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

SAFETY EVALUATION REPORT
DOCKET NO. 72-16
LICENSE NO. SNM-2507
AMENDMENT NO. 4

INTRODUCTION

By letter dated May 27, 2014 (Agencywide Documents Access and Management System (ADAMS) accession number ML14160A707), as supplemented, November 7, 2014 (ML14317A086), Virginia Electric and Power Company (Dominion or the applicant) submitted a license amendment request (LAR) to the U.S. Nuclear Regulatory Commission (NRC) requesting to amend Special Nuclear Materials (SNM) license number 2507 (SNM-2507) for the North Anna Power Station (NA) Independent Spent Fuel Storage Installation (ISFSI) located in Louisa County, Virginia. Dominion is proposing to amend Technical Specification (TS) 4.2.3, "Storage Pad," to change the center-to-center spacing for Transnuclear-32 (TN-32) casks with heat loads not greater than 27.1 kilowatts (kW) from a "nominal" 16 feet (ft.) to a minimum of 14 ft.

In accordance with NRC regulations, Title10 of the Code of Federal Regulations (10 CFR) Part 72, "Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste", the NRC staff reviewed the proposed LAR. Staff documented, in this safety evaluation report (SER), the assessment of the potential safety impacts of the proposed license amendment.

The NRC staff also published a Notice of Docketing (notice for the opportunity to request a hearing and to petition for leave to intervene), and a finding of no significant impact (FONSI) related to this proposed LAR. The Notice of Docketing was published in the *Federal Register* on July 22, 2014 (79 FR 42557). The Notice of Availability of Environmental Assessment and FONSI for the NA ISFSI were published in the *Federal Register* on February 27, 2015 (80 FR 10726).

BACKGROUND

On June 30, 1998, the NRC issued Dominion a 20-year license to receive, possess, store, and transfer the NA Units 1 and 2 spent nuclear fuel to an ISFSI located on the NA site. The NA specific license, SNM-2507, allows for the storage of eighty-four (84) TN-32 sealed surface storage casks (SSSCs) on three pads - 28 SSSCs per pad. Each TN-32 cask is designed to hold 32 pressurized water reactor (PWR) fuel assemblies. Currently, the ISFSI consists of one pad with 27 loaded TN-32 SSSCs.

On August 23, 2011, a 5.8 magnitude earthquake was recorded in Mineral, Virginia, which is approximately 10 km (6 mi) from the NA site. During the seismic event, 25 of the 27 SSSCs on the NA ISFSI Pad 1 shifted from their original positions. The shifting of the casks changed the center-to-center spacing from a "nominal" distance of 16 ft. to a distance ranging from 15 ft. 2.25 inches (in.) to 16 ft. 11.25 in. (ML14160A707). While the movements of the casks resulting from that earthquake were no more than a few inches (up to 4.5 inches), the applicant determined that it was not clear that the casks' spacing on the pad continued to meet the current spacing requirements in the license's TS 4.2.3. A detailed inspection and monitoring was performed by

both NA and Transnuclear personnel to determine if there was any damage that could impact safety-related features (ML13037A549). The licensee submits that, based on these inspections and monitoring, no indications of cracks in the casks or pad were found. Thermal, nuclear, and structural analyses were conducted to support the amendment request.

NRC inspections in response to the earthquake found that the casks withstood the earthquake and concluded that there was no immediate safety issue associated with the movement of the casks (ML113290182). The spent fuel continues to be surrounded by several tons of steel and sealed in an inert helium environment. Radiation surveys indicated no changes to cask surface dose rates. The two casks with the least separation (15 ft., 2.25 in.) are casks that had decay heats when loaded in 2000 and 2001, of 15.4 kW and 18.0 kW, respectively. Both casks are well below the 27.1 kW allowable decay heat (ML12037A030).

Dominion is requesting to amend license SNM-2507, TS 4.2.3, "Storage Pad," which in part defines the distance between individual casks (center-to-center) on the ISFSI pad. The licensee is proposing to change the allowable distance between individual casks from a "nominal" 16 ft. to a minimum of 14 ft. (center-to-center) for casks with a heat load not greater than 27.1 kW on ISFSI Pad 1. In a response to an NRC request for additional information (RAI, ML14275A025), Dominion confirmed that because the casks would remain in place, the LAR would not result in changes to routine operations and maintenance activities (ML14317A086).

STRUCTURAL EVALUATION

TS 4.2.3 states, in part, that "[T]he SSSCs in each row will be spaced a nominal 16 feet apart center to center. Each row of SSSCs will be spaced a nominal 16 feet apart center to center. For SSSCs whose heat load exceeds 27.1 kW the spacing shall be a minimum of 16 feet apart center to center."

