use of TN-32 casks to store spent fuel with the proposed limits at the North Anna ISFSI will not increase the exposure pathway associated with ISFSI operation, which is from direct radiation to site workers and nearby residents. As previously discussed, the maximum annual dose at the site boundary with 84 TN-32 casks storing fuel with the proposed characteristics, is less than the 10 CFR 20.1301 limit. The dose to the nearest resident from the North Anna ISFSI containing 84 TN-32 casks storing fuel with the proposed criteria is also below the limit.

The accident evaluation for a loss of confinement accident with fuel with the proposed criteria results in an offsite dose that is in compliance with 10 CFR 72.106.

Since TN-32 casks are already being used at the North Anna ISFSI, the use of TN-32 casks storing fuel with the proposed criteria will not introduce any new non-radiological impacts.

D. Criticality Evaluation

The criticality evaluation from Chapter 6 of the TN-32 FSAR Revision 0 includes an evaluation of the storage of the Westinghouse 17x17 Standard Fuel design. This evaluation is summarized below.

Criticality control in the TN-32 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, and by dissolved boron in the spent fuel pool water. The criticality evaluation performed in the TN-32 FSAR Revision 0 takes credit for 90% of the boron 10 in the borated aluminum absorber plates rather than the maximum value of 75% used in prior evaluations. NUREG/CR-5661 indicates this is allowable if tests capable of verifying the presence and uniformity of the neutron absorber are implemented. A description of the tests and examinations justifying the use of 90% credit is provided in the TN-32 FSAR Revision 0.

Transnuclear evaluated five Westinghouse fuel designs to determine the most reactive fuel configuration. The five were the Westinghouse 14x14 Standard, 14x14 OFA, 15x15 Standard, 17x17 Standard, and 17x17 OFA designs. Of these five designs, the Westinghouse 17x17 Standard design with BPRA was determined to be the most reactive, and this fuel design was used for the criticality evaluation.

The contents of a TN-32 cask at the North Anna ISFSI are limited to the Westinghouse 17x17 Standard Fuel and North Anna Improved Fuel (NAIF) designs. The NAIF design envelope has dimensions identical to the Standard Fuel design, but several structural elements are made of different materials. These material differences do not affect the criticality analyses, however, and so the criticality evaluations for these fuel types are equivalent.

The fuel assemblies were evaluated with and without burnable poison rod assemblies (BPRA). BPRA were modeled using aluminum rods containing no boron. This displaces the borated water and bounds the effect of depleted BPRA. The criticality evaluations did not rely on any special loading patterns or orientation of the fuel assemblies for criticality control. However, a boron concentration of 2300 ppm in the water used in the cask was assumed in the TN-32 FSAR Rev. 0 analysis.

The evaluations assumed that each fuel assembly design contained a certain amount of uranium. In the case of the Westinghouse 17x17 Standard Fuel design, this content was 467.1 kgU per fuel assembly. Therefore, a limit of 467.1 kgU/fuel assembly will be added to the ISFSI Technical Specifications to ensure compliance with this design input. Based on a review of all existing North Anna fuel assemblies, this would only exclude a limited number of lead test assemblies from being stored in a TN-32 spent fuel storage cask at this time.

Criticality Calculation

The criticality evaluations were performed by Transnuclear using the CSAS25 sequence from the SCALE4.3 code system (Reference 13) with the SCALE 27-group ENDF/B-IV cross section library. Within this sequence, resonance correction based on the fuel pin cell description is provided by NITAWL using the Nordheim Integral method, and k_{eff} was determined by the KENO-Va code. A sufficiently large number of neutron histories were run so that the standard deviation was below 0.0020 for all calculations. These calculations and results are described further in the TN-32 FSAR Revision 0.

The TN-32 was evaluated for a variety of configurations intended to bound all normal, off-normal, and accident conditions. The following conditions were evaluated individually.

1. Baseline: Most reactive TN-32 fuel configuration, 100% borated water density. The fuel assemblies are shifted toward the cask vertical axis until the outer pin cells contact the basket compartment wall. This condition bounds all possibilities of fuel assemblies positioned off-center in the compartment.

2. The neutron absorber plates and the active fuel zone are offset by two inches axially. This condition might occur due to fuel design differences in the distance from the bottom of the fuel assembly to the beginning of the active fuel, or due to fuel pins slipping in the spacer grids during handling.

3. The inside dimension of the compartment is increased and decreased by 0.06 inches. All compartments move correspondingly further apart or closer together. This condition bounds the dimensional tolerance on the basket tubes.

4. The width of the neutron poison plate is reduced by 0.06 inches, corresponding to its dimensional tolerance. It is not necessary to evaluate the tolerance in length because it is bounded by the two-inch axial offset condition above.

5. Fresh water is placed in the gap of all fuel rods. Although a fuel rod that develops a cladding breach during reactor operations could be saturated with unborated water at the end of its operating cycle, it is unlikely that the water in the fuel rod would remain unborated after years of storage in borated water.

