SAFETY EVALUATION REPORT

FOR THE THREE MILE ISLAND UNIT 2

INDEPENDENT SPENT FUEL STORAGE INSTALLATION

SPECIFIC LICENSE NO. SNM-2508 RENEWAL

DOCKET NO. 72-20

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

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CONTENTS

TABLES

Table Page

INTRODUCTION

Under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste,” the U.S. Nuclear Regulatory Commission (NRC) issued a specific license for the Three Mile Island Unit 2 (TMI-2) independent spent fuel storage installation (ISFSI), Special Nuclear Material (SNM) License No. SNM-2508, for 20 years, with an expiration date of March 19, 2019. SNM-2508 authorizes the U.S. Department of Energy (DOE) Idaho Operations Office (DOE-ID, licensee, or applicant) to receive, possess, transfer, and store radioactive material from the TMI-2 reactor core (TMI-2 core debris) at the TMI-2 ISFSI. The TMI-2 ISFSI is located at the Idaho National Laboratory (INL) within the perimeter of the Idaho Nuclear Technology and Engineering Center site in Scoville, ID.

By letter dated March 6, 2017, as supplemented on August 9, 2017; October 3, 2017; October 18, 2017; November 16, 2017; September 26, 2018; October 2, 2018; November 15, 2018; November 21, 2018; April 1, 2019; and May 21, 2019 (DOE-ID, 2017a, 2017c, 2017d, 2017e, 2017f, 2018a, 2018b, 2018c, 2018d, 2019a, 2019b), DOE-ID submitted an application to the NRC for renewal of SNM-2508 for an additional 20 years beyond the initial license term (the “period of extended operation”). This application, as supplemented, is generally referred to as the “license renewal application” in this safety evaluation report (SER). Any specific references to sections of the license renewal application are to Revision 3 of the license renewal application, which was included in DOE-ID’s May 21, 2019, submittal (DOE-ID, 2019b). The license renewal would authorize DOE-ID to continue to store the radioactive material in the TMI-2 ISFSI until March 19, 2039. No additional radioactive material will be added to the ISFSI under the license renewal. The applicant submitted the license renewal application in accordance with the regulatory requirements of 10 CFR 72.42, “Duration of license; renewal.” Because the license renewal application was submitted more than 2 years before the license expiration date, under 10 CFR 72.42(c), this application constitutes a timely renewal.

The TMI-2 ISFSI uses the NUHOMS®-12T dry storage system, which provides for the horizontal, dry storage of canisterized TMI-2 core debris in a reinforced concrete horizontal storage module (HSM). The TMI-2 core debris is stored in TMI-2 canisters, which provide the function of maintaining the core debris in a known geometric configuration. Three types of stainless steel TMI-2 canisters are used: (1) fuel canisters for large pieces of debris, (2) knockout canisters for smaller debris, and (3) filter canisters for fines resulting from defueling the TMI-2 reactor. The TMI-2 canisters are stored within a dry shielded canister (DSC), which is a cylindrical carbon steel vessel with welded closure end plates and vent and purge ports with high-efficiency particulate air grade filters. The DSC provides confinement for the TMI-2 canisters, and each DSC stores up to 12 TMI-2 canisters within an internal basket assembly.

The DSC is stored in an HSM, which is a prefabricated, reinforced concrete vault that serves to provide shielding for the DSC to minimize the radiation dose rate from the ISFSI and to transfer decay heat from the contents inside the DSC. The HSM is a low-profile structure 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. The HSM includes a steel-lined door that is removed for insertion and retrieval of the DSC and a rear door that provides access to the DSC vent and purge ports. The TMI-2 HSMs do not rely on internal natural convection cooling and are not ventilated.

The TMI-2 ISFSI comprises 341 TMI-2 canisters loaded in 29 DSCs and 29 HSMs on a load-bearing foundation at the Idaho Nuclear Technology and Engineering Center. The load-bearing foundation consists of a reinforced concrete pad on a subgrade suitable to support the loads (i.e., basemat). The approach slab is a reinforced concrete slab that provides access and support to the DSC transfer system. Individual HSMs are not anchored to the pad but arranged adjacent to each other, with a nominal 6-inch gap between modules. The TMI-2 ISFSI includes an extra HSM (HSM-15) with its pre-installed DSC overpack, which is not relied on for safe storage operations under normal, off-normal, or credible accident conditions in the TMI-2 ISFSI design bases.

In addition to these components, transfer equipment was used to move each DSC from the Test Area North facility on the INL site (where the DSCs were loaded with TMI-2 canisters and readied for storage) to the HSMs at the TMI-2 ISFSI. This transfer system included the transfer cask, lifting slings, hydraulic ram system, transfer trailer, tractor for towing, cask transportation skid, and skid positioning system. Other than the lifting slings, the intention of the transfer cask and other transfer equipment is to allow future retrieval of the DSCs from storage. Two types of transfer casks—the NUHOMS®-MP187 Multi-Purpose Cask and OS197 Transfer Cask—are included in the TMI-2 ISFSI design bases.

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

The NRC staff reviewed the applicant’s technical bases for safe operation of the ISFSI for an additional 20 years beyond the term of the current operating license. This SER summarizes the results of the staff’s review for compliance with 10 CFR 72.42. In its review of the license renewal application and development of the SER, the staff used the guidance in (1) NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC, 2016), and (2) NUREG-2214, Revision 0, “Managing Aging Processes In Storage (MAPS) Report,” issued July 2019 (NRC, 2019a). NUREG-2214 establishes a generic technical basis for the safety review of ISFSI license renewal applications, in terms of the evaluation of (1) aging mechanisms and effects that could affect the ability of ISFSI SSCs to fulfill their safety functions in the period of extended operation (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 period of extended operation. The staff evaluated the applicant’s technical basis for its aging management review 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 TMI-2 ISFSI are bounded by those evaluated in NUREG-2214.

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

1 GENERAL INFORMATION

1.1 Specific License Holder Information

The license renewal application includes general information on the specific license holder, the U.S. Department of Energy Idaho Operations Office (DOE-ID, licensee, or applicant). The license renewal application includes the name, address, and description of the applicant, including a description of the delegations of authority and assignment of responsibilities. The U.S. Nuclear Regulatory Commission (NRC) staff finds that the applicant provided the information required in paragraphs (a)–(d) of Title 10 of the *Code of Federal Regulations* (10 CFR) 72.22, “Contents of application: General and financial information.”

1.2 Financial Qualifications

The regulation in 10 CFR 72.22(e) contains a requirement for an applicant, other than DOE, to show that the applicant will have the necessary funds available to cover estimated construction costs, estimated operating costs over the requested period of extended operation, and estimated decommissioning costs. As the 10 CFR 72.22(e) requirement provides an exception for DOE, no information is required from the applicant as to its financial qualifications related to the renewal of the Three Mile Island Unit 2 (TMI-2) independent spent fuel storage installation (ISFSI) license.

1.3 Decommissioning Funding Assurance

Under paragraph (b) of 10 CFR 72.30, “Financial assurance and recordkeeping for decommissioning,” each holder of, or applicant for, a license under 10 CFR Part 72 must submit for NRC review and approval a decommissioning funding plan containing information on how reasonable assurance will be provided that funds will be available to decommission its ISFSI. Under 10 CFR 72.30(c), at the time of license renewal and at intervals not to exceed 3 years, the decommissioning funding plan must be resubmitted with adjustments as necessary to account for changes in decommissioning costs and the extent of contamination.

The license renewal application references a December 14, 2012, DOE-ID letter (DOE-ID, 2012), which is considered DOE-ID’s decommissioning funding plan submittal. The letter provided DOE-ID’s opinion that a current license condition for the TMI-2 ISFSI satisfies the 10 CFR 72.30 requirements related to decommissioning financial assurance (license condition 15). The specific condition at issue requires DOE-ID to request the necessary decommissioning funds from Congress through the Federal budget planning process. The license condition also requires DOE-ID to notify the NRC, in writing, of any anticipated or forecasted budget shortfalls, as soon as they are known, along with a plan detailing the specific measures that will be taken by DOE-ID to obtain the required funding and prevent adverse impacts on ISFSI operations. The NRC staff responded to DOE-ID by letter dated November 20, 2018 (NRC, 2018). In the letter, the NRC staff recognized the current license condition 15 and also noted that the regulation in 10 CFR 72.40(a)(10) provides an exception for DOE with respect to the findings associated with decommissioning financial assurance requirements in 10 CFR 72.30. Accordingly, the NRC finds that the information DOE-ID provided is sufficient to support compliance with the decommissioning financial assurance requirements in 10 CFR 72.30, and no further information is needed in the license renewal application.

1.4 Environmental Review

Regulations in 10 CFR 72.34, “Environmental report,” require that each application for an ISFSI license under this part must be accompanied by an environmental report that meets the requirements of Subpart A, “National Environmental Policy Act—Regulations Implementing Section 102(2),” of 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.” The applicant submitted an environmental report and supplemented the report as part of the license renewal application. The environmental report, as supplemented (DOE-ID, 2017a, 2017c, 2017e), contained sufficient information to aid the staff in its independent analysis. In September 2019, the staff issued an environmental assessment (NRC, 2019b) for the TMI-2 ISFSI license renewal.

1.5 Safety Review

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

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

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

The applicant stated that it prepared the license renewal application in accordance with applicable provisions of 10 CFR Part 72 and NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC, 2016). The applicant performed a scoping evaluation and aging management review (AMR) to identify all SSCs within the scope of the license renewal and pertinent aging mechanisms and effects, respectively. The applicant developed AMPs and evaluated TLAAs to ensure that the SSCs identified to be within the scope of renewal will continue to perform their intended functions during the period of extended operation. This review documents the staff’s evaluation of the applicant’s scoping analysis, AMR, and supporting AMPs and TLAAs.

1.6 Application Content

The applicant’s license renewal application provided the following information:

- general and financial information
- scoping evaluation
- AMR
- AMPs
- TLAAs
- updated final safety analysis report (UFSAR) (i.e., final safety analysis report (FSAR), as updated, per the requirements of 10 CFR 72.70(b) and (c)) supplement
- proposed license conditions

- environmental report supplement
- results of pre-application inspections
- ISFSI decommissioning funding plan

The UFSAR supplement submitted by the applicant (in Revision 3 of the license renewal application, Appendix C (DOE ID, 2019b)) provides proposed changes and additions to the TMI-2 ISFSI UFSAR to document the results of the scoping evaluation, AMR, TLAAs, and AMPs.

1.7 Evaluation Findings

The staff reviewed the general information in the license renewal application. The staff performed its review following the guidance in NUREG-1927, Revision 1. Based on its review, the staff determined that the applicant has provided sufficient information with adequate details to support the license renewal application, with the following findings:

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

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

2 SCOPING EVALUATION

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

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

   i. maintain the conditions required by the regulations or the specific license 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 that are classified as not important to safety but, according to the design bases, their failure could prevent fulfillment of a function that is important to safety

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

2.1 Scoping and Screening Methodology

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

- a description of the scoping and screening methodology for the inclusion of SSCs and SSC subcomponents in the scope of 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 renewal review and the basis for the scope determination

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

2.1.1 Scoping Process

In Section 2.2 of the license 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 renewal.

The staff notes that the applicant's scoping evaluation process and methodology is consistent with the criteria defined in NUREG-1927, Revision 1. However, in addition to scoping criteria 1 and 2, as discussed above, the applicant defined an additional scoping criterion (described as scoping criterion 3 in Section 2.2 of the license renewal application). The applicant justified this new criterion by stating that the scoping of storage contents (i.e., fuel assemblies) is suggested via paragraph 2.4.2.1 of NUREG-1927, Revision 1, which discusses demonstrating "that the analyzed fuel configuration is maintained during the period of extended operation." Therefore, the applicant applied this new criterion to the dry-stored contents, which the applicant stated may include the TMI-2 core debris or the TMI-2 canisters.

The staff reviewed the applicant's justification for a new scoping criterion besides those defined in NUREG-1927, Revision 1. The staff recognized in NUREG-1927, Revision 1, Section 2.4.2.1, that the safety analyses for an ISFSI (e.g., criticality and shielding analyses) may rely on the fuel assembly having a specific configuration (e.g., geometric form, a certain number of fuel rods, or solid replacement filler rods in the assembly lattice). As the renewal of a specific license is based on continuation of the approved design bases throughout the period of extended operation, the license renewal application should demonstrate that the analyzed fuel configuration is maintained during the period of extended operation. Therefore, any aspects of the stored contents or dry storage system that maintain the analyzed fuel configuration are within the scope of renewal and should be reviewed for any aging mechanisms and effects that may lead to a change in the analyzed fuel configuration. The staff has determined that the applicant's justification for a new scoping criterion is consistent with the discussion in NUREG-1927, Revision 1; Section 2.4.2.1, in terms of maintaining the analyzed configuration of the core debris that is stored at the TMI-2 ISFSI.

Therefore, the staff finds that the applicant's new scoping criterion is an acceptable approach for ensuring aspects of the stored contents or dry storage system that maintain the analyzed configuration of the core debris are adequately included in the scope of renewal review.

The applicant reviewed the following design-bases and licensing documents to identify SSCs with safety functions meeting either scoping criterion 1 or 2, or the dry-stored contents per scoping criterion 3, as defined above:

- SNM-2508, Amendment No. 5, license and technical specifications (TS) (NRC, 2017), which incorporates prior amendments

- approved exemptions from the regulations as defined in SNM-2508 license condition 12 and further discussed in Section 1.3.4 of the license renewal application, including the following:

    – exemption from requirements of 10 CFR 72.102(f)(1) related to the specified seismic design criteria of 10 CFR Part 100, "Reactor Site Criteria," Appendix A, "Seismic and Geologic Siting Criteria for Nuclear Power Plants"

    – exemption from requirements of 10 CFR 20.1501(c) to use National Voluntary Laboratory Accreditation Program (NVLAP) accredited dosimetry and instead authorize use of DOE Laboratory Accreditation Program (DOELAP) dosimetry

    – exemption from requirement of 10 CFR 72.124(b) that the design of the ISFSI shall provide for positive means to verify the continued efficacy of solid neutron absorbing materials

- exemption from requirements of 10 CFR 72.82(e) that a report of the preoperational test acceptance criteria and test results be submitted at least 30 days before loading the ISFSI

- UFSAR, Revision 8, and UFSAR drawings (DOE-ID, 2017b)

- most recent biennial report on changes, tests, and experiments authorized under 10 CFR 72.48, “Changes, tests, and experiments” (DOE-ID, 2017b)

- design calculations, analyses, and reports that the UFSAR references, either directly or indirectly

- docketed licensing correspondence, including docketed commitments

- fabrication drawings (referred to also as “Design” drawings in the license renewal application) and associated bill of material

- safety evaluation reports (SERs) for the original license and the approved amendments

As part of this review, the applicant reviewed the UFSAR and fabrication drawings listed in SER Table 2.1-1. The applicant stated that the fabrication drawings were reviewed due to their higher level of detail (including subcomponent safety categorization) relative to the UFSAR drawings. However, the UFSAR drawings would continue to represent the design bases safety classifications/quality categories from the initial license through the period of extended operation.

Table 2.1-1 UFSAR and Fabrication Drawings Used for Scoping Evaluation

UFSAR Drawing/Revision	Fabrication Drawing/Revision	Fabrication Drawing Title
Horizontal Storage Module (HSM)		
219-02-6000, Revision 1	219-02-5100, Revision 1	Horizontal Storage Module ISFSI General Arrangement
219-02-6000, Revision 1	219-02-5101, Revision 1	Standard Module Main Assembly
219-02-6000, Revision 1	219-02-5103, Revision 1	Horizontal Storage Module Standard Module Base Unit
219-02-6000, Revision 1	219-02-5104, Revision 2	Horizontal Storage Module Roof Slab
219-02-6000, Revision 1	219-02-5105, Revision 1	Horizontal Storage Module DSC Support Structure
219-02-6000, Revision 1	219-02-5107, Revision 1	Horizontal Storage Module Erection Hardware and Miscellaneous, Steel Doors and Fabricated Fasteners
219-02-6000, Revision 1	219-02-5108, Revision 0	Horizontal Storage Module End Module Shield Wall

UFSAR Drawing/Revision	Fabrication Drawing/Revision	Fabrication Drawing Title
ISFSI Basemat and Approach Slab		
219-02-6000, Revision 1	219-02-5200, Revision 3, Sheet 1 and Revision 2, Sheet 2	Horizontal Storage Module Basemat
Dry Shielded Canister (DSC)		
219-02-2000, Revision 2	219-02-1000, Revision 1	DSC Basket Assembly
219-02-2001, Revision 2	219-02-1001, Revision 1	DSC Shell Assembly
219-02-2002, Revision 2	219-02-1002, Revision 1	DSC Basket-Shell Assembly
219-02-2003, Revision 2	219-02-1003, Revision 1	DSC Main Assembly
219-02-2010, Revision 2	219-02-1010, Revision 2	DSC Purge Port Filter Assembly
219-02-2011, Revision 3	219-02-1011, Revision 2	DSC Vent Port Filter Assembly
TMI-2 Canister (Fuel)		
1161300-D, Revision B1	1154070-F, Revision 3	Fuel Canister Assembly
TMI-2 Canister (Knockout)		
1161301-D, Revision 1	1154041-F, Revision 3	Knockout Canister Assembly
TMI-2 Canister (Filter)		
1161299-D, Revision 1	1154018-F, Revision 5	Filter Canister Assembly

2.1.2 Scoping Results

SER Table 2.1-2 lists the SSCs included and excluded from the scope of renewal review per the license renewal application.

Table 2.1-2 SSCs/Contents Within and Not Within the Scope of Renewal Review

SSC / Contents	Criterion 1	Criterion 2	Criterion 3	In-Scope (Yes / No)
Dry Shielded Canister (DSC)[1]	Yes	N/A	N/A	Yes
Horizontal Storage Module (HSM) (except HSM-15)[2]	Yes	N/A	N/A	Yes
Overpack HSM (HSM-15)[3]	No	No	N/A	No
Transfer Casks	Yes	N/A	N/A	Yes
Dry Film Lubricant	No	No	N/A	No
Handling and Transfer Equipment[4]	No	No	N/A	No
ISFSI Basemat and Approach Slab	No	Yes	N/A	Yes
Other Transfer Equipment[5]	No	No	N/A	No
Auxiliary Equipment[6]	No	No	N/A	No

SSC / Contents	Criterion 1	Criterion 2	Criterion 3	In-Scope (Yes / No)
Miscellaneous Equipment[7]	No	No	N/A	No
TMI-2 Core Debris	N/A	N/A	No	No
TMI-2 Canisters[8]	N/A	N/A	Yes	Yes

[1] DSC includes the DSC shell, top/bottom cover plates, purge and vent block, grapple ring, and high efficiency particulate air (HEPA) filters.

