SAFETY EVALUATION REPORT

FOR THE NORTH ANNA POWER STATION

INDEPENDENT SPENT FUEL STORAGE INSTALLATION

LICENSE RENEWAL

DOCKET NO. 72-16

LICENSE NO. SNM-2507

Office of Nuclear Material Safety and Safeguards
United States Nuclear Regulatory Commission
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INTRODUCTION

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,” the U.S. Nuclear Regulatory Commission (NRC) issued a specific license for the independent spent fuel storage installation (ISFSI) at the North Anna Power Station (North Anna), Special Nuclear Material (SNM) License No. SNM-2507, for 20 years, with an expiration date of June 30, 2018. SNM-2507 authorizes Virginia Electric and Power Company (Dominion Energy Virginia) and the Old Dominion Electric Cooperative (together, the “licensee” or “applicant”) to receive, possess, transfer, and store spent fuel from North Anna, Units 1 and 2, in the North Anna ISFSI. The North Anna site is located in the north-central portion of Virginia in Louisa County, on a peninsula on the southern shore of Lake Anna. The 11-acre ISFSI is approximately 2,000 feet southwest of North Anna, Units 1 and 2, and within the boundaries of the North Anna site.

By letter dated May 25, 2016, as supplemented January 20, 2017, February 28, 2017, June 5, 2017, July 10, 2017, and August 16, 2017 (Dominion Energy Virginia, 2016a, 2017a, 2017b, 2017c, 2017d, 2017e), Dominion Energy Virginia, on behalf of itself and Old Dominion Electric Cooperative, submitted an application to the NRC for renewal of SNM-2507 for an additional 40 years beyond the initial license term. The license renewal, if approved, would authorize the applicant to continue storing spent fuel in the North Anna ISFSI until June 30, 2058. The applicant submitted the license renewal application in accordance with the regulatory requirements of 10 CFR 72.42, “Duration of License; Renewal.” Because the license renewal application was submitted more than 2 years before the license expiration date, pursuant to 10 CFR 72.42(b) and (c), this application constitutes a timely renewal.

The North Anna specific license, SNM-2507, allows the applicant to store 84 TN-32 sealed surface storage casks (TN-32 casks) on three pads (i.e., 28 TN-32 casks per pad). In 2017, the NRC modified the license to allow storage of 32 high-burnup (HBU) spent fuel assemblies in a modified TN-32 bolted lid cask, referred to as a TN-32B HBU cask, as part of the High Burnup Dry Storage Cask Research and Development Project sponsored by the U.S. Department of Energy and the Electric Power Research Institute. Currently, the specifically-licensed ISFSI consists of one pad (pad No. 1) with 27 TN-32 casks and 1 TN-32B HBU cask. The applicant also operates a generally-licensed ISFSI (NRC Docket No. 72-56) on pad No. 2, adjacent to the specifically-licensed ISFSI. However, this generally-licensed ISFSI is not included in the SNM-2507 specific license and is not part of the license renewal application.

Each TN-32 cask is designed to hold 32 pressurized-water reactor spent fuel assemblies. The TN-32 and TN-32B HBU cask body consists of a welded low-alloy steel inner shell surrounded by a carbon steel outer shell, outer bottom plate, and lid, with metallic seals. Borated polyester resin enclosed in aluminum containers, which are attached to the outside of the carbon steel side wall, provides radial neutron shielding. An outer steel shell encloses the polyester/aluminum shielding containers. A polypropylene disc encased in a steel shell that is bolted to the cask lid provides neutron shielding for the top of the cask. An internal fuel basket provides alignment and separation of the spent fuel assemblies and contains neutron absorber plates. After fuel is loaded, the cask is drained and vacuum-dried to remove the borated spent fuel pool water and backfilled with helium. The cask is then sealed. The helium gas provides an inert atmosphere to the fuel and other components inside the cask cavity. An overpressure monitoring system monitors helium leakage through the cask lid seals. A protective cover provides weather protection to the top of the cask and the overpressure monitoring system components. The TN-32 cask is designed to shield the radiation from the contents to meet the regulatory requirements of 10 CFR 72.104, “Criteria for Radioactive Materials in Effluents and Direct Radiation from an ISFSI or MRS [monitored retrievable storage installation],” and 72.106, “Controlled Area of an ISFSI or MRS,” to dissipate decay heat, and to ensure the fuel cladding temperatures remain below allowable technical limits without active cooling systems.

In the license renewal application, the applicant documented the technical bases for renewal of the license and proposed actions for managing potential aging effects on the structures, systems, and components (SSCs) of the ISFSI that are important to safety to ensure that these SSCs will maintain their intended functions during the period of extended operation. The applicant presented general information about the ISFSI design and a scoping evaluation to determine the SSCs within the scope of license renewal and subject to an aging management review. The applicant further screened the in-scope SSCs to identify and describe the subcomponents that support the intended functions of the in-scope SSCs. For each in-scope SSC with an identified aging effect, the applicant proposed an aging management program to ensure that the SSC will maintain its intended function(s) during the period of extended operation.

The NRC staff reviewed the applicant’s technical bases for safe operation of the ISFSI for an additional 40 years beyond the term of the current operating license. This safety evaluation report (SER) summarizes the results of the staff’s review for compliance with 10 CFR 72.42. In its review of the license renewal application and development of the SER, the staff used the guidance in NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC, 2016), and NUREG-1757, Volume 3, Revision 1, “Consolidated Decommissioning Guidance—Financial Assurance, Recordkeeping, and Timeliness,” issued February 2012 (NRC, 2012a), to ensure compliance with the NRC’s financial qualification requirements, including those associated with decommissioning of the ISFSI, as appropriate.

This SER is organized into six sections. Section 1 provides the staff’s review of the general and financial information provided in the license renewal application. Section 2 presents the staff’s review of the scoping evaluation for determination of which SSCs are within the scope of renewal. Section 3 provides the staff’s evaluation of the aging management review for assessment of aging effects and aging management activities for SSCs within the scope of renewal. Section 4 documents the additions and changes to the license that resulted from the review of the license renewal application. Section 5 presents the staff’s conclusions from its review. Section 6 lists the references supporting the staff’s review and technical determinations.

1 GENERAL INFORMATION

1.1 Specific License Holder Information

The license renewal application includes general information on the specific license holders, Dominion Energy Virginia and Old Dominion Electric Cooperative (ODEC). The license renewal application includes the names and addresses of the applicants; a description of the business of the applicants and the State in which it is incorporated and does business; and the organization and management of the applicants, including the names, addresses, and citizenship of the directors and principal officers.

According to the applicant, Dominion Energy Virginia is a wholly owned subsidiary of Dominion Resources, Inc., and a regulated public utility that generates, transmits, and distributes electricity for sale in Virginia and North Carolina. ODEC, which was incorporated under the laws of the Commonwealth of Virginia in 1948, is a not-for-profit wholesale power supply cooperative engaged in the business of providing wholesale electric service to member distribution cooperatives, which in turn are engaged in the retail sale of power to more than 565,000 retail electric customers located in its service territory.

The NRC staff finds that the applicant provided the information required in paragraphs (a)–(d) of 10 CFR 72.22, "Contents of Application: General and Financial Information."

1.2 Financial Qualifications

The license renewal application also includes information on financial qualifications per the requirements in 10 CFR 72.22(e), to show that the applicant will have the necessary funds available to cover estimated construction costs, estimated operating costs over the requested period of extended operation, and estimated decommissioning costs.

1.2.1 ISFSI Construction Cost Estimate

According to the applicant, the North Anna Independent Spent Fuel Storage Installation (ISFSI) Safety Analysis Report states that up to three concrete storage pads could be used under the specific license. Currently, the specifically-licensed ISFSI consists of only one pad (pad No. 1). While there are no current plans to expand the ISFSI beyond pad No. 1, Dominion Energy Virginia and ODEC retain the authority to do so under the terms of the license. According to the applicant, one-time construction costs for the remaining unconstructed portion of the ISFSI are estimated at $17 million in 2016 dollars.

The ISFSI pad No. 1 is already constructed, and the licensee has indicated that there are no plans for expansion of the ISFSI to the full licensed capacity. Therefore, there are no construction costs associated with this license renewal.

1.2.2 ISFSI Operating Cost Estimate

According to the applicant, the operating costs over the requested period of extended operation for the North Anna ISFSI are estimated to be $400 million in 2016 dollars. This equates to approximately $10 million per year. The cost estimate for North Anna considers factors found in the decommissioning cost analyses, including costs associated with ISFSI security (shared with the generally-licensed ISFSI pad No. 2), project management, cask maintenance, and equipment surveillance. The estimated operating costs also include hypothetical costs associated with purchasing and loading additional casks until the ISFSI meets its full licensed capacity.

To determine reasonable assurance of the provided cost estimate, the NRC staff considered ISFSI operating costs cited by other sources, including costs cited in a 2001 Massachusetts Institute of Technology (MIT) report, "Interim Storage of Spent Fuel in the United States" (Macfarlane, 2001), and estimated operations costs reported by other NRC licensees. In the MIT report, estimated ISFSI "at-reactor dry storage" operations and maintenance costs, during reactor operations, ranged from $470,000 to $750,000 per year. Accounting for inflation through 2016, the cost estimates would range from $695,000 to $1,110,000. The MIT report also cited the range of ISFSI operations and maintenance costs for a shutdown reactor at $4 million to $9 million per year. Accounting for inflation through 2016, the cost estimates ranged from $5.9 million to $13.3 million. The staff recognizes that while an operating cost estimate of $10 million per year does not fall within the range of the MIT study estimate for reactors in operation, it is consistent with the cost range in the study for ISFSIs at reactor sites in decommissioning. Furthermore, the staff finds the estimate conservative when considering that North Anna, Units 1 and 2, have about 19 and 21 years, respectively, of operations remaining on their operating licenses, respectively. The staff also finds the estimate conservative when considering that the estimate includes hypothetical costs associated with purchasing and loading additional casks, but the licensee has no plans for storing additional casks at the ISFSI.

For comparison, publicly available information from Connecticut Yankee, Maine Yankee, and Yankee Rowe decommissioned facilities indicate that the annual cost to operate each of the three ISFSIs was approximately $10 million (see http://www.connyankee.com, http://www.maineyankee.com, and http://www.yankeerowe.com). The annual operating cost for each of the Yankee ISFSIs is consistent with the MIT report and appears reasonable.

The staff recognizes that the MIT study was drafted in 2001, site-specific variations among ISFSI sites could drive estimates higher (or lower) than the study estimates, actual operating costs at the Yankee ISFSI facilities are consistent with the applicant's operating cost estimate, and the applicant stated that its estimate is "conservative." For these reasons, the staff finds the annual operating cost estimate for the North Anna ISFSI of $10 million, or $400 million in 2016 dollars over the requested period of extended operation, to be reasonable.

1.2.3 ISFSI Operating Funds Availability

According to 10 CFR 50.2, "Definitions," the applicant is an electric utility that generates or distributes electricity and recovers the cost of this electricity, either directly or indirectly, through rates established by the entity itself or by a separate regulatory authority. In its submittal, the applicant stated that it would recover ISFSI operating costs through rates that will be adjusted, as needed, to cover the operating costs throughout the life of the facility. Therefore, the staff concludes that the applicant has demonstrated reasonable assurance that funding will remain available to cover the operating costs of the North Anna ISFSI (pad No. 1) for the life of the facility license.

1.2.4 Conclusion

Based on an analysis of the information in the license renewal application, the NRC staff finds that there is reasonable assurance that Dominion Energy Virginia and ODEC are financially qualified to engage in the proposed activities regarding the North Anna ISFSI, as described in the license renewal application.

1.3 Decommissioning Funding Assurance

Pursuant to paragraph (c) of 10 CFR 72.30, "Financial Assurance and Recordkeeping for Decommissioning," each holder of, or applicant for, a license under 10 CFR Part 72 must submit for NRC review and approval a decommissioning funding plan (DFP) containing information on how reasonable assurance will be provided that funds will be available to decommission its ISFSI. At the time of license renewal and at intervals not to exceed 3 years, the DFP must be resubmitted with adjustments as necessary to account for changes in decommissioning costs and the extent of contamination. The DFP must update the information submitted with the original or prior approved plan under 10 CFR 72.30(b). In addition, the DFP must also specifically consider the effect of the following events on decommissioning costs:

- spills of radioactive material producing additional residual radioactivity in onsite subsurface material
- facility modifications
- changes in authorized possession limits
- actual remediation costs that exceed the previous cost estimate

The DFP must contain a detailed decommissioning cost estimate (DCE), in an amount reflecting the cost of an independent contractor to perform all decommissioning activities; an adequate contingency factor; and the cost of meeting 10 CFR 20.1402, "Radiological Criteria for Unrestricted Use" (or the cost of meeting 10 CFR 20.1403, "Criteria for License Termination under Restricted Conditions," provided the licensee can demonstrate its ability to meet these criteria). The licensee's DFP must also identify and justify using the key assumptions contained in the DCE. Further, the DFP must describe the method of assuring funds for ISFSI decommissioning, including the means for adjusting cost estimates and associated funding levels periodically over the life of the ISFSI. Finally, the DFP must specify the volume of onsite subsurface material containing residual radioactivity that will require remediation to meet the criteria for license termination and contain a certification that financial assurance for ISFSI decommissioning has been provided in the amount of the DCE.

The applicant provided its original DFP for review and approval in December 2012 (Dominion Energy Virginia, 2012; ODEC, 2012), and the NRC staff issued a request for additional information. The applicant responded to the request for additional information in September and October 2013 (Dominion Energy Virginia, 2013; ODEC, 2013). Dominion Energy Virginia submitted its most recent DFP update to the NRC on December 2, 2015 (Dominion Energy Virginia, 2015). ODEC submitted its most recent DFP update on December 15, 2015 (ODEC, 2015). In support of the review of the DFP updates, the applicant provided additional information on June 5, 2017 (Dominion Energy Virginia, 2017c).

Pursuant to 10 CFR 72.30(c), Dominion Energy Virginia and ODEC updated the DFP, including the DCE for the North Anna ISFSI, as part of the license renewal application. Dominion Energy Virginia and ODEC estimated the cost to decommission the North Anna ISFSI for unrestricted use to be $1.59 million (2015 dollars), which includes a 25-percent contingency factor. The cost estimates were prepared by an independent third party and updated to consider changes in the cost of decommissioning the ISFSI at the North Anna facility. The staff's review of Dominion Energy Virginia and ODEC's updated DFP considered guidance in NUREG-1757, Volume 3, Revision 1 (NRC, 2012a). In this regard, the staff concluded that the DCE appears to (1) be based on reasonable costs provided by a third-party contractor in 2014 and updated in the 2016 submittal, (2) include an adequate contingency factor of 25 percent; and (3) consider reasonable and documented assumptions described in detail in the licensee's submittal.

According to the applicant, Dominion Energy Virginia and ODEC provides financial assurance for the decommissioning of North Anna, including the North Anna ISFSI, using the external sinking fund method. In the external sinking fund method, according to 10 CFR 50.75, "Reporting and Recordkeeping for Decommissioning Planning," a fund is established and maintained by setting funds aside periodically in an account segregated from licensee assets and outside the administrative control of the licensee and its subsidiaries or affiliates to pay decommissioning costs. The funds may be in the form of a trust, escrow account, or government fund, with payment by certificate of deposit, deposit of government, or other methods acceptable to the NRC. Dominion Energy Virginia and ODEC maintain a site-specific DCE for North Anna, which is updated about every 5 years to determine whether there is a need to adjust rates collected from ratepayers and contributions to the external sinking fund. Dominion Energy Virginia, as an operator of the ISFSI, also prepared a DCE for the North Anna ISFSI (for both the specifically-licensed and generally-licensed pads) in 2014.