6. The borated water density is varied, except in the homogenized basket rail/borated water

zone, to simulate the reduction in density that might occur during unloading operations.

7. Borated water is drained down to the top of the active fuel, except in the basket rail zone. This is the most reactive configuration expected during loading and unloading operations, because it reduces the boron capture of reflected neutrons.

As expected, reduction of the neutron absorber plate width, reduction of compartment size, borated water drain-down, and inclusion of fresh water in the fuel rod gap all cause a slight increase in k_{eff}. The optimal borated water density was found at about 95%.

These conditions were combined for a "worst-normal" condition and the borated water density was varied from 85% to 100%. This resulted in a maximum k_{eff} = 0.9264 ± 0.0009 at 90% borated water density.

To evaluate accident conditions, the worst-normal case model was re-run with a single fuel assembly of 5 weight percent U-235 enrichment. This fuel assembly was placed in one of the four center basket locations. This case demonstrated compliance with the requirement of 10 CFR 72.124 by combining at least two unlikely, independent, and concurrent changes in the conditions essential to nuclear criticality safety; worst case geometry and accidental loading of a fuel assembly with enrichment greater than assumed in the analysis. This resulted in a k_{eff} = 0.9315 ± 0.0009.

Recently, Transnuclear performed analyses to determine what initial enrichment could be stored if the water in the spent fuel pool had a boron concentration of 2500 ppm. This is the current minimum Technical Specification limit for North Anna. These analyses assumed that the most reactive fuel design and worst-normal configuration remained the same even with the boron increase.

The same criticality model as before was used, however the CSAS25 sequence from SCALE-4.4 was used to determine the k_{eff} using KENO-Va and the 44-group ENDF/V cross section library. The worst-normal case from before with the enrichment changed to 4.30 weight percent U-235 and the soluble boron concentration changed to 2500 ppm was analyzed. As before, the water density was varied to simulate the reduction in density that might occur during unloading operations. Similarly, the accident condition (assembly misload), was simulated as before but with a loading of 4.30 weight percent assemblies and a misloaded 5 weight percent U-235 assembly in an interior cell. A new upper subcritical limit (USL) was determined using SCALE-4.4 for comparison to the calculated keff's for the analyzed conditions. These analyses verified that under normal, off-normal, and accident conditions, that the maximum value of $k_{eff} + 2\sigma$ is less than the USL of 0.9419. The worst case, which combines two independent conditions of a misloaded single fuel assembly with the "worst-normal" configuration at reduced (optimum, 92.5% density) water moderation, has a $k_{eff} + 2\sigma = 0.9404$.

Conclusions For Criticality Evaluation

The TN-32 cask is designed to be substantially subcritical under all credible conditions. The criticality design is based on favorable geometry, fixed neutron poisons, and soluble poisons in the spent fuel pool, with unirradiated fuel having an initial enrichment up to and including 4.30 weight percent U-235. An appraisal of the fixed neutron poisons has shown that they will remain effective for the 20-year storage period, and there is no credible way to lose them. The analysis and evaluation of the criticality design and performance have demonstrated that the cask will provide for the safe storage of spent fuel for a minimum of 20 years with an adequatesubcritical margin.

The criticality design features for the TN-32 are in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the criticality design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel.

Revision of the North Anna ISFSI Technical Specifications is required to ensure that a boron concentration of greater than or equal to 2500 ppm is maintained during loading or unloading of this cask. Currently the North Anna Plant Technical Specifications require a minimum boron concentration in the spent fuel pool of 2500 ppm. A limit of 467.1 kgU per fuel assembly will also be added to the North Anna ISFSI Technical Specifications to ensure compliance with this design input. The proposed Technical Specifications include a requirement that the basket absorber plates have a minimum boron-10 areal density of 10 mg/cm^2. A description of the testing and evaluation of the absorber plates which allows credit for 90% of the boron-10 content will be placed in the North Anna ISFSI SAR and referenced in the Technical Specifications.

E. Thermal Evaluation

The thermal evaluation from Chapter 4 of the TN-32 FSAR Revision 0 is being used to support the change to the North Anna ISFSI Technical Specifications for fuel with the proposed limits. Both normal and loading/unloading conditions were evaluated.

Normal Conditions

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

1. A maximum heat load of 32.7 kilowatts from 32 fuel assemblies with BPRAs or TPDs, or 1.02 kilowatts/fuel assembly and insert.

2. An ambient temperature range of -30 to 115°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. A total solar heat load for a 12-hour period of 1475 Btu/ft^2 for curved surfaces and 2950 Btu/ft^2 for flat surfaces, per 10 CFR 71.71(c). Since the cask has a large thermal inertia, the total insolation is averaged over a 24-hour period.

Using these inputs, the thermal analysis for normal storage concluded that the TN-32 design meets all applicable requirements. The maximum temperature of any confinement structure component is less than 315°F, which has an insignificant effect on the mechanical properties of the confinement materials used. The predicted maximum fuel cladding temperature is 565°F, which is well below the allowable fuel temperature limit of 622°F.

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.