[2] HSM includes HSM-1 through HSM-30, excluding HSM-15. Subcomponents include (but are not limited to) the HSM reinforced concrete walls, roof, and end shield walls; DSC steel structure support assembly; HSM accessories (DSC seismic retainer, shielded door assemblies and door supports); and associated attachment/installation hardware (tie rods, bolts, nuts, washers, embedment assemblies, mechanical splices).

[3] Overpack HSM includes all of HSM-15 and its pre-installed DSC overpack.

[4] Handling and Transfer Equipment includes cask rigging, cask bottom/top spacers, and transfer cask lifting yoke.

[5] Other Transfer Equipment includes a hydraulic ram system, a transfer trailer, a prime mover for transfer trailer towing, cask support skid, auxiliary equipment mounted on the skid, and skid positioning system.

[6] Auxiliary Equipment includes a vacuum drying system and an automated welding system.

[7] Miscellaneous Equipment includes ISFSI security fence and gates, lighting, lightning protection, communications, monitoring, and alarm systems.

[8] The three TMI-2 Canister types include the TMI-2 Fuel Canister, TMI-2 Knockout Canister, and TMI-2 Filter Canister.

The applicant referred to Table 3.4-1 of the UFSAR for defining if the SSC was important to safety (ITS) or not important to safety (NITS). SSCs ITS were determined to be within the scope of renewal per criterion 1. The applicant provided additional discussions for concluding that both the ISFSI basemat and approach slab (NITS SSCs) should be scoped in under criterion 2 – see SER Section 2.1.3.

As discussed in this SER Section 2.1.1, in addition to the scoping criteria 1 and 2, as discussed above, the applicant defined an additional scoping criterion (described as scoping criterion 3 in Section 2.2 of the license renewal application). The applicant justified this new criterion by stating that the scoping of storage contents (i.e., fuel assemblies) is suggested via paragraph 2.4.2.1 of NUREG-1927, Revision 1, which discusses demonstrating "that the analyzed fuel configuration is maintained during the period of extended operation." Therefore, the applicant applied this new criterion to the TMI-2 canisters – see SER Section 2.1.3.

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 UFSAR. SER Section 2.1.3 provides the staff's conclusions regarding SSCs (and SSC subcomponents) within the scope of renewal review, as defined in SER Table 2.1-2. SER Section 2.1.4 provides the staff's conclusions regarding SSCs (and SSC subcomponents) outside the scope of renewal review.

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

Per the scoping evaluation process and methodology, as discussed in Section 2.2 of the license renewal application, the applicant identified the SSC subcomponents considered to be within the scope of 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, Revision 1. These subcomponents are tabulated in Table 2-3 of the license renewal application and in the supplement to be incorporated in the UFSAR upon license renewal (see SER Section 4.1).

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

Dry Shielded Canister

The applicant included the DSCs within the scope of renewal review. The applicant clarified that DSC subcomponents support ITS functions of confinement, radiation shielding, sub-criticality control, heat-removal capability, structural integrity, and retrievability. The staff confirmed that DSC subcomponents are scoped within the renewal review because these are classified as ITS in accordance with UFSAR, Table 3.4-1.

Although the licensee did not initially determine the DSC purge port block or the DSC basket to be within the scope of renewal, following a supplemental analysis, the licensee modified its license renewal application to identify that the DSC purge port block and the DSC basket are within the scope of renewal under criterion 2 and have a shielding function.

As part of its review of the licensee's scoping evaluation, the staff considered the shielding analyses in the UFSAR and the calculation packages that supported the initial licensing of the TMI-2 ISFSI. As part of this review, the staff identified the SSCs, including subcomponents, that were relied on in these analyses. The DSC purge port block and DSC basket are among the items relied on in these analyses. The DSC purge port block is needed to ensure the design-bases analyses (both in the UFSAR and supporting calculation package analyses) assumptions are maintained, regarding the similarity of the purge and vent ports and the bounding nature of the vent port dose rates. The purge port block does this in two ways, as described below. The DSC basket maintains the positioning and distribution of the TMI-2 canisters within the DSC. This positioning is credited in the UFSAR and supporting calculation package analyses in which the TMI-2 core debris material and radiation source term are smeared throughout the DSC cavity. Thus, while not identified in either the UFSAR drawings or the fabrication drawings as ITS and so would not be within the scope of the renewal review per scoping criterion 1, the items would fall within the scope of the renewal review per scoping criterion 2, as discussed in SER Section 2.1.1.

In the revision of the scoping evaluation for the DSC basket, the licensee only identified the basket as having a shielding function. The licensee did not identify a criticality function for the basket. The staff finds this acceptable because the UFSAR criticality analyses did not rely on the DSC basket, whether for its material (neutron absorption) or its positioning of the TMI-2 canisters (affecting intercanister moderation and separation of fissile material). Instead, the UFSAR analyses use the most reactive configuration while neglecting the basket. Thus, the staff finds that the basket does not perform a criticality function.

The DSC's vent port shield block also is within the scope of renewal. This is because the UFSAR shielding analyses credit it in the calculations of dose rates at the vent port and the vent port filter housing. The analyses credit both the material of the shield block and its function to keep TMI-2 canisters at some minimum distance from the vent port. The shield block also ensures the TMI-2 canisters cannot sit directly beneath the vent port. The licensee's supplemental shielding analyses for the license renewal application also rely on this shield block in the same manner. Thus, the staff finds that the licensee has correctly included this subcomponent in the scope of renewal.

Horizontal Storage Module

The applicant stated that the HSMs are scoped within the renewal review because these are classified as ITS in accordance with UFSAR, Table 3.4-1. The applicant clarified that HSM subcomponents support ITS functions of radiation shielding, sub-criticality control, heat-removal capability, structural integrity, and retrievability.

Transfer Casks

The applicant stated that the transfer casks are scoped within the renewal review because these are classified as ITS and a transfer cask is required to provide retrievability of the DSC. While outside the HSM and still within the ISFSI limits, a transfer cask is also necessary as it provides protection, including radiological shielding, for the DSC during such operations. The applicant scoped in the transfer casks under criterion 1, as an ITS item in accordance with UFSAR, Table 3.4-1. Further, the applicant clarified that, in accordance with the UFSAR, Section 1.3.1, the two transfer casks in the approved design bases are the NUHOMS®-MP187 Multi-Purpose Cask (MP187) and OS197 Transfer Cask (OS197 TC). The applicant clarified that the TMI-2 ISFSI does not currently have these transfer casks on site, and either of them would need to be procured for eventual retrievability of the DSCs.

The applicant stated that the scoping evaluation for the OS197 TC was addressed in the Standardized NUHOMS® Certificate of Compliance (CoC) renewal application (under NRC Docket No. 72-1004) (AREVA TN Americas, 2016). The applicant clarified that this scoping evaluation will be incorporated by reference into the TMI-2 ISFSI design bases upon renewal of the TMI-2 ISFSI specific license. More specifically, the applicant included in its proposed UFSAR supplement the sections of the Standardized NUHOMS® CoC renewal application (specifically, Sections 1.2.2.3, 3.3.3, 3.4, 3.4.1, 3.4.2, 3.4.3, and 3.7, and Appendices 1A–1K, Appendix 2C (pertaining to the OS197 TC), Appendix 2E (Table 2E-3 only), Appendix 3B (pertaining to the OS197 TC), and Appendix 6A (Section 6A.7 only)) that will be incorporated by reference into the TMI-2 ISFSI USFAR upon renewal (see Section C.2.6.3 of the license renewal application (DOE-ID, 2019b)) and SER Section 4.1). The staff considers that the scoping evaluation for the OS197 TC (as provided in Appendices 1A–1K, 2C, and 2E of the Standardized NUHOMS® CoC renewal application) is adequate for incorporation by reference in the TMI-2 ISFSI design bases since equivalent scoping criteria were used in both renewals.

The applicant stated that the scoping evaluation for the MP187 is addressed in the Rancho Seco ISFSI license renewal application. The staff notes that the review of the Rancho Seco ISFSI license renewal application is still ongoing, and the staff has not finalized an SER documenting the staff's findings on that license renewal application. Since that safety review is not complete, the applicant proposed a new license condition (see SER Section 4.4), which would prohibit the use of an MP187 aged greater than 20 years. The staff recognizes that the applicant does not currently have an MP187 on site. Since the transfer cask would need to be procured for eventual DSC retrieval operations, the staff considers that controls per the licensee's NRC-approved quality assurance (QA) program are adequate for ensuring that a transfer cask aged less than 20 years is procured when needed. Therefore, the staff considers that the applicant-proposed license condition is adequate for demonstrating compliance with the requirement in 10 CFR 72.42(a), and the staff concludes that an AMR of the MP187 is not necessary, per the license condition discussed in SER Section 4.4.

Basemat (Storage Pad) and Approach Slab

The applicant stated that the ISFSI basemat (storage pad) and approach slab are classified as NITS, because the HSM is not anchored to the basemat. The applicant clarified that the ISFSI basemat provides a level and stable surface for placement and storage of HSMs with reinforcement on the top and bottom of the slab. The applicant further clarified that the approach slab is an asphalt slab providing access and support for the Transfer Trailer while transitioning onto the basemat. The applicant concluded that differential settlement of the ISFSI basemat and approach slab could affect retrievability, could lower the elevation of the pad below the Predicted Maximum Flood (PMF) level, and in the unlikely event that large settlements of the ISFSI foundation occur, the resultant shifting of adjacent HSMs may cause the HSMs to separate, reducing HSM self-shielding. The applicant further concluded that, there are no other credible failure modes of the basemat and approach slab that could prevent the ISFSI intended functions from being fulfilled. Therefore, the applicant concluded that the basemat and approach slab are within scope of renewal with respect to assessing for differential settlement on retrievability.

The applicant did not provide a breakdown of subcomponents within the scope of renewal for the ISFSI basemat and approach slab. The staff reviewed Fabrication Drawing No. 219-02-5200, Revision 3, Sheet 1, and Revision 2, Sheet 2, to determine if the drawings identified subcomponents and their corresponding safety (quality) category. Drawing No. 219-02-5200, Revision 3, Sheet 1, states that all work associated with the basemat is classified as quality category NITS. Therefore, the staff instead relied on the license renewal application's discussion on the AMR of the ISFSI basemat and approach slab to determine the acceptability of the applicant's approach for addressing those aging effects (see SER Section 3.3.1.10). Per the discussion in SER Section 3.3.1.10, the applicant reviewed aging effects due to differential settlement of the ISFSI basemat and approach slab, as this was determined to be the only credible aging effect that (1) may impact retrievability of the DSC, (2) may reduce the elevation of the basemat relative to the predicted maximum flood level, or (3) may result in shifting of HSM placement relative to one another.

TMI-2 (Knockout, Filter, Fuel) Canisters

The applicant stated that the TMI-2 canister subcomponents are scoped within the renewal review because these provide geometric confinement to the TMI-2 core debris. The TMI-2 canisters do not provide primary confinement in the DSS. However, the TMI-2 canisters provide reasonable assurance that the TMI-2 debris remains subcritical during postulated accident conditions. The staff notes that safety classification/quality categories are not defined in the UFSAR drawings or fabrication drawings of all three variants of the TMI-2 canisters. The applicant clarified that this is consistent with Table 3.4-1 of the UFSAR, which does not list the canisters as either ITS or NITS. The staff reviewed the applicant's scoping results for TMI-2 canister subcomponents within the scope of renewal (as defined in Table 2-3 of the renewal application). The staff considers that the applicant has adequately identified all TMI-2 canister subcomponents and has conducted an adequate assessment of the subcomponents identified to be within the scope of renewal for which aging effects are to be managed during the period of extended operation. The staff notes that, even without design-bases information on the quality categories (safety classification) of the TMI-2 canister subcomponents, the staff considers that the applicant has adequately addressed all potential materials and environments in the TMI-2 canisters for all subcomponents. Therefore, the staff considers that the applicant has adequately demonstrated that credible aging mechanisms for all TMI-2 canister subcomponents have been evaluated.

Scoping Findings

The staff reviewed the applicant's screening of the TMI-2 ISFSI SSCs to identify subcomponents within the scope of renewal review. The staff's review considered the intended function of the subcomponent, its safety classification per the UFSAR or fabrication drawings or basis for inclusion in the scope of renewal review, and design-bases information in the UFSAR. The staff's safety review followed the guidance in NUREG-1927, Revision 1 (NRC, 2016) and was informed by NUREG-2214, "Managing Aging Processes In Storage (MAPS) Report," issued July 2019 (NRC, 2019a). The staff notes that NUREG-2214 includes aging management tables developed per the UFSAR drawings of the TMI-2 ISFSI, which provide a generic basis for scoping of the TMI-2 ISFSI SSCs. However, these aging management tables were developed per the UFSAR drawings, while the applicant's scoping evaluation was performed by review of the UFSAR drawings and augmented by the supporting fabrication drawings and other technical documents (e.g., fabrication specifications). The staff further notes that a one-to-one correlation of the applicant's scoping evaluation results to the TMI-2 ISFSI aging management tables in NUREG-2214 was not possible, as the fabrication drawings and other technical documents (used by the applicant) contained a higher level of detail than the UFSAR drawings.

Based on this review, the staff finds that the applicant screened the in-scope SSCs in a manner consistent with NUREG-1927, Revision 1, therefore, the staff finds the screening results for in-scope SSC subcomponents to be acceptable. The staff notes that, even if the applicant did not define all the intended functions of an SSC subcomponent within the scope of renewal review, this would not represent an increased risk to safety, as the AMR is independent of the subcomponent's safety function.

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

Per the scoping evaluation process and methodology, as discussed in Section 2.2 of the license renewal application, the applicant identified the SSC subcomponents considered not to be within the scope of 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, Revision 1. Consistent with that scoping evaluation, the applicant identified these subcomponents as not needing an AMR. These subcomponents are tabulated in Table 2-4 of the license renewal application. The following discussions address the applicant's basis for exclusion of an SSC from the scope of renewal review. The discussions also provide clarifications on the staff's review of that basis for exclusion.

Overpack HSM—Extra HSM-15 and its Pre-Installed DSC Overpack

The applicant stated that the UFSAR, Section 3.1, specifies that an extra unloaded HSM (defined by the applicant as HSM-15) with a pre-installed DSC overpack (together referred to as the "overpack HSM" in this SER) in the ISFSI serves as a backup in case temporary storage of a DSC is required or in case a challenged DSC needs an additional confinement barrier. Section 8.2.7 of the UFSAR evaluates the consequences of a breach of confinement due to a simultaneous rupture of the TMI-2 canisters with an instantaneous rupture of the DSC seam or HEPA filter trains. This event is considered a non-mechanistic event, and a loss of confinement is considered not credible. Further, UFSAR Section 5.3.2 states that the TMI-2 ISFSI is designed to withstand all postulated design-bases events. Therefore, no storage component or equipment spares are required for the standardized NUHOMS®-12T system, except for changeout of the HEPA filters. Therefore, the TMI-2 ISFSI design bases do not rely on the use of the overpack HSM for safe storage operations under normal, off-normal, or credible accident conditions.

As the TMI-2 ISFSI design bases do not rely on the use of the overpack HSM, the applicant concluded that the overpack HSM is not within the scope of renewal review. Further, the applicant proposed a license condition that would prevent the use of the overpack HSM during the period of extended operation (see SER Section 4.3). The staff reviewed the justification and approved design bases and considers that the overpack HSM is not necessary, consistent with the approved design bases. The staff agrees that the HSM-15 and its pre-installed DSC overpack is only included in the TMI-2 ISFSI UFSAR to address a non-mechanistic event, although a cause for such event is not identified in the analyses of off-normal and accident events and conditions (i.e., the event was analyzed only as a defense-in-depth measure to provide additional assurance that the TMI-2 ISFSI dry storage system will maintain its intended safety functions during storage). The staff also confirmed that the HSM-15 and its pre-installed DSC overpack are not in service. Because the TMI-2 ISFSI design bases do not rely on the use of the overpack HSM, and with the addition of the license condition ensuring the overpack is not used during the period of extended operation (see SER section 4.3), the staff finds the applicant's exclusion of the overpack HSM from the scope of renewal review to be acceptable.

Dry Film Lubricant

The applicant justified the exclusion of the dry film lubricant from the scope of renewal review. The applicant stated that the sliding surfaces of the DSC support rails of all the HSMs are fabricated from hardened carbon steel and are coated with a dry film lubricant to minimize friction during insertion and retrieval of the DSC. The applicant further stated that the effect of radiation on these lubricants does not credibly affect its intended function, since these are inorganic and consist entirely of graphite. The applicant referenced design-bases calculations in UFSAR Section 8.1.1.1, which employed a coefficient of friction of 0.25 that is higher than the coefficient of friction associated with these types of lubricants. The applicant also clarified that the hydraulic ram system to be used for DSC transfer is capable of exerting an extraction force equal to the loaded weight of a DSC (i.e., 70,000 pounds). Further, the applicant referenced the "*Jammed DSC*" analysis in UFSAR Section 8.1.2.1, which assumed an effective coefficient of friction of 100 percent of the loaded DSC. The applicant also referenced UFSAR Section 8.1.1.4, which clarifies that the DSC support structure is designed for this loading. The staff reviewed the justification and the design bases as discussed in the UFSAR and finds the applicant's conclusion that lubricant failure does not prevent the HSM or the DSC from satisfactorily accomplishing its intended functions to be acceptable. Therefore, the staff finds the applicant's exclusion of the dry film lubricant from the scope of renewal review to be acceptable.

Handling and Transfer Equipment

The applicant justified the exclusion of handling and transfer equipment from the scope of renewal review. The applicant clarified that handling and transfer equipment includes transfer cask rigging, transfer cask top and bottom spacers and the transfer cask lifting yoke. The equipment was used for handling the transfer cask at the Test Area North facility during loading and transfer operations. The applicant referenced Section 3.1.2.1 of the UFSAR, which states that the equipment is not required to meet accident-related criteria as its failure cannot result in an unanalyzed safety condition. Further, in Section 3.4.4.1 of the UFSAR, the rigging used for transfer handling at the Test Area North facility is not a part of the ISFSI licensed activities.

The staff reviewed the approved design bases to determine if any of these subcomponents would be necessary for DSC retrieval operations and concluded that the transfer cask top and bottom spacers may be necessary for these operations. The staff reviewed the approved design bases and determined that, although the UFSAR shielding analyses do not credit the material of the transfer cask spacers, the analyses do credit the spacers' function of axially positioning the DSC within the transfer cask. The staff determined that the positioning of the DSC within the transfer cask has an important effect on transfer cask dose rates, both axially (due to changes in proximity of the radioactive debris versus the transfer cask's lid and base) and radially (due to axial variations in the transfer casks' radial shielding). Consistent with the review guidance in NUREG-1927, Revision 1, the staff considers that the top and bottom transfer cask spacers would be expected to be scoped into the renewal review per the previously defined scoping criterion 2. The applicant performed a supplemental shielding analysis of the impacts of neglecting the spacers to justify the conclusion that the spacers were out of the renewal scope, but the staff was unable to find that the supplemental analysis demonstrated that the shielding and radiation protection design bases (described in the SER Section 2.1.3 discussion on the DSC purge port block and basket below) were maintained without the spacers.

