SAFETY EVALUATION REPORT

FOR THE
TN-68 DRY STORAGE CASK
CERTIFICATE OF COMPLIANCE RENEWAL

DOCKET NO. 72-1027

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

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EXECUTIVE SUMMARY

In accordance with 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 certificate of compliance (CoC) to TN Americas LLC, for the TN-68 Dry Storage Cask design, for 20 years, with an expiration date of May 28, 2020. The NRC approved the CoC under 10 CFR Part 72, Subpart K which allows for storage of Spent Nuclear Fuel (SNF) in an independent spent fuel storage installation (ISFSI) at power reactor sites to persons authorized to possess or operate nuclear power reactors under 10 CFR Part 50 and 10 CFR Part 52.

By letter dated April 9, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession Number ML20100F295), as supplemented by letters dated July 29, 2020 (ADAMS Accession Number ML20211L707), February 9, 2021 (ADAMS Accession Number ML21040A406), and March 24, 2021 (ADAMS Accession Number ML21083A029), TN Americas LLC, hereafter referred to as the "applicant," submitted an application to the NRC for renewal of CoC No. 1027, for a period of 40 years beyond the initial certificate period. The applicant submitted the renewal application in accordance with the regulatory requirements of 10 CFR 72.240, "Conditions for spent fuel storage cask renewal." Under 10 CFR 72.240(b), because the applicant submitted more than 30 days before the Certificate's expiration date, this application constitutes a timely renewal. In the application, the applicant documented the technical bases for renewal of the certificate and commitments to actions for managing the potential aging effects of the systems, structures, and components (SSCs) of the dry storage system to ensure that these SSCs will maintain their intended functions during the period of operation that extends beyond the length of the term certified by the current certificate (referred to hereafter as the period of extended operation (PEO) or extended storage).

The TN-68 Dry Storage Cask is a bolted lid, metal cask dry storage system (DSS). The TN-68 Dry Storage Cask has integrated trunnions that allow the cask to be lowered into the spent fuel pool for loading, and transferred to the storage pad. The TN-68 Dry Storage Cask has integrated gamma and neutron shielding to minimize the radiation dose rate from the ISFSI. The TN-68 Dry Storage Cask is designed to withstand all normal and off-normal loads as well as loads potentially created by earthquakes, tornado missiles, and other loads during design-bases accident conditions.

In the renewal application, the applicant presented general information about the DSS design with a scoping analysis to determine the SSCs that are within the scope of the renewal and subject to an aging management review (AMR). The applicant further screened the in-scope SSCs to identify and describe the subcomponents that support the in-scope SSC intended function(s). The applicant documented the technical bases for renewal of the CoC and proposed actions for managing potential aging effects on the SSCs of the ISFSI that are within the scope of the CoC No. 1027 renewal to ensure that these SSCs will maintain their intended functions during the PEO. For each in-scope SSC subcomponent, the applicant provided one of the following to assure that the SSC will maintain its intended function(s) during the PEO: (1) an analysis which supports no aging management is necessary because no aging effects are relevant for the SSC, (2) an updated time-limited aging analyses (TLAA), (3) a supplemental aging analysis, or (4) an aging management program (AMP).

The NRC staff (staff) reviewed the technical bases for safe operation of the DSS for an additional 40 years beyond the current CoC term of 20 years. This safety evaluation report

(SER) summarizes the results of the staff's review for compliance with 10 CFR 72.240. In its review of the application and development of the SER, the staff followed the guidance provided in NUREG-1927, Revision 1, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," dated June 2016 (NRC, 2016) (ADAMS Accession No. ML16179A148), and (2) NUREG-2214, "Managing Aging Processes In Storage (MAPS) Report," issued July 2019 (NRC, 2019) (ADAMS Accession No. ML19214A111). NUREG-2214 establishes a generic technical basis for the safety review of ISFSI license and DSS CoC renewal applications, in terms of the evaluation of (1) aging mechanisms and effects that could affect the ability of ISFSI and DSS SSCs to fulfill their safety functions in the PEO (i.e., credible aging mechanisms and effects) and (2) aging management approaches to address credible aging effects, including examples of aging management programs that are considered generically acceptable to address the credible aging effects to ensure that the design bases will be maintained in the PEO. The staff evaluated the applicant's technical basis for its AMR and proposed aging management programs and compared it to the generic technical basis in NUREG-2214. For comparison to the generic technical basis in NUREG-2214, the staff ensured that the design features, environmental conditions, and operating experience for the TN-68 Dry Storage Cask are bounded by those evaluated in NUREG-2214.

This SER is organized into six sections. Section 1 provides the staff's review of the general information of the DSS. Section 2 presents the staff's review of the scoping evaluation performed for determining which SSCs are within the scope of renewal. Section 3 provides the staff's evaluation of the AMR 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 CoC and CoC Holder Information

On April 9, 2020 (ADAMS Accession Number ML20100F295), as supplemented on July 29, 2020 (ADAMS Accession No. ML20211L707), February 9, 2021 (ADAMS Accession Number ML21040A406), and March 24, 2021 (ADAMS Accession Number ML21083A029), the applicant submitted an application to renew CoC No. 1027 for the TN-68 Dry Storage Cask under the provisions of 10 CFR Part 72, subparts K and L.

The applicant requested renewal of the initial CoC and Amendment No. 1. The NRC issued the initial CoC (Amendment 0) on May 30, 2000, and Amendment No. 1 on October 30, 2007. In its renewal application, the applicant provided a description of the certification basis for the TN-68 Dry Storage Cask initial issuance; general descriptions of the changes and reasons for the Amendment No. 1; the date of the CoC and CoC amendment issuance; and the corresponding updated final safety analysis report (UFSAR) revisions which incorporated the changes from Amendment No. 1. The applicant also provided a list of the amendments (i.e., Amendment No. 0 and Amendment No. 1) in Chapter 1 of the renewal application, with details and references.

1.2 Safety Review

The objective of this safety review is to determine whether the TN-68 Dry Storage Cask continues to meet the requirements of 10 CFR Part 72 during the period of operation that extends beyond the length of the term certified by the current certificate (referred to hereafter as the period of extended operation (PEO) or extended storage). The NRC staff safety review is a detailed and in-depth assessment of the technical aspects of the TN-68 Dry Storage Cask conducted for the CoC No. 1027 renewal application. Pursuant to 10 CFR 72.240(c)(1), 10 CFR 72.240(c)(2), and 10 CFR 72.240(c)(3), an application for renewal of a spent fuel storage cask CoC must be accompanied by a safety analysis report (SAR). The SAR must include the following: (i) design-bases information as documented in the most recently UFSAR as required by 10 CFR 72.248, (ii) time-limited aging analyses (TLAAs) that demonstrate that structures, systems, and components (SSCs) important to safety will continue to perform their intended function for the requested PEO, and (ii) a description of the aging management program(s) (AMP(s)) for management of issues associated with aging that could adversely affect structures, systems and components (SSCs) that are important to safety (ITS).

The applicant stated in renewal application Section 1.1 that the application is consistent with guidance provided 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 (ADAMS Accession No. ML16179A148) (NRC, 2016). In addition, the applicant stated that credible aging mechanisms for the material/environment combinations for the SSCs included in the scope of the renewal followed the guidance in NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report," issued July 2019 (ADAMS Accession No. ML19214A111) (NRC 2019). The applicant provided a scoping evaluation; an aging management review (AMR); and TLAAs and AMPs to assure that the SSCs within the scope of renewal will continue to perform their intended function during the PEO. The applicant stated that the renewal application is based on the continuation of the approved design basis throughout the PEO in accordance with NUREG-1927. In addition, the applicant stated that the identification and management of potential aging degradation mechanisms for different material/environment combinations was consistent with the generic evaluation in NUREG-2214 in support of the renewal application. This review documents the staff's evaluation of the applicant's scoping and screening evaluation, aging management review, and supporting AMPs and TLAAs per the guidance in NUREG-1927 as informed by NUREG-2214.

1.3 Application Content

The applicant's renewal application provided the following:

- general information
- scoping evaluation
- operating experience (OE) review
- AMR
- TLAAs
- AMPs
- changes to the TN-68 Dry Storage Cask UFSAR
- changes to the TN-68 Technical Specifications (TS)

The applicant had previously provided UFSAR revisions for all CoC amendments. The UFSAR revisions incorporated all changes to the TN-68 Dry Storage Cask previously made without prior NRC approval in accordance with 10 CFR 72.48(c) and (d). The applicant included the UFSAR changes for the updated TLAAs and AMPs in Attachment A of the renewal application. The applicant included proposed changes to the TS and CoC conditions in Attachment B of the renewal application.

1.4 NRC Guidance Documents

The staff relied on the guidance in NUREG-1927 to conduct the review of the renewal application. Specifically, the staff used the guidance in NUREG-1927, Chapter 2, Scoping Evaluation, to review the process used by the applicant for the scoping evaluation and the scoping evaluation results. The guidance in NUREG-1927, Chapter 3, Aging Management Review, was used to evaluate the applicant's AMR process, and results. The guidance in NUREG-1927, Section 3.4, Materials, Service Environments, Aging Mechanisms and Effects, and Aging Management Activities, was used to review the applicant's evaluation of aging mechanisms and effects of the materials and service environments for the SSCs and their subcomponents that were in the scope of renewal. The guidance in NUREG-1927, Section 3.5, Time-Limited Aging Analyses, was used to review the applicant's updated TLAAs, and supplemental analyses, and the guidance in Section 3.6, Aging Management Programs, was used to review the applicant's AMPs.

The staff used the information in NUREG-2214 to inform its use of the guidance in NUREG-1927. NUREG-2214 is a technical basis document that provides additional guidance to NRC staff to improve the effectiveness and efficiency of the renewal process for the dry storage of SNF. NUREG-2214 provides a generic evaluation of the aging mechanisms that have the potential to challenge the ability of the dry storage system (DSS) SSCs to fulfill their ITS functions. NUREG-2214 also describes acceptable generic AMPs that an applicant may use to maintain the approved design bases of its storage system during the 20- to 60-year PEO. The staff used the information in NUREG-2214 to inform the review of the information in the renewal application related to the identification of materials, environments, aging mechanisms, and aging effects for the SSCs and their subcomponents within the scope of renewal. The staff used the example aging management programs in NUREG-2214, Chapter 6, Example Aging Management Programs, to supplement the guidance on AMPs in NUREG-1927, Section 3.6.

The staff developed Interim Staff Guidance (ISG) to clarify or to address issues not addressed in a standard review plan (SRP) including NUREG-1536, “Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility,” Revision 1 (ADAMS Accession No. ML101040620) (NRC, 2010), and NUREG-1927. ISGs are to be used by the staff, industry, and other interested stakeholders until incorporated into staff guidance documents such as a SRP. The applicant specifically referenced ISG-2, Revision 0 (ADAMS Accession No. ML092800367) (NRC 1998), and ISG-11, Revision 3 (ADAMS Accession No. ML033230335) (NRC 2003). Therefore, the staff used the guidance contained in these ISGs to review the applicant’s evaluation of retrievability and fuel cladding temperatures in the renewal application.

The staff evaluated the information included in the renewal application by comparing the description of the AMR process and results to the guidance in NUREG-1927 as informed by NUREG-2214, ISG-2, and ISG-11, as well as additional NRC documents, and other references as necessary. The staff determined that the information and descriptions in the renewal application that followed the guidance in NUREG-1927 were acceptable. For the evaluation and descriptions of materials, environments, aging mechanisms, aging effects, and AMPs for the SSCs and their subcomponents within the scope of renewal, the staff determined that the information and description provided in the renewal application was acceptable if it was consistent with, or bounded by, the generic evaluation in NUREG-2214.

1.5 Evaluation Findings

The staff reviewed the general information provided in Chapter 1 of the renewal application. The staff performed its review following the guidance provided in NUREG-1927, and relevant ISGs. Based on its review, the staff finds:

F1.1 The information presented in the renewal application satisfies the requirements of 10 CFR 72.2, “Scope,” 10 CFR 72.48, “Changes, tests, and experiments,” and 10 CFR 72.240, “Conditions for spent fuel storage cask renewal”.

F1.2 The applicant has provided a tabulation of all supporting information and docketed material incorporated by reference, in compliance with 10 CFR 72.240, “Conditions for spent fuel storage cask renewal”.

2 SCOPING EVALUATION

As described in NUREG-1927, Chapter 2, a scoping evaluation is necessary to identify the SSCs subject to an AMR, where the effects of aging are assessed. More specifically, NUREG-1927, Section 2.4.2, states that the scoping evaluation is used to identify SSCs (and associated subcomponents) meeting any of the following criteria (scoping criteria 1 and 2):

(1) SSCs (and associated subcomponents) that are classified as ITS, as they are relied on for one of the following functions:

   i. maintain the conditions required by the regulations or the CoC to store spent fuel safely;

   ii. prevent damage to the spent nuclear fuel during handling and storage; or

   iii. 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 (and associated subcomponents) that are classified as not important to safety (NITS) but, according to the design bases, their failure could prevent fulfillment of a function that is ITS.

The applicant stated that the ITS functions include (1) sub-criticality control, (2) radiation shielding, (3) confinement, (4) heat-removal capability, (5) structural integrity, and (6) retrievability. If SSCs and associated subcomponents satisfy one of these criteria, they are within the scope of the renewal review.

After the determination of in-scope SSCs, the SSCs are screened to identify and describe the subcomponents that support the SSC intended functions. This screening identifies the SSC subcomponents that the applicant evaluates for potential aging effects and mechanisms that may require an aging management activity in the PEO.

2.1 Scoping and Screening Methodology

In Section 2 of the 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 scope of the renewal review
- 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 the renewal review and the basis for the scope determination.

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

2.1.1 Scoping Process

In Section 2.2 of the renewal application, the applicant discussed the scoping evaluation process and methodology used to determine the SSCs and associated subcomponents and subcomponent parts that are within the scope of the renewal. The applicant's scoping evaluation process and methodology identified SSCs as either being scoped into the review under scoping criteria 1 and 2, or not scoped into the review for NITS items that did not meet scoping criterion 2.

The staff reviewed the applicant's scoping process and determined that the applicant's process followed the guidance described in NUREG-1927, Section 2.4, and was acceptable.

2.1.2 Scoping Results

The applicant provided a summary of the results of the scoping evaluation in the renewal application, Table 2-1, and Section 2.3. The applicant provided detailed scoping analysis results for the TN-68 Dry Storage Cask in the renewal application, Table 2-2. The detailed scoping analysis results for the spent fuel assemblies were provided by the applicant in the renewal application, Table 2-3.

The applicant stated that the sources of information reviewed for the scoping evaluation that describe the approved design basis and the intended safety functions of the SSCs (and associated subcomponents) included:

- TN-68 Dry Storage Cask UFSAR, Revision 9, May 2018. (ADAMS Accession No. ML18136A548).
- CoC No. 1027 Certificate and TN-68 TS for each amendment as follows.
    - Amendment 0: CoC (ADAMS Accession No. ML003714545), and TS (ADAMS Accession No. ML003713477).
    - Amendment 1: CoC (ADAMS Accession No. ML073050254) and TS (ADAMS Accession No. ML073050262).
- NRC SERs for Amendment 0 (ADAMS Accession No. ML003713477) and Amendment 1 (ADAMS Accession No. ML073050286).

The applicant stated that, in defining if SSCs and their subcomponents were ITS or NITS, it used the drawings in Section 1.5 and information in Table 2.3-1 of the UFSAR as the source for the TN-68 Dry Storage Cask SSCs and subcomponents, the material specifications, and safety classification. SSCs that were ITS were determined to be within the scope of renewal per criterion 1. The applicant provided additional information concluding that the storage pad for the independent spent fuel storage installation (ISFSI) should be scoped in under criterion 2 in the renewal application Section 2.3.3.

The staff reviewed the scoping results to determine whether the applicant reviewed all SSCs in the approved design bases and whether the conclusions regarding the out-of-scope SSCs accurately reflect the design bases in the TN-68 Dry Storage Cask UFSAR. SER Table 2.1-1 lists the SSCs included and excluded from the scope of the renewal review per the renewal application. SER Section 2.1.3 provides the staff's conclusions regarding SSCs (and SSC subcomponents) within the scope of the renewal review. SER Section 2.1.4 provides the staff's conclusions regarding SSCs (and SSC subcomponents) outside the scope of the renewal review.

Table 2.1-1. SSCs/Contents Within and Not Within the Scope of the Renewal Review

SSC / Contents	Criterion 1	Criterion 2	In-Scope (Yes / No)
TN-68 Dry Storage Cask	Yes	N/A	Yes
Spent Fuel Assemblies	Yes	N/A	Yes
ISFSI Concrete Storage Pad	No	Yes	Yes
Auxiliary Equipment[1]	No	No	No
Miscellaneous Equipment[2]	No	No	No

[1] Auxiliary equipment used to facilitate cask loading, draining, drying, inerting, and sealing operations include, but are not limited to, special lifting devices, vertical cask transporter, and vacuum drying/helium leak test equipment.

[2] Miscellaneous Equipment includes ISFSI security fence and gates, lighting, lightning protection, communications, and monitoring equipment.

2.1.3 Structures, Systems, and Components Within the Scope of the Renewal Review

Per the scoping evaluation process and methodology, as discussed in Section 2.2 of the renewal application, the applicant identified the SSCs (and subcomponents) considered to be within the scope of the renewal review. As previously discussed in SER Section 2.1.1, this approach is consistent with the criteria defined in NUREG-1927. The applicant provided the scoping evaluation of TN-68 Dry Storage Cask system SSCs in the renewal application, Table 2-1. The scoping evaluation of the TN-68 Dry Storage Cask subcomponents and the spent fuel assembly subcomponents are tabulated in the renewal application, Tables 2-2, and 2-3, respectively.

The following discussions address the applicant's basis for inclusion of an SSC within the scope of the renewal review. The discussions also provide clarifications on the staff's review of that basis for inclusion.

<u>TN-68 Dry Storage Cask</u>

The applicant included the TN-68 Dry Storage Casks within the scope of the renewal review under criterion 1 because these are classified as ITS in accordance with the renewal application, Table 2-1. The applicant stated that the ITS functions provided by the TN-68 Dry Storage Casks and its subcomponents include confinement, radiation shielding, sub-criticality control, structural integrity, heat-removal capability, and retrievability. The applicant provided a scoping evaluation for the TN-68 Dry Storage Casks subcomponents in the renewal application, Table 2-2. The scoping evaluation included the subcomponent classification, the subcomponent safety function (if any), the subcomponent material, and if the failure of the subcomponent would affect the function of another ITS subcomponent (i.e., criterion 2 in NUREG 1927, Section 2.4.1). For the NITS TN-68 Dry Storage Cask subcomponents that were not screened in under criterion 2, the applicant provided a description of these subcomponents along with an analysis of the consequences of a failure of these subcomponents to support the determination that the subcomponents were categorized as NITS and not screened in under criterion 2.