Dominion Energy Virginia and ODEC provided funding reports for each of the decommissioning trusts for North Anna Unit 1 and North Anna Unit 2. These reports include total funds in the trusts (as of December 31, 2015), funds allocated for radiological decommissioning, and funds allocated for other expenses (including ISFSI decommissioning). The staff notes that both Dominion Energy Virginia and ODEC clearly delineated funds designated for radiological decommissioning expenses from the funds designated for all other expenses. According to the fund reports, Dominion Energy Virginia and ODEC have a total of $308.98 million dollars, as of December 31, 2015, dedicated to expenses other than the radiological decommissioning of North Anna, Units 1 and 2, including ISFSI decommissioning. This amount exceeds the ISFSI decommissioning cost estimate of $1.59 million. Based on the amount of funds allocated to, among other things, ISFSI decommissioning as compared to the ISFSI decommissioning cost estimate, as well as the applicant's ability to request rate relief for decommissioning activities, the staff finds that the applicant has demonstrated decommissioning funding assurance for the North Anna ISFSI.

Based on the review of the license renewal application and all associated documentation, the NRC staff finds that the applicant has provided a reasonable cost estimate for the radiological decommissioning of the North Anna ISFSI and has provided reasonable assurance that funds will be available for radiological decommissioning of the ISFSI at the time of license termination. Based on an independent analysis of the information in the application, the NRC staff finds that there is reasonable assurance that Dominion Energy Virginia and ODEC have demonstrated decommissioning funding assurance.

1.4 <u>Environmental Review</u>

Regulations in 10 CFR 72.34, "Environmental Report," require that each application for an ISFSI license under this part must be accompanied by an environmental report that meets the requirements of Subpart A, "National Environmental Policy Act—Regulations Implementing Section 102(2)," of 10 CFR Part 51, "Environmental Protection Regulations for Domestic

Licensing and Related Regulatory Functions." The applicant submitted an environmental report supplement as part of the license renewal application. The environmental report, as supplemented (Dominion Energy Virginia, 2017a), contained sufficient information to aid the staff in its independent analysis. In January 2018, the staff issued an environmental assessment (NRC, 2018) for the North Anna ISFSI license renewal.

1.5 Safety Review

The objective of this safety review is to determine whether there is reasonable assurance that the ISFSI will continue to meet the requirements of 10 CFR Part 72 during the requested period of extended operation. Pursuant to 10 CFR 72.42(a), an application for ISFSI license renewal must include the following:

- time-limited aging analyses (TLAAs) that demonstrate structures, systems, and components (SSCs) important to safety will continue to perform their intended functions for the requested period of extended operation

- a description of the aging management program (AMP) for management of issues associated with aging that could adversely affect SSCs important to safety

The applicant stated that it prepared the license renewal application in accordance with applicable provisions of 10 CFR Part 72 and NUREG-1927, Revision 1 (NRC, 2016). The applicant performed a scoping evaluation and aging management review (AMR) to identify all SSCs within the scope of the license renewal and pertinent aging mechanisms and effects, respectively. The applicant developed AMPs and evaluated TLAAs to ensure that the SSCs identified to be within the scope of renewal will continue to perform their intended functions during the period of extended operation. This review documents the staff's evaluation of the applicant's scoping analysis, AMR, and supporting AMPs and TLAAs.

1.6 Application Content

The applicant's license renewal application, as supplemented, provided the following information:

- general and financial information
- scoping evaluation
- AMR
- AMPs
- TLAAs
- safety analysis report (SAR) supplement
- proposed license conditions
- environmental report supplement
- results of pre-application inspections
- ISFSI DFP

In particular, the SAR supplement provided by the applicant provides changes and additions to the North Anna ISFSI SAR (Dominion Energy Virginia, 2016b) to document the results of the AMR, TLAAs, and AMPs. The applicant updates the North Anna ISFSI SAR per paragraphs (b) and (c) of 10 CFR 72.70, "Safety Analysis Report Updating."

1.7 Safety Review Evaluation Findings

The staff reviewed the information in the license renewal application and supplemental documentation. The staff performed its review following the guidance in NUREG-1927, Revision 1 (NRC, 2016), and NUREG-1757, Volume 3, Revision 1 (NRC, 2012a). Based on its review, the staff determined that the applicant has provided sufficient information with adequate details to support the license renewal application with the follow findings:

F1.1 The information presented in the license renewal application satisfies the requirements of 10 CFR 72.2, "Scope," 72.22, 72.30, 72.34, and 72.42.

F1.2 The applicant has provided a tabulation of all supporting information and docketed material incorporated by reference in accordance with 10 CFR 72.42.

2 SCOPING EVALUATION

As described in NUREG-1927, Revision 1 (NRC, 2016), a scoping evaluation is necessary to identify the SSCs subject to an AMR, where the effects of aging are assessed. More specifically, the scoping evaluation is used to identify SSCs meeting any of the following criteria:

1. SSCs that are classified as important to safety, as they are relied on for one of the following functions:

    a. Maintain the conditions required by the regulations or specific license to store spent fuel safely.

    b. Prevent damage to the spent fuel during handling and storage.

    c. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.

2. SSCs that are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

After the determination of in-scope SSCs, the SSCs are screened to identify and describe the subcomponents that support the SSC intended functions.

2.1 Scoping and Screening Methodology

In Section 2 of the license renewal application, the applicant performed a scoping evaluation and provided the following information:

- a description of the scoping and screening methodology for the inclusion of SSCs and SSC subcomponents in the renewal scope
- a list of sources of information used for the scoping evaluation
- descriptions of the SSCs
- a list of the SSCs identified to be within and outside the scope of renewal review and the basis for the scope determination

The staff reviewed the scoping process and results provided in the license renewal application. The following section discusses the staff's review and findings regarding the applicant's scoping evaluation.

2.1.1 Scoping Process

In Section 2.2.2 of the license renewal application, the applicant reviewed the following design-basis documents to identify SSCs with safety functions meeting either scoping criterion 1 or 2, as defined above:

- North Anna ISFSI SAR (Dominion Energy Virginia, 2016b)
- Materials License No. SNM-2507 (NRC, 2017)
- North Anna ISFSI Technical Specifications (NRC, 2017)
- North Anna ISFSI SER (NRC, 1998)
- TN-32 Dry Storage Cask Topical Safety Analysis Report, Revision 9A (Transnuclear, 1996)
- SER for the TN-32 Dry Storage Cask Final Safety Analysis Report, Revision 0 (NRC 1996c)

Appendix A.1 to the North Anna ISFSI SAR provides the licensing bases with respect to which versions of the TN-32 dry storage cask SARs apply to North Anna. The SAR states the following:

> TN-32 casks used at the North Anna ISFSI are fabricated to the requirements of the TN-32 Topical Safety Analysis Report (TSAR), Revision 9A, or the TN-32 Final Safety Analysis Report (FSAR), Revision 0. TN-32 casks fabricated to the requirements of the TN-32 FSAR, Revision 0, have been evaluated with respect to the design bases for the TN-32 TSAR, Revision 9A, and have been found to be acceptable. Analyses included in the TN-32 FSAR, Revision 0, may not be credited in the use of TN-32 casks unless they have been added to the ISFSI SAR.

The SAR also states:

> The North Anna ISFSI Technical Specifications, and the TSAR, Rev. 9A, however will govern the use of TN-32, Rev. 0, casks at the North Anna ISFSI, except to the extent that specific analyses (e.g., criticality or thermal performance) from the FSAR, Rev. 0, have been added to the ISFSI SAR.

Table 2.1-1 lists the SSCs included and excluded from the scope of renewal review and identifies the scoping criterion met by each in-scope SSC.

Table 2.1-1 SSCs Within and Outside the Scope of Renewal Review

SSCs	Criterion 1	Criterion 2	In-Scope
TN-32 dry storage cask	Yes	N/A	Yes
Spent fuel assemblies	Yes[1]	N/A	Yes
Reinforced concrete pad No. 1	No	Yes[2]	Yes
Transporter and supporting equipment	No	No	No
Lift beam and lid-handling tools	No	No	No
Cask overpressure instrumentation	No	No	No
Lighting	No	No	No
Backup diesel generator and fuel tank	No	No	No
Security fence	No	No	No
Earth berm	No	No	No
TN-32B HBU demonstration cask	-	-	No[3]

[1] The applicant stated that, although the design-basis documentation does not define the safety classification of the spent fuel assemblies, the assemblies support license renewal intended functions (e.g., retrievability).

[2] The applicant stated that the pad is non-safety-related; however, the ISFSI SAR refers to concrete strength as being a factor in design accidents.

[3] The TN-32B HBU cask is associated with the HBU Dry Storage Cask Research and Development Project and will remain on site for less than 20 years. See evaluation below and License Condition 4.3.

The staff reviewed the scoping results to determine whether the applicant's conclusions regarding the out-of-scope components accurately reflect the design-basis documentation in the North Anna ISFSI SAR and the TN-32 TSAR.

The applicant stated that the cask transporter and supporting equipment are not important to safety. The staff reviewed Section 4.3 of the North Anna ISFSI SAR, which states that no components of the transporter are important to the safety function of the storage casks. The staff notes that the ISFSI SAR also states that the transporter is not credited for shielding and that the cask lift height is limited to 15 inches, a drop height that will not result in damage to the cask or release of radiation in excess of the limits in 10 CFR Part 100, "Reactor Site Criteria." The staff finds the applicant's determination that the transporter and associated equipment are not in scope to be acceptable because the design-basis documentation identifies these components as not important to safety, and the documentation shows that failure of the transporter and related subcomponents would not affect the safety functions of the storage casks.

The applicant stated that the lift beam and cask lid handling tools are important to safety; however, this equipment is addressed under the power plant operating license. As a result, the applicant did not include these SSCs in the scope of the storage renewal review. The applicant stated that the equipment is used only during fuel loading and unloading within the Fuel Building and Decontamination Building. The applicant also stated that the site's Heavy Loads AMP manages the aging of this equipment to meet the requirements of 10 CFR Part 54, "Requirements for Renewal of Operating Licenses for Nuclear Power Plants." In its review of the applicant's scoping of the lift beam and cask lid handling tools, the staff notes that the applicant's license for the storage of spent nuclear fuel specifies that activities associated with these components are to be governed by the North Anna's reactor operating license (NRC, 1998). The staff also notes that North Anna's renewed reactor operating license includes NRC-approved activities to manage the effects of aging for these components (NRC, 2002). Therefore, the staff finds the applicant's determination that the lift beam and cask lid handling tools are not in scope to be acceptable because the licensing documentation places the governance of these activities within the reactor operating license, and the renewed reactor license includes activities to manage the effects of aging of the subject components.

The applicant stated that the cask overpressurization monitoring equipment is not required for safe operation of the ISFSI and cited NRC Interim Staff Guidance (ISG) 5, Revision 1, "Confinement Evaluation," which states, "The staff has accepted monitoring systems as not important to safety…." (NRC, 1999). The staff notes that the basis for this statement is that a failure of the monitoring equipment does not result in a gross release of radioactive material. Thus, the staff finds the applicant's determination that the overpressurization equipment is not in scope to be acceptable because this determination is consistent with the guidance in ISG-5 for the safety significance of components whose failure will not impact the confinement boundary.

The applicant stated that the lighting, backup diesel generator, and the fuel oil tank are not in the scope of renewal, as these components are not important to safety. The applicant clarified that failure of the lighting and loss of electrical power have no safety or radiological consequences. The staff reviewed Section 8.1.1.3 of the North Anna ISFSI SAR and confirmed that the design basis of the ISFSI describes the lighting and electrical power as having no safety consequence, as the lighting is for convenience only, and the long-term integrity of the cask seals does not depend on having electrical power to the pressure monitoring equipment. Based on the staff's confirmation that these components are not relied on for safe storage of spent fuel in the design-basis documentation, the staff finds the applicant's determination that the lighting and electrical equipment is not in scope to be acceptable.

The applicant stated that the ISFSI security fence is not in the scope of renewal, as it is not important to safety. The staff reviewed Section 4.5 of the North Anna ISFSI SAR and confirmed that the design basis of the ISFSI describes the security fence as not performing a safety function. The staff also notes that, in accordance with 10 CFR 73.55, "Requirements for Physical Protection of Licensed Activities in Nuclear Power Reactors against Radiological Sabotage," applicants must maintain the performance of security equipment at all times (not just during the period of extended operation). Based on the staff's review of the applicant's design-basis documentation, the staff finds the applicant's determination that the security fence is not in scope to be acceptable.

The applicant stated that the earth berm constructed within the north and east perimeter fences of the ISFSI is not in the scope of the renewal because the dose analyses performed to show compliance with the requirements of 10 CFR Part 20, "Standards for Protection against Radiation," 10 CFR 72.104, and 10 CFR 72.106, do not credit the berm as part of the ISFSI shielding design. However, in its review of the applicant's design-basis documentation, the staff noted that Section 7.3.2, "Shielding," of the North Anna ISFSI SAR states that the berm was constructed to reduce direct radiation (Dominion Energy Virginia, 2016b). As a result, the staff asked the applicant to clarify the design basis for the berm. The applicant responded by stating that neither ISFSI SAR Section 7.4, "Estimated Onsite Collective Dose Assessment," nor Section 7.5, "Offsite Collective Dose Assessment," takes credit for the berm for reducing dose (Dominion Energy Virginia, 2017a and 2017b). The staff reviewed the cited design-basis documentation and confirmed that the dose assessments do not credit the berm. On these bases, the staff finds the applicant's determination that the earth berm is not in scope to be acceptable.

Following the initial submittal of the license renewal application, the NRC amended North Anna's specific ISFSI license to authorize the storage of HBU fuel in a modified TN-32B HBU cask (NRC, 2017). The cask is associated with the joint initiative by the Electric Power Research Institute (EPRI) and the U.S. Department of Energy, "HBU Dry Storage Cask Research and Development Project," which plans to store 32 HBU fuel assemblies for approximately 10 years on the North Anna ISFSI pad No. 1, after which the fuel will be transported off site for examination and testing (EPRI, 2014). The staff notes that this cask has unique SSCs that are not present in the TN-32 casks. For example, the TN-32B HBU cask will contain HBU fuel assemblies and unique monitoring instrumentation associated with this research project. However, the TN-32B HBU cask is expected to be on site for less than 20 years, and thus its SSCs do not require aging management. Therefore, the staff finds the applicant's determination that the modified TN-32B HBU cask is not in scope to be acceptable. To provide additional assurance that the TN-32B HBU cask will not remain at the North Anna ISFSI for a period that would require aging management, the staff has added a condition to the license (see Section 4.3) to prevent extended storage of the TN-32B HBU cask.

Based on its review, the staff finds that the applicant has identified the in-scope SSCs in a manner consistent with NUREG-1927, Revision 1, and therefore the staff finds the scoping results to be acceptable. The applicant screened the in-scope SSCs to identify and describe the subcomponents that support the SSC intended functions. Section 2.1.2 describes the SSC subcomponents within the scope of the renewal review, and Section 2.1.3 covers those outside the scope of the review.

2.1.2 Structures, Systems, and Components within the Scope of Renewal Review

Using the scoping process discussed in Section 2.2 of the license renewal application, the applicant identified three SSC groups to be within the scope of renewal review. Table 2.1-2 describes the subcomponents that support the intended functions of the SSCs that are within the scope of renewal review and thus subject to an AMR.

Table 2.1-2 SSC Subcomponents within the Scope of Renewal Review

Dry Storage Cask	Spent Fuel Assemblies	Reinforced Concrete Pad
Cask Shell Lid and Shield Plate Inner Containment Cask Bottom Bottom Containment Trunnions Outer Shell Top Neutron Shield Top Neutron Shield Enclosure Top Neutron Shield Bolts Radial Neutron Shield Radial Neutron Shield Box Lid Bolts Lid Seals Vent and Drain Port Covers Vent and Drain Port Cover Bolts Vent and Drain Port Cover Seals Basket Rails Fuel Basket Aluminum Plates Poison Plates Flange	Fuel Cladding Fuel Cladding End Plug Guide Tubes Grid Assemblies Bottom and Top Nozzles	Concrete Pad

The staff reviewed the applicant's screening of the in-scope SSCs to identify subcomponents within the scope of renewal review. The staff's review considered the intended function of the subcomponent, its safety classification or basis for inclusion in the scope of renewal review, and design-basis information in the North Anna ISFSI SAR and the TN-32 TSAR. Based on this review, the staff finds that the applicant screened the in-scope SSCs in a manner consistent with NUREG-1927, Revision 1, and therefore, the staff finds the screening results for in-scope SSC subcomponents to be acceptable.