The applicant, however, clarified that the transfer cask spacers used during the initial ISFSI loading campaign no longer remain on site; therefore, new transfer cask spacers would need to be fabricated at the time they are required for future DSC retrieval operations. Thus, to address the scoping evaluation of the transfer cask spacers and the need to replace them for future DSC retrieval operations, the applicant proposed a license condition to require transfer cask spacers used at the TMI-2 ISFSI be aged less than 20 years (see SER Section 4.5). Consistent with the discussion in NUREG-1927, Revision 1, Section 2.4.3, on replaceable SSC subcomponents, the staff considers that, because of the limited service life of the transfer cask spacers specified in the license condition discussed in SER Section 4.5, the transfer cask spacers may be excluded from the scope of renewal review. Therefore, the staff concludes that an AMR of the transfer cask spacers is not necessary per the revised design bases (i.e., per the revised specific license).

<u>Other Transfer Equipment</u>

The applicant justified the exclusion of other transfer equipment from the scope of renewal review. This equipment includes the following:

- a transfer trailer used to move the transfer cask and cask support skid from the Test Area North facility (where the TMI-2 canisters were loaded into the DSCs) to the ISFSI during transfer operations

- a conventional heavy haul truck tractor or other suitable prime mover for towing the transfer trailer

- a cask transport skid/turning skid used at the Test Area North facility to allow rotation of the transfer cask between horizontal and vertical positions, with the equipment mounted on the transfer trailer to support transfer operations

- a skid positioning system used to hold the transfer cask support skid in a stationary position (with respect to the transfer trailer) during transfer cask loading and transfer, and to provide alignment between the transfer cask and the HSM before insertion of the DSC

- a hydraulic ram system insertion/extraction assembly that provides the motive force for transferring the DSC between the transfer cask and the HSM

The staff reviewed the justification and the design bases as discussed in the UFSAR and finds the applicant's conclusion, that the other transfer 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 license renewal. The staff notes that, while other transfer equipment may be necessary for retrieval of the transfer cask, such equipment would be designed, constructed, and tested in accordance with accepted engineering practices consistent with that specified in Section 3.4.4.2 of the UFSAR. Therefore, the staff finds the applicant's exclusion of other transfer equipment from the scope of renewal review to be acceptable.

Auxiliary Equipment

The applicant justified the exclusion of auxiliary equipment from the scope of renewal review. The applicant clarified that this equipment includes a vacuum drying system and an automated welding system, which are used to facilitate DSC loading, draining, drying, inerting, and sealing operations. The applicant referenced Section 3.4.5 of the UFSAR, which states that these SSCs are classified as NITS. Further, the applicant clarified that these SSCs no longer exist as they are not required to provide reasonable assurance that TMI-2 canisters could be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public. Since no additional DSCs will be loaded and the auxiliary equipment is not required for retrieval operations, the auxiliary equipment does not meet any of the scoping criteria and, therefore, is not within the scope of renewal.

The staff reviewed the justification and the design bases as discussed in the UFSAR and finds the applicant's conclusion 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 license renewal. Therefore, the staff finds the applicant's exclusion of the auxiliary equipment from the scope of renewal review to be acceptable.

Miscellaneous Equipment

The applicant justified the exclusion of ISFSI miscellaneous equipment (e.g., ISFSI security fences and gates, lighting, lightning protection, communications, monitoring and alarm equipment) from the scope of renewal review, since this equipment is not part of the TMI-2 ISFSI storage system and is specifically excluded from the scope of license renewal by Section 2.4.3 of NUREG-1927, Revision 1. Since the applicant's conclusion is consistent with staff's review guidance, the staff finds the applicant's exclusion of the miscellaneous equipment from the scope of renewal review to be acceptable.

TMI-2 Core Debris

The applicant justified the exclusion of the TMI-2 core debris from the scope of renewal review. The applicant clarified that the material stored inside the TMI-2 canisters consists of TMI-2 core debris removed from the damaged TMI-2 reactor during defueling operations. Retrieved materials from the TMI-2 reactor core include rubble bed debris, partially intact fuel assemblies, debris bed stratified material, miscellaneous core component pieces (e.g., fuel rod segments, neutron startup sources, spacer grids, end fittings, control rod assembly spiders, springs, fuel pellets), and in-core instrument assemblies. In addition, non-core material is also considered part of the TMI-2 “core debris.” This debris can range in size and configuration from partially intact fuel assemblies in the TMI-2 fuel canisters to micron-sized particulate matter adhered to filter media in the TMI-2 filter canisters.

The applicant referenced Section 3.3.7.1.1 of the UFSAR, which states that a majority of the cladding on the fuel rods either melted during the accident or was cut during dismantling of the core debris for storage in the TMI-2 canisters. Therefore, the applicant concluded that the fuel cladding cannot be and is not relied on to maintain the analyzed configuration of the core debris. Instead, for the TMI-2 ISFSI, this is the function of the TMI-2 canisters, not the TMI-2 core debris payloads. Therefore, the applicant concluded that the condition of the TMI-2 core debris is not within the scope of renewal review.

The staff reviewed the justification and the design bases as discussed in the UFSAR and finds the applicant’s conclusion that the TMI-2 core debris is not relied on for maintaining its analyzed configuration to be acceptable because the debris does not meet any of the scoping criteria that would bring it within the scope of license renewal. Therefore, the staff finds that the applicant’s exclusion of the TMI-2 core debris from the scope of renewal review to be acceptable.

<u>Scoping Findings</u>

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

2.2 Evaluation Findings

The staff reviewed the scoping evaluation provided in the license 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, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” issued February 1996 (NRC, 1996), as a reference for classifying components as important to safety.

Based on its review, the staff finds the following:

F2.1 The applicant has identified all SSCs important to safety and SSCs the failure of which could prevent an SSC from fulfilling its safety function, per the requirements of 10 CFR 72.3, “Definitions”; 10 CFR 72.24, “Contents of application: Technical information”; 10 CFR 72.42; 10 CFR 72.120, “General considerations”; 10 CFR 72.122, “Overall requirements”; 10 CFR 72.124, “Criteria for nuclear criticality safety”; 10 CFR 72.126, “Criteria for radiological protection”; and 10 CFR 72.128, “Criteria for spent fuel, high-level radioactive waste, reactor-related greater than Class C waste, and other radioactive waste storage and handling,” as applicable.

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

3 AGING MANAGEMENT REVIEW

3.1 Review Objective

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

3.2 Aging Management Review Process

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

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

The applicant evaluated the materials of construction, the environments, and the potential aging effects and the associated aging mechanisms for each SSC and associated subcomponent within the scope of renewal. The aging effects and associated aging mechanisms that could cause degradation resulting in loss of intended function are evaluated. These evaluations result in the final aging effects requiring management, and the required aging management activities, either TLAAs or AMPs.

The applicant provided a summary of the pre-application inspections performed before the license renewal application submittal. The applicant also discussed other relevant operating experience for dry storage. This includes an overview of AMR-relevant design, fabrication, and maintenance (if applicable) aspects for the SSCs within the scope of renewal.

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

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

The staff evaluated the applicant's technical basis for its AMR by comparing it to the generic technical basis in NUREG-2214. In this evaluation, the staff ensured that the design features, environmental conditions, and operating experience for the TMI-2 ISFSI are bounded by those evaluated in NUREG-2214.

SER Table 3.3-1 identifies the environments considered for SSC subcomponents, as defined in the license renewal application. The staff compared these environments to determine equivalency to the environments evaluated in NUREG-2214. SER Table 3.3-2 identifies the comparison results. SER Tables 3.3-3 through 3.3-7 provide the results of the applicant's AMR and identify the disposition of each potential aging effect for SSC subcomponent materials within the scope of renewal review. These tables identify whether the applicant's conclusion on the credibility of each aging effect is consistent with the generic technical bases and conclusions discussed in NUREG-2214. The tables also identify the disposition of the aging effect, in terms of whether: (1) an aging management activity (i.e., AMP or TLAA) is, or is not, needed to address the aging effect (consistent with NUREG-2214), or (2) there is a separate technical basis or supporting analyses that justify either that an aging effect is not credible or that an aging management activity is not needed for the aging effect (for items either not addressed in, or inconsistent with, NUREG-2214).

Table 3.3-1 Aging Management Review—Environments

Environment	Description
Outdoor (HSM exterior subcomponents, basemat and approach slab)	The environment per the ambient conditions of DOE's Idaho Site. Exposure includes all weather conditions, including insolation, wind, rain, snow, ambient temperatures, and humidity.
Sheltered (HSM interior, DSC exterior, DSC support structure)	A protected ambient environment with no direct exposure to sun, wind, or precipitation, although some subcomponents may receive these conditions intermittently during hydrogen sampling. Otherwise, the only moisture is from humidity brought in due to diffusion and diurnal pressure and temperature fluctuations. The sheltered environment may contain moisture and other contaminants from the external ambient air. The temperature inside the sheltered environment depends on the ambient air temperature and the heat load of the loaded DSC, which decreases over the period of extended operation. More specifically, the temperature may range from ambient air temperature to just above ambient (as shown in Table 3-3 of the license renewal application). Subcomponents in the sheltered environment are exposed to neutron and gamma radiation fields, which decrease over the period of extended operation.
Internal DSC (DSC interior, TMI-2 canister exterior)	The environment within the DSC's annular cavity. The internal DSC environment is the product of the exchange of air and moisture between the sheltered environment and that of the inside of the DSC, including products generated by radiolysis or other chemical processes within the DSC. Any radiolytic production of hydrogen is due to interactions within the TMI-2 canisters between any remaining bound water and the core debris radiation. The chemical aging processes within the DSC are due to oxidation of the sacrificial zinc coating applied to the interior DSC subcomponents, in addition to any limited corrosion processes of the TMI-2 canisters, including their contents. Subcomponents in the internal environment experience neutron and gamma fluences higher than the sheltered environment, as described in Section 3.3.1.2.2 of the license renewal application. The environment within the DSCs is nearly ambient since it is vented and decay heats within are low, as discussed in Section 3.3.1.2.3 of the license renewal application. Per Table 3-3 of the license renewal application, the maximum temperature in this environment is less than 90 °F, and

Environment	Description
	temperatures within some DSCs are considered equivalent to average outside temperatures due to their low decay heat.
Internal TMI-2 canister (TMI-2 canister interior)	The environment located within the annular cavity of the TMI-2 canisters. This environment is protected from outdoor ambient conditions and exposed to slightly higher temperatures and higher neutron and gamma fluences than the internal DSC environment (as discussed in Sections 3.3.1.2.3 and 3.3.1.2.2 of the license renewal application). There are two possible vent paths from the internal TMI-2 canister environment to the internal DSC environment: one vent penetration and one dewatering penetration, both located on the TMI-2 canister upper head. These provide a diffusion pathway for possible hydrogen and other gases produced from mechanisms such as radiolysis or corrosion.
Embedded or encased	Environment of a material embedded or sealed inside another material. More specifically, the environment applies to: • the rebar and anchorage embedded in the HSM concrete • the DSC bottom shield plug encased between the bottom inner and outer cover plates, and the volume between the top shield plug weld and the top cover plate—this is a dry, air-filled environment with moisture content limited to that present when the welds were applied at the fabricator or in the field in the case of the top cover plate field welds • the encased environment of the sample port cavity—this is an air-filled environment with moisture content retained following hydrogen sampling through the port circa 2003 • the BORAL® neutron poison material enclosed between the inner and outer skin on the TMI-2 Fuel Canister • the boron carbide pellets encased in the TMI-2 Knockout and TMI-2 Filter Canister poison rod tubes

Table 3.3-2 Comparison of Environment Definitions

Environment Defined in Application	Equivalent Environment in NUREG-2214
Outdoor (HSM exterior subcomponents, basemat and approach slab)	Outdoor-Air
Sheltered (HSM interior, DSC exterior, DSC support structure)	Sheltered
Internal DSC (DSC interior, TMI-2 canister exterior)	Sheltered
Internal TMI-2 canister (TMI-2 canister interior)	Sheltered
Embedded or encased	Embedded in concrete Embedded in metal

Table 3.3-3 Aging Management Review Results—Dry Shielded Canister[8]

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Carbon steel	Sheltered, internal DSC	General corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-1
		Crevice corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-1
		Pitting corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-1
		Galvanic corrosion[1]	Loss of material	Yes	Yes	AMP— See SER Table 3.5-1
		Microbiologically influenced corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Wear[2]	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Cracking	Yes	Yes	TLAA—See SER Section 3.4.1
		Intergranular corrosion	Change in material properties	No	Not discussed in NUREG-2214	Technical basis— See SER Section 3.3.1.1
		Creep	Change in material properties	No	Yes	AMP/TLAA not necessary
		Thermal aging	Change in material properties	No	Yes	AMP/TLAA not necessary
		Irradiation embrittlement	Change in material properties	No	Yes	AMP/TLAA not necessary
		Hydrogen damage	Change in material properties	No	Not discussed in NUREG-2214	Technical basis— See SER Section 3.3.1.2
Carbon steel	Encased[3]	General corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Crevice corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Pitting corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Microbiologically influenced corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Wear[2]	Loss of material	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Stress corrosion cracking	Cracking	No	Yes[4]	AMP/TLAA not necessary
		Thermal fatigue	Cracking	Yes	Yes	TLAA—See SER Section 3.4.1
		Intergranular corrosion	Change in materials properties	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.1
		Creep	Change in materials properties	No	Yes	AMP/TLAA not necessary
		Thermal aging	Change in materials properties	No	Yes	AMP/TLAA not necessary
		Irradiation embrittlement	Change in materials properties	No	Yes	AMP/TLAA not necessary
		Hydrogen damage	Change in materials properties	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.2
		Stress relaxation	Loss of preload	No	Yes	AMP/TLAA not necessary
Stainless steel and elastomeric (neoprene) seal[5,6]	Sheltered, internal DSC	General corrosion	Loss of material	Yes	No	Technical basis—See SER Section 3.3.1.3
		Crevice corrosion	Loss of material	Yes	Yes	Technical basis—See SER Section 3.3.1.3
		Pitting corrosion	Loss of material	Yes	Yes	Technical basis—See SER Section 3.3.1.3
		Galvanic corrosion	Loss of material	Yes	Yes	Technical basis—See SER Section 3.3.1.3
Zinc-rich coating[7]	Sheltered, internal DSC	Blistering	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Cracking	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Flaking	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Peeling	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Physical damage	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7

[1] The applicant stated that the graphite lubricant is noble relative to the steel base metal and zinc-based coating of the DSC shell; therefore, the possibility exists of inducing galvanic corrosion of the steel DSC shell or zinc coating. This could occur in areas where the zinc coating was scuffed during loading. The zinc coating is not credited in the UFSAR corrosion evaluation since there is already a corrosion allowance on the DSC shell.

[2] The applicant defined three types of potential wear: (1) adhesive wear, (2) abrasive wear, and (3) erosive wear.

[3] The environment “Encased,” as described in the license renewal application, is consistent with the environment “Embedded in metal,” as described in NUREG-2214.

[4] Stress corrosion cracking in the environment “embedded in metal” is not addressed in NUREG-2214. However, the staff considers that this environment is bounded by the “Sheltered” and “Outdoor air” environments in NUREG-2214. NUREG-2214 concluded that stress corrosion cracking is not credible in “Sheltered” and “Outdoor air” environments; therefore, the staff concludes that it is also not credible in the applicant-defined environment “embedded in metal.”

[5] The material combination pertains to the HEPA filter assemblies and associated gaskets; see SER Section 3.3.1.3.

[6] The applicant did not identify aging mechanisms and effects for the neoprene elastomeric seal associated with the HEPA filter assembly. Further, the applicant did not address potential radiation embrittlement of the HEPA stainless steel subcomponents. Instead, the applicant assessed the consequences of the failure of these seals; see SER Section 3.3.1.3.

[7] The applicant stated that failure of the coating does not prevent the DSC steel subcomponents from satisfactorily accomplishing their intended functions. However, the applicant recognized that the coating may disguise indications of corrosion of the underlying component. Therefore, the applicant opted to monitor the exposed coating adverse or abnormal aging effects during the period of extended operation; see SER Section 3.3.1.7.

[8] In addition to the material/environment assessment provided in this table, the applicant provided supplemental analyses to support the conclusions that aging effects on certain DSC subcomponents will not compromise their intended functions. These discussions are provided in SER Section 3.3.1.4 for the DSC sample port bolt and seal and SER Section 3.3.1.5 for the HEPA filter housing attachment bolts and washers on DSC vent and purge ports.