After the August 23, 2011 seismic event, inspections determined the TN-32 casks had shifted, resulting in cask spacing ranging from 15 feet 2.25 inches to 16 feet 11.25 inches, center-to-center. Because "nominal" is not a defined term, it is unclear as to whether the current cask spacing meets the intent of the nominal spacing statement in TS 4.2.3. Specifically, the design basis analysis assumed a 16 feet center-to-center spacing.

To resolve this situation, the applicant proposes to change TS 4.2.3 so that it defines a minimum allowable center-to-center spacing between casks of 14 feet for casks with heat loads not greater than 27.1 kW. For casks with heat loads in excess of 27.1 kW, the minimum spacing shall be 16 feet center-to-center.

Detailed visual and performance inspections performed by the applicant following the seismic event revealed that there was no damage or cracking to the pad surface and no visible structural damage to the TN-32 casks. To confirm that areas unavailable for inspection had also not been impacted, the applicant performed several analyses, evaluations and assessments. The only abnormality noted was the change in the center-to-center spacing of the casks.

TN-32 EVALUATION

The TN-32 cask structural design was evaluated by the applicant for accelerations of 1g horizontally and 2g vertically. The cask basket system design was evaluated for accelerations of 1g horizontally and 3g vertically. In addition, the basket was evaluated for an 18 inch drop onto the pad and the cask was evaluated for tip-over, both of which assumed 50g downward accelerations.

The applicant stated that peak ground accelerations, as a result of the 5.8 magnitude earthquake, measured at the NA Unit 1 basemat were: 0.26g north-south, 0.11g east-west and 0.12g vertical. The applicant performed a soil structure interaction (SSI) analysis for ISFSI Pad 1 and determined that the peak seismic accelerations in the TN-32 casks as a result of the seismic event are bounded by previously analyzed conditions from the FSAR.

The applicant performed a sliding evaluation that indicated that cask sliding will occur at accelerations of 0.28g horizontal and 0.189g vertical with a coefficient of friction of 0.35. Because horizontal accelerations from the seismic event ranged from 0.398g to 0.55g, the applicant stated that the movement of the casks was expected.

The staff reviewed the application and the FSAR and determined that the design basis earthquake conditions for the cask and the basket bound the conditions that resulted from the seismic event on August 23, 2011. In addition, based on the inspection results, the staff concludes that there was no structural damage to the cask or the basket and that they maintain their ability to withstand the design basis loads as presently licensed.

ISFSI PAD 1 ANALYSIS

Although the ISFSI pad is not considered a component that is important to safety, based on the FSAR, the applicant performed an SSI analysis of the ISFSI pad. To generate the largest seismic reactions, the applicant used the earthquake response spectra observed at the NA Unit 1 basemat, amplified it through the rock and soil layers, through the thickness of the pad, to the center of gravity of the TN-32 cask. Applying the casks as point loads at 14 feet center-to-center and weak soil springs, the applicant calculated the worst-case moment and shear load demands on the pad. The results of this analysis established that the seismic load demand on the pad was approximately 75% of the ACI 349-01 design code capacity.

The staff reviewed the application and the FSAR. Based on these documents and the inspection results, the staff determines there was no structural damage to the ISFSI pad and that it is capable of withstanding the design basis loads as presently licensed.

EVALUATION FINDINGS

The staff concludes that the structural properties of the structures, systems, and components of the TN-32 casks continue to be in compliance with 10 CFR Part 72, and that the applicable design and acceptance criteria remain satisfied. The evaluation of the structural properties provides reasonable assurance that the TN-32 casks will continue to allow safe storage of spent nuclear fuel. This finding is reached on the basis of a review that considered the regulation itself, appropriate regulatory guides, applicable codes and standards, and accepted engineering practices.

THERMAL EVALUATION

The original design basis thermal analysis was performed by assuming a spacing distance of 16 feet center-to-center and a maximum cask heat load of 32.7 kW.

After the August 23rd seismic event near NA, instead of moving the casks back to their pre-earthquake locations, the applicant performed a thermal analysis and proposed to change TS 4.2.3 to allow a minimum center-to-center spacing of 14 feet for casks with heat loads less than 27.1 kW. For casks with heat loads in excess of 27.1 kW, the applicant stated that the current minimum 16 feet center-to-center spacing requirement would still be maintained.

The applicant performed thermal analyses using the same methodology as that used for the design basis thermal analysis to evaluate the thermal performance for center-to-center cask spacing of 16 feet and 14 feet with a 27.1 kW heat load. The applicant's results are shown in Table 1.