The staff confirmed that the TN-68 Dry Storage Casks subcomponents are scoped within the renewal review because these are classified as ITS in accordance with drawings in Section 1.5 and Table 2.3-1 of the TN-68 Dry Storage Cask UFSAR. The staff reviewed the ITS functions 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 (ADAMS Accession No. ML15127A114) (NRC 1996a), as a reference for classifying components as ITS. The staff reviewed the applicant's description and analysis for the NITS subcomponents that were not screened in under criterion 2. The staff determined that the applicant's assessment of these subcomponents followed the guidance in NUREG-1927, Section 2.4.2, which includes equipment associated with cask loading and unloading; instrumentation and other active components/systems; and miscellaneous hardware that does not support or perform any function that is ITS. The staff confirmed that the applicant provided scoping evaluation results for the TN-68 Dry Storage Casks in Table 2-2 of the renewal application. Therefore, the staff determined that the applicant's screening assessment for the TN-68 Dry Storage Cask subcomponents followed the guidance in NUREG-1927, Chapter 2, and the results of the applicant's scoping evaluation were acceptable.

Spent fuel assemblies

The applicant included the spent fuel assemblies within the scope of the renewal review because the ITS functions for the fuel assemblies include confinement, sub-criticality control, structural integrity, and heat-removal capability as shown in the renewal application, Table 2-1. Therefore, the applicant stated that the spent fuel assemblies satisfy criterion 1 and are within the scope of the renewal review. The applicant provided a scoping evaluation of the subcomponents of the spent fuel assemblies in Table 2-3 of the renewal application.

The staff notes that, in accordance with drawings in Section 1.5 and Table 2.3-1 of the TN-68 Dry Storage Cask UFSAR, the subcomponents of the spent fuel assemblies are not classified as ITS. Nevertheless, the applicant's classification of the spent fuel assemblies as ITS is in agreement with NUREG-1927, Section 2.4.2, which states that the renewal application should demonstrate that the analyzed fuel configuration relied on in the safety analyses will be maintained. In addition, NUREG-1927, Section 2.4.2.1, states that the spent fuel cladding and assembly hardware provide structural support to ensure that the spent fuel is maintained in a known geometric configuration and that the criticality and shielding safety analyses for a DSS may rely on the fuel assembly having a specific configuration. The staff confirmed that the applicant provided a scoping evaluation of the subcomponents of the spent fuel assemblies in Table 2-3 of the renewal application.

ISFSI concrete storage pad

The applicant stated that the ISFSI concrete storage pad is classified as NITS; however, the applicant clarified that a portion of the pad is included in the thermal models. The applicant stated that failure of the pad could affect the heat-removal capability of the system. Therefore, the applicant determined that the reinforced concrete storage pad meets criterion 2, and is in-scope for renewal as indicated in the renewal application, Table 2-1.

The staff notes that, in accordance with drawings in Section 1.5 and Table 2.3-1 of the TN-68 Dry Storage Cask UFSAR, the ISFSI concrete storage pad is not classified as ITS. The staff reviewed the applicant's assessment for including the ISFSI concrete storage pad under scoping criterion 2 and determined that this assessment is appropriate because a portion of the ISFSI concrete storage pad is credited in for heat-removal capability.

Scoping Findings

The staff reviewed the applicant's screening of the SSCs (and subcomponents) within the scope of the renewal review. The staff's review followed the guidance in NUREG-1927. The staff reviewed the intended function of the SSCs and their subcomponents; the SSCs and subcomponents safety classification per the UFSAR, the basis for inclusion in the scope of the renewal review; and design-bases information in the UFSAR. The staff notes that NUREG-2214 includes aging management tables developed using the UFSAR drawings for the TN-68 Dry Storage Cask system which provide a generic basis for scoping of the SSCs. The staff compared the applicant's scoping evaluation results to the TN-68 Dry Storage Cask aging management tables in NUREG-2214. Based on this review, the staff finds that the applicant screened the in-scope SSCs in a manner consistent with NUREG-1927. Therefore, the staff finds the screening results for in-scope SSCs and subcomponents to be acceptable.

2.1.4 Structures, Systems, and Components Not Within the Scope of the Renewal Review

Per the scoping evaluation process and methodology, as discussed in Section 2.2 of the renewal application, the applicant identified the SSCs and subcomponents considered to be not within the scope of the renewal review. As previously discussed in SER Section 2.1.1, the staff considers this approach to be consistent with the criteria defined in NUREG-1927. Consistent with that scoping evaluation, the applicant identified SSCs and subcomponents as not needing an AMR. These SSCs are identified in Table 2-1 of the renewal application. The following discussions address the applicant's basis for exclusion of an SSC from the scope of the renewal review. The discussions also provide clarifications on the staff's review of that basis for exclusion.

Auxiliary Equipment

The applicant stated that auxiliary equipment used to facilitate cask loading, draining, drying, inerting, and sealing operations include, but are not limited to, special lifting devices, vertical cask transporter, and vacuum drying/helium leak test equipment. The applicant cited CoC No. 1027 condition 1(b) which states, "The auxiliary equipment necessary for ISFSI operation is not included as part of the TN-68 Dry Storage Cask reviewed for a Certificate of Compliance under 10 CFR Part 72, Subpart L. Such equipment may include, but is not limited to, special lifting devices, transfer trailers or equipment, and vacuum drying/helium leak test equipment." Based on CoC No. 1027 condition 1(b) and the results of the applicant scoping analyses, the applicant concluded that the auxiliary equipment is not within the scope of the CoC No. 1027 renewal.

The staff reviewed the justification in the renewal application and CoC No. 1027 condition 1(b). The staff notes that the TN-68 Dry Storage Cask UFSAR, Table 2.3-1 does not provide a safety classification for the auxiliary equipment. Nevertheless, the staff finds that the applicant's determination that the auxiliary equipment is NITS and will not prevent fulfillment of an ITS function to be acceptable because the equipment does not meet any of the scoping criteria that would bring it within the scope of the renewal review. Thus, the staff determined that the identification of the auxiliary equipment as NITS is consistent with the guidance in NUREG-1927, Section 2.4.3 which states that such equipment may be excluded from the scope of the renewal review. This equipment is necessary for cask loading, drying, and transfer operations but are not relied on for ITS functions in cask storage operations. Therefore, the staff finds the applicant's exclusion of the auxiliary equipment from the scope of the renewal review to be acceptable.

Miscellaneous Equipment

The applicant stated that miscellaneous ISFSI equipment including ISFSI security fences and gates, lighting, lightning protection, communications, and monitoring equipment are not part of the TN-68 Dry Storage Cask approved in accordance with 10 CFR Part 72, Subpart L. The applicant further stated that this miscellaneous equipment is not classified as ITS, nor would their failure prevent the fulfillment of a function that is ITS. Based on the safety classification and the results of the scoping review the applicant stated that the miscellaneous equipment is not within the scope of the CoC No. 1027 renewal.

The staff reviewed the applicant's assessment of the miscellaneous ISFSI equipment and noted that the guidance in NUREG-1927, Section 2.4.3, states that this type of equipment is specifically excluded from the scope of the renewal review provided that the equipment does not meet the scoping criteria in Section 2.4.2 of that report. The staff finds that the applicant's determination is consistent with staff's review guidance. The staff determined that the miscellaneous ISFSI equipment identified by the applicant—including ISFSI security fences and gates, lighting, lightning protection, communications, and monitoring equipment—are not part of the TN-68 Dry Storage Cask, the miscellaneous equipment is NITS, and failure of the miscellaneous equipment would not affect an ITS function. Therefore, the staff finds the applicant's exclusion of the miscellaneous equipment from the scope of the renewal review to be acceptable.

Scoping Findings

The staff reviewed the applicant's screening of the out-of-scope SSCs. The staff's review considered, the SSCs and subcomponents; their safety classification per the UFSAR or basis for exclusion from the scope of the renewal review; and design-bases information in the UFSAR. Based on this review, the staff finds that the applicant screened the out-of-scope SSCs and subcomponents in a manner consistent with NUREG-1927. Therefore, the staff finds the screening results for out-of-scope SSCs and subcomponents to be acceptable.

2.2 Evaluation Findings

The staff reviewed the scoping evaluation provided in the renewal application. The staff performed its review following the guidance provided in NUREG-1927, Revision 1. To determine the accuracy and completeness of the scoping evaluation, the staff also used the information in NUREG/CR-6407 as a reference for classifying components as ITS.

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 72.124, “Criteria for nuclear criticality safety”; 10 CFR 72.236, “Specific requirements for spent fuel storage cask approval and fabrication” and 10 CFR 72.240, “Conditions for spent fuel storage cask renewal”.

F2.2 The justification for any SSC determined not to be within the scope of the renewal 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 reviewed applicable materials, environments, and aging mechanisms and effects, as well as to determine whether the applicant has proposed acceptable 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 PEO.

3.2 Aging Management Review Process

In the renewal application Section 3.2, the applicant described its AMR methodology 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 and mechanisms of aging

The applicant stated that the AMR follows the methodology provided in NUREG-1927, which provides an acceptable methodology for applicants to use, and which results in an assessment of the aging effects that could adversely affect the ability of the SSCs to perform their intended safety functions during the PEO. The applicant provided a description of the SSCs and their subcomponents within the scope of renewal. For each SSC subcomponent, the applicant identified the materials of construction and the operating environments. The applicant also reviewed OE as part of the AMR process. For the TN-68 Dry Storage Casks, the fuel assemblies, and the ISFSI concrete pad, the applicant identified aging mechanisms and aging effects for these material and environment combinations, along with the necessary activities to manage the effects of aging.

The staff reviewed the applicant's AMR process, including a description of the review process and the design-bases references. The staff determined that the applicant evaluated the SSCs and their subcomponents using the SSC design, intended function of the subcomponent, and the subcomponent materials and operational environments. The staff then evaluated potential aging mechanisms and effects identified for these SSCs and their subcomponents to determine whether aging management was required to ensure that the intended functions of these SSCs and subcomponents were maintained throughout the PEO. Based on its review, the staff finds that the applicant's AMR process was acceptable because it is consistent with the methodology in NUREG-1927, and was acceptable for identifying credible aging effects for the SSCs within the scope of renewal. The staff determined that the applicant's AMR process was consistent with the generic evaluations for the TN-68 Dry Storage Cask components, spent fuel assemblies and hardware, and ISFSI concrete pad included in NUREG-2214. Therefore, the staff finds the applicant's AMR process to be acceptable.

3.3 Aging Management Review Results

The applicant identified the materials of construction for the SSCs and the subcomponents that were determined to be within the scope of the review. The applicant's identification of materials was conducted for the TN-68 Dry Storage Cask the ISFSI concrete pad and the spent fuel assemblies determined to be within the scope of the renewal review. The applicant stated that the materials of construction and the operating environments for the SSCs and their subcomponents were identified through a review of the drawings provided in the UFSAR, along with other pertinent design information.

The staff reviewed the materials of construction, the operating environments, and the AMR provided by the applicant. To conduct this review, the staff compared the information provided by the applicant to the guidance in NUREG-1927, Chapter 3, Aging Management Review, and the information included in NUREG-2214, Chapter 2, Definitions, and Chapter 3, Evaluation of Aging Mechanisms, along with appropriate industry guidance. If the staff determined that the applicant's conclusions were consistent with expected aging management activities per NUREG-2214, the staff considered the results acceptable, and this determination is documented in this SER. The discussions in the following sections address the applicant's AMR results including materials and environments in SER Section 3.3.1, OE in SER Section 3.3.2, and aging mechanisms and effects in SER Section 3.3.3.

3.3.1 Materials and Service Environments

In the renewal application Section 3.2.1, the applicant stated that the first step in the AMR process was to identify the materials of construction for each subcomponent of the in-scope SSCs and the environments to which those materials are exposed during normal storage conditions. The applicant then used these combinations of materials and environments to identify the potential aging effects that require management during the PEO.

In the renewal application Section 3.3.1, the applicant provided a description of the TN-68 Dry Storage Cask and its subcomponents. The applicant's description included the materials of construction and applicable codes for design, fabrication, and inspection. The applicant cited the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (B&PV) Code sections used for the TN-68 Dry Storage Cask design and fabrication. The applicant provided a listing of the TN-68 Dry Storage Cask subcomponents in the renewal application, Table 3-5, which included the material group and the operating environment(s) for each subcomponent.

The applicant described the ISFSI reinforced concrete storage pad in renewal application Section 3.3.2. The applicant stated that the storage pad is a reinforced concrete structure designed and constructed in accordance with codes and standards set by the general licensee. It is subject to site-specific foundation analyses and design considerations, including licensee-specific TN-68 Dry Storage Cask loading configurations. The applicant stated that the reinforced concrete pad was composed of concrete and steel reinforcement and identified the operating environments for these materials in the renewal application, Table 3-7.

The applicant described the spent fuel assemblies and their subcomponents in renewal application Section 3.3.3. The applicant stated that the TN-68 Dry Storage Cask is designed to store 68 boiling water reactor (BWR) spent fuel assemblies with or without fuel channels. The applicant provided the fuel types, cladding material, and burnup limits approved for storage in the TN-68 Dry Storage Casks in the renewal application, Table 3-1. The applicant provided a listing of the spent fuel assembly subcomponents, the subcomponent material group, and the operating environment in the renewal application, Table 3-8.

The staff used the guidance in NUREG-1927, Section 3.4.1.1, Identification of Materials and Environments, to review the SSC subcomponents materials and operational environments provided in the renewal application. The staff also used the information in NUREG-2214, Chapter 2, to inform the review of the applicant's descriptions of materials and environments.

The staff compared the materials identified in the renewal application Section 3.2.1 to the list of materials included in NUREG-2214, Table 2-1. SER Table 3.3-1 identifies the materials of construction for the SSC within the scope of the renewal that were included in the renewal application, Table 3-2. SER Table 3.3-1 also provides a comparison of the materials in the renewal application to the materials evaluated in NUREG-2214. The staff determined that the materials of construction identified by the applicant were the same as those considered in NUREG-2214 for the assessment of aging mechanisms and aging effects of the storage system components. Therefore, the staff finds the applicant's AMR process for the identification of materials relevant to the TN-68 Dry Storage Cask, spent fuel assemblies, and the concrete storage pad to be acceptable.

The staff compared the environments identified in the renewal application Section 3.2.1 to the environments evaluated in NUREG-2214, Table 2-2, to determine equivalency. SER Table 3.3-2 identifies the environments considered for SSC subcomponents, as defined in the renewal application Section 3.2.1. SER Table 3.3-2 also identifies the comparison results for the SSC operating environments in the renewal application and the SSC operating environments evaluated in NUREG-2214. The staff determined that the operating environments for the SSC identified by the applicant in the renewal application are consistent with the environments considered in NUREG-2214 for the assessment of aging mechanisms and aging effects of the storage system components. Therefore, the staff finds the applicant's AMR process for the identification of environments relevant to the TN-68 Dry Storage Cask, spent fuel assemblies, and the concrete storage pad to be acceptable.

Table 3.3-1. Aging Management Review—Materials

Material group in the CoC 1027 Renewal Application	Material Description in the CoC 1027 Renewal Application Section 3.2.1 and Table 3-2	Equivalent Material(s) in NUREG-2214, Table 2-1
Steel	Carbon steels, alloy steels, high-strength low-alloy (HSLA) steels, galvanized steel, aluminum-coated steel, and electroless nickel-plated steel	Steel
Stainless steel	Austenitic, martensitic, and chrome-plated stainless steel	Stainless steel
Aluminum	Commercially pure aluminum (1100) and precipitation-hardened alloys 6061 and 6063	Aluminum
Concrete	A mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibers, or other cementitious materials	Concrete
Spent fuel assembly cladding	Zircaloy	Zirconium-based alloys
Spent fuel assembly hardware	Stainless steel, zirconium-based alloys, nickel alloys	Stainless steel, zirconium-based alloys, nickel alloys
Borated aluminum	An aluminum alloy typically containing up to 4.5 weight percent boron used as a neutron poison material. The boron is incorporated in the aluminum matrix as discrete particles of AlB2 or TiB2 (for alloys also containing titanium). Aluminum alloys 1100, 6063, and 6351 have been used as base materials for boron additions. This group also includes laminate composite neutron poison material consisting of a core of aluminum and boron-carbine powder sandwiched between sheets of aluminum, e.g., Boral®.	Borated aluminum Boral® Boralyn®
Nickel Alloys	This group is limited to the nickel alloy option for the liner of the metallic seals.	Nickel alloys
Polymers	This group includes the polypropylene used in the top neutron shield and the borated polyester used in the radial neutron shield.	Borated polymers

Table 3.3-2. Aging Management Review—Environments

Environment in CoC 1027 Renewal Application	Description of the environment in the CoC 1027 Renewal Application Section 3.2.1	Equivalent Environment in NUREG-2214, Table 2-2
Air-Outdoor	The components are directly exposed to all outdoor weather conditions including insolation, wind, rain, snow, and site-specific ambient air conditions including moist, possibly salt-laden atmospheric air, ambient temperatures, and humidity.	Air-Outdoor (OD)
Embedded-in-Concrete	One or more surfaces of a component are in contact with concrete. This may prevent ingress of water and contaminants to the embedded surface, depending on the permeability of the embedding environment.	Embedded in concrete (E-C)
Embedded-in-Metal[1]	One or more surfaces of a component are in contact with another component or material. While this may prevent ingress of water and contaminants to the embedded surface, the materials in this environment are treated as though they are exposed to the surrounding environment.	Embedded in metal (E-M)
Fully Encased	The component is fully enclosed inside another component, or the surface between two components is sealed or fully lined by another material which prevents ingress of water and contaminants.	Fully encased or lined (FE)
Helium	The component surface is exposed to the helium fill gas inside the cask and trace quantities of other gases, such as nitrogen, oxygen, argon, and fission product gases.	Helium (HE)
Groundwater/Soil	the component surface is exposed to a soil environment with groundwater. Soil is a mixture of organic and inorganic materials produced by the weathering of rock and clay minerals or the decomposition of vegetation.	Groundwater/soil (GW)

[1] For the Embedded-in-Metal environment, the applicant assumed that the materials in this environment are treated as though they are exposed to the environment surrounding the embedding material.

3.3.2 Operating Experience

In the renewal application Section 3.8 and Appendix 3C, the applicant also discussed the review of OE conducted for the renewal application. The sources of OE reviewed by the applicant included:

- Internal and industrywide condition reports
- Relevant international and non-nuclear OE
- Previous independent spent fuel storage installation inspection results
- Licensee event reports
- Vendor-issued safety bulletins
- NRC generic communications
- Updated consensus codes, standards, or guides
- Applicable industry-initiatives

The applicant stated that the OE review did not identify any aging mechanisms and/or effects that were not already identified in NUREG-2214 for the TN-68 Dry Storage Cask components. The applicant also stated that no incidents were identified where aging effects lead to the loss of intended safety functions of the TN-68 Dry Storage Cask SSCs. Based on this review, the applicant concluded that the aging effects identified in the AMR will be managed so that the SSC intended safety functions will be maintained during the PEO.