Table 3.3-4 Aging Management Review Results—Horizontal Storage Module

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Concrete/ cementitious grout[1]	Outdoor	Freeze-thaw	Loss of material (spalling, scaling)	Yes	Yes	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Loss of material (spalling, scaling)	No	No	Technical basis— See SER Section 3.3.1.11
		Thermal fatigue	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Irradiation	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Reaction with aggregates	Loss of material (spalling, scaling)	No	No	Technical basis— See SER Section 3.3.1.12
		Delayed ettringite formation	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Shrinkage	Loss of material (spalling, scaling)	Yes	No	AMP— See SER Table 3.5-2
		Freeze-thaw	Cracking	Yes	Yes	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Cracking	No	No	Technical basis— See SER Section 3.3.1.11
		Thermal fatigue	Cracking	No	Yes	AMP/TLAA not necessary
		Irradiation	Cracking	No	Yes	AMP/TLAA not necessary
		Reaction with aggregates	Cracking	No	No	Technical basis— See SER Section 3.3.1.12
		Delayed ettringite formation	Cracking	No	Yes	AMP/TLAA not necessary
		Shrinkage	Cracking	Yes	No	AMP— See SER Table 3.5-2
		Elevated temperatures	Cracking	No	Yes	AMP/TLAA not necessary
		Irradiation	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Aggressive chemical attack	Reduction of concrete strength and modulus[2]	No	No	Technical basis— See SER Section 3.3.1.11
		Reaction with aggregates	Reduction of concrete strength and modulus[2]	No	No	Technical basis— See SER Section 3.3.1.12
		Delayed ettringite formation	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Leaching of calcium hydroxide	Reduction of concrete strength and modulus[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Elevated temperatures	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Creep	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Leaching of calcium hydroxide	Increase in concrete porosity and permeability[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Reduction of concrete pH[2]	No	No	Technical basis— See SER Section 3.3.1.11
		Leaching of calcium hydroxide	Reduction of concrete pH[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Microbiological degradation[3]	Not identified in the application	No	Yes	AMP/TLAA not necessary
Concrete	Sheltered	Freeze-thaw	Loss of material (spalling, scaling)	Yes	No	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Irradiation	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Reaction with aggregates[6]	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Delayed ettringite formation	Loss of material (spalling, scaling)	No	Yes	AMP/TLAA not necessary
		Shrinkage	Loss of material (spalling, scaling)	Yes	No	AMP— See SER Table 3.5-2
		Freeze-thaw	Cracking	Yes	No	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Cracking	No	Yes	AMP/TLAA not necessary
		Irradiation	Cracking	No	Yes	AMP/TLAA not necessary
		Reaction with aggregates[6]	Cracking	No	Yes	AMP/TLAA not necessary
		Delayed ettringite formation	Cracking	No	Yes	AMP/TLAA not necessary
		Shrinkage	Cracking	Yes	No	AMP— See SER Table 3.5-2
		Elevated temperatures	Cracking	No	Yes	AMP/TLAA not necessary
		Irradiation	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Aggressive chemical attack	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Reaction with aggregates[6]	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Delayed ettringite formation	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Leaching of calcium hydroxide	Reduction of concrete strength and modulus[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Elevated temperatures	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Creep	Reduction of concrete strength and modulus[2]	No	Yes	AMP/TLAA not necessary
		Leaching of calcium hydroxide	Increase in concrete porosity and permeability[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Aggressive chemical attack	Reduction of concrete pH[2]	No	Yes	AMP/TLAA not necessary
		Leaching of calcium hydroxide	Reduction of concrete pH[2]	Yes	Yes	AMP— See SER Table 3.5-2
		Microbiological degradation[3]	Not identified in the application	No	Yes	AMP/TLAA not necessary
Reinforcement steel	Embedded	Corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
Carbon steel, ferritic steel, carbon/boron steel, or alloy steel (including weld filler material)	Outdoor	General corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Crevice corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Pitting corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Cracking	Yes	Yes	Technical basis— See SER Section 3.3.1.18
		Irradiation	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Loss of strength	No	Yes	AMP/TLAA not necessary
		Irradiation	Loss of strength	No	Yes	AMP/TLAA not necessary
Carbon steel, ferritic steel, carbon/boron steel, or alloy steel (including weld filler material)	Sheltered	General corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Crevice corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Pitting corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Cracking	Yes	Yes	Technical basis— See SER Section 3.3.1.18
		Irradiation	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Loss of strength	No	Yes	AMP/TLAA not necessary
		Irradiation	Loss of strength	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Carbon steel, ferritic steel, carbon/boron steel, or alloy steel (including weld filler material)	Embedded in concrete	General corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Crevice corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Pitting corrosion	Loss of material	Yes	Yes	AMP— See SER Table 3.5-2
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Cracking	Yes	Yes	Technical basis— See SER Section 3.3.1.18
		Irradiation	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal fatigue	Loss of strength	No	Yes	AMP/TLAA not necessary
		Irradiation	Loss of strength	No	Yes	AMP/TLAA not necessary
Stainless steel[4]	Outdoor	General corrosion	Loss of material	Yes	No	AMP— See SER Table 3.5-2
		Crevice corrosion	Loss of material	No	No	AMP— See SER Table 3.5-2
		Pitting corrosion	Loss of material	No	No	AMP— See SER Table 3.5-2
		Stress corrosion cracking	Cracking	No	No	Technical basis— See SER Section 3.3.1.13
Zinc-rich coating[7]	Sheltered	Blistering	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis— See SER Section 3.3.1.7

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Cracking	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Flaking	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Peeling	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
		Physical damage	Loss of coating integrity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.7
Silane water-repellent coating	Sheltered	Coating breakdown[5]	Loss of water repellence/loss of coating integrity[5]	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.8
Chemical grouts (silicone sealant, polyurethane foam, epoxy sealants)	Outdoor	Premature degradation	Adhesive failure between silicone sealant (chemical grout) and substrate and cohesive failure within chemical grout	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.9
		Premature degradation	Loss of material/reduction of material elasticity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.9

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Premature degradation	Reduction of material elasticity	Yes	Addressed on case-by-case basis per NUREG-2214	Technical basis—See SER Section 3.3.1.9

[1] Section 3.5.2.4 of the license renewal application defines the cementitious materials as grouts, SONOGROUT® and SikaGrout® 212.

[2] The staff considers that the applicant-defined aging effects of "Reduction in concrete strength and modulus" and "Reduction in concrete pH" are consistent with the aging effect, "Change in material properties," discussed in NUREG-2214.

[3] The applicant did not explicitly discuss the aging mechanism of microbiological degradation of the concrete, which is addressed in NUREG-2214. A brief statement is provided in the license renewal application stating that microbiological forms of chemical attack may also be induced from microbial growths on the concrete, but there has not been operating experience at dry storage facilities and therefore would not be considered credible at the TMI-2 ISFSI. This conclusion is consistent with the technical basis in NUREG-2214, and, therefore, the staff considers the applicant's conclusion to be acceptable.

[4] The only stainless steel subcomponents of the HSM are the roof bolt protective covers, which are NITS. However, the applicant included these covers within the scope of renewal review per scoping criterion 2 per historical operating experience of freeze-thaw cracking of HSMs at the TMI-2 ISFSI. These covers were installed as a preventive action to preclude any future freeze-thaw cracking of HSM concrete subcomponents.

[5] The aging mechanism and effect is not defined in the license renewal application. However, the staff considers these to be the pertinent aging mechanism and effect per the acceptance criteria of the HSM AMP (Section A2.6.3 of the license renewal application).

[6] NUREG-2214 concludes that alkali-silica reaction (ASR) is credible for concrete structures subject to moisture and water. The staff considers that the sheltered environment at the TMI-2 ISFSI does not credibly allow for the reaction of aggregates in the concrete due to the negligible amount of moisture, as justified by the annually low average relative humidity for the INL site ranging from 30% to 70% and less than 10 inches per year of rainfall. Further, any residual heat of the TMI-2 canisters will aid in the vaporization of any residual moisture. The staff notes that the applicant added ASR of HSM concrete subcomponents exposed to outdoor environment to the AMP corrective action program (see SER Section 3.3.1.12), to ensure it is not the apparent or root cause of any premature degradation. The staff considers that this inclusion provides defense in depth that any inadvertent aging effects from ASR of the HSM concrete subcomponents in the sheltered environment will be properly managed.

[7] The applicant stated that failure of the coating does not prevent the HSM steel subcomponents from satisfactorily accomplishing their intended functions. However, the applicant recognized that the coating may disguise indications of corrosion of the underlying material. Therefore, the applicant opted to monitor the exposed coating adverse or abnormal aging effects during the period of extended operation; see SER Section 3.3.1.7.

Table 3.3-5 Aging Management Review Results—ISFSI Basemat and Approach Slab

Material	Environment	Aging Mechanism	Aging Effect	Credible Yes or No	Consistent with NUREG-2214 Yes or No	TLAA, AMP, Supporting Analysis or Technical Basis
Reinforced concrete	Sheltered/ outdoor	Differential Settlement	Not identified in the application	No	No	Technical basis— See SER Section 3.3.1.10

Table 3.3-6 Aging Management Review Results—TMI-2 Canisters (Knockout, Filter, Fuel)

Material	Environment	Aging Mechanism	Aging Effect	Credible Yes or No	Consistent with NUREG-2214 Yes or No	TLAA, AMP, Supporting Analysis or Technical Basis
Stainless steel (all canisters)	Internal DSC, internal TMI-2 canister	General corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Crevice corrosion	Loss of material	No	No	Technical basis— See SER Section 3.3.1.14
		Pitting corrosion	Loss of material	No	No	Technical basis— See SER Section 3.3.1.14
		Galvanic corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Microbiologically induced corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Wear	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	No	Technical basis— See SER Section 3.3.1.14
		Thermal fatigue	Cracking	No	Yes	AMP/TLAA not necessary
		Intergranular corrosion	Change in material properties	No	Not discussed in NUREG-2214	Technical basis— See SER Section 3.3.1.15
		Creep	Change in material properties	No	Yes	AMP/TLAA not necessary
		Thermal aging	Change in material properties	No	Yes	AMP/TLAA not necessary
		Irradiation embrittlement	Change in material properties	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Credible Yes or No	Consistent with NUREG-2214 Yes or No	TLAA, AMP, Supporting Analysis or Technical Basis
		Radiation-induced localized corrosion	Not defined	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.16
Licon (TMI-2 Fuel Canister)	Sheltered/ internal DSC	Not defined[1]	Loss of material	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.6
		Not defined[1]	Cracking	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.6
		Not defined[1]	Reduction in material properties	No	Not discussed in NUREG-2214	Technical basis—See SER Section 3.3.1.6
Neutron absorber material (Boral®, boron carbide pellets)[2]	Sheltered/ internal DSC	Not defined	Loss of material	No	Yes	AMP/TLAA not necessary
		Not defined	Reduction of strength	No	Yes	AMP/TLAA not necessary
		Boron depletion	Loss of neutron absorber efficacy	No	Yes	AMP/TLAA not necessary
		Irradiation embrittlement	Change in material properties	No	Yes	AMP/TLAA not necessary

[1] The applicant recognized that there is limited information available on Licon degradation and its aging mechanisms. Therefore, the applicant evaluated the consequences of potential aging effects to the intended functions of the Licon material (see SER Section 3.3.1.6).

[2] The applicant only defined the aging effects considered for the neutron absorber materials. Per NUREG-2214, the applicable aging mechanisms to Boral® are general and galvanic corrosion, wet corrosion and blistering, boron depletion, creep, thermal aging, and radiation embrittlement. NUREG-2214 concludes that none of these aging mechanisms are credible during the period of extended operation. The applicant provided supporting evaluation consistent with the conclusions of NUREG-2214. Since the applicant's conclusions per this supporting evaluation are consistent with NUREG-2214, no additional discussion is provided in this SER. The reader may refer to Section 3.8.4.4 of the license renewal application for the applicant's supporting evaluation. The staff further considers that the technical basis in NUREG-2214 for Boral® is also applicable to boron carbide pellets. The staff also confirmed that the depletion of the boron-10 in the Boral® and boron carbide rods in the TMI-2 canisters would be negligible.

Table 3.3-7 Aging Management Review Results—OS197 Transfer Cask

Material	Environment	Aging Mechanism	Aging Effect	Disposition
Various	Various	Various—see SER Section 3.6.1.17 (for AMR) and 3.4.3 (TLAA)	Various—see SER Section 3.6.1.17 (for AMR) and 3.4.3 (TLAA)	AMP— See SER Section 3.5.3

The staff reviewed the applicant's AMR results for consistency with the technical bases for aging mechanisms and effects provided in NUREG-2214. 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 no additional discussion is provided in this SER. The following discussions address the applicant's conclusions on aging mechanisms and effects for which the staff was not able to verify consistency with NUREG-2214.

3.3.1 Technical Bases/Supplemental Analyses

The applicant provided technical bases and supplemental analyses to justify the conclusion that an AMP is not needed for addressing certain aging mechanisms and effects, or for adequate performance of certain SSC subcomponents. The staff's assessment on adequacy of the applicant's conclusions is discussed next.

3.3.1.1 **Aging effect assessment: intergranular corrosion of DSC carbon steel subcomponents**

The applicant described the mechanism of intergranular corrosion and stated that its occurrence is not typical in carbon steel systems, therefore concluding it was not credible. The applicant justified the conclusion by describing operating experience results from inspections of dry storage systems and providing characterization results of carbon steel corrosion coupons at another facility within INL. This facility, the Irradiated Fuel Storage Facility (IFSF), includes carbon steel subcomponents that are exposed to outside air and similar temperatures to the TMI-2 ISFSI DSCs. Intergranular corrosion has not been observed on the IFSF corrosion coupons or within the carbon steel in the IFSF dry storage facility over the 40 years that the facility has been in service. As such, it is unlikely that the TMI-2 ISFSI, which has a similar environment, will have intergranular corrosion on carbon steel.

NUREG-2214 does not specifically address the mechanism of intergranular corrosion of carbon steel subcomponents and therefore does not identify a position on the credibility of this aging mechanism for various potential environments. Therefore, the staff reviewed the applicant's justification and agrees with the applicant's conclusion that it is unlikely that carbon steel subcomponents will experience intragranular corrosion during the period of extended operation, and therefore that aging management due to this aging mechanism is not required.

3.3.1.2 **Aging effect assessment: hydrogen damage of DSC carbon steel subcomponents**

The applicant described the mechanism of hydrogen damage (embrittlement, hydrogen-induced cracking (HIC)) and concluded that its occurrence is not likely due to the welding conditions used for the TMI-2 ISFSI DSCs, therefore concluding it was not credible. The applicant justified the conclusion by describing operating experience from the VSC-24 dry storage system design (not the TMI-2 ISFSI NUHOMS®-12T design) in which hydrogen-induced damage was observed at a highly constrained closure weld produced in a moist environment. The weld in the cited operating experience was conducted with consumables with high hydrogen content. The applicant clarified that, as part of the initial license review, the concern about hydrogen damage per the VSC-24 operating experience was addressed. The applicant clarified that the NUHOMS®-12T DSC closure weld is similar to the original DSC designed, developed, and tested as part of an Electric Power Research Institute (EPRI) demonstration project at the Robinson Station. This same closure weld design used with the NUHOMS® DSCs is a standard design feature of the NUHOMS® design and is used at other ISFSIs, including, at the time, Oconee, Calvert Cliffs, and Davis-Besse stations. The applicant clarified that the NUHOMS® closure welding program and joint design has not fundamentally changed since the EPRI demonstration project; with circa 30 years of operating experience, without such HIC weld issues as experienced by the VSC-24 dry storage system. The applicant further clarified that low hydrogen filler material and welding processes were used to prevent hydrogen embrittlement and cracking. Further, the loading of the TMI-2 canisters was not done in a spent fuel pool but was done in a dry environment, eliminating a significant potential source of hydrogen contamination of the molten weld metal. The applicant also qualified both the manual and automated weld processes used for the DSC closure welds. The applicant stated that there is no evidence or indications of HIC or other anomalous failures or other unexpected degradation of either the closure welds or heat-affected zones since the DSCs were closed and loaded into the HSMs. The applicant concluded that hydrogen damage including HIC from original welding operations is not considered credible for DSC subcomponents since a low-hydrogen filler material was used to prevent hydrogen embrittlement and cracking, and the DSC welds were designed to minimize residual stresses.

NUREG-2214 does not specifically address the mechanism of hydrogen damage (embrittlement, hydrogen-induced cracking) of carbon steel subcomponents and therefore does not identify a position on the credibility of this aging mechanism for various potential environments. The staff reviewed the applicant's justification and agrees with the applicant's conclusion that it is unlikely that carbon steel subcomponents will experience hydrogen damage during the period of extended operation. Therefore, the staff agrees that aging management due to this aging mechanism is not required.

3.3.1.3 **SSC subcomponent performance assessment: HEPA filters and associated seals of DSC vent and purge ports**

The TMI-2 canisters have two small penetrations, a purge port, and a fill port, which are left open during storage operations. These penetrations allow for escape of hydrogen potentially created by the TMI-2 core debris via HEPA filters in the DSC top cover. Four HEPA filters on the DSC vent port and a single HEPA filter on the DSC purge port provide a diffusion path for hydrogen from the internal DSC environment to the HSM sheltered environment. There is no motive force for transporting radioactive debris from the TMI-2 canisters into the DSC interior.

The HEPA filters consist of stainless steel media certified to have an efficiency of greater than 99.97 percent for particulate down to 0.3 microns. The filter media material is welded into a threaded stainless steel filter body, which in turn is threaded into a filter housing. An elastomeric (neoprene) gasket is situated under the flange of the filter body against the filter housing. The interface between the filter housing and the DSC top cover plate are dual, concentric, metallic seals situated between polished surfaces. The design bases allow for replacement of the dual metallic seals with dual elastomeric seals (ethylene propylene diene monomer-based elastomer), which was approved in Amendment No. 4 of SNM-2508 (NRC, 2005).

The approved design bases state that neither the vent/purge ports' sealing grooves, nor the dual seals themselves (whether metallic or elastomeric) perform a confinement function. As a result, the applicant stated that any postulated aging effects on those SSCs would not prevent fulfillment of the DSC's confinement function. TS Limiting Condition of Operation (LCO) 3.1.1, Surveillance Requirement (SR) 3.1.1.1, and SR 3.1.1.2 require periodic leak testing of the dual metallic DSC vent/purge housing seals on a 5-year basis or annually if the metallic seals are ever replaced with dual elastomeric seals. The applicant stated that this activity assures conformance with a defense-in-depth confinement function provided by the seals.

The safety consequence of the vent or purge ports' sealing surfaces failing to meet the leak rate specification was addressed in Amendment No. 4 of SNM-2508 (NRC, 2005). UFSAR Section 8.1.4.2 states that the gaps between the vent and purge ports' filter housings and the DSC lid are so small that it would be difficult for particulate radioactive material to pass through without significant motive force. The worst case would be all the particulate radioactive material that could potentially be released from the DSC during normal operation is released unfiltered through the leaking double metallic seals.

The applicant clarified that a radiological evaluation of a complete radioactive particulate release was conducted as part of Amendment No. 4 of SNM-2508, with no confinement credit taken for the seals (NRC, 2005). The total dose at the INL site boundary was calculated and incorporated into UFSAR Section 8.1.4. The resulting dose at the INL site boundary, which was evaluated as the 10 CFR Part 72 controlled area boundary for the ISFSI, when combined with the INL sitewide operations' (including the ISFSI under normal operations that credit the seals) annual dose contributions, was less than the annual whole body dose limit in 10 CFR 72.104(a).[1]

The applicant clarified that, as part of Condition A of TS LCO 3.1.1, if the filter housing seal leak rate is exceeded, the filter housing attachment bolts are reseated, and the leak test is repeated. As a separate defense-in-depth reassurance, the exposed bolt head surfaces may be opportunistically inspected for any observed abnormal aging effects and corrective actions implemented, as outlined in the DSC AMP (see SER Table 3.5-1).

The applicant clarified that annual sampling of the gas within the DSC is also used for assuring that hydrogen gas concentration stays below the TS limit. If hydrogen levels exceed the TS limits, the filters are replaced. In addition, TS LCO 3.2.2 requires the surface dose rate of each HSM rear access door and the purge/vent port filter housings be surveyed on an annual basis. Per the TS LCO bases, if the radiation field approaches the specified limits, the applicant clarified that the cause will be evaluated and corrective action taken. Therefore, the applicant stated that the associated TS SR 3.2.2.1 may also provide data representative of potential increased dose measurements attributable to hypothetical filter housing seal leaks and HEPA filter leaks. Corrective actions would be taken should this occur. The applicant also proposed using these measurements for annual trending analyses as defense in depth, as outlined in the DSC AMP (see SER Table 3.5-1).