2.1.3 Structures, Systems, and Components Not within the Scope of Renewal Review

The applicant reviewed the in-scope SSCs to identify and describe any subcomponents that do not support the SSC intended functions and thus do not require an AMR. The applicant provided a basis for the exclusion of these components in Section 2.5.1 of the license renewal application. Table 2.1-3 tabulates these subcomponents.

Table 2.1-3 SSC Subcomponents Not within the Scope of Renewal Review

Dry Storage Cask	Spent Fuel Assemblies	Reinforced Concrete Pad
Overpressure Monitoring System	Fuel Assembly Inserts	Joint Sealant
External Coating	Fuel Pellets	Cask Electrical Junction Boxes and Conduit
Protective Cover	Fuel Rod Springs	
Drain Tube	Protective Grid Assembly	
Vent and Drain Port Quick Disconnects	Instrument Tube	
	Nozzle Spring Set	

The staff reviewed the applicant's screening of the out-of-scope SSCs. The staff's review considered the intended function of the subcomponent, its safety classification or basis for exclusion in the scope of renewal review, and design-basis information in the North Anna ISFSI SAR and the TN-32 TSAR. Based on this review, the staff finds that the applicant screened the in-scope SSCs in a manner consistent with NUREG-1927, Revision 1, and therefore, the staff finds the screening results for out-of-scope SSC subcomponents to be acceptable.

2.2 Evaluation Findings

The NRC staff reviewed the scoping evaluation provided in the license renewal application and supplemental documentation. The staff performed its review following the guidance provided in NUREG-1927, Revision 1, and relevant ISG documents. To determine the accuracy and completeness of the scoping evaluation, the staff also used the information in NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," issued February 1996 (NRC, 1996a), as a reference for classifying components as important to safety.

Based on its review, the staff finds the following:

F2.1 The applicant has identified all SSCs important to safety and SSCs the failure of which could prevent an SSC from fulfilling its safety function, per the requirements of 10 CFR 72.3, "Definitions"; 10 CFR 72.24, "Contents of Application: Technical Information"; 10 CFR 72.42; 10 CFR 72.120, "General Considerations"; 10 CFR 72.122, "Overall Requirements"; 10 CFR 72.124, "Criteria for Nuclear Criticality Safety"; 10 CFR 72.126, "Criteria for Radiological Protection"; and 10 CFR 72.128, "Criteria for Spent Fuel, High-Level Radioactive Waste, and Other Radioactive Waste Storage and Handling," as applicable.

F2.2 The justification for any SSC determined not to be within the scope of the renewal review is adequate and acceptable.

3 AGING MANAGEMENT REVIEW

3.1 Review Objective

The objective of the staff's evaluation of the applicant's AMR is to determine if the applicant has adequately reviewed applicable materials, environments, and aging mechanisms and effects and proposed adequate aging management activities for in-scope SSCs. The AMR addresses aging mechanisms and effects that could adversely affect the ability of the SSCs and associated subcomponents to perform their intended functions during the period of extended operation.

3.2 Aging Management Review Process

The applicant described its AMR process as consisting of three steps:

1. identification of materials and environments
2. identification of aging mechanisms and effects requiring management
3. determination of the activities required to manage the effects of aging

The applicant stated that the AMR identified the aging mechanisms and effects applicable to each SSC subcomponent based on its material of construction and the service environment that the subcomponent could reasonably be expected to experience during normal operation. Then, the applicant identified aging mechanisms and effects (the manifestation of aging mechanisms) based on a review of NRC reports, industry studies, and consensus standards. Finally, for each identified aging mechanism or effect, the applicant identified an AMP to ensure that the intended function of the SSC would be maintained during the period of extended operation.

The staff reviewed the applicant's AMR process, including a description of the review process and the design-basis references. Based on its review, the staff finds that the applicant's AMR process is acceptable because it is consistent with the methodology recommended in NUREG-1927, Revision 1 (NRC, 2016) and adequate for identifying credible aging effects for the SSCs within the scope of renewal.

3.3 Aging Management Review Results: Materials, Service Environment, Aging Effects, and Aging Management Programs

Tables 3.3-1 through 3.3-3 show the results of the applicant's AMR and identify the AMPs that are credited to manage the aging mechanisms and effects for SSC subcomponents within the scope of renewal.

Table 3.3-1 AMR Results—TN-32 Dry Storage Cask

Subcomponent	In-Scope Classification Criterion 1 or 2	Materials	Environment (E) external (I) internal	Aging Effect/ Mechanism	AMR SER Section	AMP SER Section
Cask shell	1	Carbon steel	(I) Air[1]	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1
Lid and shield plate (includes stainless steel overlays)	1	Stainless steel	(E) Atmosphere / weather	Loss of material due to crevice and pitting corrosion	3.3.1.2	3.5.1
			(I) Helium	None	3.3.1.2	N/A
		Carbon steel and low-alloy steel	(I) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1
Inner containment (includes sprayed aluminum coating)	1	Low-alloy steel	(E) Air[1]	None	3.3.1.2	N/A
		Aluminum	(I) Helium	None	3.3.1.2	N/A
Cask bottom	1	Carbon steel	(I) Air[1]	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1
Bottom containment (includes sprayed aluminum coating)	1	Low-alloy steel	(E) Air[1]	None	3.3.1.2	N/A
		Aluminum	(I) Helium	None	3.3.1.2	N/A
Trunnions	1	Carbon steel	(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1

Subcomponent	In-Scope Classification Criterion 1 or 2	Materials	Environment (E) external (I) internal	Aging Effect/ Mechanism	AMR SER Section	AMP SER Section
Outer shell	1	Carbon steel	(I) Air[1]	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1
Top neutron shield	1	Polypropylene (encased in carbon steel)	(E) Air[1]	Loss of material and cracking due to radiolytic decomposition and thermal degradation	3.3.1.2	3.5.1
Top neutron shield enclosure	1	Carbon steel	(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1
			(I) Air[1]	None	3.3.1.2	N/A
Top neutron shield bolts	1	Stainless steel	(E) Atmosphere / weather	Loss of material due to crevice and pitting corrosion	3.3.1.2	3.5.1
Radial neutron shield	1	Borated polyester (encased in aluminum)	(E) Air[1]	Loss of material and cracking due to radiolytic decomposition and thermal degradation	3.3.1.2	3.5.1
Radial neutron shield box	1	Aluminum	(I) Air[1]	None	3.3.1.2	N/A
			(E) Air[1]	None	3.3.1.2	N/A
Lid bolts	1	Low-alloy steel	(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1

Lid seals	1	Silver	(E) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	None	3.3.1.2	N/A
		Aluminum	(E) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, and galvanic corrosion	3.3.1.2	3.5.1
		Nickel-based alloy	(E) Helium[2]	None	3.3.1.2	N/A
Vent and drain port covers	1	Stainless steel	(I) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice and pitting corrosion	3.3.1.2	3.5.1
Vent and drain port cover bolts	1	Stainless steel	(E) Atmosphere / weather	Loss of material due to crevice and pitting corrosion	3.3.1.2	3.5.1
Vent and drain port cover seals	1	Aluminum	(E) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, and galvanic corrosion	3.3.1.2	3.5.1
		Silver	(E) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	None	3.3.1.2	N/A
		Nickel-based alloy	(E) Helium	None	3.3.1.2	N/A
Basket rails	1	Aluminum	(E) Helium	None	3.3.1.2	N/A
Fuel basket (including basket rail bolts, washers, and spacers)	1	Stainless steel	(E) Helium	None	3.3.1.2	N/A
Aluminum plates	1	Aluminum	(E) Helium	None	3.3.1.2	N/A
Poison plates	1	Aluminum (including borated aluminum)	(E) Helium	None	3.3.1.2	N/A

Flange (including stainless steel weld overlay)	1	Stainless steel	(E) Atmosphere / weather	Loss of material due to crevice and pitting corrosion	3.3.1.2	3.5.1
		Carbon steel	(I) Helium	None	3.3.1.2	N/A
			(E) Atmosphere / weather	Loss of material due to crevice, pitting, galvanic, and general corrosion	3.3.1.2	3.5.1

[1] "Air" reflects an embedded environment with small gaps that may exist at metal-to-metal or metal-to-polymer subcomponent interfaces. These gaps may contain a limited amount of air.
[2] Although the LRA identified the nickel alloy spring in the lid seal as having a helium environment, the staff notes that the spring may also be exposed to an atmosphere environment. The staff's evaluation of the aging of the nickel alloy spring is documented in SER Section 3.3.1.2.

Table 3.3-2 AMR Results—Spent Fuel Assemblies

Subcomponent	In-Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	AMP SER Section
Fuel cladding	1	Zirconium-based alloy	(E) Helium	None	3.3.2.2	N/A
			(I) Helium	None	3.3.2.2	N/A
Fuel cladding end plug (including welds)	1	Zirconium-based alloy	(E) Helium	None	3.3.2.2	N/A
Guide tubes (including sleeves)	1	Stainless steel	(E) Helium	None	3.3.2.2	N/A
		Zirconium-based alloy	(E) Helium	None	3.3.2.2	N/A
Grid assemblies (except protective grid assemblies)	1	Zirconium-based alloy	(E) Helium	None	3.3.2.2	N/A
		Nickel-based alloy	(E) Helium	None	3.3.2.2	N/A
Bottom and top nozzles	1	Stainless steel	(E) Helium	None	3.3.2.2	N/A

Table 3.3-3 AMR Results—Reinforced Concrete Pad No. 1

Subcomponent	In-Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	AMP SER Section
Concrete pad	2	Concrete (reinforced)	(E) Atmosphere / weather	Loss of material due to freeze-thaw	3.3.3.2	3.5.2
				Cracking due to freeze-thaw and reaction with aggregates	3.3.3.2	3.5.2
				Change in material properties due to leaching of calcium hydroxide	3.3.3.2	3.5.2
			(E) Soil	Cracking due to reaction with aggregates and settlement	3.3.3.2	3.5.2

3.3.1 TN-32 Dry Storage Cask

The applicant described the TN-32 dry storage cask in Section 2.4.1 of the license renewal application. The cask is a vertical metal cylinder capable of holding 32 pressurized-water reactor spent fuel assemblies, which are stored within an internal fuel basket in an inert helium atmosphere. A bolted top lid and metallic O-rings form the top confinement boundary.

3.3.1.1 Materials and Environments

The applicant described the materials and environments of the TN-32 dry storage cask in Section 3.2 of the license renewal application. The cask confinement boundary consists of a welded low-alloy steel inner shell surrounded by a carbon steel gamma shield side wall and bottom. The cask is sealed with a carbon steel closure lid and metallic O-rings that are constructed of a nickel alloy spring surrounded by an aluminum or silver outer jacket. The sealing surfaces of the lid are clad in stainless steel for corrosion resistance. The bottom and side inner shell surfaces are spray-coated with aluminum for corrosion protection. The fuel baskets are constructed of stainless steel cells separated by aluminum and Boral neutron absorber plates.

On the outside of the carbon steel side wall, borated polyester (cast within an array of aluminum containers) provides for radial neutron shielding. A steel-encased polypropylene disc is bolted to the cask lid to provide the top-side neutron shielding. An outer steel shell encloses the polyester/aluminum shielding containers. The cask external surfaces are painted for corrosion protection and ease of decontamination; however, the applicant stated that no credit is taken for the presence of the paint with respect to aging management.

The external surfaces of the cask are exposed to the outdoor air environment, which includes precipitation, wind, ultraviolet radiation, and ozone. A protective cover provides weather protection to the top of the cask and the overpressure monitoring system components; however, the applicant is not taking credit for this cover because of the potential for moisture to penetrate under it.

After fuel loading, the cask is drained and vacuum-dried to remove the borated spent fuel pool water, then backfilled with helium. The applicant stated that the helium gas temperature is expected to be 128 degrees Celsius (C) (262 degrees Fahrenheit (F)) after 20 years of spent fuel storage. The applicant also stated that, after 20 years of storage, the conservative estimate of the fast neutron fluence and gamma radiation levels are expected to be 10^{14} neutron per square centimeter (n/cm^2) and 10^9 radiation absorbed dose (rad), respectively. The staff reviewed the applicant's estimated total neutron and gamma radiation levels and performed confirmatory calculations. Based on its calculations, the staff finds that the applicant's estimates of the radiation levels are conservative and acceptable.

The staff reviewed the applicant’s description of the materials and environments for the TN-32 dry storage cask to confirm that the description is consistent with the descriptions and engineering drawings in the TN-32 TSAR and the North Anna ISFSI SAR. Based on its confirmation of consistency with these design-basis documents, the staff finds the applicant’s identification of the materials and environments for the TN-32 cask to be acceptable.

3.3.1.2 Aging Effects and Mechanisms for the TN-32 Dry Storage Cask During the Period of Extended Operation

In Section 3.2.3 of the license renewal application, the applicant stated that loss of material is the only aging effect for the TN-32 cask that requires management. In making this determination, the applicant cited the operating experience of external surface coating degradation, as well as loss of material of the outer metallic O-ring seals due to rainwater intrusion under the protective weather cover.

The applicant cited its pre-application inspection results as supporting the conclusion that no aging effects other than loss of material are required to be managed. Section F2 of the license renewal application summarizes the results and provides photographs of the applicant's visual inspections of the bottom of one cask and top (including under the weather cover) of a second cask. These inspections were performed in 2015 to provide aging information to support the license renewal application. NRC staff members attended a portion of these inspections.

The pre-application inspections of the cask bottom revealed some loss of the paint coating and the presence of rust stains, but no apparent loss of material from the base metal of the cask bottom. While the cask was lifted to inspect the bottom, the underlying concrete also was inspected. Following the guidance of American Concrete Institute (ACI) 349.3R, "Evaluation of Existing Nuclear Safety-Related Concrete Structures" (ACI, 2002), visual inspections did not reveal any degradation of the concrete other than light cracking, which the applicant attributed to shrinkage cracking that occurred during the initial concrete curing.

The pre-application inspections on the cask top focused on the protective cover, the components under the cover (e.g., lid, neutron shield, bolts, overpressure monitoring system components), and the trunnions. Some light surface corrosion and stains were found in some areas; however, the applicant stated that the inspection identified no detectable loss of material due to corrosion on any of the components.

The staff notes that, in response to a request for additional information (RAI), the applicant added cracking of the polymeric neutron shielding material as an aging effect requiring management (Dominion Energy Virginia, 2017d). The staff's evaluation of the applicant's conclusion is documented below.

For the loss of material aging effect, the applicant identified the following associated aging mechanisms for metallic components in the outdoor atmosphere/weather environment:

- loss of material due to general corrosion (carbon and low-alloy steel)
- loss of material due to crevice corrosion (carbon, low-alloy, and stainless steel; aluminum)
- loss of material due to pitting corrosion (carbon, low-alloy, and stainless steel; aluminum)
- loss of material due to galvanic corrosion (carbon and low-alloy steel; aluminum)

The applicant also identified the following aging mechanisms and effects for the polymeric neutron shield materials that are encased within a metallic shell:

- loss of material due to thermal degradation and radiolytic decomposition (polypropylene and borated polyester)

- cracking due to thermal degradation and radiolytic decomposition (polypropylene and borated polyester)

The staff reviewed the applicant's identification of aging mechanisms and effects for the TN-32 cask and associated subcomponents. In its review, the staff considered NRC guidance (NRC, 2010b, 2016), technical literature, and operating experience from nuclear and nonnuclear applications. A summary of the staff's evaluation of the aging effects and mechanisms follows.