The staff reviewed the applicant's thermal analyses and found that both fuel cladding temperature and cask component temperatures are still below the original licensing basis temperature limits with significant margins under a center-to-center spacing of 14 feet and a heat load of less than 27.1 kW. Based on the staff's review, the staff concludes that the thermal performance of the TN-32 casks located on Pad 1 with the center-to-center spacing of 14 feet and a heat load of not greater than 27.1 kW still meets the thermal requirements of 10 CFR Part 72 (i.e., 72.122 for protection of cladding and 72.128 for cask component temperature limits).

Table 1. Maximum TN-32 Component Temperatures – Design Basis and Analyzed Conditions

Component	**T_{lim} (°F)**	**T_{max} (°F)*** 16 ft, 32.7 kW	**T_{max} (°F)** 16 ft, 27.1 kW	**T_{max} (°F)** 14 ft, 27.1 kW
Outer Surface	-	240	233.4	237.5
Radial Neutron Shield (Resin/Aluminum)	300	280	253.6	257.6
Seal/Lid	570	256	233.6	237.1
Fuel Compartment	-	527	462.7	466.1
Fuel Cladding	622	565	498.2	501.4

*Design Basis

EVALUATION FINDINGS

F4.1 Based on the staff's review of the applicant's thermal analysis, the staff has reasonable assurance that the thermal requirements of 10 CFR 72.122 and 72.128 continue to be met. Specifically, the staff has reasonable assurance that the fuel cladding and cask component temperatures will remain below the allowable temperature limits under normal, off-normal, and accidental conditions. The finding is reached on the basis of a review that considered the regulations, appropriate regulatory guides, applicable codes, model assumptions/methodology, and accepted engineering practices.

F4.2 The staff determines that the proposed change to allow a minimum center-to-center spacing of 14 feet for the TN-32 casks with heat loads not greater than 27.1 kW meets the thermal requirements of 10 CFR Part 72.

F4.3 The staff confirms that for the casks with heat load exceeding 27.1 kW, a cask center-to-center spacing of a minimum of 16 feet apart will meet the thermal requirements of 10 CFR Part 72.

After reviewing the amendment application, the staff concludes that the proposed changes to TS 4.2.3 are acceptable and are in compliance with 10 CFR Part 72.

RADIATION PROTECTION EVALUATION

The applicant's evaluation considered the possible radiological impacts to public and occupational doses resulting from both the movement of the casks due to the earthquake and the proposed change in the center-to-center spacing. The applicant concluded that the cask movement and the proposed spacing change both result in negligible impacts to public doses and minor impacts to occupational doses (i.e., well within the site's ALARA program controls and limits). The applicant arrived at this conclusion by performing analyses of a change in cask spacing from 16 feet to 14 feet and outcomes of post-earthquake inspections and radiation surveys. Current licensee (applicant) plans regarding storage under its specific license, as described in the next paragraph, also factored into the applicant's analyses and conclusion. These analyses and inspection and survey results are described in the applicant's submittal of May 27, 2014, as supplemented on November 7, 2014.

The staff reviewed the applicant's evaluation, accounting for various considerations, as described below. As part of its review, the staff also considered the information in the current ISFSI FSAR and supporting documents. The applicant stated that it does not anticipate storing any casks under this specific license in addition to those currently in storage and that it intends to leave the currently loaded casks at the post-quake positions (not move them to a 14 ft center-to-center spacing). Therefore, the applicant framed its analyses in terms of only the currently loaded casks. The staff recognizes the applicant's current plans and intentions; however, the staff considered the proposed changes in terms of both the casks that are currently loaded on the existing pad and the loading of additional casks up to the 27.1 kW heat limit at the proposed minimum 14 feet spacing. The staff's evaluation of the currently loaded casks included consideration of the applicant's inspection findings regarding the casks' condition after the earthquake (i.e., no damage) and post-quake positions. The staff considered the loading of additional casks because the license allows for storage of more fuel than is currently loaded at the applicant's specific-license ISFSI.

The staff's evaluation is focused, as was the applicant's, on the results of direct radiation. This is based on the determination from the applicant's post-earthquake inspections that the casks, including components related to confinement and confinement monitoring, were not damaged or degraded. Since the confinement and confinement monitoring components were not damaged or degraded, the staff finds that the casks' confinement capability remains as designed and analyzed in the FSAR. This means that there are no effluents from the casks and therefore no doses due to effluents. Further, with no damage to the casks, the staff only evaluated the dose impacts related to changes in the cask position resulting from the earthquake and the differences that would result from the change in center-to-center spacing as proposed in the LAR.