The staff reviewed the applicant's OE review. As noted by the applicant, the operational experience review in the renewal application takes credit for the OE review conducted as part of the Prairie Island ISFSI Renewal Application (ADAMS Accession No. ML11304A068) and North Anna ISFSI Renewal Application (ADAMS Accession No. ML16153A140). The Prairie Island ISFSI uses the TN-40 Dry Storage Casks. The North Anna ISFSI uses TN-32 Dry Storage Casks. The TN-40 Dry Storage Casks and the TN-32 Dry storage Casks have designs and subcomponent materials that are similar to the TN-68 Dry Storage Cask. Because the designs and materials are similar, the OE and aging effects observed in the TN-40 and TN-32 Dry Storage Casks are expected to be a good analog to the TN-68 Dry Storage Cask. The review also included the various sources for new age-related degradation OE. The staff compared the list of OE sources cited by the applicant to the information in NUREG-1927, Section 3.6.1.10. The staff determined that the OE review by the applicant followed the guidance in NUREG-1927. Therefore, the staff determined that the OE review conducted by the applicant was acceptable.

3.3.3 Aging Mechanisms and Aging Effects

To determine the potential aging mechanisms and effects, the applicant used the environments to which the SSCs and associated subcomponents are usually exposed. The applicant determined the environmental conditions to which the SSCs and subcomponents are typically exposed using the information presented in the TN-68 Dry Storage Cask UFSAR, Chapter 2, Principal Design Criteria, and Chapter 4, Thermal Evaluation, which includes allowable temperature ranges for components under normal conditions and accident conditions. The applicant provided the relevant materials and environments in the CoC renewal application Section 3.2.1. More specifically, the applicant provided the maximum component and fuel cladding temperatures during normal storage in the renewal application, Table 3-3.

The applicant described the TN-68 Dry Storage Cask design, subcomponents, the fabrication considerations, the concrete storage pad subcomponents, and the spent fuel assembly subcomponents in the renewal application Section 3.3. The applicant provided an evaluation of materials of construction, environments, and the potential aging effects and the associated aging mechanisms for each SSC and associated subcomponent within the scope of renewal in renewal application Section 3.4. In Section 3.4.3 of the renewal application, the applicant provided an assessment of the possible aging mechanisms for the materials used in the TN-68 Dry Storage Cask subcomponents, reinforced concrete storage pad, and the spent fuel assemblies. Aging mechanisms deemed credible were evaluated by the applicant to determine if the aging mechanisms could result in aging effects requiring management in the PEO. The applicant provided a summary of the aging mechanisms for materials used in the TN-68 Dry Storage Cask, concrete storage pad, and spent fuel assemblies in the renewal application, Table 3-4.

The staff relied on the guidance in NUREG-1927, Section 3.4.1.2, Identification of Aging Mechanisms and Effects, to review the applicant's assessment of the aging mechanisms and effects for the SSC subcomponents. The staff also used the information in NUREG-2214, Section 2.3, Aging Mechanisms, Section 2.4, Aging Effects, and the information in Chapter 3, Evaluation of Aging Mechanisms, to review the applicant's AMR for the material and environment combinations that are relevant to the TN-68 Dry Storage Cask, the reinforced concrete storage pad, and the spent fuel assemblies. In this evaluation, the staff ensured that the materials, design features, environments, and OE for the TN-68 Dry Storage Cask described in the renewal application are bounded by those evaluated in NUREG-2214. The staff conducted this evaluation by comparing the information provided by the applicant for the TN-68 Dry Storage Cask in the renewal application to the information contained in NUREG-2214, Chapter 2, for the description of materials, environments, aging mechanisms and aging effects; and Chapter 3 for the evaluation of aging mechanisms for the material/environment combinations. NUREG-2214, Chapter 4, Analysis of Dry Storage Systems and Spent Fuel Assemblies, provides AMR tables for those SSCs and their subcomponents for selected DSS designs, concrete storage pads, and fuel assemblies. The AMR tables included in Chapter 4 identify the aging mechanisms and effects that could challenge the capability of each of the SSCs and their subcomponents to fulfill its ITS function(s) in the 20- to 60-year PEO. For those credible aging effects, the AMR tables recommend aging management approaches including AMPs, TLAAs, or supplemental analyses. The staff used the information in NUREG-2214, Section 4.4, TN-32 and TN-68 Systems, that was specifically developed to inform the review of the applicant's AMR results for those dry storage casks. In addition, the staff used the information in NUREG-2214, Sections 4.7 and 4.8 to inform the review of the applicant's AMR results for the reinforced concrete storage pad and fuel assembles, respectively.

As previously noted, the applicant referenced the OE at the Prairie Island Nuclear Generating Plant ISFSI and the North Anna ISFSI. As noted above, because of the similarities in the design, materials, and operation of the TN-40 Dry Storage Cask and TN-32 Dry Storage Cask, the staff compared the TN-68 Dry Storage Cask AMP to the previously approved AMP for the TN-40 Dry Storage Casks AMP in the Prairie Island ISFSI renewal and the TN-32 Dry Storage Cask AMP in the North Anna ISFSI renewal.

SER Tables 3.3-3 through 3.3-11 provide a summary of the aging mechanisms and aging effects for the material and environment combinations for the components and subcomponents that are included within the scope of the renewal based on the AMR results. In addition, SER Tables 3.3-3 through 3.3-11 identify whether the approach taken by the applicant is consistent with aging mechanism and aging effects analysis included in NUREG-2214 for the comparable material and environment combination. For all cases where the applicant approach differs from that in NUREG-2214, additional information or description is provided in the footnotes for each table.

<u>Steel materials</u>

The summary of the aging mechanisms and aging effects for carbon steel included in the renewal application Section 3.4.3.1 is shown in SER Table 3.3-3. The applicant's evaluation of corrosion mechanisms, creep, thermal aging, and radiation embrittlement for the steel materials was consistent with the evaluation in NUREG-2214, Section 3.2.1, and is therefore acceptable. Additional details of the applicant's evaluation of fatigue, stress relaxation, and wear of steel subcomponents are provided in the following paragraphs.

NUREG-2214, Section 3.2.1.7 states that reviewer should review all fatigue analyses contained in the applicant's design bases documents to determine whether the renewal application adequately addresses the implications of extending the operating period to 60 years. In the renewal application Section 3.4.3.1.7 the applicant also stated that the design basis review for the TN-68 Dry Storage Cask review did not identify any fatigue analyses/evaluations for the TN-68 Dry Storage Cask system components. Further, the applicant stated that the only source of potential thermal fatigue of the TN-68 Dry Storage Cask is ambient seasonal and daily temperature fluctuation but due to the large thermal inertia of the TN-68 Dry Storage Cask, it does not experience the full amplitude of ambient temperature cycles, and a gradual, long-term temperature decrease occurs during the course of storage. The staff reviewed the applicant's evaluation and confirmed that the TN-68 Dry Storage Cask did not include a fatigue assessment. The staff determined that thermal fluctuations are insufficient to result in fatigue of the TN-68 confinement boundary. Therefore, the staff determined that no fatigue evaluation is required for the PEO.

The applicant stated in the renewal application Section 3.4.3.1.10 that the TN-68 Dry Storage Cask bolts in contact with the lid and top neutron shield may be at temperatures where stress relaxation could occur. Therefore, the applicant stated that stress relaxation is considered credible for an air-outdoor environment. The applicant stated that there are no bolts used in concrete, helium, or fully encased environments, and therefore, stress relaxation of steel in these environments is not a credible aging mechanism. The staff noted that the evaluation of stress relaxation in NUREG-2214, Section 3.2.1.10 is limited to bolts and assumes that the bolts are torqued and are placed in service under an applied tensile load but are at temperatures below those necessary for stress relaxation to occur. Although different from the assessment in NUREG-2214, Section 3.2.1.10, the staff noted that in the renewal application Section 3.4.3.1.10, the applicant provided a justification for the evaluation that stress relaxation of bolts is a credible aging mechanism in an air-outdoor environment. Therefore, the staff determined that the applicant's assessment was acceptable, and that stress relaxation is an aging effect that requires aging management in the PEO.

The assessment of wear in NUREG-2214, Section 3.2.1.11, states that wear is a credible aging mechanism for carbon steels used in moving components such as doors used on transfer casks. The applicant stated in the renewal application Section 3.4.3.1.11, that rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. The applicant stated that wear is not a credible aging mechanism because there are no moving components while the TN-68 Dry Storage Casks are in storage. The staff finds this justification for excluding wear acceptable because the staff confirmed that there are no moving components while the TN-68 Dry Storage Casks are in storage. The staff determined that the applicant's assessment of aging effects and aging mechanisms for carbon steel materials was acceptable because the applicant's assessment followed the guidance in NUREG-2214 and the applicant provided acceptable justification for the exclusion of wear consistent with the design and operation of the TN-68 Dry Storage Casks.

Stainless steel materials

The aging mechanisms and aging effects for stainless steel included in renewal application Section 3.4.3.2 is shown in SER Table 3.3-4. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.2.2. The applicant's evaluations for general corrosion, pitting and crevice corrosion, galvanic corrosion, creep, fatigue, radiation embrittlement, and stress relaxation for the stainless steel materials were consistent with the evaluations in NUREG-2214, Section 3.2.2, and are therefore acceptable. Additional details of the applicant's evaluation of stress corrosion cracking (SCC), thermal aging, and wear of stainless steel subcomponents are provided in the following paragraphs.

The applicant stated that all austenitic stainless steels are susceptible to chloride-induced SCC in the normal wrought condition and the susceptibility increases when the material is sensitized. The applicant stated that in the welded condition, the heat affected zone (HAZ), which is a thin band located adjacent to the weld, can be sensitized by the precipitation of carbides that extract chromium out of the metal matrix. The applicant stated that there is a lack of halides and very little residual water in internal environments of a TN-68 Dry Storage Cask following drying and refilling with inert helium gas. Thus, the applicant concluded that SCC is not considered credible. Similarly, there is a lack of halides and very little moisture in a fully encased environment and, thus, SCC is not considered credible. The applicant stated that the construction of the TN-68 Dry Storage Cask system does not involve welding of stainless steel material together in an air-outdoor environment. The applicant determined that SCC of the stainless steel material is not credible in air-outdoor, helium, or fully encased environments.

The staff reviewed the TN-68 Dry Storage Cask design and determined that there is no welded stainless steel in an air-outdoor environment. The staff noted that NUREG-2214, Section 3.2.2.5, identified multiple sources of applied and residual stresses that could be sufficient for the initiation of stress corrosion crackling. In addition to welding residual stresses, these include stresses from fabrication processes, contacts between components, and bolted structures. However, the staff noted that OE with SCC of stainless steels is usually associated with welds or associated with fabrication processes. The staff determined that because the TN-68 Dry Storage Cask design does not used welded stainless steels exposed to an air-outdoor environment, SCC is not a credible aging mechanism.

The applicant stated that thermal aging of stainless steel was not a credible aging mechanism for the TN-68 Dry Storage Casks. The evaluation of thermal aging of stainless steels in NUREG-2214, Section 3.2.2.8, includes assessments for welded and nonwelded austenitic and precipitation-hardened martensitic stainless steels. The applicant stated that the TN-68 Dry Storage Casks do not include precipitation-hardened martensitic stainless steels. For the austenitic stainless steels, the applicant stated that based on the maximum temperatures as laid out in Table 3-3 of the renewal application, that the austenitic stainless steels will not reach temperatures where thermal aging could occur. The staff reviewed the material specifications for the subcomponents of the TN-68 Dry Storage Cask and confirmed that precipitation-hardened martensitic stainless steels are not specified and therefore, no evaluation of these materials were required. The staff noted that the applicant's assessment is consistent with the guidance NUREG-2214, Section 3.2.2.8. The staff determined that the maximum temperature of the austenitic stainless steel components in the TN-68 Dry Storage Casks are below the temperatures necessary for thermal aging and the temperatures of these subcomponents will decrease over time as a result of the gradual decrease in decay heat. Therefore, the staff determined that the applicant's assessment was acceptable, and that thermal aging of the austenitic stainless steel materials is not a credible aging effect and no aging management is required for the PEO.

The evaluation of wear in NUREG-2214, Section 3.2.2.11, and Table 4-11 shows that wear is a credible aging mechanism for stainless steel materials in components that are subjected to repeated motion such as transfer operations. The applicant stated in the renewal application Section 3.4.3.2.11 that rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. The applicant stated that wear is not a credible aging mechanism because there are no moving components while the TN-68 Dry Storage Casks are in storage. The staff finds this justification for excluding wear acceptable because the TN-68 Dry Storage Cask has no moving components in normal storage operations. Therefore, the staff determined that the applicant's assessment was acceptable, and that wear of the steel subcomponents is not a credible aging effect and no aging management is required for the PEO.

Aluminum materials

The aging mechanisms and aging effects for aluminum alloys included in the renewal application Section 3.4.3.3 is shown in SER Table 3.3-5. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.2.3. The applicant's evaluations for creep, fatigue, thermal aging, and radiation embrittlement were consistent with the evaluation in NUREG-2214, Section 3.2.3. The staff's review of the applicant's evaluation of general corrosion, pitting and crevice corrosion, galvanic corrosion, and microbiologically influenced corrosion of the aluminum alloys are provided in the following paragraphs. In addition, information with respect to the applicant's evaluation of creep and thermal aging are also described in the following paragraphs.

The applicant stated that general corrosion, pitting corrosion, crevice corrosion, and galvanic corrosion of aluminum are credible in an air-outdoor environment but are not credible in either a fully encased or a helium environment as a result of the lack of available water. The applicant stated that an air-outdoor environment does not have the continuous electrolyte necessary to sustain microbial activity necessary for microbiologically influenced corrosion. The staff determined that the applicant's assessment of corrosion mechanisms in fully encased and helium environments is consistent with the assessment in NUREG-2214, Section 3.2.3. The staff noted that while these corrosion mechanisms were not evaluated for an air-outdoor environment in NUREG-2214 because most dry storage systems do not use this material-environment combination. Nevertheless, the applicant's evaluation is consistent with the general information regarding the corrosion of aluminum alloys (ASM International 2000; Revie 2000), which indicates that general corrosion, pitting corrosion, crevice corrosion, galvanic corrosion are credible in an air-outdoor environment. In addition, the available information on aluminum alloys indicates that microbiologically influenced corrosion is not credible in an air-outdoor environment because of the lack of a suitable environment for the sustained microbial activity necessary for microbiologically influenced corrosion to occur. Therefore, the staff found that the applicant's assessment of corrosion related aging mechanisms and aging effects for aluminum alloys was acceptable.

The applicant provided an analysis showing that creep of the aluminum alloys was not expected based on the maximum temperature and applied load on these components. The applicant noted that the only aluminum subcomponents with a structural function are the basket rails. The applicant stated that the maximum temperature for the basket rails is slightly above the creep threshold temperature but noted that the temperature of this component decreases with time. In addition, the applicant noted that the basket rails are not under a sustained loading other than their own weight and, thus, are not expected to experience creep. The staff reviewed the applicant's analysis for the effect of temperature and applied loads for the assessment of creep for the aluminum components. The staff determined that creep of the basket rails is not an issue for the PEO, because the basket rails are not under a sustained, applied load, and the temperature of the basket rails decreases with time. Therefore, the staff found that the applicant's assessment of creep aging mechanisms and effects for aluminum alloys was acceptable.

The applicant stated that thermal aging of the precipitation-hardened 6061-T6 aluminum alloy basket rails is not an issue during the PEO, because the maximum temperature of the basket rails would be below the temperature where thermal aging could be expected at the start of the PEO. The applicant cited the evaluation in NUREG-2214, Section 3.2.3.7, which stated that when alloy 6061-T6 is held at 392 °F its yield strength drops from approximately 18 ksi at 10,000 hours (1.14 years) to approximately 11.5 ksi at 100,000 hours (11.4 years). The applicant stated that because of this sensitivity to exposure time, ASME B&PV Code, Section II, requires that time-dependent properties be used for exposures above 350 degrees F (177 degrees C) for this alloy. In addition, the applicant provided an analyses in the TN-68 Dry Storage Cask UFSAR, Appendix 3B, showing that there is a large margin of safety for the aluminum basket rails, particularly under the critical tip-over accident where the acceleration that would cause the maximum stress in the basket aluminum rail to reach the allowable stress limit was much more than the acceleration on the basket resulting from the design basis tip-over accident.

The staff reviewed the applicant's analysis for the effect of temperature on thermal aging of the aluminum alloy basket rails and noted that while temperatures of the basket rail may be too low for thermal aging at the start of the PEO, thermal aging could be possible during the initial 20 years of operation based on the maximum basket rail temperatures. The staff noted that the extent of thermal aging and its effect on the basket rail mechanical properties would depend on the time temperature profile of the basket rails. The staff noted that the effect of temperature and times up to 100,000 hours for aluminum alloy 6061-T6 has been reported by Farrell (1995). In addition, the staff noted that mechanical properties as a function of temperature for aluminum alloy 6061 in the fully annealed condition (6061-O) has been reported by Martin and Weir (1964). The staff compared the maximum stresses on the basket rails under the normal, off-normal, and accident conditions described in TN-68 Dry Storage Cask UFSAR to the yield and tensile strength of aluminum alloy 6061-T6 aged at 400°F for 100,000 hours (Farrell 1995) and the yield and tensile strength of aluminum alloy 6061-O at 400°F (Martin and Weir 1964). Based on the large margin of safety for the basket rails and the comparison of the maximum stresses on the basket rails to the reported mechanical properties of aluminum with thermal aging, the staff determined that thermal aging would not result in a reduction in the mechanical properties of the aluminum alloy basket rails that would affect the structural integrity of the TN-68 Dry Storage Cask. Therefore, the staff found that the applicant's assessment of thermal aging mechanisms and effects for aluminum alloys was acceptable.

Nickel alloys

The aging mechanisms and aging effects for nickel alloys included in the renewal application Section 3.4.3.4 is shown in SER Table 3.3-6. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.2.4. The applicant's evaluations for nickel alloy corrosion mechanisms, fatigue, radiation embrittlement, stress relaxation, and wear for the nickel alloy materials were not consistent with the evaluation in NUREG-2214, Section 3.2.4, because NUREG-2214 only evaluated the aging mechanisms for nickel alloys in an air-outdoor environment. The applicant stated that the nickel alloy metallic seal components are only exposed to a helium environment.

The evaluation of fatigue in NUREG-2214, Section 3.2.4.5, states that fatigue is a credible aging mechanism for nickel alloy materials in components that are subjected to repeated cyclic loads including cyclic loads as a result of thermal effects. The applicant stated that the nickel alloy metallic seals are crushed during installation and the thermal cycling of the liner will not affect the ability of the aluminum jacket to fulfill the confinement function. The staff finds this justification for excluding fatigue acceptable because the TN-68 Dry Storage Cask seal is not subjected to cyclic loading in normal storage operations.

The evaluation of wear in NUREG-2214, Section 3.2.4, states that the only credible aging mechanism for nickel alloys in an air-outdoor environment is wear. NUREG-2214, Section 3.2.4.8, states that wear is a credible aging mechanism for nickel alloy materials in components that are subjected to repeated motion such as transfer operations. The applicant stated in the renewal application Section 3.4.3.4.7 that rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. The applicant stated that wear is not a credible aging mechanism because there are no moving components while the TN-68 Dry Storage Casks are in storage. The staff finds this justification for excluding wear acceptable because the TN-68 Dry Storage Cask has no moving components in normal storage operations.