<u>Loss of Material due to General Corrosion</u>

The staff reviewed the applicant's evaluation of the potential effects of general corrosion on metallic cask components in the outdoor atmosphere environment. The staff notes that general (or uniform) corrosion of carbon and low-alloy steels in moisture-bearing atmospheres is a well-known aging mechanism, the rate of which depends on factors including humidity, time of wetness, atmospheric contaminants, and oxidizing species (Fontana, 1986). The staff also notes that stainless steels and aluminum form an oxidized protective film on their surfaces that effectively prevents uniform corrosion (Grubb et al., 2005; Kaufman, 2005). Therefore, the staff finds the applicant's evaluation of loss of material due to general corrosion to be acceptable because the applicant has identified and will manage this well-known mechanism and effect for carbon and low-alloy steels and has appropriately excluded the consideration of general corrosion for stainless steels and aluminum, given the passivity of these alloys in the outdoor atmosphere environment.

The applicant did not identify loss of material due to corrosion as an aging mechanism and effect for metallic components that are either exposed to the helium internal cask environment or enclosed within another component. The staff notes that, because very little residual moisture is expected in the internal cask environment following drying and refilling with helium, corrosion of the metallic components in the helium environment will be limited. Similarly, metallic surfaces that are enclosed within another component are not expected to be exposed to sufficient moisture or oxygen to support significant corrosion. Therefore, because loss of material due to metallic corrosion is not expected to occur in the helium or enclosed environments, the staff finds the applicant's decision not to manage this aging mechanism and effect to be acceptable.

As shown in Table 3.3-1, the applicant identified a helium environment for the nickel-based alloy spring in the Helicoflex lids seals. The staff notes, however, that some Helicoflex designs include a break in the outer jacket that would expose the spring to the same external environment as the jacketing material, which includes both helium and the outdoor atmosphere. The staff evaluated the potential for nickel alloy corrosion in an outdoor atmosphere environment and found the applicant's determination of no applicable aging mechanism to be acceptable for this environment as well. The staff notes that nickel alloys are characterized by a high resistance to general and pitting corrosion in outdoor environments, and nickel alloys, in general, are more resistant to corrosion than stainless steels (Crook, 2005).

<u>Loss of Material due to Pitting and Crevice Corrosion</u>

The staff reviewed the applicant's evaluation of the potential effects of pitting and crevice corrosion on metallic cask components in the outdoor atmosphere environment. The staff notes that, in addition to moisture, the outside atmosphere can transport contaminants (e.g., chlorides) to cask external surfaces. Thus, the conditions necessary for pitting and crevice corrosion may be present for carbon and low-alloy steels (Revie, 2000), stainless steels (Grubb et al., 2005), and aluminum (Kaufman, 2005). Therefore, the staff finds the applicant's evaluation of loss of material due to pitting and crevice corrosion to be acceptable because the applicant's management of these aging mechanisms and effect for all metallic components in the outdoor atmosphere is consistent with their observed occurrence in potentially contaminated, aqueous environments.

Loss of Material due to Galvanic Corrosion

The staff reviewed the applicant's evaluation of the potential effects of galvanic corrosion. The staff notes that galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. The less noble of the two materials oxidizes and can experience a loss of material. Because the outdoor atmosphere can provide the necessary conducting solution, all dissimilar material contacts may result in galvanic corrosion. Of the metallic materials in the cask, stainless steel is the most noble material, and thus would not be expected to corrode when in contact with the other less noble metals: carbon steel, low-alloy steel, aluminum (Baboian, 2003). The staff notes that the applicant identified galvanic corrosion as an aging mechanism for all of these less noble metals, and thus the staff finds the applicant's evaluation of loss of material due to galvanic corrosion to be acceptable.

Loss of Material and Cracking due to Thermal Degradation and Radiolytic Decomposition

The staff reviewed the applicant's evaluation of the potential effects of radiolytic decomposition and thermal degradation of the polymeric neutron shielding materials. The staff notes that polymers can be susceptible to both heat- and radiation-induced changes, such as embrittlement, shrinkage, decomposition, and changes in physical configuration (EPRI, 2002; McManus and Chamis, 1996; Cota et al., 2007, Fu et al., 1988). Shrinkage and embrittlement can locally displace shielding material and potentially diminish shielding effectiveness. The applicant identified thermal degradation and radiolytic decomposition as potential aging mechanisms and cited loss of material and cracking as the associated aging effects. Therefore, the staff finds the applicant's evaluation of loss of material and cracking due to thermal degradation and radiolytic decomposition to be acceptable because the applicant has identified and will manage these known aging mechanisms and effects for polymeric materials.

The staff notes that an additional potential effect of the degradation of the polymeric neutron shield is the generation of hydrogen gas that could reach flammable concentrations. In its response to an RAI (Dominion Energy Virginia, 2017a), and as described in license renewal application Section 2.4.1, the applicant stated that a relief valve in the radial neutron shield and a hole in the top neutron shield provide a vent path. The applicant also presented an analysis comparing the amount of hydrogen gas generated in the neutron shield polymer to the amount of hydrogen gas dissolved in the polymer over a 60-year period, which would encompass the requested period of extended operation (Dominion Energy Virginia, 2017b). The analysis concluded that the amount of hydrogen gas that can be dissolved by the polymer is greater than the hydrogen gas generated in the polymer. The staff finds the applicant's decision not to address the buildup of hydrogen gas with an aging management activity to be acceptable because the design of the storage system effectively prevents flammable conditions.

Change in Material Properties due to Elevated Temperature Exposure

The applicant did not identify any aging effects associated with elevated temperature exposure for the aluminum basket components. However, in its response to an RAI on the potential for loss of aluminum strength due to elevated temperature exposure (Dominion Energy Virginia, 2017e), the applicant provided an analysis to demonstrate the structural integrity of the aluminum basket in a tip-over event, even with a loss of aluminum strength. This analysis also considered the effects of hardening of the concrete pad as it continues to cure with time. The tip-over event is considered a non-mechanistic event; although there is no regulatory requirement to evaluate the cask against a non-mechanistic event, it is analyzed as a defense-in-depth measure to provide additional assurance that the cask will maintain the intended functions during storage.

The applicant's analysis discussed the changes in strength of aluminum as a function of operating time and temperature. Specifically, the applicant provided test data of yield and tensile strengths of aluminum alloy 6061-T6 as a function of time and temperature. The staff reviewed the data against the long-term cask temperatures described in Table 4.4-1 of the TN-32 TSAR (Transnuclear, 1996) and verified that the yield strength of 2.4 ksi (1,000 pounds per square inch) and tensile strength of 4.3 ksi used in the analysis of fuel basket structural integrity are conservative values and acceptable (Ferrell, 1995).

The applicant's analysis also evaluated the change in the hardness of the concrete pad as it cures, which influences the impact inertia force associated with postulated cask handling accidents. The applicant evaluated how the concrete curing would affect the structural integrity of the fuel basket undergoing the design-basis cask tip-over accident. In response to an RAI (Dominion Energy Virginia, 2017a), the applicant considered the data in NUREG/CR-6424, "Report on Aging of Nuclear Power Plant Reinforced Concrete Structures," issued March 1996, and estimated that the increase in concrete strength at 20 years and beyond would be less than 41 percent of the as-built, average, 28-day compressive strength of 5,060 pounds per square inch (psi) for ISFSI pad No. 1. To add conservatism to the estimate, the applicant applied a 1.67 factor to the as-built, 110-percent average 28-day concrete compressive strength to result in a concrete compressive strength of 9,295 psi (1.67 x 110% x 5,060 = 9,295) to be used in evaluating the hardening of concrete pad No. 1 for 60 years of service life.

In response to an RAI regarding the calculation of peak deceleration on the aluminum basket in a tip-over event (Dominion Energy Virginia, 2017e), the applicant used results of the EPRI NP-4830 target hardness method (EPRI, 1986) and considered the increased concrete compressive strength from 5,060 psi to 9,295 psi to calculate a scale factor of 1.17 for estimating the cask deceleration associated with an equivalent side impact for the cask tip-over onto pad No. 1. As noted in Section 3.3.3.1 of the SER for the TN-32 cask (NRC, 1996c), the staff has not endorsed the EPRI report. Nevertheless, since the applicant used the method only to evaluate the relative contribution of the concrete compressive strength to estimate the cask side impact deceleration, and the tip-over event is a non-mechanistic event, the staff finds it acceptable to use the 1.17 factor for scaling up the previously accepted maximum peak cask side deceleration to estimate the peak cask deceleration corresponding to the pad concrete compressive strength of 9,295 psi.

In Calculation 503065-0201 (Dominion Energy Virginia, 2017e), the applicant used an LS-DYNA model to evaluate the structural performance of the TN-32 fuel basket by applying a maximum single-pulse side-drop load of 63 g to the basket for three orientations at 0, 45, and 90 degrees to represent the loads experienced during a tip-over event. For this analysis, the applicant continued to use the modeling methodology and assumptions used in TN Calculation 19885-0215, Revision 0, "TN-32B HBU Basket Accident Analysis," for Amendment No. 5 of the ISFSI license (NRC, 2017). Table 1 of Calculation 503065-0201 summarizes the margins of safety for the basket components, including the stainless steel compartment box and peripheral support. The large margins are only slightly less (and still positive) than those reported in TN Calculation 19885-0215, Revision 0, and are therefore acceptable. For the aluminum conduction plates, which are sandwiched between the steel tubes, the applicant noted that the stresses in the steel tube components are below their respective stress limits with insignificant plastic strain, which suggests that the integrity of the aluminum plates is also being maintained. The staff reviewed the applicant's assessment of basket component structural performance by verifying that the finite element analysis was implemented appropriately. On this basis, the staff has reasonable assurance to conclude that the TN-32 basket components are adequately designed to meet the structural impact conditions due to a 63 g side drop load, which accounts for the reduced strength of aluminum due to exposure time and temperature and the aging effects on concrete strength.

Change in Material Properties due to Radiation Exposure

The applicant did not identify any aging effects associated with radiation exposure for the aluminum basket components. The staff notes that studies using simulated reactor irradiation conditions (10^{22} n/cm^2) have shown an effect on mechanical properties (Alexander, 1999); however, these radiation levels are 7 to 9 orders of magnitude greater than the level of fluence after dry storage for 60 years, based on the typical neutron flux of 10^4–10^6 n/cm^2-s (Sindelar et al., 2011). Also, radiation testing of an aluminum-based sintered composite subjected to up to 1.5 x 10^{20} n/cm^2 fast neutron fluence and a maximum of 3.8 x 10^{11} rad gamma exposure showed little change in the yield or ultimate tensile strength of the material (EPRI, 2009). As a result, changes in mechanical properties from radiation during dry storage are not expected to be significant.

Therefore, because the aluminum basket components have been demonstrated to be capable of fulfilling their structural function after elevated temperature exposure, and because the irradiation effects of aluminum properties have been found to be minimal, the staff finds the applicant's decision not to manage the aging of the aluminum baskets to be acceptable.

Loss of Neutron Shielding due to Boron Depletion

The applicant did not identify an aging effect associated with loss of neutron shielding for the TN-32 cask neutron shield. In response to an RAI (Dominion Energy Virginia, 2017a), the applicant stated that boron depletion of the radial neutron shield material is negligible and aging management is not required. The staff notes that the boron concentration in the neutron shield decreases as boron-10 atoms in the material absorb neutrons. Significant depletion of the boron-10 atoms may occur over time if the shielding material is exposed to sufficient neutron fluence. The applicant referred to the analysis of the neutron absorbing material in the fuel basket in Section 6.3.2 of the TN-32 FSAR, Revision 0 (Transnuclear, 2000). The analysis assumes the neutron fluence is constant and that all neutrons are thermal neutrons. These are conservative assumptions, as (1) the actual neutron fluence declines over time, (2) most of the neutrons are at higher than thermal energy and boron-10 has a much lower absorption cross section at higher energies. As a result, the estimated boron-10 depletion is much higher than the actual loss. In addition, the applicant has calculated the boron-10 based on these conservative assumptions, and the applicant's calculation demonstrates that loss of boron-10 in the neutron shield is negligible over 1,000 years. The staff reviewed the applicant's calculations and finds that the applicant's analysis of loss of boron-10 in the neutron shields is conservative and the results are acceptable. On this basis, the staff determined that loss of boron-10 in the neutron shields due to depletion does not require any aging management.

3.3.1.3 Proposed Aging Management Activities

The applicant credited the TN-32 Dry Storage Cask AMP to manage loss of material due to corrosion mechanisms for metallic components and loss of material due to thermal degradation and radiolytic decomposition for the polymeric neutron shield materials.

The staff reviewed the TN-32 Dry Storage Cask AMP. Based on its review of the information provided in the license renewal application and responses to the staff's RAIs, the staff concludes that the aging management activities in the proposed TN-32 Dry Storage Cask AMP are an acceptable means of ensuring that the identified aging effects will not result in a loss of intended functions of the in-scope SSCs. Section 3.5.1 of this SER documents the staff's evaluation of the TN-32 Dry Storage Cask AMP.

3.3.2 Spent Fuel Assemblies

The applicant described the spent fuel assemblies in Section 2.4.2 of the license renewal application. The TN-32 casks at North Anna are permitted to hold 32 spent fuel assemblies, burnable poison rods, and thimble plugging devices. The subcomponents of the assemblies include the fuel cladding, guide tubes, grid assembly, bottom nozzle, and top nozzle. The fuel burnup is limited to less than 45 gigawatt-days per metric ton uranium (GWd/MTU) and decay heat to less than 1.02 kilowatts per assembly. As discussed in Section 2.1.1, the license authorizes storage of HBU fuel (greater than or equal to 45 GWd/MTU) in one TN-32 HBU cask. However, the TN-32 HBU cask and its spent fuel contents are not within the scope of the renewal.

3.3.2.1 Materials and Environments

Sections 2.4.2 and 3.3 of the license renewal application describe the materials and environments of the spent fuel assemblies. The assemblies are constructed of zirconium-based alloys (fuel cladding, end plugs, guide tubes, grid assemblies), nickel-based alloys (grid assemblies), and stainless steel (guide tube sleeves, guide tube fasteners, top and bottom nozzles).

The applicant described the external environment for all fuel assembly components as the same as that for the dry storage cask internal environment. After fuel loading, the cask is drained and vacuum-dried to remove the borated spent fuel pool water, then backfilled with helium. The applicant stated that the helium gas temperature is expected to be 128 degrees C (262 degrees F) after 20 years of spent fuel storage. The applicant also stated that, after 20 years of storage, the fast neutron fluence and gamma radiation levels are expected to be 10^{14} n/cm^2 and 10^9 rad, respectively. As the guide tubes are open on the ends, this is also their internal exposure environment.

The applicant stated that the internal environment of the fuel cladding includes helium (from the initial fuel rod fabrication) and potential fission product gases. The applicant also stated that, during fuel loading, vacuum drying was performed to ensure that the peak cladding temperature did not exceed 400 degrees C (752 degrees F) as recommended in ISG-11, Revision 3, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” dated November 17, 2003 (NRC, 2003). The applicant further stated that the fuel cladding temperature after 20 years of storage is expected to be less than 188 degrees C (371 degrees F).

The staff reviewed the applicant’s description of the materials and environments for the spent fuel assemblies to confirm that the description is consistent with the descriptions and engineering drawings in the TN-32 TSAR and the North Anna ISFSI SAR. Based on its confirmation of consistency with these design-basis documents, the staff finds the applicant’s identification of the materials and environments for the fuel assemblies to be acceptable.

3.3.2.2 Aging Effects and Mechanisms for the Spent Fuel Assemblies

In Section 3.3.3 of the license renewal application, the applicant stated that there are no aging effects requiring management for the spent fuel assemblies during the period of extended operation. The applicant stated that this conclusion is consistent with that drawn from the EPRI Dry Cask Storage Characterization Project (EPRI, 2001). The staff notes that this project involved the visual inspection and material analysis of spent fuel assemblies that were in dry storage for approximately 15 years.