The shielding and radiological analyses in the FSAR, Revision 8, and supporting documents are based on source terms for the licensee's design-basis spent fuel assembly, which is a 17x17 assembly with a forty-five gigawatt-days per metric ton of uranium (45 GWd/MTU) burnup, 3.5% minimum enrichment, and 7 years decay. Dose rates from a cask loaded with this fuel are used for occupational dose estimates. For public dose estimates, the FSAR provides results for 2 of

the 3 allowed ISFSI pads loaded with 28 casks each and results for all 3 ISFSI pads loaded with 28 casks each. The analyses assume 4 casks are loaded each year. Based on this assumption, the analyses account for the additional source decay undergone by spent fuel in the storage casks at the ISFSI at the times needed to achieve the two analyzed conditions (i.e., two filled ISFSI pads and three filled ISFSI pads).

OCCUPATIONAL DOSES

The staff first evaluated the impacts of the proposed changes to the occupational doses to evaluate compliance with 10 CFR Part 20 and 10 CFR Part 72 requirements. The staff used a simple model to determine the change in dose rates due to the change in the cask spacing from 16 feet to 14 feet (center-to-center). The staff assumed the individual is at the surface of one cask at a position that is inside the cask array. With the change in cask spacing, the shortest distance between cask surfaces reduces from about 7.9 feet to about 5.9 feet. This distance is for casks that are directly opposite each other in the two rows of the cask array. The distances to other neighboring casks are greater than this. Based on its simple model, the staff estimated a dose rate increase that is consistent with that determined by the applicant.

The staff determined that this result is conservative for casks that are currently loaded at the ISFSI because the casks' movement due to the earthquake was random and only a few inches from their previous positions. Thus, the staff finds that the impacts to occupational doses (post-quake vs. pre-quake) will be much smaller than the impacts shown in the calculation, no more than a few percent versus the current doses. In terms of the dose estimates provided in the ISFSI FSAR, the staff finds that the additional radioactive decay of the spent fuel resulting from the time the fuel has been stored at the ISFSI versus that analyzed in the FSAR means that the dose estimates in the FSAR remain bounding. Based on information available to the staff regarding cask loading at NA, the staff estimates that the spent fuel experienced a minimum of about three years additional radioactive decay at the time of the earthquake. This additional decay results in source terms that are several percent lower than the source terms used in the FSAR analysis.

For any casks that may be loaded in the future as part of the specific license, the staff finds the FSAR analysis is still acceptable for occupational dose estimates based on the following. While the reduced distance between casks will increase doses, the staff's analysis indicates that there are conservatisms in the analysis that adequately offset the increase in doses. The staff performed source term calculations using the ORIGEN-ARP code from the SCALE 5.0 code system for the applicant's design-basis fuel assembly. The results indicated that the decay heat for a cask loaded with the design-basis assembly is several percent higher than the maximum heat load allowed for the proposed minimum cask spacing of 14 feet (center-to-center). Thus, the staff varied the decay time to determine the radiation source terms (neutron and gamma) that are associated with an assembly decay heat for which the cask decay heat would just meet the maximum decay heat allowed for the proposed minimum cask spacing. The source terms for this decay heat are less than the analyzed source terms by several percent, particularly for gamma energies that are significant contributors to cask dose rates. In the cask analyses, the gamma source dominates the dose rates. While there is no simple one to one correlation

between decay heat and radiation source terms, the analysis does indicate that there are conservatisms in the analyzed source terms that are comparable to the dose rate increase estimated for the proposed change to the cask spacing. Accounting for these conservatisms, the staff finds that the occupational dose estimates in the FSAR remain acceptable.

DOSES TO THE PUBLIC

The staff also evaluated the impacts of the proposed changes to members of the public, particularly for those at or beyond the controlled area boundary. For this evaluation, the staff considered the applicant's analysis and dose rate measurements for each quarter of 2011 through 2013. These dose rates were determined from measurements taken at the ISFSI fence. The applicant also reported that no discernable increase in exposure levels was detected by environmental thermoluminescent dosimeters located at or near the site boundary (versus pre-quake levels). The shortest distance from the ISFSI to the site boundary is 2500 feet. Annual dose estimates of a maximum of 5.10 mrem in the ISFSI FSAR for a fully loaded ISFSI (3 pads containing 28 casks each), which includes 3 mrem from NA Units 1 and 2 operations, are well below the limits in 10 CFR 72.104 for the nearest permanent resident (located 2860 feet from the ISFSI).