The staff reviewed the applicant's justification and the applicant's conclusion that aging effects of the DSC vent and purge ports' HEPA filters and seals will not compromise the intended function of these subcomponents.

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[1] It should be noted that the evaluation calculated total effective dose equivalent, whereas the limit is for whole body. While not the same dose quantity, the staff finds that the evaluated dose is sufficient for representing that the whole body dose is met since it includes both internal and external contributions (whole body is external only) and, for the external dose, the scenario is consistent with the discussion in Regulatory Guide 1.195, "Methods and Assumptions for Evaluating Radiological Consequences of Design Basis Accidents at Light-Water Nuclear Power Reactors," Section 4.1.4, regarding use of effective dose conversion factors as a surrogate for whole body dose conversion factors.

The staff reviewed the applicant's justification and agrees with the applicant's conclusion that the existing maintenance activities on the HEPA filters will adequately address aging effects experience during the period of extended operation. More specifically, the staff considers the applicant's conclusion to be acceptable upon review of the basis for the approval of Amendment No. 4 of SNM-2508, the existing TS LCO and SR requirements and associated basis, and the inspection and monitoring activities under the purview of the DSC AMP (see SER Table 3.5-1). The staff further considers that any degradation of the neoprene elastomeric seal associated with the HEPA filters, including that potentially caused by irradiation-induced embrittlement of these seals, would be adequately identified per the activities under the purview of the DSC AMP (see SER Table 3.5-1). Therefore, the staff finds that the inclusion of existing maintenance activities as a preventative action of the DSC AMP provides reasonable assurance that the HEPA filters and associated seals of DSC vent and purge ports will perform as intended during the period of extended operation, and thus, no additional aging management activities are required.

3.3.1.4 SSC subcomponent performance assessment: DSC sample port bolt and seal

The applicant stated that a metallic seal ring sits under the sample port bolt on the vent and purge port assemblies. Other than the bottom shank surface, the sample port bolt on the vent and purge port assemblies is completely encapsulated by the HEPA filter housing body and the sample tube plug. The applicant clarified that the sample port fitting is unused. The sample port bolt functions as a confinement barrier by preventing radioactive particulate from migrating out of the internally machined sampling duct and into the sampling port cavity. The applicant stated that, as long as the bolt exists and remains threaded into the sampling port cavity, it will continue to perform its intended function. The applicant concluded that there are no credible postulated aging effects that could adversely affect the sample port bolt's confinement function to change the continued storage analysis outlined in UFSAR Section 8.1.4.3. Further, the applicant considers that the sample port plug, which is not within the scope of renewal review, also acts in the capacity of an uncredited defense-in-depth confinement barrier.

The staff reviewed the applicant's justification, which did not discuss the effects of stress relaxation on the stainless steel DSC sample port bolt. As discussed in NUREG-2214, stress relaxation of bolting is the steady loss of stress due to atomic movement at elevated temperature in a loaded part with dimensions that are fixed. NUREG-2214 states the staff's conclusion that the loss of initial applied stress in austenitic stainless steel bolting due to stress relaxation is negligible at temperatures below 300 degrees Celsius (C) (572 degrees Fahrenheit (F)). This temperature exceeds that experienced by the sample port bolt. Therefore, the staff considers that stress relaxation of the sample port bolt is not credible.

The metallic seal ring underneath the sample port bolt is similar to that used for the DSC vent and purge ports. Since stress relaxation of the sample port bolt is not credible, the staff agrees that there are no credible aging effects that would compromise the integrity of the double metallic seal during normal and off-normal conditions of storage. In addition, as discussed in SER Section 3.3.1.3, the noncredible complete release of radioactive particulate with no confinement credit taken for the seals was evaluated as part of Amendment No. 4 of SNM-2508 (NRC, 2005). The total dose at the INL site boundary was calculated and incorporated into UFSAR Section 8.1.4. The resulting dose at the INL site boundary, which was evaluated as the 10 CFR Part 72 controlled area boundary for the ISFSI, when combined with the INL sitewide operations' (including the ISFSI under normal operations that credit the seals) annual dose contributions, was less than the annual whole body dose limit in 10 CFR 72.104(a).[2]

The staff reviewed the applicant's justification and agrees with the applicant's conclusion that it is unlikely that potential aging effects will compromise the intended functions of the sample port bolt and seal during the period of extended operation, and thus, aging management is not required.

3.3.1.5 SSC subcomponent performance assessment: HEPA filter housing attachment bolts and washers on DSC vent and purge ports

The applicant stated that the sole function of the eight HEPA filter housing attachment bolts and washers on the vent and purge port filter assemblies is to attach the filter housing to the top cover plate of the DSC. The applicant further states that, as long as the hardware maintains the clamp load, the vent/purge port seals will continue to perform their uncredited confinement function. As a result, any postulated aging effects (e.g., crevice or galvanic corrosion) on the filter housing attachment bolts and washers will not credibly change the above-described, sealing confinement function.

The applicant referenced the periodic leak testing required by TS SR 3.1.1.1 and SR 3.1.1.2, which occurs every 5 years for the dual metallic seals and annually if the metallic seals are ever replaced with dual elastomeric seals. The applicant concluded that this activity directly assures conformance with the intended function provided by the HEPA filters and helps ensure no unintended leakage through the seals. As part of Condition A of TS LCO 3.1.1, if the filter housing seal leak rate is exceeded, the filter housing attachment bolts are reseated, and the leak test repeated, showing a direct correlation as to the function provided by these bolts and washers. As a separate defense-in-depth reassurance, the applicant states that exposed bolt head surfaces may be opportunistically inspected for any observed abnormal aging effects and corrective actions implemented, as outlined in the DSC AMP (see SER Table 3.5-1).

The applicant also referenced TS LCO 3.2.2, which requires the surface dose rate of each HSM rear access door and the purge/vent port filter housings be surveyed on an annual basis. The applicant stated that the associated TS SR 3.2.2.1 may also provide data representative of potential increased dose measurements attributable to hypothetical filter housing seal leaks, HEPA filter leaks, or sample port bolt leaks. Therefore, the applicant credited this defense-in-depth preventative action in the DSC AMP (see SER Table 3.5-1). The applicant clarified that corrective actions would be taken should this occur.

The staff reviewed the applicant's justification, which did not discuss the effects of stress relaxation on the stainless steel attachment bolts for the DSC HEPA filter housing. As discussed in NUREG-2214, stress relaxation of bolting is the steady loss of stress due to atomic movement at elevated temperature in a loaded part with dimensions that are fixed. NUREG-2214 states the staff's conclusion that the loss of initial applied stress in austenitic

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[2] It should be noted that the evaluation calculated total effective dose equivalent, whereas the limit is for whole body. While not the same dose quantity, the staff finds that the evaluated dose is sufficient for representing that the whole body dose is met since it includes both internal and external contributions (whole body is external only) and, for the external dose, the scenario is consistent with the discussion in Regulatory Guide 1.195, Section 4.1.4, regarding use of effective dose conversion factors as a surrogate for whole body dose conversion factors.

stainless steel bolting due to stress relaxation is negligible at temperatures below 300 degrees C (572 degrees F). This temperature exceeds that experienced by the attachment bolts for the DSC HEPA filter housing. Therefore, the staff considers that stress relaxation of the attachment bolts for the DSC HEPA filter housing is not credible.

The staff reviewed the applicant's justification and agrees with the applicant's conclusion that it is unlikely that potential aging effects will compromise the intended functions of the filter housing attachment bolts and washers of the DSC vent and purge ports, and therefore that aging management of these subcomponents is not required.

3.3.1.6 **SSC subcomponent performance assessment: TMI-2 Fuel Canister Licon**

The TMI-2 Fuel Canister incorporates a low-density concrete mixture of calcium aluminate cement, hollow glass spheres, and demineralized water. The material, named Licon, is almost entirely within the encased environment, except for the top surface, which instead is exposed to the internal TMI-2 canister environment. The other bounds of the encased environment include the outer skin of the neutron poison shroud, the inner surfaces of the TMI-2 Fuel Canister shell, and the top surface of the TMI-2 Fuel Canister bottom support plate. The applicant characterized this environment as air filled with moisture content limited to that present when the welds were applied at the fabricator. The applicant further characterized the environment as bounded by the conditions representative of the internal canister environment.

The applicant determined that the Licon provides the intended functions of radiation shielding, subcriticality, heat-removal capability, and structural integrity. The applicant provided evaluations based on the design-bases assumptions and analyses to demonstrate that the postulated aging effects of loss of material, cracking, or reduction in material properties would not adversely affect these intended functions. These evaluations are discussed next.

<u>Radiation Shielding</u>

The licensee performed a supplemental shielding and radiation protection analysis to demonstrate that the Licon is not needed to meet the dose rate requirements in the TS and in the regulations. The Licon is credited in the DSC top-end dose rate analysis in the UFSAR,[3] but it was not credited in the other UFSAR shielding analyses and dose rate calculations. The licensee performed a supplemental analysis to calculate a dose rate for the vent port filter housing for the effect of losing the Licon (looking at just the loss of the material). Since the method in the supplemental analysis differs from the method used in the UFSAR analysis, a valid direct comparison between the UFSAR analysis result and the supplemental analysis result for the loss of Licon is not possible, nor is it appropriate. Thus, the licensee's supplemental analysis also includes a recalculation of the dose rate for the vent port filter housing for the configuration used for the UFSAR analysis. The recalculation allows a comparison of dose rates that were determined using the same calculation method.

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[3] For the shielding analyses, some analyses and results are in the UFSAR and some are in calculation packages that support the original licensing of the ISFSI and the license amendments. References in this section of this SER to UFSAR analyses include analyses from the UFSAR and from those supporting calculation packages, even for analyses that only show up in either the UFSAR or in the calculation packages.

The TMI-2 Fuel Canisters were assumed to retain their cylindrical shape although the Licon material was removed from the model. The staff finds this to be acceptable because the configuration of the TMI-2 Fuel Canister components make it unlikely that collapsing of the space occupied by the Licon would significantly affect the position of the TMI-2 canisters within their respective locations in the DSC basket.

The licensee performed the supplemental dose rate calculations with Monte Carlo N-Particle Transport Code (MCNP) version 6.1.0. The MCNP has widespread use throughout the industry, including in shielding analyses for spent fuel dry storage and adequate capabilities to model complex geometries and radiation source terms. The code continues to be updated and maintained by its developer to ensure correction of errors that have been identified and the use of the best available data. For these reasons, the staff finds the use of this code to be acceptable for this analysis.

For the supplemental analysis, the licensee used the source term defined in Section 7.2.1 of the UFSAR and did not credit any decay of the design-bases source term over the initial storage period. The neutron dose rates were not calculated since they were found to be small compared to the gamma dose rates in the UFSAR analysis (less than 5 percent). While the supplemental analysis has some similarities with the UFSAR analysis, there are some differences that help to reduce the relative computational uncertainties in the results (which were large in the UFSAR analysis) and improve the calculation results.

The licensee calculated dose rates at the vent port filter housing for the configuration of the TMI-2 Fuel Canisters in the DSC that was analyzed in the UFSAR. The resulting dose rate for this design-bases configuration was 35 millirem/hour (mrem/hr). The licensee also evaluated the TMI-2 Fuel Canisters in their nominal position in the DSC basket but with the Licon removed. The resulting dose rate on the vent port's filter housing surface was 55 mrem/hr. While the UFSAR tables and figures do not clearly indicate the dose rate at the vent port's filter housing for the design-bases configuration, the supporting calculation for the UFSAR indicates the originally calculated dose rate was about 3 mrem/hr. However, that calculation was done with an older code version and the results included a significant relative computational uncertainty. Thus, the staff finds it is more appropriate to compare the 55 mrem/hr with the Licon removed to the 35 mrem/hr for the design-bases configuration since both calculations use the same code version and analysis techniques that help to reduce the relative error in the results.

The staff notes that TS 3.2.2 of the license requires the licensee to measure the dose rates of the filter housings of the DSC's vent and purge ports annually. The results of these measurements have been reported in the annual radiological environmental monitoring program reports for the site. The maximum measured dose rates, which were measured about 11 years after the license was issued, for this same surface location, were higher than the dose rate calculated in the UFSAR analysis. The maximum measured dose rates, measured shortly after the license was granted and all HSMs were loaded (in 2001), were significantly higher (by about 50 times) than the calculated dose rate in the UFSAR. This is atypical of comparisons between measured and calculated dose rates. Calculated dose rates in the UFSAR are typically bounding versus the measured dose rates, given the bounding nature of the analyzed source term and conservatisms that are usually included in the UFSAR analysis. The maximum measured dose rates from 2001 were still significantly higher than the dose rate calculated in the supplemental analysis (by a little over 4 times). This is in part due to the analysis configuration in both the UFSAR analysis and the supplemental analysis, which differed from the actual configuration of the DSCs in storage. One difference is the inclusion of large amounts of steel in the form of a steel cover over the purge and vent ports' filter housings. In its review of the license renewal application, the staff focused on the relative difference between the dose rates for the design-bases configuration and the configuration without the Licon. Since the differences in the model versus the actual DSC design would affect both configurations, the staff considered that the relative difference in dose rates between the two configurations would not be significantly impacted.

The licensee's analysis of the change in dose rates focused on showing the dose rates would not exceed the limit for the filter housing in the license's TS LCO 3.2.2. This TS imposes a limit of 1,200 mrem/hr on dose rates at the surface of the vent port filter housing, and the dose rate resulting from loss of the Licon does not exceed that limit. Thus, the Licon is not needed to meet the TS LCO 3.2.2 limit for the filter housing surface dose rates. With the dose rates on the filter housing less than 100 mrem/hr, the staff finds that the Licon is not needed to meet the LCO 3.2.2 dose rate limit for the HSM's rear access door, which is 100 mrem/hr.

However, the design bases are more than just these two TS limits. The dose rates and occupational and public dose estimates in the UFSAR are part of the shielding and radiation protection design bases, as described in SER Section 2.1.3. The filter housing dose rates increased by about 60 percent when neglecting the Licon. The staff does not expect the public dose estimates to be affected by neglecting the Licon, since the analysis only affects dose rates in a small location that would not impact doses at or beyond the controlled area boundary (for 10 CFR 72.104(a) and 72.106(b) limits).

The staff determined that there would likely be some impact to the occupational dose evaluations in the UFSAR. These evaluations are performed for the purpose of demonstrating compliance with requirements such as 10 CFR 72.24(e), which states the application for a license must include information about the means for controlling and limiting occupational radiation exposures within the limits given in 10 CFR Part 20, "Standards for Protection Against Radiation," and for meeting as-low-as-is-reasonably-achievable (ALARA) objectives. Thus, the licensee analyzed the impacts of the dose rate increases on the estimated personnel doses that are given in the UFSAR and evaluated them against the 10 CFR Part 20 limits and requirements. The evaluation considered operations on a single DSC/HSM. While acceptable for purposes of this evaluation, it should be noted that, because operations would be expected for multiple DSCs/HSMs within a given year, annual doses from operations with multiple DSCs/HSMs should be considered when determining compliance with the regulatory limits and requirements for occupational doses.

In considering the licensee's evaluation of dose rates and dose estimates for neglect of the Licon, the staff recognizes the licensee did not credit the decay of the TMI-2 debris' radiation source term over the initial license period. Thus, in its evaluation, the staff considered the 20 years of decay. While the neutron source would decay negligibly over the 20 years, the staff determined that the neutron source could be ignored since it contributed negligibly to the total (gamma plus neutron) dose rates. The staff's evaluation indicated that the gamma source from the debris would decay by a significant fraction of the design-bases source term and that this decay would be sufficient to offset the increase in dose rates estimated to result from neglecting the Licon. This in turn means that the dose rates and dose assessments for the design bases in the UFSAR would bound the dose rates and dose assessments for the configurations without Licon when decay of the source after 20 years in storage is also considered. Therefore, the staff finds that management of aging of the Licon is not needed for shielding and radiation protection.

Subcriticality

The licensee performed a supplemental criticality analysis to demonstrate that the Licon is not important for criticality safety. Licon is used only in the TMI-2 canisters that are referred to as the TMI-2 Fuel Canister. The TMI-2 Knockout and Filter Canisters do not use the Licon material. According to the criticality analyses that were done for the UFSAR, the TMI-2 Knockout Canister is the most reactive of the three TMI-2 canister types. It was not clear, however, that the TMI-2 Fuel Canister would be subcritical and bounded by the TMI-2 Knockout Canister when the TMI-2 Fuel Canister analysis more completely evaluated the effects of the degradation or loss of Licon, including any structural effects and material properties of the Licon. Hence, the licensee performed the supplemental criticality analysis to address the impacts due to loss of these attributes of the Licon.

Model Geometry and Material Properties

The TMI-2 Fuel Canisters include a cavity of square cross section (9 inches, nominal, on a side) that is surrounded by a steel shroud that includes Boral®. The Boral® extends the full length of the canister cavity. The TMI-2 Fuel Canister is a round canister (14 inches outer diameter, 0.25-inch-thick steel). The Licon fills the volume between the outer shell and the Boral® shroud. Twelve TMI-2 canisters are in a DSC. For this analysis, all twelve canisters are TMI-2 Fuel Canisters. The licensee credited only 75 percent of the boron-10 in the Boral®. This is consistent with the staff's guidance regarding credit for solid neutron absorber materials in criticality analyses (see Section 8.4.1.1 of NUREG-1567, "Standard Review Plan for Spent Fuel Dry Storage Facilities," issued March 2000 (NRC, 2000). The licensee also has a requirement that the TMI-2 canisters be dried such that no more than 8 liters of water could be in each canister. This water quantity includes any bound and unbound water remaining in the canisters after drying, as well as any moisture that could be reacquired during storage at the ISFSI. The licensee demonstrated that the TMI-2 canisters have been sufficiently dried such that the water limit, which is used in the criticality analysis, will not be exceeded over the life of the ISFSI, including the period of extended operation, as this is a key assumption in the criticality analysis.

The staff notes that, in several of the analyses supporting the UFSAR, the solid neutron poisons were neglected or replaced by water. Thus, crediting the Boral® for the TMI-2 Fuel Canister in the supplemental analysis is different from what was done in the UFSAR analyses. However, the staff finds that crediting the Boral® in the supplemental analysis is acceptable since degradation of the Boral® is not credible (see SER Table 3.3-6).