The staff determined that the applicant's assessment of aging effects and aging mechanisms for nickel alloy materials was acceptable because the applicant followed the guidance in NUREG-1927. The staff noted that NUREG-2214, Section 3.2.4 states that nickel alloys are not susceptible to stress relaxation or radiation embrittlement. While NUREG-2214 only assesses stress relaxation and radiation embrittlement for an air-outdoor environment, the evaluation in NUREG-2214 can be applied to helium environments because these aging mechanisms are dependent on temperature and radiation exposure and are not dependent on the chemical composition of the environment. Therefore, the staff determined that the applicant's evaluation was acceptable. The staff noted that the while helium environments were not evaluated in NUREG-2214, nickel alloys have sufficient corrosion resistance such that corrosion mechanisms are not credible in air-outdoor environments. Because helium environments inside the dry storage cask do not contain moisture or contaminants that would promote corrosion, the staff determined that the applicant's evaluation was acceptable, meaning corrosion is not a credible aging mechanism.

Polymer materials

The aging mechanisms and aging effects for polymer materials included in the renewal application Section 3.4.3.5 is shown in SER Table 3.3-7. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.3.1. The staff found the applicant's evaluations for thermal aging and radiation embrittlement to be acceptable because these assessments were consistent with the evaluations in NUREG-2214, Sections 3.3.1.2 and 3.3.1.3, respectively. The following paragraph provides additional information on the boron depletion of the polymer neutron shielding materials.

The applicant provided a calculation for the boron-10 depletion of the neutron shield that considered the boron-10 density. Using the generic analysis for the depletion of boron-10 from the stainless steel neutron poison material in NUREG-2214, Section 3.4.1.1, the applicant showed that boron depletion was negligible for the PEO. The applicant stated that thermal aging and radiation embrittlement of the polymer material in a fully encased environment are credible aging effects for the PEO. The staff noted that the analysis for the borated stainless steel in NUREG-2214, Section 3.4.1.1, may not be applicable to the borated polymer as the polypropylene and polyester from the polymer shield would slow down neutrons more than stainless steel and have a larger absorption/depletion of boron. However, the staff found that this does provide some confidence that boron depletion is minimal. The staff determined that the applicant's analysis for boron depletion is consistent with the guidance in NUREG-2214, Section 3.3.1.1, and conservative with respect to the analysis provided in NUREG-2214, Section 3.4.1.1, because of the concentration of boron in the TN-68 Dry Storage Cask shielding material. The staff determined that the assessment of thermal aging and radiation embrittlement were acceptable because these assessments followed the guidance in NUREG-2214, Sections 3.3.1.2 and 3.3.1.3, respectively. Based on the above considerations, the staff determined that the applicant's analysis for boron depletion was acceptable for demonstrating that the boron depletion is negligible for the PEO.

<u>Borated aluminum materials</u>

The aging mechanisms and aging effects for borated aluminum alloys included in renewal application Section 3.4.3.6 is shown in SER Table 3.3-8. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.4.2.

The applicant stated that general corrosion and galvanic corrosion of the borated aluminum alloys are not credible in an inert environment. The staff determined that the applicant's analyses for these corrosion mechanisms in inert environments are consistent with the evaluation including in NUREG-2214, Sections 3.4.2.1 and 3.4.2.2. The applicant provided an assessment for creep, thermal aging, and radiation embrittlement to support the conclusion that these aging mechanisms are not credible for the borated aluminum alloys. The staff determined that the applicant's assessment was acceptable because the assessment was consistent with the guidance included in NUREG-2214, Sections 3.4.2.5, 3.4.2.6, and 3.4.2.7, respectively.

The applicant stated that boron-10 (B10) depletion of the borated aluminum alloys is negligible during the PEO. The staff notes that NUREG-2214, Table 3-4, contains a footnote stating that when a boron depletion analysis is included in the design bases, applicants must provide a TLAA to demonstrate that depletion will not challenge noncriticality in the PEO. The TN-68 Dry Storage Cask UFSAR did not contain a boron depletion analysis. The staff compared the boron loading of the neutron poison plates for the TN-68 Dry Storage Cask to the analogous information included in the UFSAR for the TN-32 Dry Storage Cask as well as the information contained in NUREG-2214, Section 3.4.2.4. The staff noted that the TN-68 Dry Storage Cask has a minimum of 27 mg B10/cm^2 (Table 6.1-1 in the TN-68 UFSAR) and an assumed flux at the absorber of 4.91×10^5 n/cm^2·s (Table 14.1-1 in the TN-68 UFSAR). The boron-10 content and neutron flux are within the range of the values for these parameters considered in the generic calculation in NUREG-2214, Section 3.4.2.4, which states that in the worst case, only 0.02 percent of the available boron-10 atoms would be depleted after 60 years, which is too small to challenge the criticality control function of the neutron poisons. The staff did not verify the assumed neutron flux for the TN-68 in Table 14.1-1 of the TN-68 UFSAR. However, based on an independent estimate, the staff expects that it should be about an order of magnitude higher than that of the TN-32 based on the higher burnup of the fuel. Even with this possible discrepancy in the neutron flux, the staff still found there is enough evidence demonstrating that the boron depletion in the neutron poison plates is negligible. In particular, the calculations of boron depletion in the neutron poison plates included in the TN-32 Dry Storage Cask UFSAR, Section 6.3.2, show that the fraction of boron depleted in 1000 years is 0.0001, which is negligible. A flux of an order of magnitude higher would still be negligible. Also, the analysis performed for the TN-32 assumed that all neutrons are at thermal energies, which is conservative as higher energy neutrons would have a lower probability of boron capture and therefore lower depletion. The analysis also conservatively assumed a constant neutron flux, when in reality the neutron flux decays over time. Because the TN-68 Dry Storage Cask has a higher boron aerial density compared to the TN-32 Dry Storage Cask, even though it is expected to have a higher neutron flux than the TN-32, given the conservative assumptions associated with the boron depletion analysis for the TN-32, the staff determined that it can also conclude that boron depletion in the TN-68 Dry Storage Cask will be negligible throughout the PEO. Therefore, the staff found that boron depletion of the borated aluminum alloys neutron absorber for the TN-68 Dry Storage Cask was not a credible aging mechanism during the PEO.

Concrete

The summary of the aging mechanisms and aging effects for concrete included in renewal application Section 3.4.3.7 is shown in SER Table 3.3-9. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.5.1.

The applicant stated that creep, shrinkage, radiation damage, fatigue, and dehydration at high temperatures are not credible air-outdoor or groundwater/soil environments. The applicant stated that freeze-thaw, reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, leaching of calcium hydroxide and salt scaling are credible aging mechanisms for air-outdoor or groundwater/soil environments. The staff determined that the assessments by the applicant were acceptable because they are consistent with the guidance in NUREG-2214, Section 3.5.1. The applicant stated that differential settlement and microbiological degradation are credible in groundwater/soil environments but not credible in air-outdoor environments. The staff determined that the assessments by the applicant were acceptable because they are consistent with the evaluation in NUREG-2214, Section 3.5.1, which states that differential settlement and microbiological degradation are potential aging mechanisms and have aging effects on concrete in groundwater/soil environments but not in air-outdoor environments.

The staff noted that the analysis of concrete aging effects included in NUREG-2214 was based on concrete having only a structural function. Concrete aging effects such as cracks and loss of material can affect the concrete ITS structural function. Heat transfer is dependent on materials properties and material interfaces and discontinuities. Concrete aging effects that result in a loss of material or cracks are discontinuities that could affect heat transfer. The staff determined that the aging effects for concrete that result in a loss of material or the formation of cracks could affect the heat transfer by creating discontinuities in the in the concrete structure. Therefore, the staff determined that the guidance provided in NUREG-2214, Section 3.5.1, developed for a structural function may be applied to concrete having a thermal function.

The applicant stated that delayed ettringite formation (DEF) is considered credible in air-outdoor or groundwater/soil environments. The staff noted that the assessment of delayed ettringite formation by the applicant is different from NUREG-2214, Section 3.5.1.13, which states that the conditions necessary for the occurrence of DEF are excessive temperatures during concrete placement and curing, the presence of internal sulfates, and a moist environment. As noted in NUREG-2214, Section 3.5.1.13, the American Concrete Institute (ACI) guidelines during concrete placement and curing can effectively limit the concrete temperature to below 70 degrees C (158 degrees F), therefore preventing the development of DEF. As such, NUREG-2214 states that DEF is not a credible aging mechanism in any environment. While the applicant's assessment differs from NUREG-2214, the staff determined that the applicant's assessment is conservative and therefore acceptable.

The applicant provided an assessment for concrete hardening and determined that hardening was not a credible aging mechanism, as no appreciable hardening is expected during the PEO. The staff noted that some degree of concrete hardening with time after curing is expected, but rate of hardening decreases with time after curing. As such, NUREG-2214 does not consider concrete hardening as an aging mechanism. The staff reviewed the applicant assessment which was based on the data in Table 2.13 of NUREG/CR-6424 (NRC, 1996b). Based on a review of the available data, the applicant stated that concrete hardening is not expected in the PEO. The staff determined that the applicant's assessment of hardening was acceptable based on the data provided to support the analysis that concrete hardening beyond 20 years is not a credible aging mechanism.

Spent fuel assembly cladding materials

The summary of the aging mechanisms and aging effects for spent fuel assemblies included in renewal application Section 3.4.3.8 is shown in SER Table 3.3-10. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.6.1.

The applicant stated in the renewal application, Table 3-1 that the maximum fuel burnup for the TN-68 Dry Storage Cask is 60 Gwd/MTU. For high-burnup fuel, defined as fuel with a burnup greater than 45 Gwd/MTU, the applicant stated that hydride embrittlement and thermal creep are potential aging mechanisms. The applicant stated that there are no credible aging mechanisms for the spent fuel stored in an inert helium environment with burnups less than or equal to 45 Gwd/MTU. The staff verified that the maximum burnup for the TN-68 Dry Storage Cask specified in Figure 2.1.1-2 of Amendment 1 to the TN-68 generic TS is 60 Gwd/MTU (ADAMS Accession No. 073050262). Staff determined that the assessment by the applicant is consistent with the information included in NUREG-2214, Section 3.6.1. As stated in NUREG-2214, hydride reorientation and thermal creep are the only considered credible aging mechanisms for high-burnup fuel. The staff determined that hydride embrittlement and thermal creep aging mechanisms are credible for high-burnup fuel in in the TN-68 Dry Storage Cask. In addition, staff determined that there are no credible aging mechanisms for fuel loaded into the TN-68 Dry Storage Cask with burnups less than or equal to 45 Gwd/MTU. Therefore, the staff found that the applicant's assessment of aging effects and aging mechanisms for spent fuel assembly cladding materials was acceptable.

Spent fuel assembly hardware materials

The aging mechanisms and aging effects for spent fuel assembly hardware materials included in renewal application Section 3.4.3.9 is shown in SER Table 3.3-11. The staff reviewed the operational environments and potential aging mechanisms provided by the applicant using the information in NUREG-2214, Section 3.6.2.

The applicant stated that there are no credible aging mechanisms for the spent fuel assembly hardware stored in an inert helium environment. The staff determined that the assessment by the applicant is consistent with the information included in NUREG-2214, Section 3.6.2. Therefore, the staff found that the applicant's assessment of aging effects and aging mechanisms for spent fuel assembly hardware materials was acceptable.

Table 3.3-3. Summary of the aging mechanisms and aging effects for steel

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.1		Consistent with NUREG-2214 Section 3.2.1
		Credible Environments[1]	Non-Credible Environments[1]	
General corrosion	Loss of material	OD, E-C	HE, FE	Yes
Pitting and crevice corrosion	Loss of material	OD, E-C	HE, FE	Yes
Galvanic corrosion	Loss of material	OD	E-C, HE, FE	Yes
Microbiologically influenced corrosion	Loss of material	E-C	OD, HE, FE	Yes
Stress corrosion cracking	Cracking	none	OD, E-C, HE, FE	Yes
Creep	Change in dimensions	none	OD, E-C, HE, FE	Yes
Fatigue	Cracking	none	OD, E-C, HE, FE	Yes[2]
Thermal aging	Loss of fracture toughness and loss of ductility	none	OD, E-C, HE, FE	Yes
Radiation embrittlement	Cracking	none	OD, E-C, HE, FE	Yes
Stress relaxation	Loss of preload	OD	E-C, HE, FE	No[3]
Wear	Loss of material	none	OD, E-C, HE, FE	Yes[4]

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.1 that the relevant environments for carbon steel materials include Air-Outdoor (OD), Embedded-in-concrete (E-C), Helium (HE) and Fully Encased (FE).

[2] NUREG-2214, Section 3.2.1.7, states that the applicant should evaluate the design-bases documents to determine whether the renewal application adequately addresses the implications of extending the operating period to 60 years. The applicant stated that the design basis for the TN-68 system did not include a fatigue analyses for the TN-68 Dry Storage Cask system components.

[3] The analysis of stress relaxation of bolts in NUREG-2214, Section 3.2.1.10, assumes that the bolts are torqued and are placed in service under an applied tensile load operate at a temperature too low for stress relaxation in OD environments. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.1.10 that the temperatures of the bolts may be sufficient for stress relaxation.

[4] NUREG-2214, Section 3.2.1.11, stated that wear is a credible aging mechanism for moving components such as doors used on transfer casks. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.1.11 that rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. Because there are no moving components while TN-68 Dry Storage Cask in in storage, wear is not a credible aging mechanism for the TN-68 Dry Storage Cask.

Table 3.3-4. Summary of the aging mechanisms and aging effects for stainless steel

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.2		Consistent with NUREG-2214 Section 3.2.2
		Credible Environments[1]	Non-Credible Environments[1]	
General corrosion	Loss of material	none	OD, HE, FE	Yes
Pitting and crevice corrosion	Loss of material	OD	HE, FE	Yes
Galvanic corrosion	Loss of material	OD	HE, FE	Yes[2]
Microbiologically influenced corrosion	Loss of material	none	OD, HE, FE	Yes
Stress corrosion cracking	Cracking	none	OD, HE, FE	No[3]
Creep	Change in dimensions	none	OD, HE, FE	Yes
Fatigue	Cracking	none	OD, HE, FE	Yes
Thermal aging	Loss of fracture toughness and loss of ductility	none	OD, HE, FE	No[4]
Radiation embrittlement	Cracking	none	OD, HE, FE	Yes
Stress relaxation	Loss of preload	none	OD, HE, FE	Yes
Wear	Loss of material	none	OD, HE, FE	No[5]

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.2 that the relevant environments for stainless steel materials include Air-Outdoor (OD), Helium (HE) and Fully Encased (FE).

[2] Galvanic corrosion is considered credible for stainless steel in an OD environment in contact with a graphite lubricant.

[3] The applicant stated that the stainless steel exposed to an OD environment is not welded and therefore does not have stress required for SCC.

[4] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.2.8 that because the peak temperatures for stainless steel components exposed to air-outdoor, helium and fully encased environments are below the temperature required for the phase changes associated with thermal aging and embrittlement of stainless steels, thermal aging is not considered credible for these subcomponents. In addition, the applicant stated that austenitic stainless steels that are not welded are not susceptible to thermal aging and embrittlement over the range of operating temperatures for these components in the TN-68 Dry Storage Casks.

[5] NUREG-2214, Section 3.2.2.11, states that wear is a credible aging mechanism for transfer cask components such as rails that are subjected to repeated transfer operations. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.2.11 that rolling contact wear results from the repeated mechanical stressing of the surface of a body rolling on another body. The applicant stated that for the TN-68 Dry Storage Cask there are no bodies rolling on another body while the TN-68 Dry Storage Cask is in storage.

Table 3.3-5. Summary of the aging mechanisms and aging effects for aluminum

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.3		Consistent with NUREG-2214 Section 3.2.3
		Credible Environments[1]	Non-Credible Environments[1]	
General corrosion	Loss of material	OD	HE, FE	No[2]
Pitting and crevice corrosion	Loss of material	OD	HE, FE	No[2]
Galvanic corrosion	Loss of material	OD	HE, FE	No[2]
Microbiologically influenced corrosion	Loss of material	none	OD, FE, HE	No[3]
Creep	Change in dimensions	none	OD, FE, HE	Yes[4]
Fatigue	Cracking	none	OD, FE, HE	Yes
Thermal aging	Loss of strength	none	OD, FE, HE	Yes[5]
Radiation embrittlement	Cracking	none	OD, FE, HE	Yes

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.3 that the relevant environments for aluminum materials were limited to Air-Outdoor (OD), Helium (HE) and Fully Encased (FE).

[2] The applicant stated that general corrosion, pitting corrosion, crevice corrosion and galvanic corrosion are considered credible in an OD environment. NUREG-2214, Section 3.2.3, did not consider OD environments for the evaluation of possible aging mechanisms and effects for aluminum.

[3] The applicant stated that microbiologically influenced corrosion is not credible in OD environments. NUREG-2214, Section 3.2.3.4, did not consider OD environments for the evaluation of microbiologically influenced corrosion as a possible aging mechanisms and effects for aluminum.

[4] The applicant provided an analysis to show that the highest temperatures of the aluminum components were below the temperature value where creep would be expected to occur.

[5] NUREG-2214, Section 3.2.3.7, states that precipitation-hardened aluminum alloys such at 6061-T6 will have reduced strength after prolonged exposure to temperatures above 177°C [350°F]. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.3.7 that Type 6061 subcomponents could exceed 170°C [339°F] during the initial storage period but would be below that temperature in the PEO. The applicant provided an analysis in the CoC No. 1027 renewal application Section 3.4.3.3.7 to show that any credible thermal aging of the basket rails would not adversely affect the structural function of these components.

Table 3.3-6. Summary of the aging mechanisms and aging effects for nickel alloys

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.4		Consistent with NUREG-2214 Section 3.2.4
		Credible Environments[1]	Non-Credible Environments[1]	
General corrosion	Loss of material	none	HE	No[2,3]
Pitting and crevice corrosion	Loss of material	none	HE	No[2,3]
Microbiologically influenced corrosion	Loss of material	none	HE	No[2.3]
Stress corrosion cracking	Cracking	none	HE	No[2.3]
Fatigue	Cracking	none	HE	No[2,4]
Radiation embrittlement	Loss of fracture toughness and loss of ductility	none	HE	No[2,5]
Stress relaxation	Change in dimensions	Not Assessed	Not Assessed	No[2,6]
Wear	Loss of material	none	HE	No[2,7]

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.4 that the only nickel alloy component is the liner of the metallic O-ring which is exposed to a Helium (HE) environment.

[2] NUREG-2214, Section 3.2.4, did not consider HE environments for the evaluation of possible aging mechanisms and effects for nickel alloys.

[3] The applicant stated that general corrosion, pitting corrosion, crevice corrosion, microbiologically influenced corrosion, and stress corrosion cracking are not credible in HE environments. NUREG-2214, Section 3.2.4, only considered OD environments and concluded these corrosion mechanisms were not credible. Because these mechanisms are not credible in an OD environment, the applicant's assessment that these corrosion mechanisms are not credible for the less aggressive HE environment is valid.

[4] The applicant stated that fatigue in an HE environment is not credible because the nickel alloy components are not subjected to cyclic loading.

[5] The applicant stated that radiation embrittlement in a HE environment would not affect the function of the seal.

[6] The applicant stated that the function of the nickel alloy liner and spring is to maintain the shape of the seal prior to installation.

[7] The applicant stated that wear of the nickel alloy seal liner in a HE environment is not credible because there is no sliding or motion that would lead to wear.