The loading condition evaluated for the TN-32 was the heatup of the cask before its cavity can be backfilled with helium. This occurs during the vacuum drying operation of the cask cavity. Transient thermal analyses are provided in the TN-32 FSAR Revision 0 to predict the heatup time history for the cask components assuming air is in the cask cavity.

The results of the transient thermal analysis for the maximum heat load of 32.7kw predict that the fuel cladding reaches a maximum temperature of 935°F. This is well below the loading/unloading temperature limit of 1058°F. Therefore, the duration of the cask drying procedure is not constrained by the fuel cladding temperature limit. However, transient analyses showed that in order to prevent cask component peak temperatures from exceeding their analyzed temperature range, in particular the basket, the time before backfilling the cask with helium must be limited to less than 36 hours for the new design heat load.

Unloading of a cask requires the flooding of the cask prior to the removal of the fuel. A quench analysis of the fuel is provided in the TN-32 FSAR Revision 0, and concludes that the total stress on the fuel cladding is below the cladding material's minimum yield stress. In addition, by limiting the water flow rate into the cask and monitoring the pressure of the air/steam outflow mixture, the buildup of steam pressure in the cavity will be limited to less than the cask design pressure.

Conclusions For Thermal Evaluation

The thermal design of the TN-32 cask is in compliance with 10 CFR 72 and the applicable design and acceptance criteria have been satisfied. The evaluation of the thermal design provides reasonable assurance that the TN-32 will allow the safe storage of spent fuel for a minimum of 20 years.

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 assuming the cask was backfilled with a helium atmosphere within 36 hours of draining. Cask internal pressures under normal conditions were acceptable. The TN-32 cask is designed with a heat removal capability having testability and reliability consistent with its importance to safety.

The TN-32 cask provides adequate heat removal capacity 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 North Anna ISFSI Technical Specifications will be revised to specify the maximum heat generation rate of 1.02 Kw per fuel assembly and insert. To ensure that the heat transfer properties used in the cask thermal analysis were appropriate for this increase in heat load, a thermal test was performed. Technical Specifications and Surveillance Requirements will be added to ensure that a helium atmosphere of at least 99.99% purity is provided within the cask within the time limitations indicated by the evaluation. As the thermal evaluation assumed a nominal 16 feet center-to-center spacing of the casks, the Technical Specifications will be modified to ensure a minimum spacing of 16 feet center-to-center is provided.

F. Conclusions

Based on the evaluations discussed above, the use of TN-32 casks with higher enrichment and burnup fuel at the North Anna ISFSI will comply with the requirements of 10 CFR 20 and 10 CFR 72. The limits to be placed on the use of TN-32 casks are provided below.

Initial Enrichment	≤ 4.30 weight percent U-235
Assembly Average Burnup	≤ 45,000 MWD/MTU
Time After Irradiation	SAR Figure 2-5.1
Heat Generation	≤ 1.02 Kw/Assembly
Fuel Assembly Uranium Content	≤ 467.1 KgU/Assembly
Boron Content of Water	≥ 2500 ppm

These limits are to be incorporated into Table 2-5 of the North Anna ISFSI Technical Specifications. The side surface dose rate limit in Section 3.3 of the Technical Specifications will be changed to 218 mrem/hour and the top surface dose rate changed to 58 mrem/hr. Actions will be modified to ensure that a loaded SSSC will not be without a helium atmosphere for more than 36 hours.

G. References

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

2. TN-32 Dry Storage Cask System Safety Evaluation Report, TAC No. L22909, US Nuclear Regulatory Commission, March 28, 2000.

3. TN-32 Dry Storage Cask Final Safety Analysis Report, Revision 0, Transnuclear Inc., January 2000.

4. Calculation 1066-128, Criticality Evaluation at Higher Enrichment, Transnuclear Inc., November 2001.

5. MCNP4C, Monte Carlo N-Partical Transport Code System, Los Alamos National Laboratory, CCC-660.

6. Calculation PA-0181, North Anna ISFSI Perimeter Fence, Boundary and Nearest Permanent Resident Dose Rates Based on the TN-32 Dry Storage Cask, December 2001.

7. NUREG-1536, Standard Review Plan for Dry Cask Storage Systems, US Nuclear Regulatory Commission, January 1997.

8. Interim Staff Guidance - 5, Revision 1, Confinement Evaluation, US Nuclear Regulatory Commission, Spent Fuel Project Office.

9. Interim Staff Guidance - 6, Minimum Enrichment for Design Basis, US Nuclear Regulatory Commission, Spent Fuel Project Office.

10. U.S. Environmental Protection Agency, Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, DE89-01 1065, 1988.

11. U.S. Environmental Protection Agency, Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil, EPA 402-R-93-081, September 1993.

12. Calculation PA-0182, Site Boundary Dose from Leak of a TN-32 Cask Containing High Burnup Fuel at the North Anna ISFSI, December 2001.

13. SCALE 4.4, A Modular Code System For Performing Standardized Computer Analyses for Licensing Evaluation, CCC-545, Oak Ridge National Laboratory.