The analysis assumes the contents of the TMI-2 Fuel Canister to be unclad fuel rods or stacks of pellets having the dimensions of full-sized pellets (diameter and length). Each TMI-2 Fuel Canister is assumed to contain the maximum amount of fuel material that was identified to be loaded into a TMI-2 Fuel Canister and no other material (i.e., no assembly hardware). The fuel is assumed to be at the highest enrichment of the fuel in the TMI-2 reactor at the time of the accident. The rods are stacked in triangular pitch arrays at optimum moderation for the portion of fuel that is in the 8 liters of water, with the rods touching in the portion of the fuel that is not moderated. The pellet diameter used in the supplemental analysis differs from the pellet diameter used in some of the UFSAR analyses. However, the UFSAR criticality analyses indicate that there was a range of diameter values that had been found to maximize reactivity. The pellet diameter used in the supplemental analysis is within this range of values. However, use of a different pellet diameter may introduce some small amount of uncertainty into the analysis result.

The licensee modeled the water in the TMI-2 Fuel Canister at full density and occupying the volume that 8 liters of full density water would occupy in the cavity of the TMI-2 Fuel Canister. This configuration had been found in the UFSAR analyses to be more reactive than water at partial density filling a greater volume of the can cavity. The staff noticed that the licensee also modeled the TMI-2 Fuel Canister components at dimensions that differed from the nominal values but that were not at the maximum variation allowed by the tolerances in the canister drawings. Thus, while the selected dimensions tend to increase reactivity, it is unclear whether the dimensions are those that maximize reactivity within the allowed tolerances. This also adds some uncertainty to the analysis results, although the staff expects that uncertainty to be relatively small due to the small magnitude of the differences between the selected dimensions and the maximum allowed by the defined tolerances. Since the UFSAR analyses indicated that a dry DSC cavity (i.e., no water in the DSC cavity outside of the TMI-2 Fuel Canisters) was most reactive, the licensee's supplemental analysis used that configuration. The analysis also assumes the DSC and HSM are collapsed around the twelve TMI-2 Fuel Canisters, similar to the analysis for the UFSAR. This configuration optimizes the HSM concrete's reflection of neutrons back into the TMI-2 Fuel Canisters. The material properties of the system components are the same as for the UFSAR analyses, with the Boral® credited to 75 percent of the actual boron-10 present.

Analysis of Licon Degradation Effects

The licensee analyzed various Licon degradation effects. Initially, the TMI-2 Fuel Canister's round cross section was maintained for these analyses. The effects included reducing Licon density and varying the amount of water absorbed in the Licon. The licensee found that both conditions of reducing Licon density and increasing the water absorbed in the Licon reduced reactivity. The licensee also evaluated the structural loss of the Licon by collapsing the TMI-2 Fuel Canister's outer shell to immediately surround the Boral® shroud. This made the can have a square cross section. The licensee then placed the cans in a close packed array and found that a 3×4 array of the cans with no interstitial space was the most reactive configuration.

A full and complete evaluation of the effects of Licon degradation on criticality safety would involve a consideration of additional Licon properties. These properties include varying the amounts of the different Licon constituents. However, the staff finds that complete removal of the Licon along with the collapse of the TMI-2 Fuel Canister outer shell would bound any effect that varying the Licon constituent amounts would have. The staff also considered whether having some moderator between the collapsed TMI-2 Fuel Canisters would increase reactivity, given the significant amount of unmoderated fuel in each can. The staff performed a simple calculation using a model similar to the applicant's, but with the TMI-2 Fuel Canisters spaced a little apart and the DSC filled with low-density water. The result confirmed that having the TMI-2 Fuel Canisters adjacent to each other was more reactive.

Computer Code and Benchmark Analysis

The licensee performed this supplemental criticality analysis using the CSAS5 criticality sequence in the SCALE code system and version 6.2.1 of the SCALE code system. The licensee used the ENDF/B-VII.0 238-group cross section library. The staff finds this code system acceptable because the SCALE code system is specifically designed for criticality analyses and has capabilities sufficient to analyze the TMI-2 Fuel Canisters in the DSC and HSM. The cross section library is included with the SCALE code system.

The staff noted the number of particles run for each calculation and confirmed that the number was sufficient to ensure adequate convergence of the problem solution. The staff also noted that the licensee used the cellmix option in the cell data block. This option creates a homogenized material that neutronically represents the heterogeneous configuration of fuel and other materials specified in the cell data input. The licensee used this option for both the fuel in water and the fuel in void (i.e., the unmoderated fuel outside the region with 8 liters of water). The licensee used the homogenized materials in the geometry portion of the model. This technique is the same as the licensee used in the criticality analyses in the UFSAR. While an older feature of the SCALE code that is generally no longer used, the staff finds this approach acceptable in this case because of its consistency with the approach in the UFSAR criticality analyses and because the licensee's benchmark analysis included use of this technique.

To benchmark the analysis, the licensee considered 50 experiments from four groups of experiments that are described in the *International Handbook of Evaluated Criticality Safety Benchmark Experiments*. These experiments all include water moderated uranium dioxide fuel rods of enrichments a little lower and a little higher than in the TMI-2 Fuel Canister analyses. They also include different reflectors and absorber materials between fuel rod clusters. The licensee performed a trending analysis on two parameters, the energy of the average lethargy of fission and the uranium-235 density in the fuel. Based on staff concerns, the licensee expanded the benchmark analysis to include trends on two additional parameters, the hydrogen-to-uranium-235 atom ratio and the enrichment. The applicant also modified the benchmark analysis to determine the minimum upper subcritical limit for each parameter for both the full set of benchmark experiments and for the subset of experiments that excludes those that have materials that are not relevant to the TMI-2 Fuel Canister analysis. The staff reviewed the benchmark analysis and finds the applicant considered trends on an appropriate number of parameters and performed a trending analysis that is sufficient to ensure that trends for experiments that are relevant to the analysis are not masked by inclusion of experiments with materials and properties that are not relevant to the analysis.

The staff notes that the benchmark analysis should use the code features and options that are used in the analysis of the TMI-2 Fuel Canisters. The licensee used the same code version, criticality sequence, and cross section library. The licensee also used the cellmix option to represent the fuel material in the benchmark experiments similar to the analyses for the TMI-2 Fuel Canister. Thus, in this regard, the staff finds the benchmark analysis to be acceptable since it uses the same code features and options that are used in the analysis of the TMI-2 Fuel Canisters. Using the same modeling options ensures that the benchmark analysis adequately captures the effects of the analysts' approach on determining reactivity. The minimum USL [Upper Subcritical Limit] in the licensee's modified benchmark analysis is 0.9435.

A thorough benchmark analysis includes sufficient benchmark experiments with appropriately similar properties to the analyzed storage system such that the parameters from the analyses of the storage system are bounded within the ranges of those parameters for the benchmark experiments, and the experiments' results provide a well-defined range of applicability for determining trends in any computational bias. In cases where sufficient benchmarks are not available to make this possible, the benchmark analysis addresses uncertainties and the acceptability of extrapolation of the benchmark results beyond the area of applicability. In evaluating the licensee's modified benchmark analysis, it was noted that none of the benchmark experiments had uranium-235 densities or enrichments that were not at the endpoints of the applicability range. The staff also noted that the energy of the average lethargy of fission for the most reactive case was outside the range of applicability; it was more than double the upper limit of the applicability range. Although these characteristics add uncertainty to the behavior of the trends on these parameters, the staff recognizes that there is significant margin between the reactivity for the most reactive case in the supplemental analysis and the minimum upper subcritical limit (over 8 percent). Based on its engineering judgement, the staff does not expect that the impacts of actions to address these aspects of the licensee's benchmark analysis would exceed the available margin to the upper subcritical limit. Because of this, the staff finds the benchmark analysis to be sufficient for this supplemental criticality analysis.

Maximum Reactivity and Staff Finding Regarding Criticality

The most reactive case determined by the licensee was 0.85926 (includes two times the code Monte Carlo uncertainty). Applying the bias and bias uncertainty to the calculated maximum TMI-2 Fuel Canister reactivity shows the TMI-2 Fuel Canister reactivity to still be bounded by the TMI-2 Knockout Canister reactivity. This is also true if even a few percent more is added to the maximum TMI-2 Fuel Canister reactivity to account for the uncertainties from the TMI-2 Fuel Canister components' tolerances and the pellet size that were described previously. Thus, the staff finds the supplemental analysis demonstrates that the TMI-2 Knockout Canister is still bounding for criticality purposes and that a DSC loaded with the bounding TMI-2 Fuel Canister will remain subcritical without the Licon present or any of its properties or functions credited in the criticality analysis. Therefore, the staff finds that management of aging of the Licon is not needed for criticality.

Heat-Removal Capability

The applicant stated that credible changes to the Licon effective thermal conductivity will not adversely affect the ability to comply with the TMI-2 core debris temperature limits. The applicant depicts the HEATING 7 thermal model of the HSM in UFSAR Figures 8.1-1 and 8.1-4 and calculates the thermal conductivity of the Licon (0.726 British thermal unit (BTU)/hr-ft-degrees F). The applicant states that the percent of water in the overall Licon composition can vary after the heated vacuum drying process and after a period in dry storage, due to the potential for Licon reabsorbing atmospheric water vapor. However, the applicant concludes that small differences in the weight percent of the Licon constituents, including water, glass bubbles, and concrete, have negligible effect on the thermal analysis result of the core debris and TMI-2 canisters due to the sizeable margins between the maximum calculated TMI-2 core debris temperature and the acceptance criteria.

In response to staff questions during the review, the applicant evaluated bounding values of the Licon thermal conductivity to assess the maximum increase in the calculated temperature drops across the Licon. The applicant used this evaluation to demonstrate that the potential change to the thermal conductivity of the Licon material as a result of water absorption during the period of extended operation will continue to provide sufficient thermal margin, and any absorbed water will not impact the effective thermal conductivity assumed in the design-bases thermal evaluation, and thus the heat-removal capabilities of the Licon material. From the bounding thermal conductivity values evaluated by the applicant, the resultant TMI-2 ISFSI UFSAR fuel cladding temperature acceptance criteria were reviewed to determine that any magnitude of change in the Licon thermal conductivity will support adequate heat-removal capability.

The fuel cladding temperature limits are listed in TMI-2 ISFSI UFSAR Table 8.1-10 as 724 degrees F and 1,058 degrees F for normal conditions and off-normal/accident conditions, respectively. Using the Licon normal thermal conductivity, the maximum calculated TMI-2 core debris temperature remains under 174 degrees F, which provides a 550 degrees F margin under normal operating conditions, and remains below 219 degrees F, providing an 839 degrees F margin, under accident conditions.

The applicant discussed the weight percents of the constituent materials for the Licon thermal conductivity in the TMI-2 ISFSI UFSAR Section 8.1.3.2 thermal analysis. The respective thermal conductivities of the constituent materials are such that the addition of water results in a decrease in the Licon conductivity. The applicant states that, in the extreme case, the water would displace all other materials resulting in a thermal conductivity equal that of the water (0.348 BTU/hr-ft- degrees F), which is less than the thermal conductivity used in the thermal analysis. On the other hand, the applicant presents that, if the Licon were to lose water, the thermal conductivity may be reduced to a value near that of sand (0.19 BTU/hr-ft-degrees F).

The applicant evaluated the thermal profile through the TMI-2 Fuel Canister and determined the resultant average temperature drop across the Licon. The resultant average temperature drop across the Licon using the thermal conductivity used in the thermal analysis is 1.8 degrees F, decreasing the bounding margin under normal operations to 548.2 degrees F. The applicant evaluated this temperature drop using the extreme bounding cases of the Licon thermal conductivity described above. With the lower credible-bounding thermal conductivity, the temperature drop becomes 6.8 degrees F, which leads to a bounding margin of 543.2 degrees F.

The applicant states that any reasonably bounding amount of change in the Licon thermal conductivity would continue to maintain adequate heat-removal capability during the period of extended operation such that the fuel cladding temperature remains within the TMI-2 ISFSI UFSAR limits with significant margin. The staff reviewed the applicant's justification, as discussed above, and considers the conclusion to be acceptable. The staff finds this acceptable because the bounding cases of potential change in the Licon thermal conductivity provide sufficient thermal margin that any loss of the Licon thermal conductivity will continue to provide adequate heat removal, and therefore, management of the aging of Licon for heat removal is not required.

Structural Integrity

The applicant concluded that the Licon material provides structural support for the shroud walls of the TMI-2 canisters and, therefore, it is a consideration in the renewal of the TMI-2 ISFSI. More specifically, the structural performance of the Licon is a consideration during design-bases accident-drop conditions.

Per UFSAR Section 8.2.5.1.B, the range of 10 CFR Part 72 transfer-drop scenarios conservatively selected for TMI-2 DSC design bases include the following cases:

- The first is a horizontal side drop from a height of 2.0 meters (80 inches) after the impact limiters have been removed.
- The second is an oblique corner drop from a height of 2.0 meters (80 inches) at an angle of 30° to the horizontal, onto the top or bottom corner of the cask after the impact limiters have been removed (two cases). The angle of inclination for the corner drop of 30° represents the maximum possible impact angle that the cask can rotate downward with one end supported horizontally on the transport skid trailer at a height of 80 inches.

The height of 2.0 meters (80 inches) was chosen as this envelopes the maximum vertical height of the cask when secured to the transport skid/trailer assembly. Per UFSAR Section 1.3.2.2, the nominal trailer bed height during DSC transfer to (and from) the HSM is such that the cask is elevated less than 1.68 meter (5.5 feet) above grade as measured from the lowest point on the cask. This is well below the 2.0-meter (80-inch) drop height elected for TMI-2 DSC design bases.

As discussed previously, the Licon is not considered important for ensuring compliance with 10 CFR Part 72 criticality and radiation shielding requirements. Therefore, the staff reviewed the structural performance of the Licon to ensure that any inadvertent degradation of the Licon during the period of extended operation does not pose a safety risk during DSC retrieval operations. More specifically, the staff reviewed the discussion on the structural evaluation of the Licon during postulated accidents. The applicant stated, that, during original TMI-2 canister certification testing, a 30-foot horizontal drop test showed the Licon concrete supported the shroud and prevented any significant deformation of the shroud. According to the criticality evaluation in UFSAR Section 3.3.4.2.A, the TMI-2 Fuel Canister does not experience any deformation or displacement of the poison shroud during accident conditions. Per UFSAR Section 8.2.5.2.A, the TMI-2 canisters were drop tested to 190g during their design program and can support the weight of all TMI-2 canister assemblies without affecting any of the criticality assumptions described in UFSAR Section 3.3. Since these analyses were performed in support of transportation per 10 CFR Part 71, “Packaging and Transportation of Radioactive Material,” the staff considers that these loads would be reasonably bounding to a 2.0-meter (80-inch) design-bases drop event during retrieval operations. Therefore, the staff expects that Licon, subject to inadvertent degradation during the period of extended operation, would still be able to retain the shroud in place, since the loads of the TMI-2 canisters during transfer operations will be significantly lower than those tested in the 10 CFR Part 71 test program. In addition, the applicant notes that the transfer cask, the transfer cask internal spacers, and the DSC would absorb the majority of the dynamic energy (UFSAR Table 8.2-3) in a 2.0-meter (80-inch) drop event. Therefore, the staff agrees with the applicant’s conclusion that the original UFSAR conclusions on structural integrity of the Licon remain valid for the period of extended operation and no aging management is required.

3.3.1.7 **SSC subcomponent performance assessment: zinc-rich coating**

The applicant referenced UFSAR Section 4.6, which states that carbon steel DSC subcomponents are coated with a zinc-rich inorganic coating with a high resistance to temperature and radiation (CARBOZINC® 11 or CARBOZINC® 11 HS). The applicant clarified the limits to the coating coverage as discussed in Section 3.4.2.1 of the license renewal application. The same coating is applied to both the interior and exterior of the DSC as well as the internal DSC SSCs (e.g., vent port shield block). The coating is exposed to the sheltered environment (on the exterior surfaces of the DSC) and to the internal DSC environment (on the interior surfaces of the DSC). The coating is the primary mitigating corrosion protection mechanism for the DSC carbon steel SSCs structural integrity. The applicant defined the minimum possible thickness as 50 micrometers (2×10^{-3} inches).

The applicant also stated that all exposed steel surfaces on HSM subcomponents within the scope of renewal are either hot-dip galvanized or covered with a zinc-rich coating, with threaded fasteners electroplated consistent with the requirements of American Society for Testing and Materials International (ASTM) B633. Hot-dip galvanizing was performed consistent with the requirements of ASTM A123 with a minimum thickness coating grade of 100. The applicant defined the coated HSM subcomponents in Table 3-6 of the license renewal application. The applicant clarified that the DSC support structure in the HSM was coated, per the fabrication specification, with 50 micrometers (2×10^{-3} inches) to 150 micrometers (6×10^{-3} inches) inorganic zinc-rich primer (CARBOZINC® 11) with a finish top coat of high-build epoxy enamel at 125 micrometers (5×10^{-3} inches) to 175 micrometers (7×10^{-3} inches) (CARBOLINE® 890). In addition, as-welded areas and areas needing touch up (due to installation or transfer damage) are specified to be coated with these same materials. The applicant stated that these coating systems have excellent adhesion to steel and resistance to alkalis and were incorporated into the HSM design to provide protection for the steel against corrosion in the TMI-2 ISFSI environment.

The applicant defined numerous mechanisms for coating degradation including mechanical removal (scraping), corrosive oxidation, and cracking, as discussed in Section 3.4.4 of the license renewal application. The applicant clarified that failure of the coating does not prevent the DSC steel SSCs from satisfactorily accomplishing their intended functions. However, the applicant acknowledged that coating degradation may disguise indications of corrosion of the underlying steel. Therefore, the applicant included defense-in-depth activities in the DSC AMP to evaluate the coated exterior surfaces of the DSC for adverse or abnormal aging effects during the period of extended operation. Similarly, the applicant included defense-in-depth activities in the HSM AMP to evaluate coated surfaces of the HSM subcomponents for adverse or abnormal aging effects during the period of extended operation. These activities are intended to manage loss of coating integrity due to blistering, cracking, flaking, peeling, or physical damage.

The staff notes that the applicant did not address thermal and radiation effects on their potential to degrade the zinc-rich coatings. However, the staff considers that radiation embrittlement of these coatings due to irradiation is not credible (Dupont et al., 2001, and Beenken et al., 2016). Further, upon consideration that these coatings are NITS per the design bases and that aging management activities will be implemented under the aegis of both the DSC and HSM AMPs, the staff considers that potential degradation of the zinc-rich coatings due to thermal or radiation effects will be properly managed by these activities. The staff further considers that these aging mechanisms will manifest as loss of coating integrity, an aging effect that will be managed under the aegis of both the DSC and HSM AMPs.