Table 3.3-7. Summary of the aging mechanisms and aging effects for polymer materials

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.5		Consistent with NUREG-2214 Section 3.3.1
		Credible Environments[1]	Non-Credible Environments[1]	
Boron depletion	Loss of shielding	none	FE	Yes[2]
Thermal aging	Shrinkage, cracking, loss of fracture toughness and loss of ductility	FE	Not applicable	Yes
Radiation embrittlement	Cracking	FE	Not applicable	Yes

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.5 that the relevant environment for polymer materials is limited to Fully Encased (FE).

[2] The applicant provided an analysis to show that boron depletion was negligible over a 60-year period.

Table 3.3-8. Summary of the aging mechanisms and aging effects for borated aluminum material

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.6		Consistent with NUREG-2214 Section 3.4.2
		Credible Environments[1]	Non-Credible Environments[1]	
General corrosion	Loss of material	none	HE	Yes
Galvanic corrosion	Loss of material	none	HE	Yes
Boron depletion	Loss of neutron absorber	none	HE	Yes[2]
Creep	Change in dimensions	none	HE	Yes
Thermal aging	Loss of strength	none	HE	Yes
Radiation embrittlement	Cracking	none	HE	Yes
Wet corrosion and blistering	Change in dimensions	none	HE	Yes

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.6 that the relevant environment for borated aluminum is limited to Helium (HE).

[2] The TN-68 UFSAR did not contain a boron depletion analysis for the neutron absorber plates. In the CoC No. 1027 renewal application Section 3.4.3.6.3, the applicant referred to the generic analysis in NUREG-2214, Section 3.4.2.4. The staff's review of the information provided by the applicant is included in SER Section 3.2.2.

Table 3.3-9. Summary of the aging mechanisms and aging effects for concrete

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.7		Consistent with NUREG-2214 Section 3.5.1
		Credible Environments[1]	Non-Credible Environments[1]	
Freeze-thaw	Cracking and loss of material	OD, GW	Not applicable	Yes
Creep	Cracking	none	OD, GW	Yes
Reaction with aggregates	Cracking, loss of strength,	OD, GW	Not applicable	Yes
Differential settlement	Cracking and loss of form	GW	OD	Yes
Aggressive chemical attack	Cracking, loss of strength, loss of material, and reduction in concrete pH	OD, GW	Not applicable	Yes
Corrosion of reinforcing steel	Cracking, loss of material, loss of concrete/steel bond, and loss of strength	OD, GW	Not applicable	Yes
Shrinkage	Cracking	none	OD, GW	Yes
Leaching of calcium hydroxide	Loss of strength. increase in porosity and permeability, and reduction in concrete pH	OD, GW	Not applicable	Yes
Radiation damage	Cracking and loss of strength	none	OD, GW	Yes
Fatigue	Cracking	none	OD, GW	Yes
Dehydration at high temperature	Cracking and loss of strength	none	OD, GW	Yes
Microbiological degradation	Loss of material, increase in porosity and permeability, loss of strength, and reduction in concrete pH	GW	OD	Yes
Delayed ettringite formation	Cracking, loss of material, and loss of strength	OD, GW	See Note 2	No[2]
Salt scaling	Loss of material	OD, GW	Not applicable	Yes
Hardening	See Note 3	none	OD, GW	No[3]

1 The applicant stated in CoC No. 1027 renewal application Section 3.4.3.7 that the relevant environments for concrete includes Air-Outdoor (OD) and Groundwater/soil (GW).

2 NUREG-2214, Section 3.5.1.13, states that American Concrete Institute (ACI) design and construction codes are sufficient to preclude delayed ettringite formation. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.7.13 that delayed ettringite formation is considered credible for the storage pad in OD and GW environments unless ruled out by the specific licensee by an ISFSI-specific evaluation.

3 NUREG-2214, Section 3.5.1, did not assess hardening of the concrete. The applicant provided an assessment for the hardening of concrete in CoC No. 1027 renewal application Section 3.4.3.7.15.

Table 3.3-10. Summary of the aging mechanisms and aging effects for spent fuel assembly cladding materials

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.8		Consistent with NUREG-2214 Section 3.6.1
		Credible Environments[1]	Non-Credible Environments[1]	
Hydride-induced embrittlement	Loss of ductility	HE (high-burnup fuel with zirconium alloy cladding)	HE (low burnup fuel with zirconium alloy cladding)	Yes[2]
Delayed hydride cracking	Cracking	none	HE	Yes
Thermal creep	Change in dimensions	HE (high-burnup fuel with zirconium alloy cladding)	HE (low burnup fuel with zirconium alloy cladding)	Yes[2]
Low temperature creep	Change in dimensions	none	HE	Yes
Mechanical overload	Cracking	none	HE	Yes
Oxidation	Loss of material	none	HE	Yes
Pitting corrosion	Loss of material	none	HE	Yes
Galvanic corrosion	Loss of material	none	HE	Yes
Stress corrosion cracking	Cracking	none	HE	Yes
Radiation embrittlement	Loss of strength	none	HE	Yes
Fatigue	Loss of material	none	HE	Yes

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.8 that the relevant environment for zirconium alloy spent fuel assembly cladding materials is limited to Helium (HE).

[2] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.8 that the hydride-induced embrittlement and the thermal creep aging mechanisms for the fuel cladding are applicable to fuel with a burnup greater than 45 GWd/MTU.

Table 3.3-11. Summary of the aging mechanisms and aging effects for spent fuel assembly hardware materials

Aging Mechanism	Aging Effect	CoC 1027 Renewal Application Section 3.4.3.9		Consistent with NUREG-2214 Section 3.6.2
		Credible Environments[1]	Non-Credible Environments[1]	
Creep	Change in dimensions	none	HE	Yes
Hydriding	Cracking	none	HE	Yes
General corrosion	Loss of material	none	HE	Yes
Stress corrosion cracking	Cracking	none	HE	Yes
Radiation embrittlement	Loss of strength	none	HE	Yes
Fatigue	Cracking	none	HE	Yes

[1] The applicant stated in CoC No. 1027 renewal application Section 3.4.3.9 that the relevant environment for spent fuel assembly hardware materials is limited to Helium (HE).

SER Tables 3.3-12 through 3.3-14 show only the aging mechanisms and aging effects for the TN-68 Dry Storage Cask, storage pad, and the spent fuel assemblies, respectively, with the material-environment combinations that the applicant determined to be credible and which require an AMP to address the aging effect(s). SER Tables 3.3-12 through 3.3-14 identify whether the applicant's evaluation of each credible aging effect(s) is consistent with the generic technical bases and conclusions discussed in NUREG-2214.

The aging mechanisms and effects that require aging management applicable to the TN-68 Dry Storage Cask components are shown in SER Table 3.3-12. The staff reviewed the AMR provided by the applicant in the renewal application, Tables 3-5 and 3-6. The staff determined that the applicant's evaluation of necessary aging management activities was consistent with the assessment of aging effects and aging mechanisms for the TN-68 Dry Storage Cask components. The staff determined that the necessary aging management activities were acceptable because the applicant's assessment followed the guidance in NUREG-2214, Section 4.4 and Table 4-11. Therefore, the staff found that the applicant's necessary aging management activities were acceptable.

The aging mechanisms and effects that require aging management applicable to the storage pad for the TN-68 Dry Storage Cask are shown in SER Table 3.3-13. The staff reviewed the AMR provided by the applicant in renewal application, Table 3-7. The staff determined that the applicant's evaluation of necessary aging management activities was consistent with the assessment of aging effects and aging mechanisms for the storage pad. The staff determined that the applicant's assessment was either (1) consistent with the evaluation in NUREG-2214, Section 4-7 and Table 4-24, or (2) was conservative with respect to the evaluation in NUREG-2214. Therefore, the staff found that the applicant's necessary aging management activities were acceptable.

The aging mechanisms and effects that require aging management applicable to the spent fuel assemblies for the TN-68 Dry Storage Cask are shown in SER Table 3.3-14. The staff reviewed the AMR provided by the applicant in the renewal application, Table 3-8. The staff determined that the applicant's evaluation of necessary aging management activities was consistent with the assessment of aging effects and aging mechanisms for the spent fuel assemblies documented in the renewal application Sections 3.4.3.8 and 3.4.3.9. The staff determined that the applicant's assessment was consistent with the evaluation in NUREG-2214, Section 4.8 and Table 4-25. Therefore, the staff found that the applicant's assessment that aging management activities are necessary for the spent fuel assemblies was acceptable.

Table 3.3-12. Aging mechanisms and effects that require aging management—TN-68 Dry Storage Cask

Material	Environment	Aging Mechanism	Aging Effect	Subcomponent parts[1]	Aging Management Program	Consistent with NUREG-2214 Table 4-11
Steel	Air-Outdoor	General corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	Yes
Steel	Air-Outdoor	Pitting/crevice corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	Yes
Steel	Air-Outdoor	Galvanic corrosion	Loss of Material	Lid, protective cover, lid bolts, vent and drain port cover bolts, overpressure port cover bolts, flange, trunnion bolts	TN-68 AMP	Yes
Steel	Air-Outdoor	Stress relaxation	Loss of Preload	Lid bolts, vent and drain cover bolts, overpressure port cover bolts, trunnion bolts	TN-68 AMP	No[2]
Stainless Steel	Air-Outdoor	Pitting/crevice corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	No[3]
Stainless Steel	Air-Outdoor	Galvanic corrosion	Loss of Material	Socket Head Cap Screw threaded insert for lid bolts	TN-68 AMP	Yes
Aluminum	Air-Outdoor	General corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	No[4]
Aluminum	Air-Outdoor	Pitting/crevice corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	No[4]
Aluminum	Air-Outdoor	Galvanic corrosion	Loss of Material	All components exposed to an air-outdoor environment	TN-68 AMP	No[4]
Polymer	Fully Encased	Thermal aging	Shrinkage / Cracking	Top neutron shield	TN-68 AMP	Yes
Polymer	Fully Encased	Radiation embrittlement	Shrinkage / Cracking	Top neutron shield	TN-68 AMP	No[3]
Borated Polymer	Fully Encased	Thermal aging	Shrinkage / Cracking	Radial neutron shield	TN-68 AMP	Yes
Borated Polymer	Fully Encased	Radiation embrittlement	Shrinkage / Cracking	Radial neutron shield	TN-68 AMP	Yes

Table 3.3-12. Aging mechanisms and effects that require aging management—TN-68 Dry Storage Cask

Material	Environment	Aging Mechanism	Aging Effect	Subcomponent parts[1]	Aging Management Program	Consistent with NUREG-2214 Table 4-11

[1] The applicant included a complete list of TN-68 subcomponent parts in CoC No. 1027 renewal application, Table 3-5.

[2] The analysis of stress relaxation of bolts in NUREG-2214, Section 3.2.1.10, assumes that the bolts are torqued and are placed in service under an applied tensile load operate at a temperature too low for stress relaxation in OD environments. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.1.10 that the temperatures of the bolts may be sufficient for stress relaxation.

[3] Not considered as a credible aging effect requiring an aging management activity in NUREG-2214.

[4] This material/environment combination that was not evaluated in NUREG-2214. The basis for finding the applicant's submittal acceptable for this material/environment combination is discussed above.

Table 3.3-13. Aging mechanisms and effects that require aging management—ISFSI Storage pad

Material	Environment	Aging Mechanism	Aging Effect	Subcomponent Parts[1]	Aging Management Program	Consistent with NUREG-2214 Table 4-24
Steel	Embedded-in-concrete	General corrosion	Loss of material	Rebar	Storage pad AMP	Yes
Steel	Embedded-in-concrete	Pitting and crevice corrosion	Loss of material	Rebar	Storage pad AMP	Yes
Steel	Embedded-in-concrete	Microbiologically influenced corrosion	Loss of Material	Rebar	Storage pad AMP	Yes
Concrete	Air-Outdoor	Freeze-thaw	Cracking, Loss of material	Reinforced concrete	Storage pad AMP	Yes
Concrete	Air-Outdoor	Reaction with aggregates	Cracking, Loss of strength	Reinforced concrete	Storage pad AMP	Yes
Concrete	Air-Outdoor	Aggressive chemical attack	Cracking, Loss of strength, Loss of material, Reduction in concrete pH	Reinforced concrete	Storage pad AMP	Yes
Concrete	Air-Outdoor	Corrosion of reinforcing steel	Loss of concrete/steel bond Loss of material, Cracking, Loss of strength	Reinforced concrete	Storage pad AMP	Yes
Concrete	Air-Outdoor	Leaching of calcium hydroxide	Loss of strength, Increase in porosity and permeability, Reduction in concrete pH	Reinforced concrete	Storage pad AMP	Yes
Concrete	Air-Outdoor	Delayed ettringite formation	Loss of material, Loss of strength, Cracking	Reinforced concrete	Storage pad AMP	No[2]
Concrete	Air-Outdoor	Salt scaling	Loss of material	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Freeze-thaw	Cracking, Loss of material	Reinforced concrete	Storage pad AMP	Yes

Table 3.3-13. Aging mechanisms and effects that require aging management—ISFSI Storage pad

Material	Environment	Aging Mechanism	Aging Effect	Subcomponent Parts[1]	Aging Management Program	Consistent with NUREG-2214 Table 4-24
Concrete	Groundwater/ soil	Reaction with aggregates	Cracking, Loss of strength	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Differential settlement	Cracking	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Aggressive chemical attack	Cracking, Loss of strength, Loss of material, Reduction in concrete pH	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Corrosion of reinforcing steel	Loss of concrete/steel bond Loss of material, Cracking, Loss of strength	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Leaching of calcium hydroxide	Loss of strength, Increase in porosity and permeability, Reduction in concrete pH	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Microbiological degradation	Loss of strength, Loss of material, Increase in porosity and permeability, Reduction in concrete pH	Reinforced concrete	Storage pad AMP	Yes
Concrete	Groundwater/ soil	Delayed ettringite formation	Loss of material, Loss of strength, Cracking	Reinforced concrete	Storage pad AMP	No[2]
Concrete	Groundwater/ soil	Salt scaling	Loss of material	Reinforced concrete	Storage pad AMP	Yes

[1] The applicant included a subcomponent parts in CoC No. 1027 renewal application. Table 3-7.

[2] NUREG-2214, Section 3.5.1.13, states that ACI design and construction codes are sufficient to preclude delayed ettringite formation. The applicant stated in CoC No. 1027 renewal application Section 3.4.3.7.13 that delayed ettringite formation is considered credible for the storage pad in OD and GW environments unless ruled out by the specific licensee by an ISFSI-specific evaluation.

Table 3.3-14. Aging mechanisms and effects that require aging management—spent fuel assemblies

Material	Environment	Aging Mechanism	Aging Effect	Subcomponent Parts[1]	Aging Management Program	Consistent with NUREG-2214 Table 4-25
Zirconium alloy[2]	Helium	Hydride-induced embrittlement	Loss of ductility	Fuel Cladding and End Plugs	HBU Fuel AMP[3]	Yes
Zirconium alloy[2]	Helium	Thermal creep	Change in Dimensions	Fuel Cladding and End Plugs	HBU Fuel AMP[3]	Yes

[1] The applicant included a subcomponent parts in CoC No. 1027 renewal application. Table 3-8.

[2] Zirconium alloy cladding including Zircaloy-2.

[3] For high-burnup (HBU) fuel only.

3.4 Evaluation Findings

The staff reviewed the AMR provided in the renewal application to verify it identified the materials, environments, and aging effects of the in-scope SSCs. The staff performed its review following the guidance provided in NUREG-1927, and NUREG-2214. Based on its review of the renewal application, 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 provided appropriate descriptions of the materials and operating environments for those SSCs within the scope of the renewal information in the renewal application.

F3.2 The applicant's AMR process is comprehensive in identifying all pertinent aging mechanisms and effects applicable to the SSCs within the scope of renewal, and the applicant provided an acceptable summary of the AMR results in the renewal application.

3.5 Time-Limited Aging Analyses Evaluation

The applicant reviewed the initial application for TLAAs (i.e., calculations or analyses) used to demonstrate that in-scope SSCs will maintain their intended safety function throughout an explicitly stated period of operation. To be considered “in-scope” for TLAAs, the applicant stated that the calculations/analyses must meet all six of the following criteria as defined in 10 CFR Part 72.3, “Definitions,” which are:

1. involve structures, systems, and components ITS within the scope of the license renewal, as delineated in subpart F of Part 72, or within the scope of the spent fuel storage certificate renewal, as delineated in subpart L of Part 72, respectively;
2. consider the effects of aging;
3. involve time-limited assumptions defined by the current operating term, for example, 40 years;
4. were determined to be relevant by the licensee or certificate holder in making a safety determination;
5. involve conclusions or provide the basis for conclusions related to the capability of structures, systems, and components to perform their intended safety functions; and
6. are contained or incorporated by reference in the design bases.

Based on its review, the applicant identified the following analysis as meeting all six criteria for a TLAA:

- Ensure cavity pressure remains above one atmosphere on the coldest day at the end of the storage period

The staff reviewed the TLAA provided by the applicant in support of conclusions regarding potential aging effects for SSCs and SSC subcomponents within the scope of renewal. Based on its review of the design-bases documents, the staff confirmed that the applicant identified all calculations and analyses meeting all six criteria in 10 CFR 72.3 and therefore concludes that the applicant identified all TLAAs. The staff’s review of the applicant’s TLAAs is provided in the following subsection.

3.5.1 Ensure Cavity Pressure Remains Above One Atmosphere on the Coldest Day at the End of the Storage Period

The applicant stated that TN-68 Dry Storage Cask USFAR Section 2.2.5.3.3 contains a design criterion that one atmosphere of pressure must exist in the cavity on the coldest day at the end of life. As noted by the applicant, the purpose of pressurizing the cavity above atmospheric pressure is to prevent in-leakage of air. The applicant stated that while the design of the overpressure monitoring system ensures there will be no out-leakage past the seals during normal operations, the cavity pressure decreases over time as the decay heat decreases. The applicant clarified that the end of life cavity pressure analysis assumes a cavity gas temperature corresponding to the end of the 40-year storage period and therefore, the end of life cavity pressure analysis must be revised or updated to demonstrate that the cavity pressure will be above one atmosphere at the end of the PEO, i.e., a total of 60 years.

The applicant provided an updated cavity pressure calculation that demonstrates that the cavity pressure of a TN-68 Dry Storage Cask remains above atmospheric pressure on the coldest day at the end of the PEO. The applicant's analysis was based on the ideal gas law which governs the change in cavity pressure as the temperature inside the cavity decreases. The applicant cited Section 7.2.2.1 of the TN-68 Dry Storage Cask UFSAR for the initial gas temperature of 350°F (177°C) and CoC No. 1027 Technical Specification 3.1.2 for the cavity minimum allowed pressure of 2.0 atm (2026 mbar). The applicant stated the minimum average daily ambient design temperature for the TN-68 Dry Storage Cask is −20°F (−29°C). The applicant stated that based on the TN-68 design basis source term calculation, the heat load at the end of 60 years would be 8.42 kW. The average cavity helium gas temperature at the end of 60 years of storage was determined to be 47.5°F (8.6°C) and the pressure in the cask would be 1.127 atm (1142 mbar).