The applicant provided the quarterly dose rate measurements in graphical format, separating the neutron and gamma contributions. Data are presented for each side of the fence (i.e., North, South, East, and West). In its review of the data, the staff did not identify any discernable patterns that could indicate a change in the trends for the dose rates. Additionally, the dose rates are quite small and the fluctuations seen in the figures are also quite small (on the order of a few µrem/hr). The staff expects that such fluctuations would be a function of the instrumentation and background fluctuations.

The staff also considered the positions of the casks relative to each other both before and after the August 2011 earthquake. This was done in order to evaluate whether any significant change may have occurred in the shielding of some of the casks by other casks (either from one row or one column to the other). Based on the information regarding the casks' positions, which was presented in a public meeting on January 28, 2014, the staff finds that the differences in relative positions of the casks are quite small, such that any anticipated impacts on dose rate are negligible. Based on these considerations and the staff's evaluation of the applicant's data, the staff has reasonable assurance that the casks' movements due to the earthquake have not affected doses to members of the public.

For casks that may be loaded in the future, the staff evaluated the potential impacts on dose estimates for casks at the proposed spacing versus the spacing analyzed in the FSAR. As the applicant stated in the LAR, the spacing is more compact, resulting in a more compact set of radiation sources. The applicant also noted that the closer spacing will also mean that casks in one row or column will be shielded more by the casks in the other row or columns of the cask array and that this effect would compensate for any effects of a more compact set of sources.

In addition to reviewing the applicant's statements, the staff performed a simple calculation of the change in distances between the various casks in the array to two locations of interest as a

result of the proposed change in cask spacing. The staff considered the point on the site boundary nearest the ISFSI (2500 feet) and an approximate distance to the site's Information Center. Given the large distances from the casks to these locations, the staff used a $1/r^2$ (inverse of the square of the distance) relationship between dose and distance from each cask. The staff's results indicate that any impacts on dose are negligible, even without accounting for the shielding of one cask by its neighbors in the array. Accounting for that shielding effect would further support the conclusion of a negligible dose impact since the shielding effect would reduce the estimated dose impacts. Based on these evaluations, the staff has reasonable assurance that the proposed change in cask spacing will not impact offsite doses.

EVALUATION FINDINGS

Based on its review of the applicant's evaluation and independent staff evaluation, as described above, the staff has reasonable assurance that the North Anna specific-license ISFSI will continue to meet the 10 CFR Part 20 and 10 CFR Part 72 requirements regarding radiation protection of occupational personnel and the public.

CHANGES TO LICENSE AND TECHNICAL SPECIFICATIONS

The changes to the license conditions and technical specifications for the NA ISFSI are as follows: TS 4.2.3, Storage Pad

Current Wording:

> The North Anna ISFSI storage pads are reinforced concrete, with nominal dimensions of 224 feet x 32 feet x 2 feet thick with a 40-foot ramp on each end for vehicle access. Each pad is designed to store 28 SSSCs arranged in two rows. The SSSCs in each row will be spaced a nominal 16 feet apart center to center. Each row of SSSCs will be spaced a nominal 16 feet apart center to center. For SSSCs whose heat load exceeds 27.1 KW the spacing shall be a minimum of 16 feet apart center to center. The facility will have up to three storage pads.

Proposed Wording:

> The North Anna ISFSI storage pad is reinforced concrete, with nominal dimensions of 224 feet x 32 feet x 2 feet thick with a 40-foot ramp on each end for vehicle access. The pad is designed to store 28 SSSCs arranged in two rows. The SSSCs in each row will be spaced a minimum of 14 feet apart center to center. Each row of SSSCs will be spaced a minimum of 14 feet apart center to center. For SSSCs whose heat load exceeds 27.1 KW the spacing shall be a minimum of 16 feet apart center to center. The facility will have up to three storage pads.

The staff has reviewed these changes and found them to be acceptable based on the evaluations described in this SER.

ENVIRONMENTAL REVIEW

Pursuant to 10 CFR Part 51, an Environmental Assessment (EA, ML15022A575) has been prepared for this action and a Finding of No Significant Impact (FONSI) was issued. The EA and FONSI were published in the Federal Register on February 27, 2015 (80 FR 10726).

CONCLUSION

The staff reviewed the LAR for SNM-2507, as supplemented, including the engineering analyses, proposed FSAR revisions, and other supporting documents submitted with the application. Based on the information provided in the application, as supplemented, the staff concludes that SNM-2507, as amended, meets the requirements of 10 CFR Part 72.

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