The staff reviewed the applicant’s conclusion that identified no aging mechanisms or effects for the spent fuel assemblies. The staff based its review on NUREG-1927, Revision 1, and ISG-11, Revision 3, which state that low-burnup fuel (≤45 GWd/MTU) is expected to maintain its integrity in the period of extended operation, provided that the maximum cladding temperature limits cited in ISG-11 are followed. The discussion below summarizes the basis for that position, considering two aging mechanisms that have the potential to affect the intended functions of fuel assemblies: creep and hydride reorientation of the fuel cladding.

<u>Creep</u>

Creep is the time-dependent deformation that takes place at an elevated temperature and constant stress. The relatively high temperatures, differential pressures, and corresponding hoop stress on the cladding will result in permanent creep deformation of the cladding over time. Excessive creep of the cladding during dry storage could lead to thinning, hairline cracks, or gross ruptures.

In ISG-11, the staff concluded that creep is not expected to lead to gross ruptures in low-burnup spent fuel assemblies, provided that the maximum cladding temperature limits cited in the ISG are followed. The staff notes that the North Anna ISFSI SAR states that the maximum predicted fuel cladding temperature is 296 degrees C (565 degrees F), which is below the allowable fuel cladding temperature limit of 400 degrees C (752 degrees F) cited in ISG-11. The data and analyses in ISG-11 demonstrate that (1) deformation caused by creep will proceed slowly over time and will decrease the rod pressure, (2) the decreasing cladding temperature with time also decreases the hoop stress, and this too will slow the creep rate, and (3) in the unlikely event that a breach of the cladding occurs because of creep, it is believed that this will not result in gross rupture.

The experimental confirmatory basis that creep will not impact the ability of low-burnup fuel to remain in its analyzed configuration during the period of extended operation was provided in NUREG/CR-6745, “Dry Cask Storage Characterization Project—Phase 1; CASTOR V/21 Cask Opening and Examination,” issued September 2001 (Bare and Torgerson, 2001), and

NUREG/CR-6831, "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage," issued September 2003 (Einziger et al., 2003). This research demonstrated that low-burnup fuel cladding and other cask internals had no deleterious effects after 15 years of storage. As a result, the staff finds the applicant's decision not to manage creep to be acceptable.

Hydride Reorientation

The high cladding temperatures and hoop stresses that can occur during the cask vacuum drying process may result in hydrogen within the cladding forming a solid solution that subsequently precipitates into radially-oriented hydrides when the cladding cools. Cladding with a high concentration of these radial hydrides has been shown to have reduced ductility (Billone et al., 2013; Aomi et al., 2008).

In ISG-11, the staff concluded that significant hydride reorientation is not expected to occur in low-burnup spent fuel assemblies. The staff based its conclusion on the fact that low-burnup fuel is not expected to have a significant amount of reorientation due to limited hydride content and, as such, the network of reoriented hydrides is not expected to be extensive enough to lead to significant losses in ductility. The dry cask storage characterization project discussed above (NUREG/CR-6745 and NUREG/CR-6831) confirmed the basis for the guidance on hydride reorientation in ISG-11. As a result, the staff finds the applicant's decision not to manage hydride reorientation to be acceptable.

Based on its review of the license renewal application and the references cited above, the staff finds the applicant's aging management results for the spent fuel assemblies to be acceptable.

3.3.3 Reinforced Concrete Pad No. 1

The applicant described the concrete pad in Section 2.4.3 of the license renewal application. The steel-reinforced pad provides structural support for the storage of the TN-32 dry storage casks. The applicant stated that the pad is designed with sufficient strength to withstand cask loads while also having adequate yielding to limit impact forces during accidents.

3.3.3.1 Materials and Environments

Section 3.4 of the license renewal application describes the materials and environments of the pad. The pad is constructed of concrete and reinforcing carbon steel bars. The applicant stated that the constituents of the concrete conform to the requirements of ASTM C150, "Standard Specification for Portland Cement" (Type II cement) (ASTM, 1986a), ASTM C494, "Standard Specification for Chemical Admixtures for Concrete" (ASTM, 1986b), and ASTM C33, "Standard Specification for Concrete Aggregates" (ASTM, 1986c).

The concrete pad is exposed to soil and the outdoor atmosphere, including precipitation and wind. The applicant stated that the location of the ISFSI, near the freshwater Lake Anna, is not exposed to brackish water, saltwater spray, or high-sulfur emissions. The applicant also provided a summary of groundwater chemistry tests to show that the groundwater is not aggressive (chlorides less than 500 parts per million (ppm), sulfates less than 1,500 ppm, and pH greater than 5.5). Further, the applicant stated that the bottom of the pad is 13 to 20 feet above the groundwater table.

The staff reviewed the applicant's description of the materials and environments for the concrete pad to confirm that the description is consistent with the descriptions and engineering drawings in the TN-32 TSAR and the North Anna ISFSI SAR. Based on its confirmation of consistency with these design-basis documents, the staff finds the applicant's identification of the materials and environments for the pad to be acceptable.

3.3.3.2 Aging Effects and Mechanisms for the Reinforced Concrete Pad

In Section 3.4.3 of the license renewal application, the applicant stated that loss of material, cracking, and change in material properties are the aging effects that require management for the concrete pad. The applicant associated the following aging mechanisms with the identified aging effects in the outdoor atmosphere/weather environment:

- loss of material due to freeze-thaw
- cracking due to freeze-thaw and reaction with aggregates
- change in material properties due to leaching of calcium hydroxide

The applicant also identified the following aging mechanism associated with the aging effect in the soil environment:

- cracking due to reaction with aggregates and settlement

The applicant stated that there are multiple ways to describe concrete aging effects and provided a cross-reference table (Table 3.1-1 in the renewal application) to show how the identified aging effects are related to those referenced in NUREG-1801, Revision 2, "Generic Aging Lessons Learned (GALL) Report," issued December 2010 (NRC, 2010b) and in EPRI Report No. 1015078, "Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools)" (EPRI, 2007).

The staff reviewed the applicant's identification of aging mechanisms and effects for the concrete pad. In its review, the staff considered NRC guidance, the technical literature, and operating experience from nuclear and nonnuclear applications. A summary of the staff's evaluation of the aging mechanisms and effects follows.

<u>Loss of Material and Cracking due to Freeze-Thaw</u>

The staff reviewed the applicant's evaluation of the potential effects of freeze-thaw for the concrete pad in the outdoor atmosphere environment. The staff notes that, because water expands when freezing, fully or partially saturated concrete will experience internal stresses from the expanding ice that can cause concrete cracking or scaling (NRC, 1995, 2012b). The applicant also identified freeze-thaw as a potential aging mechanism and noted both loss of material and cracking as associated aging effects. Therefore, the staff finds the applicant's evaluation of loss of material and cracking due to freeze-thaw to be acceptable because the applicant's determination that this aging mechanism and its effects requires management is consistent with its known occurrence in water-saturated concrete.

<u>Cracking due to Reaction with Aggregates</u>

The staff reviewed the applicant's evaluation of the potential effects of reaction with aggregates for the concrete pad in the outdoor atmosphere and soil environments. The staff notes that reactions can occur between the concrete aggregate and alkaline components within the cement or from outside sources such as deicing salts and groundwater. The reaction products (e.g., alkali-silica gel in the case of alkali-silica reactions) can swell with the absorption of water, exerting expansive pressures within the concrete and leading to cracking (ACI, 2008). Such degradation has been identified in nuclear power plant concrete structures. The applicant identified reaction with aggregates as a potential aging mechanism that can lead to cracking. Therefore, the staff finds the applicant's evaluation of cracking due to reaction with aggregates to be acceptable because the applicant's determination that this aging mechanism and effect requires management is consistent with its known occurrence in concrete structures exposed to moisture.

Cracking due to Differential Settlement

The staff reviewed the applicant's evaluation of the potential effects of differential settlement for the concrete pad in the outdoor atmosphere and soil environments. Differential settlement is the uneven deformation of the supporting foundation soil (Das, 1999; NAVFAC, 1986). The staff notes that its occurrence depends on the type of soil, thickness of soil layers, water-table level, depth of the foundation mat below the ground surface, liquefaction during seismic events, and the mechanical loading. Operating experience has shown that differential settlement has occurred in nuclear power plant concrete structures (NRC, 1995). The applicant also identified settlement as a potential aging mechanism and noted this could lead to cracking of the concrete. Therefore, the staff finds the applicant's evaluation of cracking due to differential settlement to be acceptable because the applicant's determination that this aging mechanism and effect requires management is consistent with its known occurrence in concrete foundation structures.

Change in Material Properties due to Leaching of Calcium Hydroxide

The staff reviewed the applicant's evaluation of the potential effects of leaching of calcium hydroxide for the concrete pad in the outdoor atmosphere and soil environments. The staff notes that a flux of water through a concrete surface can result in the removal, or leaching, of calcium hydroxide (Hanson et al., 2011). This can cause a loss of concrete strength, an increase in the concrete porosity and permeability, and a reduction in pH. The applicant also identified leaching of calcium hydroxide as a potential aging mechanism and noted this could lead to a change in the concrete material properties. Therefore, the staff finds the applicant's evaluation of change in material properties due to leaching of calcium hydroxide to be acceptable because the applicant's determination that this aging mechanism and effect requires management is consistent with its known occurrence in concrete foundation structures exposed to a constant or intermittent flow of water.

Aging Effects due to Aggressive Chemical Attack

The applicant did not provide an evaluation of the potential effects of aggressive chemical attack of the concrete pad. The staff notes that when aggressive ions or acids intrude into the pore network of the concrete, the consequent chemical attack can cause several degradation phenomena. The aggressive chemical attack typically originates from an external source of sulfate (Nuclear Waste Technical Review Board, 2010) or magnesium ions, as well as acidic environmental conditions (Gutt and Harrison, 1997; Mehta, 1986). Depending on the type of aggressive chemical, the degradation of concrete can manifest in the form of cracking, loss of strength, concrete spalling and scaling, and reduction of pH.

Although the applicant did not provide a specific evaluation of aggressive chemical attack, the applicant provided the results of groundwater chemistry sampling to show that the groundwater is considered to be non-aggressive. In Section 3.4.2 of the license renewal application, the applicant provided groundwater chemistry results for several years of testing, which show that the levels of chloride and sulfate were well below non-aggressive thresholds as defined by the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Section XI, Subsection IWL (ASME, 2008). The results also showed pH levels to be above 5.5, the lower bound for the ASME criteria for non-aggressive environments.

The staff notes that the aging effects often associated with aggressive chemical attack (e.g., cracking, loss of strength, loss of material) can be identified by the inspections the applicant will be conducting for the other aging mechanisms (e.g., freeze-thaw, reaction with aggregates). As a result, because the applicant's groundwater testing has not shown the environment to be aggressive and because chemical attack can be identified during the planned inspections for other mechanisms, the staff finds the applicant's decision not to address this specific aging mechanism to be acceptable.

<u>Aging Effects due to Corrosion of Reinforcing Steel</u>

In response to an RAI, the applicant stated that corrosion of the reinforcing steel within the concrete pad is not an aging mechanism that requires management (Dominion Energy Virginia, 2017a). The staff notes that chloride attack of reinforcing steels within concrete structures is a well-known phenomenon (Cheung et al., 2009). The alkaline environment of the concrete typically results in a metal-adherent oxide film on the reinforcing steel bar surface, which passivates the steel. However, chloride ions can break down the passive layer, triggering corrosion that leads to cracking and spalling of the concrete.

The applicant cited the results of groundwater chemistry sampling to show that chloride levels in the groundwater are well below what is considered to be aggressive as defined by the ASME *Boiler and Pressure Vessel Code*, Section XI, Subsection IWL (ASME, 2008). The applicant also stated that the design and construction of the concrete pad in accordance with ACI 349-85, "Code Requirements for Nuclear Safety-Related Concrete Structures" (ACI, 1985), and ACI 301-89, "Specifications for Structural Concrete for Buildings" (ACI, 1989), ensure adequate concrete cover over the reinforcement, low permeability of water through the concrete, and proper reinforcement distribution, which all minimize the potential for concrete cracking and potential infiltration of water. The applicant further stated that the pad is not exposed to groundwater, as the bottom of the pad is approximately 13 to 20 feet above the groundwater table.

The applicant's groundwater testing has shown that the level of chlorides is not aggressive, and the elevation of the pad is well above the ground water table. Further, the pad is designed and constructed to ACI standards, and the corrosion of the reinforcing steel can be identified during the planned inspections for other concrete aging mechanisms. Therefore, the staff finds the applicant's decision not to manage this aging mechanism to be acceptable.

<u>Aging Effects due to Microbiological Degradation</u>

In response to an RAI, the applicant stated that microbiological degradation of the concrete pad is not an aging mechanism that requires management (Dominion Energy Virginia, 2017a). The staff notes that the colonization of microbes and microorganisms that grow on the surface of the concrete can cause biodegradation. The rate of deterioration is slow, but the degradation mode has been observed in concrete structures, such as bridge columns, within 40 years of exposure. Favorable conditions for this mechanism include available water, low pH, and high concentrations of carbon dioxide, chloride ions, or sulfates (Wei et al., 2013).

As discussed for the other concrete degradation mechanisms above, the staff notes that the environment at North Anna does not include aggressive environments known to promote microbiological degradation (e.g., low pH, high chlorides and sulfates). In addition, the staff notes that Section 3.4.2 of the license renewal application states that the bottom of the pad is 13 to 20 feet above the groundwater table. Thus, the pad is not expected to be in contact with a continuously wet environment, such as those that are often associated with biological degradation of concrete. Also, Section 2.4.3 of the license renewal application states that the pad has a slope of 1/8-inch per foot to provide drainage, which would mitigate the potential for standing water. As a result, because the environment at North Anna is not considered favorable to microbiological degradation and because microbial degradation can be identified during the planned inspections for other concrete aging mechanisms, the staff finds the applicant's decision not to address this aging mechanism to be acceptable.

<u>Aging Effects due to Salt Scaling</u>

In response to an RAI, the applicant stated that salt scaling of the concrete pad is not an aging mechanism that requires management (Dominion Energy Virginia, 2017a). The staff notes that salt scaling is the superficial damage caused by freezing a saline solution on a concrete surface. It is closely related to freeze and thaw damage.

In Section 3.4.2 of the license renewal application, the applicant provided the results of groundwater chemistry sampling to show that chloride levels in the groundwater are well below what is considered aggressive as defined by the ASME *Boiler and Pressure Vessel Code*, Section XI, Subsection IWL (ASME, 2008). The applicant also stated that the site is in a rural area, and there are no nearby industrial or chemical plants. The applicant further noted that the site is not exposed to brackish water or saltwater spray.

Because the applicant's groundwater testing has not shown the environment to be aggressive, and because salt scaling can be identified during the planned inspections for other concrete aging mechanisms, the staff finds the applicant's decision not to manage this aging mechanism to be acceptable.

<u>Coupled Mechanisms/Effects</u>

Coupled degradation mechanisms in concrete refer to degradation modes that can interact, affecting their relative times for initiation and progression (e.g., freeze-thaw cracking that leads to water ingress and subsequent leaching of calcium hydroxide). Few in-depth studies have been published on the effects of concrete damage caused by these potential coupled degradation mechanisms. However, the staff finds that an AMP is an adequate approach for addressing potential synergistic effects resulting from coupled degradation mechanisms. The example AMP for concrete structures relies on the applicant's corrective action program to ensure that conditions that may lead to a loss of intended function will be reviewed and dispositioned by trained personnel. If a particular aging effect is detected, part of the applicant's corrective action may include a root-cause evaluation to determine the cause of the aging effect. If the root-cause evaluation determines that the rate of degradation is being accelerated by the effects of coupled degradation modes, follow-up corrective actions may include a review of the inspection and monitoring procedures to ensure that aging management activities continue to be adequate for the remaining period of extended operation. Therefore, the staff finds the applicant's decision not to specifically identify coupled effects in its AMR to be acceptable.