The NRC reviewed the applicant's original assessment in TN-68 Dry Storage Cask USFAR Section 2.2.5.3.3 and the basis for the revised calculation. The staff determined that the TLAA provided by the applicant identified the affected components as those that make up the pressure boundary. The applicant stated that the aging effects are corrosion of the pressure boundary components resulting in a loss of material. The TLAA provided by the applicant considers the decay heat of the fuel, time in service at the end of the PEO and the minimum ambient operating temperature for the TN-68 Dry Storage Cask. The staff verified that Section 7.2.2.1 of the TN-68 Dry Storage Cask UFSAR states the basis for the initial gas temperature of 350°F (177°C). The staff also verified that TN-68 Technical Specification 3.1.2 specifies a helium cavity minimum allowed pressure of 2.0 atm (2026 mbar). The staff confirmed that the minimum average daily ambient design temperature for the TN-68 Dry Storage Cask is −20°F (−29°C) as shown in Table 2.5-1 of the TN-68 Dry Storage Cask USFAR. The staff verified that the applicant's calculation based on initial and assumed final helium gas temperatures resulted in a final pressure greater than one atm. The staff determined that the applicant's revised assessment was acceptable because the calculation shows that the TN-68 Dry Storage Cask design criteria is met for the PEO.

3.5.2 Evaluation Findings

The staff reviewed the renewal application and design-bases documentation to confirm that the applicant did not omit any TLAAs that were part of the approved design bases. The staff performed its review following the guidance provided in NUREG-1927, and NUREG-2214.

Based on its review of the renewal application, the staff finds the following:

F3.3 The applicant appropriately evaluated all aging mechanisms and effects pertinent to SSCs within the scope of renewal that involve TLAAs. The applicant's TLAAs require no further aging management activities, and meet the requirements in 10 CFR 72.240(c)(2).

3.6 Aging Management Programs

Under 10 CFR 72.240 requirements, the applicant must provide a description of AMPs for management of issues associated with aging that could adversely affect SSCs ITS. The applicant provided the following AMPs in the renewal application:

(1) TN-68 AMP
(2) Storage Pad AMP
(3) High-Burnup (HBU) Fuel AMP

The staff used the guidance in NUREG-1927, Section 3.6, to review the applicant's AMPs. In particular, the staff used the guidance in NUREG-1927, Section 3.6.1, which provides detailed instructions regarding the review of the ten elements that should be part of an AMP. . The staff also used the information in NUREG-2214, Chapter 6, Example Aging Management Programs, that contains example AMPs that an applicant may use to address the credible aging effects identified in the AMR tables. The staff used the information in NUREG-2214, Sections 6.6, Reinforced Concrete Structures, and the example AMP for concrete structures in NUREG-2214, Table 6-3, to inform the review of the applicant's AMP for the reinforced concrete storage pad. The staff used the information in NUREG-2214, Section 6.7, Monitoring of Metallic Surfaces, and Section 6.8, Bolted Cask Seal Leakage Monitoring, along with the example AMP for monitoring of metallic surfaces in NUREG-2214, Table 6-4, and the example AMP for bolted cask seal leakage monitoring in NUREG-2214, Table 6-5, to inform the review of the applicant's AMP for the TN-68 Dry Storage Cask. The staff used the information in NUREG-2214, Sections 6.10, High-Burnup Fuel Monitoring and Assessment, and the example AMP for high-burnup fuel in NUREG-2214, Table 6-7, to inform the review of the applicant's AMP for the high-burnup fuel.

The staff compared the content of the AMPs provided by the applicant to the results of the AMR. The staff determined that the AMPs provided by the applicant are consistent with the results of the AMR for SSCs within the scope of the renewal review and address credible aging effects that were not dispositioned with TLAAs or supplemental analyses. The staff conducted the safety review of the proposed AMPs in the renewal application per the guidance in NUREG-1927, and, when applicable, to the generically acceptable example AMPs in NUREG-2214. The staff's review of the AMPs provided by the applicant is detailed in the following subsections.

3.6.1 TN-68 AMP

The staff conducted the safety review of the proposed AMPs in the renewal application per the guidance in NUREG-1927, Section 3.6.1, specific to each AMP element. In addition, the staff used the generically acceptable example AMPs in NUREG-2214, Table 6-5, for the review of the pressure monitoring system.

<u>Scope of program</u>: The applicant stated that the program visually inspects and monitors the condition of the TN-68 subcomponents listed in the renewal application, Table 4-1. The applicant stated that the renewal application, Section 4.3, identifies the materials aging effects to be managed and includes:

- Steel
    - Loss of material due to general, pitting, crevice, and galvanic corrosion
    - Loss of preload due to stress relaxation of bolts

- Stainless Steel
    - Loss of material due to pitting, crevice, and galvanic corrosion
- Polymers
    - Shrinkage/cracking due to thermal aging and radiation embrittlement
- Aluminum
    - Loss of material due to general, pitting, crevice, and galvanic corrosion

The staff reviewed the applicant's description of the scope of program for the TN-68 AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.1. The staff verified that the scope of program identifies the specific SSCs and subcomponents covered by the AMP, the intended function to be maintained (i.e., meeting regulatory dose limits), and identifies the specific materials, environments, and aging mechanisms and effects to be managed. The staff determined that the scope of program for the TN-68 AMP covers all of the potential aging mechanisms and effects identified in the AMR for the subcomponents of the TN-68 Dry Storage Cask that are within the scope of the renewal review. Therefore, the staff determined that the applicant's description for the scope of program AMP element was acceptable.

<u>Preventive actions</u>: The applicant stated that the TN-68 AMP is a condition-monitoring program that does not include preventive actions.

The staff determined that the applicant's description of the preventive actions AMP element follows the guidance in NUREG-1927, Section 3.6.1.2, which states that some condition or performance monitoring programs do not rely on preventive actions and thus this information need not be provided. Therefore, the staff determined that the applicant's description for the preventive actions AMP element was acceptable.

<u>Parameters monitored or inspected</u>: The applicant stated that the TN-68 AMP consists of interseal pressure monitoring, radiation monitoring, and visual inspections of the subcomponents within the scope of the TN-68 AMP for the aging mechanisms and effects identified in the renewal application, Table 4-1. The applicant stated that monitoring of the interseal pressure of the TN-68 Dry Storage Cask is used to verify the integrity of the TN-68 Dry Storage Cask seals. The applicant stated that gamma and neutron radiation monitoring will be conducted to ensure that there is no loss of the shielding intended safety function. The applicant stated that visual inspections will be performed on the TN-68 Dry Storage Cask looking for loss of material for steel and stainless steel subcomponents.

The staff reviewed the applicant's description of the parameters monitored and inspected for the TN-68 AMP and determined that the description was acceptable because the program element identifies the specific parameters that will be monitored or inspected to identify degradation before a loss of intended function, meaning the program element follows the guidance in NUREG-1927, Section 3.6.1.3. Therefore, the staff determined that the applicant's description of the parameters monitored on inspected AMP element was acceptable.

<u>Detection of aging effects</u>: The applicant stated that the interseal pressure is monitoring by measuring the pressure in the overpressure system. Monitoring of the overpressure system, which controls the interseal pressure, is used to determine if the TN-68 Dy Storage Cask seals continue to function as designed. A decrease in pressure is an indication that one of the seals in TN-68 Dry Storage Cask is allowing helium gas to leak past the seal. The TN-68 AMP uses the same equipment, methods, and frequency used to comply with TS 3.1.5, "Cask Interseal

Pressure." In addition, the applicant stated that the TS Surveillance Requirement (SR) 3.1.5.1 requires verification that the cask interseal helium pressure is above 3.0 atm absolute every seven days.

The applicant stated that the detection of gamma and neutron radiation is accomplished by placing thermoluminescent dosimeters (TLDs) at the ISFSI perimeter fence and conducting surveys of neutron radiation around the perimeter of the storage pad. The applicant stated that TLDs for monitoring neutron radiation shall be capable of detecting low, intermediate, and high energy neutrons such as with a Columbia Resin (CR) 39 polycarbonate chip or equivalent dosimetry equipment. The placement of the TLDs depends on the characteristics of each site and justification of the placement of the TLDs must be documented in a site's program documentation. The applicant stated that the TLD readings are obtained quarterly and the neutron surveys will be performed annually. Increases in dose rates are attributable to deterioration of the gamma and neutron shielding because radiation from spent fuel decreases over time. Thus, the results from these monitoring activities provide a means to detect deterioration of the TN-68 Dry Storage Cask gamma and neutron shielding due to loss of material, shrinkage, or cracking before the limits in 10 CFR 20.1301 and 10 CFR 72.104 are exceeded. This is because radiation from spent fuel decreases over time and if an increase is detected, it would likely be from degradation to the shielding.

The applicant stated that visual inspection referenced under the "Parameters monitored or inspected," AMP element (either direct or remote) will be performed on the surfaces of in-scope subcomponents in the normally accessible and non-accessible areas. The applicant stated that accessible surfaces of all TN-68 Dry Storage Casks will be visually inspected on an annual basis. In addition, the applicant stated that a scheduled visual inspection of normally non-accessible areas of a lead TN-68 Dry Storage Cask will be performed within two years prior to 20 years of the first loaded TN-68 Dry Storage Cask being placed in storage, or no later than eighteen months after the effective date of the CoC No. 1027 renewal, whichever is later. The applicant stated that the initial inspection will serve as a baseline and subsequent inspections would occur on a frequency of every 20 ± 1 years thereafter.

The applicant stated that visual inspections are looking for loss of material identified by corrosion or rust stains on steel or stainless steel surfaces and rust stains on the concrete pad. The applicant clarified that removal of bolts for the annual inspection of in-scope subcomponents is not required. The applicant stated that ASME nondestructive examination (NDE) qualifications are not required to perform the visual inspections of accessible areas; however, the inspectors of accessible areas shall be trained/qualified per the licensees' specific procedures. For the visual examinations of the normally non-accessible areas the applicant stated that the personnel performing the inspection shall be qualified and certified in accordance with ASME Section XI, IWA-2300.

The staff reviewed the applicant's detection of aging effects for the TN-68 AMP and determined that the description was acceptable because the program element identifies the inspection method, samples size, timing of inspections, and inspection frequency necessary to identify degradation before a loss of intended function.

The staff found that the detection of aging effects using interseal pressure monitoring was acceptable because the TN-68 AMP utilizes the same equipment, methods, and frequency used to comply with TN-68 TS 3.1.5. The staff noted that the TN-68 Dry Storage Cask design uses an inner and outer seal with the interseal region at a higher pressure than either the cask interior or the external environment. By monitoring the pressure in the interseal region using the overpressure system, any leak of either the inner or the outer seal would be readily detected. The staff noted that the pressure monitoring systems on bolted lid spent fuel storage systems have detected the seal leakage as a result of seal corrosion prior to a loss of intended function.

The staff found that the radiation monitoring was capable of detecting any degradation to the gamma and neutron shield based on TLDs constantly monitoring the area and annual radiation surveys. The TLDs are in place to confirm compliance with limits in 10 CFR 20.1301 and 10 CFR 72.104. TLDs may not be able to detect localized failure of a single cask as they detect an average dose rate at a distance. Localized degradation that would result in a hot spot near an individual cask would affect workers near the area of degradation and would be detected when surveys are performed to obtain a radiation work permit before workers entered the area, as stated in the March 24, 2021 supplement (ADAMS Accession No. ML21083A029). Any areas that have unexpectedly high radiation would be entered into the corrective action program as a matter of standard radiation protection practices. The annual visual inspections additionally ensure that degradation to the gamma shielding would be detected because corrosion of the steel cask would be readily identified by the visual inspection and annual neutron surveys ensure that degradation to the neutron shielding would be detected. This provides assurance that any shielding degradation resulting in streaming paths not seen by the TLDs would be detected.

The staff found that the stated visual inspections, looking for loss of material identified by corrosion or rust stains on steel or stainless steel surfaces and rust stains on the concrete pad, are acceptable because corrosion of the carbon steel and stainless steel components will produce corrosion products that are readily apparent. In addition, the staff determined that the personnel requirements, which stipulate that the annual inspection will be performed by staff trained by the general licensee, and the inspection of the normally non-accessible areas which the applicant's mandate be performed by ASME qualified personnel, are sufficient for the detection of aging effects to prevent a loss of intended function. The staff determined that the 20 year inspection interval for the normally non-accessible components of the TN-68 Dry Storage Cask was acceptable because the cask design provides protection of these subcomponents and the OE review did not identify aging-related issues that would require more frequent inspection intervals.

The staff determined that the applicant's description for the detection of aging effects AMP element follows the guidance in NUREG-1927, Section 3.6.1.4, and identifies how the potential aging effects for the TN-68 Dry Storage Cask will be detected by the inspection and monitoring methods specified in the AMP. Therefore, the staff determined that the applicant's description of the detection of aging effects AMP element was acceptable.

Monitoring and trending: The applicant stated that general licensees perform the inspections and monitoring activities in the TN-68 AMP periodically to identify areas of degradation and that conditions that do not meet the acceptance criteria are entered into the general licensee's corrective action program. The applicant stated that visual inspections consider the cumulative OE from previous inspections and assessments in order to monitor and trend the progression of aging effects over time. The applicant stated that general licensees will compare the data taken from inspections and monitoring activities to past site data taken as well as to industry OE, including data gathered by the Institute of Nuclear Power Operations (INPO) Aging Management INPO Database (AMID), as discussed in Nuclear Energy Institute (NEI) 14-03 (NEI 2016).

The staff reviewed the applicant's description of the monitoring and trending element for the TN-68 AMP and determined that the applicant's description follows the guidance in NUREG-1927, Section 3.6.1.5. Specifically, the applicant's description for the AMP element includes a baseline inspection established at the beginning of the PEO and the applicant described how the data will be collected and evaluated against the results of past inspection data. The staff found the frequency of the radiation monitoring and trending reasonable and acceptable based on the requirement that there be multiple modes of detection with acceptance criteria to identify aging effects. These include, as described above in this and the preceding sections, annual visual inspections, annual neutron monitoring, continuous monitoring by the TLDs, and the necessary radiation surveys as needed to support radiation work permits. Therefore, the staff determined that the applicant's description of the detection of aging effects AMP element was acceptable.

Acceptance criteria: The applicant stated that the acceptance criterion for interseal pressure monitoring is the limit specified in TN-68 TS 3.1.5 —i.e., the cask interseal pressure shall be maintained at a pressure of a least 3.0 atm absolute. The applicant stated that the acceptance criterion for radiation monitoring is the absence of an annual increasing trend in neutron or gamma quarterly TLD readings at the ISFSI perimeter fence and absence of an annual increasing trend in the neutron surveys at the storage pad perimeter. The applicant stated that the acceptance criteria for the visual inspections are no observed corrosion, no rust stains on steel or stainless steel surfaces, and no rust stains on the concrete pad. In addition, the applicant stated that if any of the above acceptance criteria are not met, further evaluation is required through the general licensee's corrective action program.

The staff determined that the applicant's description of the acceptance criteria AMP element follows the guidance in NUREG-1927, Section 3.6.1.6. The staff determined that the acceptance criteria for interseal pressure monitoring is acceptable because it is based on the limit specified in TN-68 TS 3.1.5, which assures that the original design basis is maintained throughout the PEO. The staff determined that the applicant's acceptance criteria for gamma and neutron radiation monitoring were acceptable because the TN-68 AMP specifies measurement and monitoring of gamma and neutron radiation trends. An increasing trend might indicate degradation of the shielding, as the radiation source should decay over time. Therefore, the staff found that the acceptance criteria were appropriate. The staff determined that the applicant's acceptance criteria for visual inspection of corrosion—which specifies no observed corrosion, no rust stains on steel or stainless steel surfaces, and no rust stains on the concrete pad—were acceptable because corrosion products are readily observed in visual inspection and the observed presence of corrosion products indicates corrosion that could result in a loss of material. The staff verified that the applicant's description of the acceptance criteria AMP element includes that any inspection or monitoring result that does not meet the acceptance criteria would be entered into the general licensee's corrective action program for further evaluation. Therefore, the NRC staff found the applicant's description of the acceptance criteria AMP element to be acceptable.

Corrective actions: The applicant stated that under the AMP, general licensees implement quality assurance (QA) procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. This ensures that general licensees promptly identify and correct conditions adverse to quality. These procedures include root cause determination and prevention of recurrence. The applicant stated that general licensees either correct deficiencies (i.e., inspection results that do not meet acceptance criteria) or evaluate the cask to be acceptable for continued service through engineering analysis. This engineering analysis provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. In addition, the applicant stated that the extent of condition investigation per the licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

The staff reviewed the applicant's description of the corrective action element for the TN-68 AMP and verified that the corrective actions for the TN-68 Dry Storage Cask AMP state the measures to be taken when the acceptance criteria are not met, and include root cause determination and prevention of recurrence for significant conditions adverse to quality. Based on this, the staff determined that the corrective actions followed the guidance in NUREG-1927, Section 3.6.1.7, which states that an applicant may reference the use of the corrective action program approved under 10 CFR Part 50, Appendix B. Therefore, the staff finds the applicant's description of the corrective actions AMP element to be acceptable.

Confirmation process: The applicant stated that the confirmation process will be commensurate with the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. The applicant stated that the general licensee's QA program approved under 10 CFR Part 50, Appendix B, also contains provisions to preclude repetition of significant conditions adverse to quality.

The staff reviewed the applicant's description of the confirmation process element for the TN-68 AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.8, which states that the confirmation process AMP element is intended to verify that preventive actions are adequate and that appropriate corrective actions have been completed and are effective. The staff verified that the confirmation process for the TN-68 AMP includes provisions to verify that appropriate corrective actions have been completed and are effective and relies on the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which contains provisions to preclude repetition of significant conditions adverse to quality. Therefore, the staff determined that the applicant's description of the confirmation process AMP element was acceptable.

Administrative controls: The applicant stated that the administrative controls under the CoC holder or general licensee's QA procedures and corrective action program provide a formal review and approval process. The applicant stated that the administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. The applicant stated that general licensees and CoC holders use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.

The staff reviewed the applicant's description of the administrative controls element for the TN-68 AMP using the guidance in NUREG-1927, Section 3.6.1.9. The staff confirmed that the applicant's description of the administrative controls under the CoC holder's or general licensees' QA procedures and corrective action program provide a formal review and approval process for the TN-68 AMP. The staff determined that the applicant's description states that the administrative controls are in accordance with the general licensee QA program approved under 10 CFR Part 50, Appendix B, and will continue for the PEO. Therefore, the staff determined that the applicant's description of the administrative controls AMP element was acceptable.

Operating experience: The applicant stated that renewal application Appendix 3C documents the review of various sources of OE relevant to the TN-68 Dry Storage Cask and includes the results of inspections of the TN-68, TN-32, and TN-40 Dry Storage Casks in service. The applicant stated that the TN-68 AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. The applicant noted that future plant-specific and industry aging management and aging-related OE are captured through the general licensees' OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

The staff reviewed the applicant's description of the operating experience AMP element for the TN-68 AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.10. Specifically, the staff determined that the applicant's description identified the relevant sources of OE listed in NUREG-1927, Section 3.6.1.10. The staff determined that the applicant assessed current OE and included provisions to capture future plant-specific and industry aging management and aging-related operating experience through the general licensee's operating experience review process. Therefore, the staff determined that the applicant's description of the operating experience AMP element was acceptable.