The staff reviewed the applicant's justification and considers as acceptable the applicant's conclusion that defense-in-depth activities in both the DSC and HSM AMPs that assess zinc-rich coating degradation are appropriate for managing aging effects associated with DSC and HSM steel subcomponents (see SER Section 3.5).

3.3.1.8 **SSC subcomponent performance assessment: silane water-repellent coating on HSM concrete surfaces**

The applicant stated in Section 3.2.3.2.2 of the license renewal application that HSM concrete surfaces were sealed against moisture intrusion in October 2011 with application of a silane water-repellent coating. The applicant defined the coated HSM subcomponents in Table 3-6 of the license renewal application. The applicant further stated that the application of the silane coating on HSM concrete surfaces was implemented as a corrective action from HSM inspections conducted in 2009, which identified degradation of the HSM concrete and end shield wall subcomponents. The applicant stated that water intrusion was identified as a probable cause of the degradation observed as concrete scaling and cracking.

The applicant clarified that, similar to the steel protective coatings, the silane concrete coating does not provide a credited safety function in the design bases. However, the applicant recognized that the silane coating affords a defense-in-depth function, providing long-term water-repellent protection, inhibiting both moisture penetration and rebar corrosion. Therefore, the applicant included the silane water-repellent coating within the scope of renewal review and recognized that aging management of the silane water-based coating integrity and functionality during the period of extended operation allows continued protection of the underlying HSM concrete subcomponents.

The applicant clarified that the repellent was tested for water repellency by spraying water from a hand-held spray bottle on the concrete surface to determine if it would bead. The testing demonstrated that water successfully beads on the surfaces. Since no tests were performed before the application of the coating treatment, comparison to a before-treated condition was not possible. Therefore, the applicant stated that sealant monitoring was implemented in 2016, and this activity was incorporated in the HSM AMP per the coating's manufacturer-recommended testing protocol, along with appropriate acceptance criteria.

The staff reviewed the applicant's justification and considers as acceptable the applicant's conclusion that defense-in-depth activities in the HSM AMP that assess silane coating degradation are appropriate for managing aging effects associated with HSM concrete subcomponents.

3.3.1.9 **SSC subcomponent performance assessment: HSM chemical grouts and other sealant materials**

<u>Silicone Sealant</u>

The applicant discussed that when the HSM end shield wall panels were originally installed, plastic plugs were to be inserted into the coil inserts used for lifting (four per wall) and covered with a silicone sealant to prevent water collection and intrusion. However, filling the coil insert holes was not completed. In Section 3.2.3.2.2 of the license renewal application, the applicant stated that, in inspection findings from a pre-application inspection of the end shield walls conducted in 2012, the coil insert holes in the tops of the walls exhibited minor freeze-thaw-induced cracking. The licensee determined that water could fill the holes and continue to cause freeze-thaw degradation; therefore, the cracks were filled with a silicone sealant.

<u>Polyurethane Foam</u>

The applicant stated that a polyurethane spray foam (TIGER FOAM® product) is used as a chemical grout inside the roof slab attachment bolt holes. A polyurethane (water-resistant) gasket material is also used as a washer in the fastener joint for the roof slab attachment bolt holes, which precludes water from both entering the bolt hole and solidifying during freezing weather conditions. Protective roof bolt covers were installed on top of the bolt holes and the gaskets to limit both direct sunlight and direct exposure of the polyurethane to rain and snow. The staff notes that the NRC issued Information Notice 2013-07, "Premature Degradation of Spent Fuel Storage Cask Structures and Components from Environmental Moisture," dated April 16, 2013 (NRC, 2013), which discusses the degradation (freeze-thaw cracking due to water ingress) leading to the corrective actions implementing the use of the polyurethane spray and the protective roof bolt covers and associated polyurethane gaskets.

The applicant clarified that the polyurethane foam and gasket are NITS as they do not provide a credited safety function in the design bases. However, the applicant recognized that the inspections conducted in 2009 identified installation of these items as a recommended course of action to limit further concrete degradation from freeze-thaw cracking. The applicant cited literature from the polyurethane foam manufacturer, which states that the polyurethane foam is resistant to temperatures within minus 129 degrees C (minus 200 degrees F) and 93 degrees C (200 degrees F), although not resistant to ultraviolet light and hence should be painted, coated, or covered if exposed to direct sunlight after application. The applicant clarified that the polyurethane gasket edges may be exposed to moisture if it is allowed to collect on the roof slabs. In terms of water exposure, the applicant stated that, when polyurethane foam at constant temperature is exposed to water, in either liquid or vapor form, little moisture will accumulate in the foam since 90 percent of the cells are closed and hence bound by continuous membranes that the water cannot penetrate. The applicant further stated that the presence of air and blowing agents inside the cells also protects the foam from damage due to freeze-thaw cycling. However, the applicant recognized that polyurethane foam may be susceptible to aging as it has been exposed to radiation from the TMI-2 core debris. In addition, the applicant cited the American Concrete Institute (ACI) guide 546.3R, which recommends routine inspection and maintenance and indicates that polyurethane sealants can provide a service life from 3 to 10 years, at which time they need to be removed and replaced. Therefore, the applicant concluded that aging management of these polyurethane materials (foam filler and gasket) is necessary to limit water intrusion into the roof bolt holes and ensure continued structural performance of the HSM subcomponents during the period of extended operation.

Epoxy Sealants

The applicant stated that repairs were made to the HSM concrete matrix from 2011 through 2015 as a result of freeze-thaw degradation. The applicant further stated than an epoxy resin (CRACKBOND® SLV-302) was injected into cracks in the HSM concrete matrix under a cover paste of MIRACLE BOND® 1350 epoxy resin, preventing water intrusion and further damage to the HSMs. In addition, another epoxy resin (MIRACLE BOND® 1450) was used to repair areas impacted by spalling, which provide protection from potential degradation in those distressed sections of the HSMs.

The applicant clarified that failure of these epoxy resins will not directly affect the structural integrity of the HSM. However, the applicant recognized that, if the resin degrades prematurely or fails, a path for water intrusion into the concrete could be reopened. This could allow for renewed freeze-thaw aging and other aging conditions with the potential to adversely affect the concrete and steel HSM SSCs' structural integrity.

Aging Management Activities

The applicant referenced ASTM C717, "Standard Terminology of Building Seals and Sealants," which provides a definition for aging effects requiring management on sealants as (1) adhesive failure between the sealant and concrete substrate, and (2) other cohesive failure characterized as rupture within the sealant or filler. Therefore, the applicant recognized that aging management of these aging effects on chemical grout and other repair sealant materials is required to ensure the intended functions of the HSM subcomponents are maintained during the period of extended operation.

Staff’s Evaluation and Findings on HSM Chemical Grouts and Other Sealant Materials

The staff reviewed the applicant’s description of the HSM grouts and other chemical materials and their purpose in ensuring that the HSM subcomponents maintain their intended functions during the period of extended operation. The staff agrees with the applicant’s conclusion that activities in the HSM AMP are sufficiently adequate to assess degradation of these materials and appropriate for managing aging effects associated with HSM concrete subcomponents.

3.3.1.10 SSC subcomponent performance assessment: differential settlement of ISFSI basemat and approach slab

The applicant cited the UFSAR, which states that differential settlement could affect retrievability of the DSC; lower the elevation of the basemat below the predicted maximum flood; or, in the unlikely event that large settlements of the ISFSI foundation occur, the resultant shifting of adjacent HSMs may cause the HSMs to separate, reducing the shielding adjacent HSMs provide for each other (which the licensee refers to as self-shielding). The applicant clarified that settlement was considered in UFSAR Section 2 and was considered of relatively low potential, given the location and geological characteristics of the TMI-2 ISFSI site. The applicant further clarified that appropriate excavation, backfill, levelling, and compaction of the subbase and base limited the possibility of differential settlement. The applicant referenced visual inspection results of accessible concrete surfaces of the TMI-2 basemat performed during inspections conducted in August 2010, November 2012, and November 2014. The applicant concluded that differential settlement or unanticipated basemat cracking was not observed. Based on these inspections, the applicant concluded that age-related differential settlement of the basemat and approach slab has not occurred since original construction.

The applicant also clarified that the resultant shifting of adjacent HSMs due to differential settlement, which could cause the HSMs to separate, reducing HSM self-shielding, was previously evaluated in UFSAR Section 8.2.1. Further, the applicant stated that the maximum floodwater elevation is well below the bottom of the DSC, which is approximately 1.75 meters (69 inches) above the slab surface. Therefore, the applicant concluded that, even with gross settlements of the basemat (i.e., event-driven conditions, not age related), basemat settlement is not a credible aging effect that would affect flood loads acting on the TMI-2 ISFSI SSCs. If gross settlement did occur, the applicant clarified that recovery according to UFSAR Section 8.2.1.4 includes unloading and removing from service any affected HSMs until repairs to the foundation are made.

In terms of retrievability, the applicant clarified that the basemat provides a firm and level surface for alignment of the transfer cask with the HSM to allow loading and unloading of the DSCs. During loading operations at the HSM, four hydraulic jacks on the transfer trailer may account for variability in basemat levelness. The applicant stated that the jacks have adequate vertical stroke, allowing for vertical adjustment in either unison or individually. In addition, for accessing the basemat with the transfer trailer, the transfer trailer is equipped with a vertically articulated hydraulic suspension system, which allows for an adjustable deck height, compensating for road surface irregularities, uneven terrain, railroad tracks, and road crowns.

Therefore, the applicant concluded that any differential settlement would be expected to have occurred before the period of extended operation, and, therefore, differential settlement is not a credible aging effect and does not require management during the period of extended operation.

The staff reviewed the applicant's justification for not implementing an AMP to address aging effects due to differential settlement of the ISFSI basemat and approach slab. The staff considers the justification acceptable upon considering that retrievability of the DSC will not be affected, the predicted maximum flood level is well below the bottom of the DSC even with consideration of gross settlement of the basemat, and hypothetical shifting of HSMs has been previously analyzed in the design bases. Therefore, the staff agrees that an AMP for addressing aging effects due to differential settlement of the ISFSI basemat and approach slab is not required.

3.3.1.11 **Aging effect assessment: aggressive chemical attack of HSM concrete subcomponents**

The applicant stated that exposure to aggressive groundwater, acid rain, seawater or salt spray, or exposure to acids and caustic materials may cause chemical attack leading to loss of material, cracking, or change in material properties. Microbiological forms of chemical attack may also be induced from microbial growths on the concrete, but there has not been operating experience in dry storage facilities, and, therefore, it would not be considered credible at the TMI-2 ISFSI. The applicant concluded that the characteristic effects of chemical attack include staining, erosion, degradation of the concrete, cracking, spalling, and corrosive attack on the rebar and embedments. The applicant further defined areas on the HSM susceptible to chemical attack as including exterior surfaces exposed to the outdoor environment.

The applicant clarified that continued or frequent cyclic exposure to the following aggressive chemical environments is necessary to cause adverse degradation of steel in concrete. The applicant defined these environments as follows:

- Acidic solutions with pH less than 5.5
- Chloride solutions > 500 parts per million (ppm)
- Sulfate solutions > 1,500 ppm

The applicant clarified that these conditions do not exist in the environments of the HSM concrete subcomponents. As discussed in Section 3.3.1.2 of the license renewal application, the TMI-2 ISFSI is located remotely and not in an area where it is subjected to aggressive chemicals from environmental or industrial sources, such as sulfur or nitric-based acid rain. The applicant cited operating experience in which the chloride content in the HSM concrete of the TMI-2 ISFSI was assessed to be very low (i.e., from 30 to 60 ppm). The applicant states that acidic solutions are not permitted on the TMI-2 ISFSI, and typically concrete is highly alkaline (pH greater than 12.5); therefore, the applicant concluded that acid attack is not a credible aging mechanism. Sulfate solutions of potassium, sodium, and magnesium sometimes found in groundwater may attack concrete over time. However, since the HSMs are installed above grade on the concrete basemat, the HSM concrete is not subjected to aggressive chemical attack due to prolonged wetting. The basemat elevation is designed to preclude flooding and is installed above the site's predicted maximum flood elevation. Therefore, the applicant concluded that, since all HSM SSCs are above ground, sulfate attack with solutions greater than 1,500 ppm is not a credible aging mechanism.

The staff reviewed the applicant's justification for not implementing an AMP to address aging effects due to aggressive chemical attack of HSM concrete subcomponents. The staff considers the applicant's conditions for aggressive chemical attack to be consistent with those defined in NUREG-2214. The staff considers the justification acceptable upon considering the discussion on operating experience and the operational controls to ensure that acidic solutions are not credible in the HSM concrete subcomponents. Further, the staff considers that the HSM AMP discussed in SER Table 3.5-2 provides defense in depth for ensuring that any inadvertent degradation of the HSM concrete subcomponents due to chemical attack is properly identified via the applicant's corrective action program. For these reasons, the staff agrees that an AMP for addressing aging effects due to aggressive chemical attack of HSM concrete subcomponents is not necessary.

3.3.1.12 **Aging effect assessment: reactions with aggregates in HSM concrete subcomponents**

The applicant stated that chemical reactions may develop between certain mineral constituents of aggregates and alkalis that compose the Portland cement paste. These alkalis are principally introduced in the concrete by cement but may also be present from improper admixtures and salt-contaminated aggregates. Seawater and solutions of deicing salt can also inject alkalis into concrete by action of penetration.

The applicant cited operating experience in which the licensee conducted concrete core sampling in May 2009 on nine different HSMs, in areas including the roof, front wall, and rear wall. The testing was part of corrective actions taken due to premature degradation of the HSM concrete. The testing included depth of carbonation, petrographic examinations, chloride content, and compressive strength. In addition, the licensee tested the core samples for deleterious reactions within the concrete, such as alkali-silica reaction (ASR) and delayed ettringite formation (DEF), which can cause slow but long-term and progressive failure of the concrete. The applicant described these aging mechanisms consistent with the technical bases provided in NUREG-2214.

The applicant concluded that the 2009 core sample investigations indicated that ASR and DEF were not a factor in the premature aging evidenced by the cracking. Rather, the premature aging (i.e., cracking) was due to the freeze-thaw cycles. The concrete core samples examined were characterized as generally hard, dense, and well consolidated. No reportable differences were observed between four concrete samples that contained major cracks and two concrete samples that contained only minor cracks. The applicant clarified that evidence of DEF was not observed in the core samples. The applicant also clarified that HSMs have about 20 years of operation without ASR-type cracking ever being observed. This is primarily due to preventative measures in the concrete design and formulation. The applicant addressed the three basic conditions for ASR-induced cracking to proceed in concrete; namely, (1) high alkalinity in the cement, (2) presence of moisture, and (3) reactive silica in the concrete aggregate. The applicant stated that, during the design of the TMI-2 ISFSI, measures were taken to ensure the quality of the concrete used in the fabrication of the HSM, ensuring both low pH cement and nonreactive silica aggregate. In addition, moisture is limited due to the annually low average relative humidity for the INL site ranging from 30 percent to 70 percent and less than 10 inches per year of rainfall. The applicant stated that initiation and propagation of ASR requires a relative humidity greater than 80 percent. Therefore, the applicant concluded that all three conditions required are controlled or are limited in their existence.

The applicant also clarified that the HSM fabrication specification and the associated fabrication standard (ASTM C150) required the cement to have low alkali content (i.e., less than 0.60 percent of sodium oxide (Na_2O) equivalent alkali by weight). The applicant recognized that maintaining an alkali content of less than 0.44 percent is not a guarantee against ASR expansion. However, excessive expansion is more unlikely for alkali contents between 0.40 percent and 0.44 percent, due to the reduced ability to sustain the reaction, particularly when combined with negligible external sources of alkali. The HSM concrete is above ground and not exposed to groundwater, and there are no other external sources of alkali present; therefore, the applicant concluded that the concentration of alkalizing salts is considered to be well controlled.

The applicant cited various ACI reports, guides, and standards to justify that, since damage from ASR can take more than 10 years to develop, structures with a minimum of 15 years showing nonreactive aggregates justifies their suitability in the field. The TMI-2 ISFSI has greater than 15 years of field historical performance without any deleterious expansion in concrete from the ASR aging effect. In addition, the applicant clarified that the aggregates in the 2009 petrographic study of concrete cores were determined to be nonreactive. The applicant stated that the 2009 study did not show ASR or DEF indications and both the moisture sources are limited and the relative humidity is low on site.

The applicant therefore concluded that, even though HSM cement-aggregate reactions during the period of extended operation are considered unlikely, one reaction type (ASR) was added to the AMP corrective action program to ensure it is not the apparent or root cause of any premature degradation. Notwithstanding this AMP element inclusion, the applicant concluded that reasonable assurance exists that the HSM concrete subcomponents are not subject to alkali-aggregate chemical reactions and will continue to perform their intended functions during the period of extended operation.

The staff reviewed the applicant’s justification for concluding that ASR and DEF are not credible aging mechanisms of HSM concrete subcomponents during the period of extended operation. The staff considers the applicant’s conclusions inconsistent with the technical basis on ASR as discussed in NUREG-2214 (i.e., NUREG-2214 concludes that ASR is credible in outdoor environments subject to a moisture environment). However, the staff considers that the inclusion of ASR in the AMP corrective action program is an acceptable approach for ensuring that ASR is not operable during the period of extended operation. The staff further considers that this approach is justified in consideration of the limited moisture available at the TMI-2 site (i.e., relative humidity ranging from 30 percent to 70 percent and less than 10 inches per year of rainfall). Therefore, with the inclusion of ASR in the corrective actions of the HSM AMP, the staff considers that any unexpected aging effects due to ASR will be adequately addressed per the licensee’s quality assurance program during the period of extended operation.

3.3.1.13 **Aging effect assessment: stress corrosion cracking in HSM stainless steel subcomponents**

The only stainless steel subcomponents of the HSM are the roof bolt protective covers. The applicant stated that stress corrosion cracking of stainless steel at the TMI-2 ISFSI is limited due to the dry conditions (see SER Section 3.3.1.14) and the lack of high stresses in these subcomponents. Therefore, the applicant concluded that stress corrosion cracking of the roof bolt protective covers is not considered a credible aging mechanism and therefore does not require management during the period of extended operation. The staff reviewed the applicant’s justification and considers it to be acceptable because of the limited moisture available at the TMI-2 site (i.e., the average ISFSI site absolute humidity is about 5 grams/cubic meter (m^3)). Therefore, the staff agrees with the applicant’s conclusion that stress corrosion cracking of the roof bolt protective covers does not require aging management during the period of extended operation.