Based on its review of the license renewal application and the references cited above, the staff finds the applicant's aging management results for the concrete pad to be acceptable.

3.3.3.3 Proposed Aging Management Activities

The applicant credited the Monitoring of Structures AMP to manage loss of material, cracking, and changes in material properties for the concrete pad. Based on its review of the information in the license renewal application and responses to the staff's RAIs, the staff concluded that an AMP is an acceptable means of ensuring that the identified aging effects will not result in a loss of intended functions. Section 3.5.2 of this SER documents the staff's evaluation of the Monitoring of Structures AMP.

3.3.4 Evaluation Findings

The staff reviewed the AMR for the North Anna renewal to verify that the license renewal application adequately identified the materials, environments, and aging effects of the in-scope SSCs. Based on its review of the license renewal application, as supplemented, the staff finds the following:

F3.1 The applicant's AMR process is comprehensive in identifying the materials of construction and associated operating environmental conditions for those SSCs within the scope of renewal, and the applicant has provided a summary of the information in the license renewal application and the SAR supplement.

F3.2 The applicant's AMR process is comprehensive in identifying all pertinent aging mechanisms and effects applicable to the in-scope SSCs, and the applicant has provided a summary of the information in the license renewal application and the SAR supplement.

3.4 Time-Limited Aging Analyses

As discussed in Appendix B to the license renewal application, the applicant did not identify any TLAAs for SSCs within the scope of the license renewal. The staff reviewed the license renewal application and design-basis documentation against the TLAA definition criteria in 10 CFR 72.3 to confirm that the applicant did not omit any TLAAs that were part of its approved design basis.

Neutron Poison Effectiveness

In Appendix C3.1 to the license renewal application, the applicant proposed to change Section A.1.3 of the North Anna ISFSI SAR to revise the minimum time of the neutron poison effectiveness from 20 years to 60 years. Section A.1.1 of the ISFSI SAR identifies the basis for the neutron absorber effectiveness as a boron depletion analysis in Chapter 6 of the TN-32 FSAR, Revision 0 (Transnuclear, 2000). The staff notes that Section 6.3.2 of the TN-32 FSAR provides an analysis to show that, after 1,000 years, the degree of boron depletion is negligible. Because the design-basis analysis for boron depletion considered storage times much longer than the period of extended operation (20 to 60 years), the staff finds the applicant's decision not to reevaluate this analysis as a TLAA to be acceptable.

Thermal Evaluation

In Appendix C3.2 to the license renewal application, the applicant proposed to change North Anna ISFSI SAR Section A.1.4 to revise the time at which the thermal design of the TN-32 cask will allow safe storage of spent fuel from 20 years to 60 years. In an RAI response, the applicant clarified that the change was to reflect the fact that the original thermal design basis bounds the renewal period, as maximum decay heat and cask temperatures occur immediately after cask loading (Dominion Energy Virginia, 2017a). The applicant stated that these temperatures were shown in the design basis to be below the maximum allowable component temperatures. The staff reviewed the thermal design basis and notes that, while the cask temperatures do continue to decrease from their maximums after fuel loading, the continuous exposure of aluminum basket components to elevated temperatures may degrade their mechanical properties over time. In response to the staff's RAI on this topic, the applicant analyzed, in the AMR, the change in aluminum mechanical properties to determine if the change in properties would affect the ability of the basket components to fulfill their structural function. As documented in Section 3.3.1.2 of this SER, the staff finds the applicant's analysis to be acceptable.

3.4.1 Evaluation Findings

The staff reviewed the license renewal application and design-basis documentation to confirm that the applicant did not omit any TLAAs that were part of its approved design basis. The staff performed its review following the guidance in NUREG-1927, Revision 1 (NRC, 2016). The staff found the applicant's determination that there were no TLAAs to be acceptable.

F3.3 The applicant appropriately evaluated all aging mechanisms and effects pertinent to SSCs within the scope of renewal that had the potential to involve TLAAs. Therefore, the applicant's evaluation provides reasonable assurance that the SSCs will maintain their intended functions for the period of extended operation, require no further aging management activities, and meet the requirements in 10 CFR 72.42(a)(1).

3.5 Aging Management Programs

Pursuant to 10 CFR 72.42(a)(2) requirements, the applicant must provide a description of AMPs for management of issues associated with aging that could adversely affect SSCs important to safety. The applicant proposed two AMPs:

1. TN-32 Dry Storage Cask AMP

2. Monitoring of Structures AMP

Appendix A to the license renewal application described these AMPs, as updated in Enclosures 1 and 2 of the applicant's response to an RAI (Dominion Energy Virginia, 2017d). Appendix C to the license renewal application provided proposed changes to the North Anna ISFSI SAR (referred to as the SAR supplement). The AMPs are summarized in this SAR supplement, as updated in Enclosures 3 and 4 of the applicant's RAI response (Dominion Energy Virginia, 2017d). As specified in the new license condition in Section 4.1 of this SER, the AMPs summarized in the SAR supplement will be incorporated in the North Anna ISFSI SAR after issuance of the license renewal.

3.5.1 TN-32 Dry Storage Cask Aging Management Program

In Section A.2.1 of the license renewal application, as updated in Enclosures 1 and 2 of the applicant's response to an RAI (Dominion Energy Virginia, 2017d), the applicant described the TN-32 Dry Storage Cask AMP for managing loss of material and cracking for the cask SSC subcomponents. Section C.2.1.1.1 of the application, as updated in Enclosures 3 and 4 of the applicant's RAI response (Dominion Energy Virginia, 2017d) describes the program as it will be incorporated in the North Anna ISFSI SAR. The applicant stated that the program provides continuous monitoring of the TN-32 cask interseal pressure, visual inspections of the cask external surfaces, and radiation monitoring.

The staff reviewed the adequacy of the TN-32 Dry Storage Cask AMP to address the identified aging mechanisms and effects for the storage cask. The staff reviewed the AMP against the criteria in Section 3.6.1 of NUREG-1927, Revision 1 (NRC, 2016). The staff's evaluation of each of the AMP program elements follows.

1. Scope of Program

The applicant described the scope of the program as addressing all the subcomponents identified in Table AMR Results—1, "Transnuclear TN-32 Dry Storage Cask," of the license renewal application. This table also includes the materials, environments, aging mechanisms, aging effects, and intended functions for each of the subcomponents.

The staff reviewed the scope of the program to verify that the applicant adequately described the components covered under the program, as recommended in NUREG-1927, Revision 1. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that the program does not include any preventive actions and that the program is a condition-monitoring activity.

The staff reviewed the preventive actions program element and confirmed that the program does not rely on preventive actions to manage the effects of aging. The staff notes that the program uses pressure monitoring, radiation monitoring, and visual inspections to manage loss of material and cracking. The staff finds the applicant's preventive actions program element to be acceptable because, consistent with the recommendations in NUREG-1927, Revision 1, preventive actions do not need to be provided for condition-monitoring programs.

3. Parameters Monitored or Inspected

The applicant defined the parameters monitored or inspected for three activities: interseal pressure monitoring, radiation monitoring, and visual inspections. The applicant stated that continuous pressure monitoring of the region between the two lid seals will confirm that loss of material of the sealing components will not challenge their pressure-boundary (confinement) function. The applicant also stated that neutron and gamma radiation monitoring, using the methods described in the detection of aging effects program element (element 4), will identify loss of material and cracking of the neutron shields. Finally, the applicant stated that it will perform visual inspections of accessible external surfaces and normally inaccessible surfaces (under the protective weather cover, the cask bottom) to manage loss of material. Loss of material will be identified by the presence of coating defects, loose debris, rust spots and stains, and physical damage.

The staff reviewed the parameters monitored or inspected program element to confirm that the parameters will be capable of identifying degradation before a loss of intended function and provide a clear link to the aging effects identified in the scope of the program, as recommended in NUREG-1927, Revision 1.

The staff finds the applicant's parameters monitored or inspected program element to be acceptable because leakage past the lid seal due to corrosion will immediately actuate a pressure-monitoring alarm, a reduction in shielding effectiveness will be captured by trending of the radiation measurements, and visual inspections are capable of identifying the initiation or progression of loss of material of the cask external surfaces.

4. Detection of Aging Effects

The applicant stated that the detection of the loss of material and cracking aging effects relies on continuous interseal pressure monitoring, radiation monitoring, and periodic and opportunistic visual inspections.

Pressure Monitoring

The applicant stated that the interseal pressure is monitored continuously for all casks and that, twice a day, personnel verify that no low-pressure alarms have been activated. The staff notes that the original ISFSI license approved the use of pressure monitoring equipment as an effective means of ensuring the confinement function is maintained; this activity is captured in the license's technical specifications. As a result, the staff finds the continued use of this method to be an acceptable means of monitoring potential aging of the sealing components. The staff notes that any potential corrosion of the cask sealing surfaces is expected to develop slowly over time, and as a result, twice-daily checks for low-pressure alarms are considered adequate to provide timely identification of leakage.

Radiation Monitoring

The applicant described the radiation monitoring activities in the AMP that will be conducted to detect gamma and neutron radiation. These activities include proposed annual radiation surveys around the perimeter of the concrete pad, in addition to the current licensee activities of quarterly readings of thermoluminescent dosimeters (TLDs) at the ISFSI perimeter fence and radiological condition monitoring for occupational exposure during work activities (Dominion Energy Virginia, 2017a, 2017d).

Monitoring at ISFSI fence

The applicant stated that existing TLD monitoring at the ISFSI perimeter fence will be enhanced to improve detection of neutrons in the intermediate and fast neutron energy spectra by equipping the TLDs with an additional chip, such as a CR 39 polycarbonate chip or the equivalent.

Radiation surveys

The applicant also stated that it will conduct an annual neutron radiation survey around the entire perimeter of reinforced concrete pad No. 1 at 32 locations around the cask array. Neutron dose rate readings will be taken at an approximate elevation corresponding to the maximum neutron flux, and therefore serves as a leading indicator for axial and radial locations not specifically monitored during the annual neutron survey.

The applicant will use a tissue equivalent proportional counter, such as the REM 500 neutron survey meter or equivalent, to measure neutron dose rate at all survey points. Dominion Energy Virginia has previous operating experience using bubble dosimeters to determine the neutron energies at various distances from a TN-32 dry storage cask. The results indicate that nearly 100 percent of the neutrons at the cask surface have energies greater than 100 kiloelectronvolts (keV), while at a distance of 10 feet, approximately 70 percent of the neutrons have energies greater than 100 keV. Dominion Energy Virginia has also used the REM 500 neutron survey meter to measure the neutron dose rates from a TN-32 dry storage cask with and without the top neutron shield in place. The dose rate measurements were recorded at a distance of about 6 feet above the top of the cask. The applicant stated that the results confirm the ability of the REM 500 neutron survey meter to detect the shift in neutron energies that would result from a loss of material and cracking of the shielding material.

The applicant noted that the annual neutron radiation survey does not specifically identify an individual cask that has experienced cracking of the neutron shield, but rather is intended to assess the general neutron radiation dose rates at the edge of the reinforced concrete pad No. 1. The applicant states that once an increasing dose rate trend is detected, this result will be entered into the Corrective Action Program. The corrective actions may require detailed surveys of individual casks to identify the source of the increased dose rates (refer to program element 7). The applicant further stated that the frequency of the neutron survey is justified because of the continuous monitoring and quarterly reading of doses to the public by TLDs capable of detecting the neutron energies emitted by the TN-32 dry storage casks.

Monitoring with occupational exposure controls

The applicant stated that the current Dominion Radiological Work Control Program ensures, and will continue to ensure, that occupational workers are protected when they work in radiological controlled areas. When a radiation work permit (RWP) is initiated, health physics technicians perform surveys to determine the general radiological conditions at the job site, thus providing another opportunity to detect adverse conditions around the TN-32 dry storage cask(s). The RWP contains the survey results and additional radiological information necessary to protect maintenance personnel, such as required protective clothing, respirator requirements, and dose and dose rate limits. The RWP also specifies the required dosimetry for entry into the ISFSI. All activities in the vicinity of the TN-32 dry storage casks require workers to wear neutron and gamma dosimetry to ensure that the doses received by the occupational workers are below the regulatory limits and all operating activities follow the ALARA (as low as is reasonably achievable, for radiation exposure) principle.

For TN-32 dry storage cask maintenance activities (e.g., removal of a protective cover), an additional detailed neutron and gamma survey is performed before maintenance can begin. In accordance with station procedures, personnel performing radiation surveys are required to be qualified health physics technicians. Portable instruments used during surveys are verified to be calibrated and operable before use.

The applicant stated that the performance of health physics surveys before maintenance activities, in conjunction with personal dosimetry requirements, ensures the safety of occupational workers performing maintenance on the TN-32 dry storage casks. The applicant stated that trending of the various radiation measurements, as discussed further in program element 5, will be capable of identifying adverse trends that may be an indication of aging (loss of material and cracking) of the neutron shielding material.

Staff evaluation of radiation monitoring

The staff reviewed the proposed radiation monitoring to ensure it is capable of identifying aging of the neutron shield material before a loss of intended function. The staff finds that the radiation monitoring activities provide reasonable assurance that the program is capable of detecting aging of neutron shields to ensure that the ISFSI continues to meet the regulatory dose rate limits to the general public as well as the occupational workers for two reasons. First, the enhanced TLDs at the ISFSI fence, which are much closer to the casks compared to the controlled area boundary, will provide quarterly measured dose rates to alert the ISFSI operator of a potential dose rate increase at the controlled area boundary. Second, the measured dose rates also provide references for the potential radiation levels inside the fence. Furthermore, per the operating procedures as stated in the application, a health physicist must perform a survey of the dose rates (including both neutron and gamma) before anyone is allowed to enter the area inside the ISFSI fence. These multiple layers of protection provide reasonable assurance that aging of the neutron shields will be detected before a loss of intended function.

Regarding the proposed annual neutron survey, the staff finds that the applicant’s selection of the neutron measurement location is acceptable because this location (elevation on the cask) is where the maximum degradation would likely occur. Based on NRC staff’s evaluation, the REM 500 is a neutron detector for dose equivalent rate measurements with a response capacity of 480 millirem for neutron energies ranging from 70 KeV and 20 MeV (NRC, 2010a). Therefore, this detector, or equivalent, is adequate for measuring neutrons coming from the contents of the TN-32 cask.

The staff evaluated the applicant’s proposed parameters to be monitored for detection of aging of neutron shields and finds it acceptable because the measured dose rate using the REM 500 already factored in both the number of neutrons and the energy spectrum of the neutrons, and an increasing trend of neutron dose rates would be a reasonable indication of aging of the neutron shields.

Further, the applicant states that, once an increasing trend in measured dose rate is detected, this result will be entered into the Corrective Action Program. This program, as discussed in the corrective actions program element (element 7), will evaluate the degree of neutron shield degradation and take necessary actions, including use of temporary shields, to ensure the ISFSI continues to meet the regulatory requirements for dose limits to the general public and the occupational workers.

Regarding the proposed annual frequency of the neutron survey, the staff notes that the applicant will trend the monitoring data from the North Anna ISFSI and will also gather operating experience from other ISFSI sites, per the operating experience program element (element 10) of the AMP. The staff recognizes that the neutron survey is not the sole method relied upon for detecting potential neutron shield degradation. However, the applicant’s commitment to adjusting the survey frequency whenever industry operating experience indicates that there is suspected degradation makes this survey program effective and acceptable. In addition, the applicant's proposed AMP also includes performing an engineering evaluation every five years to review industry and plant-specific operating experience to determine whether updates to the AMP (including increasing inspection frequencies) or other corrective actions are needed.