The staff review verified that each element of the TN-68 AMP contained the provisions necessary so that the AMP will be effective for identifying degradation of the TN-68 Dry Storage Casks and implementing corrective actions before a loss of intended function. The staff determined that the AMP for the TN-68 Dry Storage Casks is consistent with the guidance provided in NUREG-1927, Section 3.6.1. Thus, the staff determined that the AMP for the TN-68 Dry Storage Casks in the renewal application was acceptable for managing the aging effects as a result of credible aging mechanisms.

3.6.2 Storage Pad AMP

This subsection documents the staff review of the storage pad AMP. The staff used the review guidance in NUREG-1927, Section 3.6.1 specific to each AMP element. In addition, the staff used the generically acceptable example AMPs in NUREG-2214, Table 6-3, for the review of the reinforced concrete structures.

Scope of program: The applicant stated that the program calls for general licensees to visually inspect the surfaces of the storage pad subcomponents listed in the renewal application, Table 4-2. The applicant stated that the renewal application Section 4.4 identifies the materials aging effects to be managed, as follows:

- Steel
    - Loss of material due to general corrosion, pitting corrosion, and crevice corrosion
- Concrete
    - Loss of material due to freeze-thaw, aggressive chemical attack, corrosion of reinforcing steel, delayed ettringite formation, salt scaling, and microbiological degradation
    - Cracking due to freeze-thaw, reaction with aggregates, differential settlement, aggressive chemical attack, corrosion of reinforcing steel, and delayed ettringite formation

- o Loss of strength due to reaction with aggregates, aggressive chemical attack, corrosion of reinforcing steel, leaching of calcium hydroxide, delayed ettringite formation, and microbiological degradation
- o Reduction of concrete pH due to aggressive chemical attack, leaching of calcium hydroxide, and microbiological degradation
- o Loss of concrete/steel bond due to corrosion of reinforcing steel
- o Increase in porosity and permeability due to leaching of calcium hydroxide and microbiological degradation

The staff reviewed the applicant's description of the scope of program for the storage pad AMP and determined that the description was acceptable because the program element follows the guidance in NUREG-1927, Section 3.6.1.1, and is consistent with the example AMP in NUREG-2214, Table 6-3. The staff verified that the scope of program identifies the specific SSCs and subcomponents covered by the AMP, the intended function to be maintained and identifies the specific materials, environments, and aging mechanisms and effects to be managed. The staff determined that the scope of the program for the Storage pad AMP covers all of the potential aging mechanisms and effects identified in the AMR for the subcomponents of the storage pad that are within the scope of renewal. Therefore, the staff determined that the applicant's description for the scope of program AMP element was acceptable.

<u>Preventive actions</u>: The applicant stated that the storage pad AMP is a condition-monitoring program that does not include preventive actions.

The staff determined that the applicant's description is acceptable because, as noted in NUREG-1927, Section 3.6.1.2, some condition or performance monitoring programs do not rely on preventive actions and thus this information need not be provided. Therefore, the staff determined that the applicant's description for the preventive actions AMP element was acceptable.

<u>Parameters monitored or inspected</u>: The applicant stated that the storage pad AMP consists of visual inspections to monitor for material degradation as identified in renewal application, Table 4-2. The applicant stated that accessible areas of the storage pad will undergo direct visual inspection, including the aboveground exposed surface of the storage pad. The applicant stated that the normally non-accessible areas of the storage pad include external surfaces of the storage pad under the TN-68 Dry Storage Casks and that the inaccessible areas of the storage pad include below-grade surfaces of the storage pad and the components embedded in concrete. The applicant did not include inspection of the normally non-accessible concrete surface area under the TN-68 Dry Storage Casks or the inaccessible areas of the storage pad that is below-grade.

The staff reviewed the applicant's description of the parameters monitored and inspected for the storage pad AMP and determined that the applicant's description of the AMP element follows the guidance in NUREG-1927, Section 3.6.1.3. The staff determined that the applicant's description identifies the specific parameters that will be monitored or inspected to identify degradation before a loss of intended function. The staff determined that the applicant's AMP element description is also consistent with the example AMP in NUREG-2214, Table 6-3. Therefore, the staff determined that the applicant's description of the parameters monitored or inspected AMP element was acceptable.

Detection of aging effects: The applicant stated that under the AMP, general licensees are to conduct direct visual inspections utilizing ACI-349.3R, "Report on Evaluation and Repair of Existing Nuclear Safety-Related Concrete Structures" (ACI 2018), Section 3.6.1, "Visual inspection," for the above-grade portions of the concrete storage pad, allowing for detection of aging effects from the renewal application, Table 4-2. In response to an RAI (ADAMS Accession No. ML21040A406), the applicant stated that the visual inspection of the storage pad shall be conducted by staff that meet the qualification requirements of ACI-349.3R, Chapter 7. The applicant stated that for storage pad concrete, crack maps are developed and dimensioning is documented in photographic records by inclusion of a tape measure/crack gauge, a comparator, or both.

The applicant stated that general licensees assess potential degradation of the below-grade portion of the concrete pad by inspecting the aboveground exposed surfaces of the storage pads for indications of aging and by reviewing the results of groundwater sampling at a minimum of three locations in the area of the ISFSI to ensure the below-grade portions are not exposed to an aggressive environment. The applicant stated that the approach is consistent with the Type 1 below-grade inaccessible areas in Section 6 of ACI 349.3R-2018 except the AMP does not explicitly call out for inspections of opportunity if the below-grade concrete is exposed due to excavation for any reason. In response to an RAI (ADAMS Accession No. ML21040A406), the applicant stated that the inspection of opportunity was not included in the AMP is because the likelihood of excavating adjacent to an existing ISFSI pad is so small that the potential aging management benefit does not warrant the additional procedural complexity required to ensure that the inspections of opportunity would be performed.

The applicant stated that the baseline AMP visual inspection and groundwater sampling is to be conducted within two years prior to 20 years of the first loaded TN-68 Dry Storage Cask being placed in storage, or no later than eighteen months after the effective date of the CoC renewal, whichever is later. The applicant stated that subsequent inspections and groundwater sampling are to be conducted every 5 years ± 1 year following the baseline inspection.

The staff reviewed the applicant's description of the detection of aging effects for the storage pad AMP element description and determined that it follows the guidance in NUREG-1927, Section 3.6.1.4. The applicant's description identifies the inspection method, sample size, timing of inspections, and inspection frequency. The staff determined that the applicant described how the potential aging effects for the storage pad will be detected by the inspection and monitoring methods identified in this AMP. The staff also determined that the description for the detection of aging effects for the storage pad AMP element is consistent with the example AMP in NUREG-2214, Table 6-3, with the exception of the opportunistic inspection associated with excavations. The staff noted that the example AMP for reinforced concrete structures in NUREG-2214, Table 6-3, relies on the methodology included in ACI 349.3R including the inspection techniques, frequency of inspection, and personal qualification requirements. The staff determined that the inspection of the above ground accessible portions of the concrete pad combined with groundwater chemistry monitoring is sufficient to monitor for aging of the storage pad and identify degradation before a loss of intended function and, based on that, inspection of opportunity is not necessary to find the applicant's description of this AMP element acceptable. Therefore, the staff determined that the applicant's description of the detection of the aging effects AMP element was acceptable.

Monitoring and trending: The applicant stated that general licensees perform the inspections and monitoring activities in the storage pad AMP periodically to identify areas of degradation and to ensure that conditions that do not meet the acceptance criteria are entered into the general licensee's corrective action program. The applicant stated that the monitoring and trending AMP element considers the cumulative OE from previous storage pad inspections and assessments in order to monitor and trend the progression of aging effects over time. The applicant stated that general licensees will monitor data from the inspections and ground water sampling. The applicant stated that the data obtained will be compared to past site data as well as to industry OE, including data gathered by the AMID as discussed in NEI 14-03.

The staff reviewed the applicant's description of the monitoring and trending element for the storage pad AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.5. The staff determined that the AMP element includes a baseline inspection established at the beginning of the PEO, describes how the data will be collected, and describes the evaluation of the results against the AMP acceptance criteria to ensure that the timing of the next scheduled inspection will occur before a loss of intended function. Therefore, the staff determined that the applicant's description of the parameters monitored or inspected AMP element was acceptable.

<u>Acceptance criteria</u>: The applicant listed the visual inspection acceptance criteria which are consistent with those in ACI 349.3R in renewal application Section 4.4.6. In response to an RAI (ADAMS Accession No. ML21040A406), the applicant stated that the justification for using the ACI 349.3R acceptance criteria was because ACI 349.3R is the recognized industry standard for managing aging effects of concrete. The applicant stated that the majority of the second-tier criteria in ACI 349.3R address conditions where the degradation results in the concrete material being replaced by discrete air pockets such as cracking or spalling. The applicant stated that since air has lower heat conductivity than the concrete material, the acceptance criteria in ACI 349.3R can be extended to be applicable for monitoring the concrete thermal function. The applicant noted that the magnitude of the acceptance criteria such as the size of cracks or spalling is very small compared to the surface area of the pad under the cask. Therefore, the applicant concluded that while the focus of ACI 349.3R may be the structural performance of the concrete, it may also be used to ensure that the thermal intended safety function is maintained. The applicant also included acceptance criteria for the groundwater chemistry-sampling program with specific criteria for pH, and the concentrations of chlorides and sulfates. In addition, the applicant stated that if any of the above acceptance criteria are not met, further evaluation is required through the general licensee's corrective action program.

The staff reviewed the applicant's description and determined that the acceptance criteria follow the guidance in NUREG 1927, Section 3.6.1.6, and are based on an accepted ACI 349.3R code second-tier acceptance criteria for the inspection of concrete structures and included specific numerical values to ensure that the design bases are maintained. The staff determined that the applicant's description of the groundwater monitoring program is also consistent with the criteria in ACI 349.3R and ASME Code Section XI, Subsection IWL. In addition, the staff determined that the applicant's acceptance criteria for visual inspection and groundwater monitoring in the storage pad acceptance criteria AMP element description are consistent with the example AMP in NUREG-2214, Table 6-3. Therefore, the NRC staff found the applicant's description of the acceptance criteria AMP element to be acceptable.

<u>Corrective actions</u>: The applicant stated that that under the AMP, the general licensee's QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. This ensures that general licensees promptly identify and correct conditions adverse to quality. These procedures include root cause determination and prevention of recurrence. The applicant stated that deficiencies are either corrected or are evaluated to be acceptable for continued service through engineering

analysis, which provides reasonable assurance that the intended safety function is maintained consistent with current licensing basis conditions. In addition, the applicant stated that the extent of condition investigation per the general licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

The staff reviewed the applicant's description of the corrective action AMP element and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.7. The staff verified that the corrective actions for the storage pad AMP state the measures to be taken when the acceptance criteria are not met and include root cause determination and prevention of recurrence for significant conditions adverse to quality. Based on this, the staff determined that the corrective action descriptions followed the guidance in NUREG-1927, which states that an applicant may reference the use of the corrective action program approved under 10 CFR Part 50, Appendix B. Therefore, the staff finds the applicant's description of the corrective actions AMP element to be acceptable.

<u>Confirmation process</u>: The applicant stated that under the AMP, the confirmation process will be commensurate with the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. The applicant stated that the general licensee's QA program approved under 10 CFR Part 50, Appendix B, also contains provisions to preclude repetition of significant conditions adverse to quality.

The staff reviewed the applicant's description of the confirmation process element for the storage pad AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.8, which states that the confirmation process AMP element is intended to verify that preventive actions are adequate and that appropriate corrective actions have been completed and are effective. The staff verified that the confirmation process for the storage pad AMP includes provisions to verify that appropriate corrective actions have been completed and are effective and that the AMP relies on the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which contains provisions to preclude repetition of significant conditions adverse to quality. Therefore, the staff determined that the applicant's description of the confirmation process AMP element was acceptable.

<u>Administrative controls</u>: The applicant stated that the administrative controls under the CoC holder or general licensee's QA procedures and corrective action program provide a formal review and approval process. The applicant stated that the CoC holder and general licensees implement the administrative controls in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue to do so for the PEO. The applicant stated that general licensees and the CoC holder use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.

The staff reviewed the applicant's description of the administrative controls element for the storage pad AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.9. The staff confirmed that the applicant's description of the administrative controls under the CoC holder's or general licensees' QA procedures and corrective action program provides a formal review and approval process for the storage pad AMP. The staff determined that the applicant's description states that the administrative controls are in accordance with the general licensees' QA program approved under 10 CFR Part 50, Appendix

B, and will continue for the PEO. Therefore, the staff determined that the applicant's description of the administrative controls AMP element was acceptable.

Operating experience: The applicant included inspections of TN-68, Dry Storage Casks as well as the TN-32, and TN-40 Dry Storage Casks, and the storage pads at specifically licensed ISFSIs that have been in service for several years in renewal application Appendix 3C. The storage pad inspections at the specifically licensed ISFSIs did not identify storage pad aging effects. The applicant stated that the storage pad AMP will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. The applicant noted that future plant-specific and industry aging management and aging-related OE are captured through the general licensee's OE review process. The ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects.

The staff reviewed the applicant's description of the operating experience element for the storage pad AMP and determined that the description follows the guidance in NUREG-1927, Section 3.6.1.10. The staff determined that the applicant assessed current OE and included provisions to capture future plant-specific and industry aging management and aging-related operating experience through the general licensee's OE review process. Therefore, the staff determined that the applicant's description of the operating experience AMP element was acceptable.

The staff's review verified that each element of the storage pad AMP contained the provisions necessary so that the AMP will be effective for identifying degradation of the storage pads for the TN-68 Dry Storage Casks and implementing corrective actions before a loss of intended function. The staff determined that the AMP for the storage pad is consistent with the guidance provided in NUREG-1927, Section 3.6.1. Therefore, the staff determined that the AMP for the storage pad in the renewal application was acceptable for managing the aging effects as a result of credible aging mechanisms.

3.6.3 HBU Fuel AMP

The staff conducted the safety review of the applicant's HBU fuel AMP in the renewal application per the guidance in NUREG 1927, Appendix D. In addition, the staff compared the HBU fuel AMP provided by the applicant to the generically acceptable example AMP in NUREG-2214, Section 6.10, and Table 6-7.

Scope of program: The applicant stated that the program relies on the joint EPRI and Department of Energy (DOE) HBU Dry Storage Cask Research and Development Project (HDRP) (EPRI 2014). The applicant stated that the AMP is conducted in accordance with the guidance in Appendix D of NUREG-1927. The demonstration program may be used as a surrogate for monitoring the performance of HBU fuel in dry storage. The HDRP is a program designed to collect data from a spent nuclear fuel storage system containing HBU fuel in a dry helium environment. The program entails loading and storing an AREVA TN-32B bolted lid cask at Dominion Virginia Power's North Anna Power Station with intact HBU pressurized water reactor (PWR) fuel with burnups ranging from 53 to 58 GWd/MTU. The applicant stated that the fuel used in the HDRP includes four kinds of cladding (Zircaloy-4, low-tin Zircaloy-4, ZIRLO®, and M5®) which are PWR fuel cladding materials. The applicant provided a justification for the use of the HDRP as a surrogate for the HBU fuel AMP, which included consideration of (1) fuel burnup, (2) a comparison of Zircalloy-2 cladding for BWR fuel to M5 cladding used in the HDRP, and (3) fuel temperature limits during drying operations and storage.

In response to a request for supplemental information (RSI) (ADAMS Accession No. ML20211L707) the applicant provided additional information to support the use of the results from the HDRP to assess the performance of high-burnup Zircaloy-2 clad fuel approved for storage in the TN-68 Dry Storage Cask. The additional information provided by the applicant addressed staff questions on the hydride reorientation embrittlement threshold, allowable burnup, threshold stresses for reorientation, and allowable temperature limits compared to the measured temperatures in the HDRP. The applicant stated that all Zircaloy-2 clad high-burnup fuel in the TN-68 Dry Storage Cask have a pure zirconium liner which was introduced in the 1980s. The additional information provided by the applicant referenced EPRI-3002016033, "Effect of Hydride Reorientation in Spent Fuel Cladding—Status from Twenty Years of Research" (EPRI 2020). As described in EPRI-3002016033, Section 7.1, the differences in the hydrogen solubility and temperature controlling the formation of hydrides for Zircaloy-2 compared to the pure zirconium liner causes the liner to act as a hydrogen sink during cooling. This effectively immobilizes the hydrogen into the thin inner layer. Consequently, hydrogen is no longer available for precipitation in the form of hydrides in the bulk of the cladding alloy, eliminating the potential for reorientation. EPRI-3002016033 concludes that BWR fuel rods with a cladding containing a zirconium liner are not susceptible to hydride reorientation during dry storage and are, therefore, expected to retain, or even improve, ductility. The applicant also provided information on end of life cladding internal pressures for Zircaloy-2 compared to the hoop stress threshold for reorientation and support the use of data on the M5® cladding included in the HDRP as an analog for Zircaloy-2 cladding. The applicant also provided a comparison of the peak cladding temperature calculated for the TN-68 Dry Storage Cask to the measured temperatures in the HDRP. Based on the information provided in the RSI response, the applicant stated that, while BWR Zircaloy-2 cladding is not expected to be sensitive to hydride reorientation embrittlement because of the inner liner and the low hoop stress, the DOE High Burnup Dry Storage Cask Research and Development Project can be used as a surrogate for the HBU Zircaloy-2 clad fuel in the TN-68 Dry Storage Cask.

The staff reviewed the applicant's description of the scope of program for the HBU fuel AMP and determined that the description follows the supplemental guidance in Appendix D to NUREG-1927 and is consistent with the example high-burnup fuel AMP in NUREG-2214, Table 6-7. The staff determined that the applicant's reliance on the HDRP for the HBU fuel AMP is acceptable because the HDRP is representative of the fuel cladding materials and burnups approved for the TN-68. In addition, the evaluations conducted by the HDRP are applicable to evaluations of the intended functions to be maintained, operating environments, and the aging mechanisms and effects for the high-burnup fuel approved for storage in the TN-68. Therefore, the staff determined that the applicant's description for the scope of program AMP element was acceptable.

Preventive actions: The applicant stated that during the initial loading operations of the cask, the design and CoC TS require that the fuel be stored in a dry and inert environment. The applicant stated that CoC TS 3.1.1 requires that the cask cavity be dried by maintaining a cavity absolute pressure less than or equal to four mbar (3 Torr) for at least 30 minutes with the cask isolated from the vacuum pump. The applicant also stated that CoC TS 3.1.2 requires that the cask then be backfilled with helium to a pressure of two atm absolute. The applicant stated that these two TS requirements ensure that the HBU fuel is stored in a dry and inert environment, thus preventing cladding degradation due to oxidation mechanisms.

The staff determined that the applicant's description of preventive actions is consistent with the example high-burnup fuel AMP in NUREG-2214, Table 6-7. The staff confirmed that the procedures and TS for spent fuel loading were consistent with the NRC guidance in ISG-11, Revision 2 (ADAMS Accession No. ML022110372) (NRC 2002), or ISG-11, Revision 3 (ADAMS Accession No. ML033230335), including the maximum fuel cladding temperature limits, and specific limits on thermal cycling during drying operations. The staff determined that the TN-68 Dry Storage Cask design basis and TS for loading operations are sufficient to prevent aging or mitigate the rates of aging for the zirconium alloy cladding in drying operations and during storage. Therefore, the staff determined that the applicant's description for the preventive actions AMP element was acceptable.