The NRC will inspect the applicant's performance of the AMP in the period of extended operation, including any actions taken to adjust AMPs to respond to operating experience, to verify that operating experience is being taken into account and AMPs are modified accordingly to ensure their effectiveness. On these bases, the staff determined that the applicant's proposed dose rate survey to be acceptable because it includes both elements: a commitment to revising the survey frequency whenever there is industry experience that indicates significant neutron shield degradation and a five-year review of the adequacy of the program.

In summary, the staff has reasonable assurance that the radiation monitoring portion of the proposed AMP will provide timely detection of neutron shield degradation and corrective actions to ensure that the North Anna specific ISFSI will continue to meet the regulatory requirements of 10 CFR 72.104 and 72.106.

Visual Inspections

The applicant stated that visual inspections will be conducted to identify loss of material on the cask external surfaces. Visual inspections are currently conducted, and will continue to be conducted, on visible surfaces during quarterly walkdowns by the system engineer and address the cask shell, outer shell, trunnions, flange, and bottom vertical surfaces. Those surfaces not readily accessible will be visually inspected on an opportunistic basis; however, an inspection of the inaccessible components will be scheduled at a frequency of 20 ± 5 years. The inaccessible surfaces include the cask bottom horizontal surface, the components under the protective weather cover (cask lid, lid bolts and neutron shield bolts, top neutron shield, flange horizontal surfaces), and the trunnion surfaces not visible during quarterly walkdowns.

The quarterly visual inspections will be performed on all casks in a manner consistent with the requirements for the North Anna plant walkdowns to detect coating defects, debris, rust, and physical damage. The opportunistic and 20-year scheduled inspections will be performed in accordance with methods in the ASME *Boiler and Pressure Vessel Code*, Section XI, VT-1 and VT-3 methods (ASME, 2008), as appropriate. The scheduled 20-year inspections will be performed on one cask, selected based on criteria consistent with those used for the pre-application inspections of the cask bottom and top (e.g., accessibility with the transporter, decay heat, time in service). The applicant stated that the first 20-year inspection of inaccessible components would occur 20 ± 5 years from the date of the pre-application inspections of the cask bottom and components under the protective cover, which were completed in October 2015 and November 2015, respectively.

Staff evaluation of walkdowns of accessible surfaces

The staff reviewed the proposed visual inspections to ensure that they can identify aging before a loss of intended function. The staff notes that, as discussed in Section A2.1, "Operating Experience," of the license renewal application, periodic walkdowns at North Anna have successfully identified and led to the remediation of minor coating defects and rust stains on the accessible cask external surfaces. As a result, the staff finds the quarterly walkdowns in accordance with current site procedures to be an acceptable means to continue to identify corrosion of readily visible surfaces well before loss of material could challenge the cask's intended functions.

Staff evaluation of inspections of inaccessible surfaces

For the normally inaccessible components, the staff considers visual inspections performed in accordance with the ASME *Boiler and Pressure Vessel Code*, Section XI, VT-1 and VT-3, to be a proven and widely accepted approach to identifying degradation of nuclear components. The staff notes that the results of the applicant's pre-application inspection showed that, after 10 years (cask bottom) and 15 years (cask top components), only light rust stains were found. The inspections identified no detectable loss of material. The staff also notes that, for many components, the dimensions of the component (e.g., cask bottom) are such that only very severe loss of material could potentially challenge the cask's intended functions. In the case of the cask bottom, such severe corrosion would be expected to be visible on the quarterly ISFSI walkdowns.

In the evaluation of the timing of the inspections of inaccessible components (20 years after the pre-application inspection), the staff reviewed the results and details of the pre-application inspections in Appendix F2 to the license renewal application to ensure that these inspections were sufficiently rigorous to provide a valid baseline of the condition of the casks.

The staff notes that the cask bottom and components under the protective cover were examined in the pre-application inspections with ASME Code VT-1 and/or VT-3 visual techniques, which included the use of a character resolution card to ensure that the lighting and remote camera (for cask bottom) were sufficient to resolve the features of interest. The staff also reviewed the casks selected for the pre-application inspections. Although the selection of the cask for the bottom inspection was limited by the accessibility of the cask by the cask transporter, the applicant selected the inspected cask by considering those with the highest decay heat, storage time, and movement during seismic events. For the inspections under the protective cover, the applicant considered the time since the protective cover was installed, movement during seismic events, and occurrence of prior inspections. The inspections of the cask bottom and under the protective cover found no detectable loss of material.

The staff finds the applicant's proposal to visually inspect the normally inaccessible components on a 20-year schedule, while crediting the pre-application inspections as a baseline, to be acceptable because the pre-application inspections found no significant degradation and the inspections were performed using techniques demonstrated to be capable of resolving the features of interest. In addition, the pre-application casks are considered to be reasonably bounding regarding the expected extent of aging degradation due to their heat load, time in service, and movement during seismic events.

In summary, the staff finds the detection of aging effects program element to be acceptable because the AMP uses techniques capable of identifying degradation and the inspections will be performed at a frequency that supports timely identification of degraded conditions and implementation of corrective actions, consistent with the guidance in NUREG-1927, Revision 1.

5. Monitoring and Trending

The applicant stated that it currently performs, and will continue to perform, monitoring and trending activities periodically to identify areas of degradation. The pressure of the cask seal is monitored continuously, and the absence of low-pressure alarms is confirmed twice a day.

Neutron and gamma TLD readings are recorded quarterly, and results of neutron surveys conducted at reinforced concrete pad No. 1 will be recorded annually. The radiation survey procedures will incorporate annual trending of these parameters. The annual neutron dose rates recorded at each survey point and the quarterly neutron and gamma TLD readings will be plotted and trended. Each neutron radiation survey point will be tracked separately. Neutron and gamma TLD readings will also be plotted on separate graphs, with each TLD location uniquely identified on each graph. Each graph will be updated annually so that trends can be easily observed on each graph over the 40-year period of extended operation. The trending evaluation will consider information pertaining to cask loading and movement to assist in evaluating trends in ISFSI dose rates. Baseline radiation values for TLD locations and annual survey locations will be established before the period of extended operation. The applicant states that because movement or placement of additional TN-32 dry storage casks at the ISFSI can influence baseline radiation values, if a TN-32 dry storage cask is removed or additional casks are placed on reinforced concrete pad No. 1, a new baseline survey will be performed. This new baseline survey will provide reference values for future trending. In the event the TLDs located at the ISFSI perimeter fence are relocated, new TLD baseline values will be established. According to the applicant, these rebaselines ensure that correct trending is performed so that the trending is not biased by the influence of the radiation from the addition or removal of cask(s) and the identification of an increasing trend in radiation values will reflect the true trend of the radiation intensity.

The applicant stated that visual inspection observations are recorded per the inspection procedure. The applicant also stated that radiation monitoring and visual inspection assessments will consider cumulative experience from previous inspections and assessments to monitor and trend the progression of aging effects over time. The applicant further stated that the Dominion Corrective Action Program includes trending of adverse conditions, as well as a process to prevent recurrence.

The staff reviewed the applicant’s monitoring and trending activities to ensure that they provide for an evaluation of the extent of aging and the need for timely corrective or mitigative actions. The staff notes that the continuous pressure monitoring and radiation monitoring provide sufficient opportunity to identify adverse trends so that corrective actions can be implemented before a loss of functions. The staff also notes that the pre-application visual inspections and trending future inspection results against that baseline can effectively evaluate and respond to any identified effects of aging. On these bases, the staff finds the monitoring and trending program element to be acceptable because activities will be in place to ensure that the rate of degradation will be adequately evaluated such that future inspections will be performed or components will be repaired before a loss of functions, consistent with the guidance in NUREG-1927, Revision 1.

6. Acceptance Criteria

With regard to the pressure monitoring system, the applicant stated that the acceptance criterion for interseal pressure monitoring is the absence of a low-pressure alarm at the set point defined in the technical specifications.

With regard to the radiation monitoring program, the applicant indicates that the acceptance criteria for the radiation monitoring is the absence of an increasing trend in neutron and gamma dose rates based on quarterly TLD readings and supplemented by the annual neutron survey results.

The applicant further stated that the acceptance criteria for the quarterly visual inspections are no coating defects, loose debris, rust spots and stains, rust stains on the concrete, physical damage, or baseplate corrosion at the interface of the concrete and cask. The acceptance criterion for the opportunistic and 20-year scheduled inspections is no detectable loss of material from the base metal as determined by the VT-1 or VT-3 visual inspections.

The staff reviewed the applicant's acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended functions. The staff notes that the criteria are consistent with the parameters monitored, and they can be detected using the inspection methods detailed in the detection of aging effects program element. In addition, establishing a threshold as the absence of a low-pressure alarm, an absence of an increasing trend in radiation readings, and an absence of signs of corrosion or coating degradation can ensure that potential signs of aging will be appropriately evaluated and addressed before a loss of function. Therefore, the staff finds the acceptance criteria program element to be acceptable because it provides clear criteria against which to evaluate the need for corrective actions, consistent with the recommendations in NUREG-1927, Revision 1.

7. Corrective Actions

The applicant stated that its corrective actions are established in accordance with the Dominion Topical Report DOM-QA-1, "Nuclear Facility Quality Assurance Program Description," which meets the requirements of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." In the ISFSI SAR Supplement, the applicant stated that monitoring and inspection results that exceed AMP acceptance criteria are entered into the Corrective Action Program. This threshold for entering results into the Corrective Action Program is consistent with the guidance in NUREG-1927, Revision 1.

With respect to the radiation monitoring and any increasing trends in radiation measurements that are entered as a condition into the Corrective Action Program, the applicant stated that the response to the condition will require health physics staff to perform more detailed cask surveys. These surveys, at multiple axial and radial locations, will ascertain which cask is the source of increased radiation. The corrective actions could include increasing the number and frequency of cask surveys, use of temporary shielding, or returning the cask to the spent fuel pool to offload the stored fuel and removal of the cask from service.

The applicant stated that condition reports are first reviewed by the submitter's supervisor and, if necessary, by the Operations Shift Manager, the Condition Report Review Team, and the Corrective Action Assignment Review Team (for conditions adverse to quality).

The staff reviewed the corrective actions program element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of the Corrective Action Program approved under 10 CFR Part 50, Appendix B. NUREG-1927, Revision 1, also states that all conditions that do not meet AMP acceptance criteria should be entered into the Corrective Action Program. On these bases, the staff finds the corrective actions program element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered in the Corrective Action Program, and the quality assurance requirements in 10 CFR Part 50, Appendix B, provide reasonable assurance that corrective actions will be adequate to manage the aging of the dry storage casks.

8. Confirmation Process

The applicant stated that the confirmation process will be conducted in accordance with the Dominion Quality Assurance Program, which is required by 10 CFR Part 50, Appendix B, and ensures the timely evaluation of adverse conditions and implementation of any required corrective actions. The applicant also stated that, every 5 years, an engineering evaluation will be performed to review operating experience to determine whether any of the AMP elements should be updated.

The staff notes that NUREG-1927, Revision 1, states that NRC-approved quality assurance programs are an accepted approach to ensuring that the effectiveness of corrective actions are verified and that adverse trends are monitored to address potential degradation before a loss of function. The staff also notes that performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the administrative controls are conducted in accordance with the Dominion Quality Assurance Program, which is required by 10 CFR Part 50, Appendix B. The applicant also stated that the Quality Assurance Program includes guidance for inspector requirements, record retention requirements, and document control. Procedures are reviewed, approved, and maintained as controlled documents.

The staff notes that NUREG-1927, Revision 1, states that NRC-approved 10 CFR Part 50, Appendix B, programs are an accepted approach to providing adequate review, approval, and fulfillment of activities that ensure SSCs will continue to perform satisfactorily in service. On this basis, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

In the operating experience program element, the applicant described its system for evaluating and sharing operating experience to improve safety and reliability. As documented in the confirmation process program element above, the applicant will perform an AMP effectiveness review every 5 years to determine whether operating experience warrants an update to the AMP or other corrective actions. The applicant will participate in the use of the ISFSI Aging Management Institute of Nuclear Power Operations Database (AMID) to share operating experience with the industry. The applicant stated that the criteria used for entering operating experience into the database would follow the recommendations of Nuclear Energy Institute (NEI) 14-03, “Format, Content and Implementation Guidance for Dry Cask Storage Operation-Based Aging Management.” The applicant will also review the AMID database periodically to ensure its AMPs are consistent with recent industry practices and findings.

The applicant provided a list of specific operating experience related to the aging of the storage casks at North Anna in Table A2.1-3 of the license renewal application. This historical operating experience included coating degradation and minor rusting of the steel components.
The staff reviewed the operating experience program element to ensure that the applicant considered past operating experience appropriately and that the program includes provisions for future reviews of operating experience to confirm the program’s continued effectiveness. The staff notes that the degradation described in the applicant’s operating experience review was

minor (e.g., coating defects, rust stains) and is effectively addressed by the proposed AMP activities. The staff also notes that the applicant's proposal to share operating experience with the industry and conduct periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to ensure continued effectiveness. Based on the applicant's commitments, the staff finds the operating experience program element to be acceptable because the applicant provided sufficient prior operating experience to support the effectiveness of AMP activities and provided a framework for future operating experience reviews to ensure that AMPs will be adjusted as knowledge becomes available from new analyses, experiments, and inspection activities.

In addition, the NRC will inspect the applicant's performance of the AMP in the period of extended operation, including any actions taken to adjust AMPs to respond to operating experience, to verify that operating experience is being considered and AMPs are modified accordingly to ensure their effectiveness.

The staff concludes that (1) the applicant adequately addressed the 10 program elements of an AMP described in NUREG-1927, Revision 1, and (2) there is reasonable assurance that the AMP is adequate for managing the aging mechanisms and effects of the in-scope SSCs identified by the AMR, such that the in-scope SSCs will continue to perform their intended functions during the requested period of extended operation.

3.5.2 Monitoring of Structures Aging Management Program

In Section A.2.2 of the license renewal application, as updated in Enclosures 1 and 2 of the applicant's response to an RAI (Dominion Energy Virginia, 2017d), the applicant proposed the Monitoring of Structures AMP to manage loss of material, cracking, and change in material properties for the concrete pad. Section C2.1.1.2 of the application, as updated in Enclosures 3 and 4 of the applicant's RAI response (Dominion Energy Virginia, 2017d), describes the program as it will be incorporated into the North Anna ISFSI SAR. The applicant stated that the program provides for visual inspections to manage the above-grade aging effects and groundwater chemistry monitoring to manage below-grade aging effects.

The staff reviewed the adequacy of the AMP to address the identified aging mechanisms and effects for the concrete pad. The staff reviewed the AMP against the criteria in Section 3.6.1 of NUREG-1927, Revision 1. NUREG-1927, Revision 1, also provides an example AMP that the staff considers generically acceptable for managing the aging of reinforced concrete structures, and the staff based its review of the applicant's proposal on that guidance. The NUREG-1927, Revision 1, example AMP references ACI standards for the inspection of concrete structures. The staff's evaluation of each of the AMP program elements follows:

1. Scope of Program

The applicant described the scope of the program as addressing the concrete pad, which is exposed to atmosphere/weather and soil, as described in Table AMR Results—3, "Reinforced Concrete Pad No. 1," of the license renewal application. The table also includes the materials, environments, aging mechanisms, aging effects, and intended functions for the pad.

The staff reviewed the scope of the program to verify that the applicant adequately described the components covered under the program, as recommended in NUREG-1927, Revision 1. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that the program does not include any preventive actions and that the program is a condition-monitoring activity.

The staff reviewed the preventive actions program element and confirmed that the program does not rely on preventive actions to manage the effects of aging. The staff notes that the program uses visual inspections and groundwater chemistry monitoring to manage the aging effects. The staff finds the applicant’s preventive actions program element to be acceptable because, consistent with the recommendations in NUREG-1927, Revision 1, preventive actions do not need to be provided for condition-monitoring programs.

3. Parameters Monitored or Inspected

The applicant stated that the parameter monitored or inspected for the visual inspections of the concrete pad is the surface condition—specifically, indications of loss of material, cracking, and white stains indicative of leaching (change in material properties), which are indicators of the overall integrity of the pad. The applicant also stated that groundwater chemistry sampling of chlorides, sulfates, and pH will identify aggressive conditions that could lead to aging.