Parameters monitored or inspected: The applicant stated that the parameters monitored or inspected are as described in the HDRP. While the research project cask is on the storage pad, these parameters include temperature measurements at various locations within the cask and noted that temperature is the key driver for hydride-induced embrittlement and thermal creep. The research project cask will be transported to an off-site fuel examination facility, where the cask will be reopened, and the fuel examined for changes that occurred as a result of the drying operation and during storage.

The staff reviewed the applicant's description of the parameters monitored and inspected for the HBU fuel AMP and determined that the applicant's description is consistent with the example burnup fuel AMP in NUREG-2214, Table 6-7, and follows the supplemental guidance in Appendix D to NUREG-1927. The staff verified that the program element identifies the specific parameters that will be monitored or inspected includes parameters that are directly tied to degradation mechanisms for HBU fuel. The staff determined that because the applicant's AMP includes examination of the fuel in the HDRP for evidence of aging mechanisms after a storage period, the parameters monitored and inspected will be capable of identifying degradation or potential degradation before a loss of intended function of the HBU fuel in the TN-68. Therefore, the staff determined that the applicant's description of the parameters monitored on inspected AMP element was acceptable.

Detection of aging effects: As previously noted, the applicant stated that while the research project cask is on the storage pad, temperature is measured at various locations within the cask because temperature is the key driver for hydride-induced embrittlement and thermal creep. The applicant stated that after approximately 10 years of storage at the ISFSI site, the research project cask will likely be transported to an off-site fuel examination facility where rods will be extracted from the HBU assemblies for nondestructive and destructive examinations. The nondestructive and destructive exams will include cladding profilometry to evaluate creep, rod internal gas pressure, hydride content and orientation, and cladding mechanical property tests. Data from these examinations will provide a direct indication of the susceptibility of high-burnup fuel to hydride-induced embrittlement and thermal creep during dry storage.

The staff reviewed the applicant's detection of aging effects for the HBU fuel AMP and determined that the description is consistent with example burnup fuel AMP in NUREG-2214, Table 6-7, and follows the supplemental guidance in Appendix D to NUREG-1927. The staff verified that the program element identifies the inspection method and the data to be collected from the HDRP while the cask is in storage and after the fuel rods are removed from the cask. For these reasons, the staff determined that the activities for the detection of the aging effect AMP element will be capable of identifying degradation or potential degradation of HBU fuel stored in the TN-68 before a loss of intended function. Therefore, the staff determined that the applicant's description of the detection of aging effects AMP element was acceptable.

Monitoring and trending: The applicant stated that as information and data from a surrogate demonstration program or from other sources such as testing or research results and scientific analyses become available, the general licensees will monitor, evaluate, and trend the information. The general licensees may use their corrective action program to determine what actions should be taken or incorporate the information into OE. Formal evaluations of the aggregate information from a surrogate demonstration program and other available domestic or international OE, including data from monitoring and inspection programs and NRC-generated communications, will be performed at specific points in time during the PEO as described in the HBU fuel AMP operating experience element and the HBU fuel AMP tollgates in Table 4-3 of the renewal application.

The staff reviewed the applicant's description of the monitoring and trending element for the HBU fuel AMP and determined that the program element is consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7. The staff verified that the AMP element identifies the sources of information that will be monitored and trended. Therefore, the staff determined that the applicant's description of the detection of aging effects AMP element was acceptable.

Acceptance criteria: The applicant provided acceptance criteria are to be applied to the data obtained from the HDRP. These included acceptance criteria on cladding temperature, cladding creep, and hydride reorientation. If any of the fuel performance criteria are not met, the condition will be addressed in accordance with general licensee's corrective action program.

The staff reviewed the applicant's acceptance criteria for the HBU fuel AMP. The staff determined that the acceptance criteria for the HBU fuel AMP will rely on the data obtained from the HDRP, which was initiated to assess the performance of high-burnup fuel in dry storage. The staff noted that the applicant's HBU fuel AMP acceptance criteria differs from the acceptance criteria in NUREG-2214, Table 6-7. Specifically, the example AMP in NUREG-2214, Table 6-7, includes criteria for hydrogen content and moisture content. Although not specifically stated in the AMP description, the staff verified that that gas sampling for water content and hydrogen generation are included the HDRP and also considered in the HBU fuel AMP tollgates provided in the renewal application. In addition, the staff noted that the CoC includes TS discussed in the preventive actions HBU fuel AMP element for drying and helium backfill to assure that moisture is removed during drying and the fuel is stored in an inert environment that also facilitates heat transfer. Therefore, the NRC staff found the applicant's description of the acceptance criteria AMP element to be acceptable.

Corrective actions: The applicant stated that under the AMP, general licensee's QA procedures, review and approval processes, and administrative controls are implemented according to the requirements of 10 CFR Part 50, Appendix B. This ensures that general licensees promptly identify and correct conditions adverse to quality. These procedures include root cause determination and prevention of recurrence. The applicant stated that general licensees either correct deficiencies or evaluate the conditions to be acceptable for continued service through engineering analysis. This engineering analysis provides reasonable assurance that the intended functions are maintained consistent with current licensing basis conditions. In addition, the applicant stated that the extent of condition investigation per the general licensee's corrective action program may cause additional inspections through means of a different method, increased inspection frequency, and/or expanded inspection sample size.

The staff reviewed the applicant's description of the corrective action element for the HBU fuel AMP and determined that the description was consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7, which states that an applicant may reference the use of the corrective action program approved under 10 CFR Part 50, Appendix B. The staff verified that the applicant's HBU fuel AMP tollgates address corrective actions required based on the result obtained from the HDRP. In addition, the staff verified that the applicant's HBU fuel AMP tollgates address actions to be taken if the destructive examination data from the HDRP has not been obtained in time to support the HBU fuel AMP tollgates. Therefore, the staff finds the applicant's description of the corrective actions AMP element to be acceptable.

Confirmation process: The applicant stated that the confirmation process will be commensurate with the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which ensures that the confirmation process includes provisions to verify that appropriate corrective actions have been completed and are effective. The applicant stated that the general licensee's QA program approved under 10 CFR Part 50, Appendix B, also contains provisions to preclude repetition of significant conditions adverse to quality.

The staff reviewed the applicant's description of the confirmation process element for the HBU fuel AMP and determined that the description is consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7. The staff verified that the confirmation process for the HBU fuel AMP includes provisions to verify that appropriate corrective actions have been completed and are effective and relies on the general licensee's QA program approved under 10 CFR Part 50, Appendix B, which contains provisions to preclude repetition of significant conditions adverse to quality. Therefore, the staff determined that the applicant's description of the confirmation process AMP element was acceptable.

Administrative controls: The applicant stated that the administrative controls under the CoC holder's or general licensee's QA procedures and corrective action program provide a formal review and approval process. The applicant stated that the administrative controls are implemented in accordance with the requirements of 10 CFR Part 50, Appendix B, and will continue for the PEO. General licensees and CoC holders use the 10 CFR Part 72 regulatory requirements to determine if a particular aging-related degradation condition or event identified via OE, research, monitoring, or inspection is reportable to the NRC.

The staff reviewed the applicant's description of the administrative controls element for the HBU fuel AMP and determined that the description is consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7, with the administrative controls performed in accordance with the general licensee's QA program approved under 10 CFR Part 50, Appendix B, and will continue for the PEO. Therefore, the staff determined that the applicant's description of the administrative controls AMP element was acceptable.

Operating experience: The applicant stated that short-term testing and analyses examining the performance of HBU fuel have provided a foundation for the technical basis for storage of HBU fuel in the PEO. The applicant also stated that there has been relatively little OE to date with dry storage of HBU fuel. Consequently, the HDRP is used as a surrogate program to monitor and assess data regarding HBU fuel performance to confirm there is no degradation of HBU fuel that would result in an unanalyzed configuration during the PEO.

The applicant stated that the HBU fuel AMP will be updated as necessary to incorporate new information on degradation due to aging effects identified from plant-specific inspection findings, related industry OE, and related industry research. The general licensee's OE review process will capture future plant-specific and industry aging management and aging-related OE. Ongoing review of both plant-specific and industry OE will continue through the PEO to ensure that this AMP continues to be effective in managing the identified aging effects. In addition to the ongoing OE review, the HBU fuel AMP requires periodic written evaluations of the aggregate impact of aging-related HBU fuel operating experience, research, monitoring, and inspections on the intended functions of the in-scope HBU fuel subcomponents as described in the renewal application, Table 4-3.

The staff reviewed the applicant's description of the operating experience element for the HBU fuel AMP and determined that the description is consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7. The staff determined that the applicant assessed current OE, identified the information to be obtained in the HDRP and actions to be taken for alternative information sources if the destructive examination data from the HDRP are not obtained in time to support the HBU fuel AMP tollgates. Therefore, the staff determined that the applicant's description of the operating experience AMP element was acceptable.

The staff review verified that each element of the HBU fuel AMP contained the provisions necessary so that the AMP will be effective for identifying degradation of the HBU fuel and implementing corrective actions before a loss of intended function. The staff determined that the AMP for the HBU fuel stored in the TN-68 Dry Storage Casks is consistent with the example AMP for high-burnup fuel in NUREG-2214, Table 6-7. Thus, the staff determined that the HBU fuel AMP in the renewal application was acceptable for managing the aging effects as a result of credible aging mechanisms.

3.6.4 Changes to the Updated Final Safety Analysis Report

The applicant provided an Appendix to the renewal application that included changes to the TN-68 Dry Storage Cask UFSAR. Appendix Table A-1 documents the changes to the UFSAR associated with the renewal and describes the bases for the changes. These changes included updated TLAAs and supporting analyses for the PEO. The applicant stated that a new Section 15, "Aging Management," will be added to the UFSAR that incorporates the approved AMPs including the TN-68 AMP, the storage pad AMP, and the HBU fuel AMP.

The staff reviewed the changes to the UFSAR and determined that the changes are acceptable because the applicant has included updated TLAAs and supporting analyses for the PEO and the AMPs that will be incorporated into the UFSAR.

3.6.5 Evaluation Findings

The staff reviewed the AMPs in the renewal application. The staff performed its review following the guidance provided in NUREG-1927, and NUREG-2214. Based on its review, the staff finds the following:

F3.4 The applicant has identified programs to ensure that aging effects will be adequately managed during the PEO, in accordance with 10 CFR 72.240(c)(3).

4 CONDITIONS TO ADDRESS RENEWAL

This section provides a consolidated list of the changes to the conditions resulting from the review of the CoC No. 1027 renewal application, some which have been described throughout the previous sections of this SER. The basis of the changes is provided here for those changes that are not described elsewhere in this SER.

4.1 Changes to Certificate of Compliance

1. Added the following condition to the initial CoC (Amendment 0) and Amendment 1:

UFSAR UPDATE FOR RENEWED COC

The CoC holder shall submit an updated final safety analysis report (UFSAR) to the Commission, in accordance with 10 CFR 72.4, within 90 days of the effective date of the renewal. The UFSAR shall reflect the changes and CoC holder commitments resulting from the review and approval of the renewal of the CoC. The CoC holder shall continue to update the UFSAR pursuant to the requirements of 10 CFR 72.248.

The CoC holder has stated that changes will be made to the UFSAR to address aging management activities resulting from the renewal of the CoC. This condition ensures that the UFSAR changes are made in a timely fashion to enable general licensees using the storage system during the PEO to develop and implement necessary procedures.

2. Added the following condition to the initial CoC (Amendment 0) and Amendment 1:

72.212 EVALUATIONS FOR RENEWED COC USE

Any general licensee that initiates spent fuel dry storage operations with the TN-68 Dry Storage Cask system after the effective date of the CoC renewal and any general licensee operating a TN-68 Dry Storage Cask system as of the effective date of the CoC renewal, including those that put additional storage systems into service after that date, shall:

a. as part of the evaluations required by 10 CFR 72.212(b)(5), include evaluations related to the terms, conditions, and specifications of this CoC amendment as modified (i.e., changed or added) as a result of the renewal of the CoC;

b. as part of the document review required by 10 CFR 72.212(b)(6), include a review of the UFSAR changes resulting from the renewal of the CoC and the NRC Safety Evaluation Report related to the renewal of the CoC; and

c. ensure that the evaluations required by 10 CFR 72.212(b)(7) and (8) capture the evaluations and review described in (a.) and (b.) of this CoC condition.

> The general licensee shall complete [this] Condition [13] prior to entering the PEO or no later than one year after the effective date of the CoC renewal, whichever is later.

The staff considers it important to ensure that appropriate considerations for the PEO are evaluated in the general licensee's report required by 10 CFR 72.212, "Conditions of general license issued under § 72.210." These considerations arise from the analyses and assumptions in the renewal application regarding operations during the PEO. This includes potential use of the TN-68 Dry Storage Cask system by general licensees after the CoC has been renewed either at a new or an existing general license ISFSI. The renewal of the CoC is based on assumptions and analyses of the DSS and the sites where it is used. Licensees considering the use of the TN-68 Dry Storage Cask system must evaluate it for use at their respective sites. This condition also makes it clear that general licensees that currently use a TN-68 Dry Storage Cask system will need to update their 10 CFR 72.212 reports even if they do not put additional DSSs into service after the renewal's effective date, in accordance with 10 CFR 72.212(b)(11).

3. Added the following condition to the initial CoC (Amendment 0) and Amendment 1:

> AMENDMENTS AND REVISIONS FOR RENEWED COC
>
> All future amendments and revisions to this CoC shall include evaluations of the impacts to aging management activities (i.e., time-limited aging analyses and aging management programs) to ensure that they remain adequate for any changes to SSCs within the scope of renewal.

The CoC may continue to be amended after it has been renewed. This condition ensures that amendments to the CoC also address aging management impacts that may arise from the changes to the system in proposed amendments.

4.2 Changes to Technical Specifications

1. Added the following section, "Aging Management Program," to the initial CoC (Amendment 0) and Amendment 1 as Section 5.2.4:

> Aging Management Program
>
> Each general licensee shall have a program to establish, implement, and maintain written procedures for each aging management program (AMP) described in the updated final safety analysis report (UFSAR). The program shall include provisions for changing AMP elements, as necessary, and within the limitations of the approved licensing bases to address new information on aging effects based on inspection findings and/or industry operating experience provided to the general licensee during the renewal period. The program document shall contain a reference to the specific aspect of the AMP element implemented by that

program document, and that reference shall be maintained even if the program document is modified.

The general licensee shall establish and implement this program document prior to entering the period of extended operation or no later than one year after the effective date of the CoC renewal, whichever is later. The general licensee shall maintain the program document for as long as the general licensee continues to operate a TN-68 dry storage cask system in service for longer than 20 years.

The CoC holder proposed a condition to revise or create programs or procedures for implementing the AMPs in the UFSAR supplement. This specification ensures that programs or procedures address AMP activities required for extended storage operations.

5 CONCLUSIONS

Pursuant to 10 CFR 72.240(d) the design of a spent fuel storage cask will be renewed if (1) the QA requirements in 10 CFR Part 72, Subpart G, “Quality Assurance,” are met, (2) the requirements of 10 CFR 72.236(a) through (i) are met, and (3) the application includes a demonstration that the storage of spent fuel has not had significant adverse effects on ITS SSCs. Additionally, 10 CFR 72.240(c), among other things, requires that the safety analysis report accompanying the application contain TLAAs demonstrating that the DSS SSCs will continue to perform their intended functions for the requested PEO and a description of the AMP for management of issues associated with aging that could adversely affect SSCs important to safety.

The NRC staff reviewed the CoC No. 1027 renewal application for the TN-68 Dry Storage Cask, in accordance with NRC regulations in 10 CFR Part 72. The staff followed the guidance in NUREG-1927, Revision 1. Based on its review of the renewal application and the CoC conditions, the staff determined that the renewal of CoC No. 1027 for the TN-68 Dry Storage Cask meets the requirements of 10 CFR 72.240. Therefore, the staff determined that the AMR, TLAAs and AMPs included in the CoC No. 1027 renewal application provide reasonable assurance that the SSCs of the TN-68 Dry Storage Cask system will maintain their intended functions for the PEO.

6 REFERENCES

ASM International, “ASM Handbook - Volume 13 Corrosion,” Materials Park, OH: ASM International, 2000.

Electric Power Research Institute, (EPRI), “High Burnup Dry Storage Cask Research and Development Project: Final Test Plan,” Revision 0, Contract No.: DE-NE-0000593, February 27, 2014, https://www.osti.gov/servlets/purl/1133392.

EPRI, “Effect of Hydride Reorientation in Spent Fuel Cladding—Status from Twenty Years of Research,” EPRI-3002016033, Palo Alto, CA, 2020, https://www.epri.com/research/programs/061149/results/3002016033.

Farrell, K., “Assessment of Aluminum Structural Materials for Service Within the ANS Reflector Vessel,” ORNL/TM-13049, Oak Ridge National Laboratory, August, 1995, https://inis.iaea.org/search/search.aspx?orig_q=RN:27048252.

Martin, W.R. and J.R. Weir, ”Mechanical Properties of X8001 and 6061 Aluminum Alloys and Aluminum-Base Fuel Dispersion at Elevated Temperatures,” ORNL-3557, February 1964, https://www.osti.gov/biblio/4114215.

Nuclear Energy Institute, NEI 14-03, “Format, Content and Implementation Guidance for Dry Cask Storage Operations-Based Aging Management,” Revision 2, December 21, 2016, ADAMS Accession No. ML16356A204.

Revie, R.W. Uhlig’s Corrosion Handbook. Second Edition. Hoboken, New Jersey: John Wiley and Sons. 2000.

U.S. Nuclear Regulatory Commission (NRC), “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” NUREG/CR-6407, Washington, DC, February 1996a, ADAMS Accession No. ML15127A114.

U.S. NRC, “Report on Aging of Nuclear Power Plant Reinforced Concrete Structures,” NUREG/CR-6424, March 1996b, ADAMS Accession No. ML072830854.

U.S. NRC, “Fuel Retrievability,” Spent Fuel Project Office Interim Staff Guidance (ISG) – 2, Washington, DC, 1998, ADAMS Accession No. ML003686776.

U.S. NRC, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” Spent Fuel Project Office Interim Staff Guidance (ISG) – 11, Revision 2, Washington, DC, 2002, ADAMS Accession No. ML022110372.

U.S. NRC, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” Spent Fuel Project Office ISG – 11, Revision 3, Washington, DC, 2003, ADAMS Accession No. ML033230335.

U.S. NRC, “Standard Review Plan for Spent Fuel Dry Storage Systems at a General License Facility.” NUREG–1536, Revision 1, Washington, DC, July 2010, ADAMS Accession No. ML101040620.

U.S. NRC, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” NUREG-1927, Revision 1, Washington, DC, June 2016, ADAMS Accession No. ML16179A148.

U.S. NRC, “Managing Aging Processes In Storage (MAPS) Report,” NUREG-2214, Washington, DC, July 2019, ADAMS Accession No. ML19214A111.