The staff reviewed the parameters monitored or inspected program element to confirm that the parameters will be capable of identifying degradation before a loss of intended function and provide a clear link to the aging effects identified in the scope of the program. The staff notes that, in the AMP’s acceptance criteria program element, the applicant stated that the visual inspections would use the acceptance criteria consistent with ACI 349.3R-02, “Evaluation of Existing Nuclear Safety-Related Concrete Structures” (ACI, 2002), to identify the specific conditions that are acceptable without the need for further evaluation, such as the absence of evidence of leaching and quantitative measures for acceptable dimensions for voids, scaling, and cracks. The staff also notes that the proposed parameters for monitoring the aggressiveness of groundwater chemistry are consistent with those recommended in NUREG-1927, Revision 1.

The staff finds the applicant’s parameters monitored or inspected program element to be acceptable because both the visual inspections and the groundwater chemistry testing will monitor conditions in a manner consistent with the recommendations in NUREG-1927, Revision 1, and the ACI standard.

4. Detection of Aging Effects

The applicant stated that the loss of material, cracking, and changes in material properties of the concrete pad will be detected by visual inspections of all exposed surfaces of the pad every 5 years using inspection and evaluation personnel qualified according to ACI 349.3R-02. The first periodic inspection will be scheduled 5 years from the time of the pre-application inspection that was performed in November 2015. The inaccessible concrete pad surfaces that are under the casks or below-grade will be inspected when they are exposed during cask lift activities or excavations, respectively.

The applicant stated that groundwater chemistry sampling will be performed every 5 years at two wells near the concrete pad to determine whether the pad could be exposed to an aggressive environment. The applicant also stated that the 5-year interval is appropriate because the pad is not in contact with the groundwater. In Table 3.4-2 of the license renewal application, the applicant provided groundwater testing results on 97 samples from 2002 through 2016 to show that the groundwater is non-aggressive with respect to chlorides, sulfates, and pH.

The staff reviewed the detection of aging effects program element to confirm that the applicant adequately described the inspection details, including the methods used, inspection frequency, and inspection timing in a manner consistent with the recommendations in NUREG-1927, Revision 1.

With respect to the visual inspections of the concrete, the staff notes that the inspection acceptance criteria and the inspection frequency are consistent with the recommendations in NUREG-1927, Revision 1, which includes the use of the ACI 349.3R acceptance criteria and a frequency of inspection of at least once every 5 years for exposed surfaces. The staff notes, however, that the inspection interval of the unexposed pad surfaces may exceed the minimum interval of at least once every 10 years recommended in ACI 349.3R and NUREG-1927, Revision 1 (the TN-32 Dry Storage Cask AMP requires at least one cask to be lifted every 20 years to view the cask bottom, which exposes normally inaccessible concrete).

In its review of the proposed inspection frequencies for the unexposed surfaces and timing of the first 5-year periodic inspection, the staff reviewed operating experience associated with concrete inspections (Section A2.2 of the license renewal application, element 10, "Operating Experience") and, specifically, the pre-application inspection (Appendix F2.2 to the application). The operating experience at the North Anna ISFSI pad (in 1998, 1999, 2004, and 2011) and the pre-application inspection in 2015 identified cracks on the pad surface, but none that the licensee considered significant enough to warrant repair. Cracks under the lifted cask were described as hairline. The staff finds the applicant's proposed inspection frequency for inaccessible areas and timing for all areas to be acceptable because prior inspections have found no significant degradation since the pad was constructed in 1997. In addition, the licensee's civil engineering group conducted the pre-application inspections by following the guidance in ACI 349.3R, which justifies the use of the pre-application inspection as a baseline for the AMP.

With respect to the groundwater chemistry monitoring, the staff notes that groundwater chemistry samples evaluated over the past 24 years at the North Anna site have found no instances of aggressive groundwater conditions. As a result, the staff finds the proposed 5-year sampling interval to be an acceptable means to confirm the continued presence of a non-aggressive environment in the period of extended operation.

In summary, the staff finds the detection of aging effects program element to be acceptable because the AMP uses techniques capable of identifying degradation and the inspections will be performed at a frequency that supports timely identification of degraded conditions and implementation of corrective actions, consistent with the guidance in NUREG-1927, Revision 1.

5. Monitoring and Trending

The applicant stated that monitoring and trending activities are performed periodically to identify areas of degradation. The applicant also stated that visual inspection assessments will consider cumulative experience from previous inspections and assessments to monitor and trend the progression of aging effects over time. This activity includes maintaining a record of deficiencies that will be updated with the results of each inspection. In addition, as described in the detection of aging effects program element above, the applicant stated that groundwater will be monitored at two wells every 5 years to ensure that aggressive environments do not exist.

The staff reviewed the applicant's monitoring and trending activities to ensure that they provide for an evaluation of the extent of aging and the need for timely corrective or mitigative actions, as recommended in NUREG-1927, Revision 1. The staff notes that the periodic groundwater monitoring and trending of deficiencies identified by visual inspections provide sufficient opportunity to identify adverse trends such that corrective actions can be implemented before a loss of functions. As a result, the staff finds the monitoring and trending program element acceptable because activities will be in place to ensure that the rate of degradation will be adequately evaluated such that future inspections will be performed, or the pad will be repaired, before a loss of function.

6. Acceptance Criteria

The applicant stated that the acceptance criteria for the visual inspections of the concrete pad are those specified in ACI 349.3R. These criteria include the absence of evidence of leaching; quantitative thresholds for acceptable dimensions of pop-outs, voids, scaling, and cracks; and no evidence of excessive deflections in the pad. The applicant also stated that the groundwater chemistry acceptance criteria to confirm a non-aggressive environment are chlorides less than 500 ppm, sulfates less than 1,500 ppm, and pH greater than 5.5.

The staff reviewed the applicant's acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended functions. The staff notes that the criteria are consistent with those recommended in NUREG-1927, Revision 1, which references ASME Code Section XI, Subsection IWL for the definition of an aggressive below-grade environment (ASME, 2008). Therefore, the staff finds the acceptance criteria program element is acceptable.

7. Corrective Actions

The applicant stated that its corrective actions are established in accordance with the Dominion Topical Report DOM-QA-1, which meets the requirements of 10 CFR Part 50, Appendix B. The applicant stated that, at a minimum, condition reports are submitted for all conditions that do not meet the AMP acceptance criteria.

The applicant stated that condition reports are first reviewed by the submitter's supervisor and, if necessary, by the Operations Shift Manager, the Condition Report Review Team, and the Corrective Action Assignment Review Team (for conditions adverse to quality).

The staff reviewed the corrective actions program element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of the Corrective Action Program approved under 10 CFR Part 50, Appendix B. NUREG-1927, Revision 1, also states that all conditions that do not meet AMP acceptance criteria should be entered into the Corrective Action Program. As a result, the staff finds the corrective actions program element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered in the Corrective Action Program and the quality assurance requirements in 10 CFR

Part 50, Appendix B, provide reasonable assurance that corrective actions will be adequate for managing the aging of the pad.

8. Confirmation Process

The applicant stated that the confirmation process will be conducted in accordance with the Dominion Quality Assurance Program, which is required by 10 CFR Part 50, Appendix B, and ensures the timely evaluation of adverse conditions and implementation of any required corrective actions. The applicant also stated that, every 5 years, an engineering evaluation will be performed to review operating experience to determine whether any of the AMP elements should be updated.

The staff notes that NUREG-1927, Revision 1, states that NRC-approved quality assurance programs are an accepted approach to ensuring that the effectiveness of corrective actions are verified and that adverse trends will be monitored to address potential degradation before a loss of function. The staff also notes that performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the administrative controls are conducted in accordance with the Dominion Quality Assurance Program, which is required by 10 CFR Part 50, Appendix B. The applicant also stated that the Quality Assurance Program includes guidance for inspector requirements, record retention requirements, and document control. Procedures are reviewed, approved, and maintained as controlled documents.

The staff notes that NUREG-1927, Revision 1, states that NRC-approved programs under 10 CFR Part 50, Appendix B, are an accepted approach to providing for adequate review, approval, and fulfillment of activities that ensure SSCs will continue to perform satisfactorily in service. Therefore, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

In the operating experience program element, the applicant described its system for evaluating and sharing operating experience to improve safety and reliability. As documented in the confirmation process program element above, the applicant will perform an AMP effectiveness review every 5 years to determine whether operating experience warrants an update to the AMP. The applicant will participate in the use of AMID to share operating experience with the industry. The applicant stated that the criteria used for entering operating experience into the database would follow the recommendations of NEI 14-03.

The applicant provided specific operating experience related to the aging of the pad at North Anna in Section A2.2 of the license renewal application, element 10, “Operating Experience.” This operating experience includes what the applicant described as shallow, stable cracks.

The staff reviewed the operating experience program element to ensure that past operating experience was appropriately considered and that the program includes provisions to conduct future reviews of operating experience to confirm the program’s continued effectiveness. The staff notes that the degradation described in the applicant’s operating experience review was minor and is considered to be effectively addressed by the proposed AMP activities. The staff also notes that the applicant's proposal to share operating experience with the industry and conduct periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to ensure continued effectiveness. Therefore, the staff finds the operating experience program element to be acceptable because the applicant provided sufficient prior operating experience to support the effectiveness of AMP activities and provided a framework for future operating experience reviews to ensure that AMPs will be adjusted as knowledge becomes available from new analyses, experiments, and inspection activities.

The staff concludes that (1) the applicant adequately addressed the 10 program elements of an AMP provided in NUREG-1927, Revision 1, and (2) there is reasonable assurance that the AMP is adequate for managing the aging mechanisms and effects of the in-scope SSCs identified by the AMR, such that the in-scope SSCs will continue to perform their intended functions during the requested period of extended operation.

3.5.3 Evaluation Findings

The staff reviewed the AMPs in the license renewal application and supplemental documentation. The staff performed its review following the guidance in NUREG-1927, Revision 1. Based on its review, the staff finds the following:

F3.4 The applicant has identified programs that provide reasonable assurance that aging mechanisms and effects will be adequately managed during the period of extended operation, in accordance with 10 CFR 72.42(a)(2).

4 LICENSE CONDITIONS TO ADDRESS RENEWAL

This section provides a consolidated list of the changes to the license conditions resulting from the review of the license renewal application and the basis of the changes.

4.1 Safety Analysis Report Update

The NRC added the following condition to the license:

> Within 90 days of the issuance of the renewed license, the licensee shall submit an updated North Anna ISFSI Safety Analysis Report (SAR) to the Commission and continue to update the SAR pursuant to the requirements in 10 CFR 72.70(b) and (c). The updated SAR shall include the revised North Anna ISFSI Safety Analysis Report Supplement, as documented in Enclosures 3 and 4 of the July 10, 2017, supplement to the license renewal application (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17198A023) (hereinafter referred to as the SAR supplement). The licensee may make changes to the SAR, including changes to the SAR supplement, consistent with 10 CFR 72.48(c).

The applicant indicated that it will change the SAR to address aging management activities resulting from the renewal of the license and provided the SAR supplement as part of the license renewal application. The applicant submitted an update to the SAR supplement in Enclosures 3 and 4 of the July 10, 2017, supplement to the license renewal application, which reflects the final proposed SAR supplement to address the aging management activities described in the license renewal application (Dominion Energy Virginia, 2017d). This condition ensures that the SAR changes are made in a timely fashion to enable the licensee to develop and implement necessary procedures related to renewal and aging management activities during the period of extended operation.

4.2 Procedures for Aging Management Program Implementation

The NRC added the following condition to the license:

> Within 180 days of the issuance of the renewed license, the licensee shall create, update, or revise procedures for implementing the activities in the Aging Management Programs (AMPs) documented in Enclosures 1 and 2 of the July 10, 2017, supplement to the license renewal application (Agencywide Documents Access and Management System (ADAMS) Accession No. ML17198A023) and described in the SAR supplement. Each procedure shall contain a reference to the specific AMP provision the procedure is intended to implement. The reference shall be maintained even if procedures are modified. The licensee shall maintain procedures that implement the AMPs throughout the term of this license.

This condition ensures that operating procedures address AMP activities required for extended storage operations. The timeframe (180 days) in the condition is to ensure that operating procedures are developed in a timely manner. This timeframe is consistent with conditions placed in specific licenses that have been renewed and is consistent with the guidance in NUREG-1927, Revision 1.

4.3 <u>TN-32B High-Burnup Cask Storage Term</u>

The NRC added the following condition to the license:

> Storage of high burnup fuel (≥ 45,000 MTU/MWD) in one TN-32B HBU cask design is authorized for a period not to exceed 20 years from the date the TN-32B HBU cask is placed in service at the North Anna ISFSI. If the storage period is expected to exceed the authorized storage period of 20 years, the licensee will either remove the cask from service at the ISFSI by the end of the authorized storage period or request an amendment to address this TN-32B HBU cask.
>
> If an amendment is filed to change this condition and renew the storage period of the TN-32B HBU cask, the licensee shall submit information that will address additional aging management considerations for the high burnup fuel and the TN-32B HBU cask design at least 2 years prior to the expiration of the authorized 20-year storage period, in accordance with 10 CFR 72.42.

One TN-32B HBU cask was approved to be stored at the North Anna ISFSI on September 13, 2017, through the issuance of Amendment No. 5 to License No. SNM-2507 (NRC, 2017). The cask was placed in service at the North Anna ISFSI on November 30, 2017. The storage of the TN-32B HBU cask supports the High-Burnup Dry Storage Cask Research and Development Project (HDRP) of the U.S. Department of Energy and EPRI. According to the applicant, under the HDRP, the cask will be stored at the North Anna ISFSI for about 10 years. The applicant stated that the plan for the HDRP is for the Department of Energy to take possession of the TN-32B HBU cask after about 10 years of storage at the North Anna ISFSI and transport it to an offsite research facility for further testing.

Therefore, the TN-32B HBU cask is not expected to remain in service at the North Anna ISFSI past the initial storage term of 20 years and thus is not expected to enter its period of extended operation. The license condition reflects this expected storage duration of the TN-32B HBU cask at the North Anna ISFSI, limiting the storage term to a period of less than 20 years and thereby preventing the TN-32B HBU cask from entering its period of extended operation when aging issues would need to be addressed.

If the TN-32B HBU cask remains in service until the end of its 20-year initial storage term, the condition requires the licensee to either remove the cask from service at the ISFSI or file a licensing action to change the condition. An amendment request to renew the storage period would follow the form of the current license renewal application, as applicable. In this case, the amendment would include a scoping evaluation and AMR, similar to the current license renewal application, to determine what aging management activities are needed for the HBU fuel or any of the in-scope SSCs that make up the cask modifications of the TN-32B HBU cask to manage aging effects during the TN-32B HBU cask’s period of extended operation.

Any amendment request filed to change this condition would be considered a request to renew the storage term of the TN-32B HBU cask. Therefore, the amendment would need to be filed in accordance with 10 CFR 72.42 and be submitted at least 2 years prior to the expiration of the authorized 20-year storage period.

5 CONCLUSION

Pursuant to 10 CFR 72.42(a), the Commission may issue a renewed license if it finds that actions have been identified and have been or will be taken such that there is reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the design bases. In 10 CFR 72.42(a), the NRC requires the application for license renewal to include TLAAs and AMPs demonstrating that the SSCs important to safety will continue to perform their intended functions for the requested period of extended operation.

The NRC staff reviewed the license renewal application for the ISFSI at the North Anna Power Station, in accordance with NRC regulations in 10 CFR Part 72. The staff followed the guidance in NUREG-1927, Revision 1 (NRC, 2016), and NUREG-1757, Volume 3, Revision 1 (NRC, 2012a). Based on its review of the license renewal application and the license conditions, the staff determines that the requirements of 10 CFR 72.42(a) have been met.

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