3.3.1.14 **Aging effect assessment: localized corrosion (pitting and crevice) and stress corrosion cracking of TMI-2 canister stainless steel subcomponents**

The applicant stated that localized corrosion is influenced by three primary factors: chloride content, pH, and temperature. The applicant provided a susceptibility assessment for localized corrosion and chloride-induced stress corrosion cracking (CISCC) based on a relative ranking of the TMI-2 ISFSI in terms of available chlorides. The applicant's review followed the assessment criteria in EPRI Report 3002005371, "Susceptibility Assessment Criteria for Chloride-Induced Stress Corrosion Cracking (CISCC) of Welded Stainless Steel Canisters for Dry Cask Storage Systems" (Fuhr et al., 2015), which assesses such conditions for stainless steel canister-based dry storage systems. The criterion in this report uses a combination of environmental factors to develop a numeric relative ranking of a given ISFSI location. This ranking is intended to identify if the ISFSI environmental conditions result in a relatively higher likelihood of CISCC due to the presence of chlorides compared to other ISFSI sites. Per this assessment, the applicant concluded that the TMI-2 ISFSI site ranks the lowest on a one-to-10 scale (i.e., one), indicating a quantifiable lack of chlorides at the TMI-2 ISFSI.

The applicant concluded that localized corrosion (pitting, crevice) is not credible for the TMI-2 canister stainless steel subcomponents based on the following:

- The TMI-2 canisters are stored in a dry environment. The average ISFSI site absolute humidity is 5 grams/m^3.

- A wet anaerobic environment is unlikely to develop due to diffusion and the natural respiration of the DSCs as the ambient temperature fluctuates.

- Low temperatures (TMI-2 core debris internal temperature is under 80 degrees F) and nearly neutral pH at the dry ISFSI environment do not favor localized corrosion aging mechanisms,

- There is not a credibly sufficient corrosive electrolyte within the TMI-2 canister environment conducive to promoting localized corrosion.

- Operating experience discussed in the license renewal application indicated that the crevice corrosion rate measured at the IFSF (a facility close to the TMI-2 ISFSI with similar environment to TMI-2 ISFSI) was below the level of measurement error for two corrosion coupon samples with the reported residual rate on the lower molybdenum content stainless steel (Grade 304L) of less than 0.0007 mils per year.

The applicant further concluded that stress corrosion cracking is not credible for the TMI-2 canister stainless steel subcomponents based on the following:

- The site ranking for chlorides is the lowest possible per the EPRI criteria for CISCC susceptibility.

- The humidity and temperatures are low during most of the year, and condensation is only present in the wintertime. The maximum TMI-2 core debris temperature is under 80 degrees F, which is unlikely for initiation of stress corrosion cracking.

- Operating experience discussed in the license renewal application indicated that stress corrosion cracking coupons (samples) at the IFSF (a facility close to the TMI-2 ISFSI with a similar environment to TMI-2 ISFSI) have shown no evidence of stress corrosion cracking.

The staff reviewed the applicant’s justification for not implementing an AMP to address aging effects due to localized corrosion (pitting, crevice) and stress corrosion cracking of TMI-2 canister stainless steel subcomponents. The staff considers the justification acceptable upon considering the discussed operating experience and the environmental conditions (canister temperature, low humidity, low chloride) of the TMI-2 ISFSI that do not lend these aging mechanisms to be credible. Therefore, the staff agrees with the applicant’s conclusion that an AMP to address aging effects due to localized corrosion and stress corrosion cracking of TMI-2 canister stainless steel subcomponents is not necessary.

3.3.1.15 **Aging effect assessment: intergranular corrosion of TMI-2 canister stainless steel subcomponents**

The applicant stated that austenitic stainless steels become sensitized or susceptible to intergranular corrosion when heated in the temperature range of 1,100 to 1,600 degrees F during such operations as welding, heat treatment, or metal fabrication. The most common reaction is formation of chromium carbide in the weld heat-affected zone during welding. When these carbides form along the grain boundaries, it is called “sensitization.” Because the carbides require more chromium than is locally available, the carbon pulls chromium from the surrounding area around the carbon. The areas immediately adjacent to the precipitate are depleted in chromium. This leaves a low-chromium grain boundary zone and creates a new low-chromium alloy in that region. This causes a galvanic potential between the base metal and the grain boundary, so galvanic corrosion begins. The grain boundaries corrode, allowing the central grain and the chromium carbides to drop out, as if particles of rusty sand.

The applicant further stated that, by lowering the content of carbon to below the saturation value for the solid solution, alloy sensitization is essentially avoided. Grades of stainless steel with this configuration are designated as “L” grades such as Types 304L, or 316L, with 0.03 percent carbon content maximum. The applicant clarified that the original specification documents for the TMI-2 canisters specifically called for the 304L or 316L grade stainless steel materials, due to their low carbon content and to avoid problems due to sensitization from welding operations. These grades are very common since the development of argon oxygen decarburization refining. Almost all stainless steel is made using this method since it allows very precise control of the alloying elements, and it is possible to routinely obtain carbon levels of approximately 0.025 percent, a level at which no chromium carbide particles form in the heat-affected zone during welding. The applicant further clarified that the fabrication documentation for the TMI-2 canisters, referenced in the renewal application, confirmed the carbon content was less than 0.030 percent, typically in the range of 0.016–0.028 percent. Despite reducing carbon content, the applicant acknowledged that TMI-2 canister stainless steel subcomponents could still be impacted if a part is to be used continuously at temperatures generally ranging from 800 to 1,500 degrees F, as it will still sensitize over time. The temperature of the stainless steel TMI-2 canisters has remained nearly ambient for their entire lifetime, except during the heated vacuum drying process where TMI-2 canister heating temperatures reached up to 900 degrees F for approximately 12 hours. However, the applicant provided a technical basis to support that 900 degrees F is below the temperature for sensitization of the low-grade 304L and 316L stainless steels. Therefore, sensitization during those operations is not considered credible.

In addition, the applicant cited operating experience that indicated that there has been no evidence of intergranular corrosion on the IFSF 304L corrosion coupons or the stainless steel structures within the IFSF, a facility close to the TMI-2 ISFSI with a similar environment to the TMI-2 ISFSI. Therefore, the applicant concluded that intergranular corrosion of the TMI-2 canister stainless steel subcomponents is not credible during the period of extended operation.

The staff reviewed the applicant's justification for not implementing an AMP to address aging effects due to intergranular corrosion of TMI-2 canister stainless steel subcomponents. The staff considers the justification acceptable upon considering the discussed operating experience and the environmental conditions of the TMI-2 canisters during loading and operations, which do not lend these aging mechanisms to be credible. Therefore, the staff agrees with the applicant's conclusion that an AMP to address aging effects due to intergranular corrosion of TMI-2 canister stainless steel subcomponents is not necessary.

3.3.1.16 **Aging effect assessment: radiation-induced localized corrosion of TMI-2 canister stainless-steel subcomponents**

The applicant discussed the potential for promotion of radiation-induced localized corrosion processes due to the presence of gamma radiation and its interaction with water within the TMI-2 canisters. The applicant considered the interaction of gamma radiation with water possibly generating radiolytic oxidizing decomposition byproducts (e.g., hydrogen peroxide, nitric acid), which may affect these corrosion processes. The applicant provided an assessment to justify that the production of hydrogen peroxide and nitric acid from radiolytic processes within the TMI-2 canisters will be limited due to the low dose rates and therefore will not credibly propagate any existing corrosion processes to sustain deleterious effects adversely influencing the TMI-2 canister's intended functions. Per this evaluation, the applicant concluded that radiation-induced localized corrosion could potentially occur only during the first few months of the initial period of operation. During the period of extended operation, the dose rate is too low to allow for a sufficient concentration of radiolytic products to both initiate and propagate any localized corrosion process.

The applicant noted that the volume of residual water potentially available inside the TMI-2 canisters is comparatively small with respect to the overall TMI-2 canister size, and any such water would not be well concentrated and necessarily localized. Therefore, the availability of reactants necessary to support radiolytic reactions, which could then support localized corrosion processes, is likewise constrained. Thus, even the ability to produce such byproducts from irradiation would not sufficiently cause adverse reactions leading to deleterious localized corrosive aging effects. As a result, the applicant concluded that a radiation-induced localized corrosion aging mechanism is not considered credibly reasonable and does not require aging management.

The staff reviewed the applicant's justification for not implementing an AMP to address aging effects due to radiation-induced localized corrosion of TMI-2 canister stainless steel subcomponents. The staff considers the justification acceptable upon considering the applicant's discussion of operating experience and the environmental conditions of the TMI-2 canisters during loading and operations, which do not lend these aging mechanisms to be credible. Therefore, the staff agrees with the applicant's conclusion that aging management to address aging effects due to radiation-induced localized corrosion of TMI-2 canister stainless steel subcomponents is not necessary.

3.3.1.17 **Aging management review: OS197 transfer cask**

The applicant's design bases as captured in the UFSAR includes two transfer casks: the OS197 TC and the MP187. The applicant clarified that the major difference between usage of the two transfer casks is that the 10 CFR 72 approved OS197 TC cannot be used for transportation on public roadways and, therefore, does not require impact limiters, evacuation and helium backfill of the DSC, leak testing of the DSC closure weld, nor installation of the vent/filter housing transportation covers The applicant provided an AMR for the OS197 TC to support its use if aged longer than 20 years. Per the applicant's request and per the license condition discussed in SER Section 4.4, an MP187 aged greater than 20 years is not allowed.

Regarding the AMR for the OS197 TC, the applicant incorporated by reference the AMR for the OS197 TC, as provided in the Standardized NUHOMS® CoC renewal application (NRC Docket No. 72-1004) (AREVA TN Americas, 2016). More specifically, the applicant incorporated the following sections of that renewal application: Sections 1.2.2.3, 3.3.3, 3.4, 3.4.1, 3.4.2, 3.4.3, and 3.7 pertaining to the OS197 TC, which discuss the following:

- a description of the OS 197 TC and its associated SSCs determined to be within renewal scope
- an identification of the OS197 TC design, fabrication, and maintenance considerations
- an identification of the materials and environments for the OS197 TC and associated subcomponents
- an identification of the OS197 TC aging mechanisms and effects requiring management
- an identification of any OS197 TC TLAAs and OS197 TC AMPs for managing aging effects

The applicant reviewed Section 3.7 of the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016) and determined that the evaluation bounds its use at the TMI-2 ISFSI. The applicant concluded that safety-significant variations on applicability at the TMI-2 ISFSI will be bounded by conditions already evaluated in the Standardized NUHOMS® CoC renewal application (i.e., stronger source terms, higher decay heat loads, ability to add contents to the ISFSI, high burn-up fuel, longer period of extended operation).

The applicant identified differences between the materials of construction of SSCs evaluated under the Standardized NUHOMS® and the SSCs of the TMI-2 ISFSI; namely, for the DSC and the transfer cask spacers. More specifically, the DSC evaluated in the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016) is fabricated from stainless steel with the transfer cask spacers being fabricated from either stainless steel or aluminum. In contrast, the TMI-2 ISFSI DSC and transfer cask spacers are coated carbon steel.

Therefore, the applicant conducted an aging assessment to account for this distinction in adjoining materials with respect to the OS197 TC. In terms of environment, the applicant noted that there is a lack of moisture within the transfer cask interior, and thus, both the transfer cask spacers and DSC are in an environment similar to the internal DSC environment, so the conditions necessary for corrosive aging mechanisms do not exist (e.g., general corrosion, galvanic corrosion, crevice corrosion, pitting corrosion). Another enveloping parameter in this environment is that the design-bases heat load for the OS197 TC is 24 kilowatts (kW).

Therefore, allowable interior transfer cask temperatures are significantly greater in the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016), bounding the original TMI-2 DSC design-bases heat load of 0.86 kW. The applicant also considered that the configuration with the DSC or transfer cask spacers loaded into the OS197 TC is an intermittent state, which occurs only during the short DSC loading and retrieval period. Hence, long-term, progressive deleterious aging mechanisms are not germane. Therefore, the applicant concluded that no new aging effects would be credible for the TMI-2 ISFSI's carbon steel DSC and transfer cask spacers due to both lack of moisture and the temporary nature of the particular configuration.

The staff reviewed the applicant's discussion on the applicability of the previously reviewed AMR under the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016) to the TMI-2 ISFSI. The staff considers the justification to be acceptable per the bounding assumptions of the Standardized NUHOMS® CoC renewal application, the dry environment inside the transfer cask, and the limited operational time of the transfer cask. The staff agrees with the applicant's conclusion that the time-limited aging analyses and aging management program for the OS197 TC, as provided in the Standardized NUHOMS® CoC renewal application, adequately address aging effects during the period of extended operation of the TMI-2 ISFSI. Therefore, the incorporation by reference of these TLAAs and AMP into the design bases of the TMI-2 ISFSI is acceptable.

3.3.1.18 **Aging effect assessment: cracking due to thermal fatigue of HSM steel components**

The applicant stated that the only source of thermal fatigue is due to environmental temperature fluctuations. Thermal fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading associated with thermal cycling. Excessive fatigue effects could lead to either cracking or loss of strength. The applicant clarified that the DSC steel support structure is located inside the HSM in the sheltered environment, where the thermal fluctuations due to external ambient temperature fluctuations are substantially reduced due to both the large thermal mass provided by the HSM enclosure walls and roof and to the low DSC decay heat.

The applicant identified that a TLAA was reevaluated and concluded that thermal fatigue of the DSC subcomponents does not need to be managed during the period of extended operation (see SER Section 3.4.1). The applicant concluded that thermal cycling fatigue due to fluctuations in the more benign conditions outside of the DSC is not considered a credible aging mechanism for the DSC steel support structure. Therefore, loss of strength and cracking due to the mechanism of fatigue are not aging effects requiring management for the HSM steel subcomponents during the period of extended operation.

The staff reviewed the applicant's justification for concluding that cracking due to thermal fatigue is not a credible aging mechanism of HSM steel subcomponents during the period of extended operation. NUREG-2214 does not specifically address thermal fatigue of steel components in concrete overpacks. However, NUREG-2214 does address thermal fatigue of steel components of cask/canister internals and concludes that this degradation mechanism is not credible for these subcomponents. The staff agrees with the applicant's conclusion that the HSM steel subcomponents are subject to thermal fluctuations that are substantially reduced by the large thermal mass provided by the HSM enclosure walls and roof, as well as the low DSC decay heat. Therefore, the staff considers that the conclusions in NUREG-2224 for thermal fatigue of cask/canister steel internals are also reasonable for HSM steel internals. The staff considers the applicant's conclusion acceptable as it is consistent with NUREG-2214. Therefore, the staff agrees with the applicant's conclusion that aging management for thermal fatigue of DSC subcomponents is not necessary.

3.3.2 Evaluation Findings

The staff reviewed the AMR provided in the license renewal application to verify it adequately identified the materials, environments, and aging effects of the in-scope SSCs. The staff performed its review following the guidance provided in NUREG-1927, Revision 1, and NUREG-2214. Based on its review of the license 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 a summary of the information in the license renewal application and UFSAR supplement.

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 a summary of the information in the license renewal application and UFSAR supplement.

3.4 Time-Limited Aging Analyses Evaluation

The staff reviewed TLAAs provided by the applicant in support of conclusions regarding potential aging effects for SSCs and SSC subcomponents within the scope of renewal. The staff reviewed the following analyses to determine those meeting all six criteria in 10 CFR 72.3 for valid TLAAs.

(1) DSC Thermal (Cyclic Loading) Fatigue Evaluation
(2) HSM Irradiation Effects Evaluation
(3) Transfer Cask Thermal (Cyclic Loading) Fatigue Evaluation

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 adequately identified all TLAAs.

3.4.1 DSC Thermal Fatigue Evaluation

The applicant stated that a thermal fatigue TLAA is incorporated in Section 8.3.2 of the UFSAR, which documents the evaluation of the DSC for temperature fluctuations in accordance with the provisions of NB-3222.4(d) of the American Society of Mechanical Engineers (ASME) Code.

Thermal fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading associated with thermal cycling. The only potential source of thermal fatigue of the DSC could be caused by ambient seasonal and daily temperature fluctuations. The average monthly temperature ranges from a low of 4 degrees F in January to a high of 87 degrees F in July. The largest mean daily temperature range for the TMI-2 ISFSI is 38 degrees F during the months of July and August. These relatively low temperature changes combined with the vented design of the DSC provide for minimal stress-inducing mechanisms that can cause any fatigue. Cyclic loading on the DSC confinement boundary is addressed in Section 8.3.2 of the UFSAR regarding all potential sources.

The applicant clarified that, consistent with NB-3222.4(d) of the ASME Code, fatigue effects need not be specifically evaluated provided the six criteria in NB-3222.4(d) are met. The applicant referenced Appendix C.4.1 of the Standardized NUHOMS® UFSAR (TN Americas LLC, 2018), which addressed these diurnal and seasonal temperature fluctuations on thermal fatigue, looking at the six criteria contained in NB-3222.4 of the ASME Code for applicability. Since all of the six ASME Code criteria are complied with over a 50-year ISFSI operating period, the applicant concluded that thermal fatigue of the DSC does not need to be managed during the period of extended operation and that the ASME Code fatigue requirements are satisfied for the DSC confinement boundary.

The staff reviewed the methodology, assumptions, and conclusions of this TLAA and finds them acceptable and consistent with the technical basis in NUREG-2214.

3.4.2 HSM Irradiation Effects Evaluation

The applicant referenced UFSAR Section 8.1.1.5.D, which documents a TLAA on the effects of cumulative neutron and gamma irradiation on the HSM concrete. The TLAA evaluated cumulative radiation exposure to the HSM concrete over a 50-year period of operation and concluded that the cumulative exposure remains below levels resulting in deleterious changes to the mechanical properties of concrete. Therefore, the applicant concluded that degradation of the mechanical properties of HSM concrete due to effects of irradiation is not credible during the period of extended operation.

The staff reviewed the gamma doses and neutron fluences the licensee calculated for the various storage system components. The licensee determined that the cumulative radiation over the life of the facility, including the period of extended operation and, for the TMI-2 canisters, the 14 years that the TMI-2 canisters were loaded with debris before the canisters' loading into DSCs, did not exceed the thresholds for inducing identifiable radiation degradation in the materials of the storage system components, including the TMI-2 canisters. The staff also performed some simple confirmatory estimates of the gamma doses and neutron fluences using conservative assumptions. Based on these confirmatory estimates, the staff confirmed the licensee's conclusion that the thresholds for radiation damage would not be exceeded for the storage system components' materials, including the materials of the TMI-2 canisters.

The staff reviewed the methodology, assumptions, and conclusions of this TLAA and finds them consistent with the technical basis in Section 3.5.1.9 of NUREG-2214, and therefore finds them acceptable.

3.4.3 Transfer Cask Thermal (Cyclic Loading) Fatigue Evaluation

The applicant incorporated by reference a TLAA for the OS197 TC as discussed in Appendix 3B to the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016). The TLAA evaluated the effects of fatigue on the mechanical properties of the OS197 materials. The applicant concluded that the TLAA bounds the TMI-2 ISFSI due to the higher OS197 TC maximum temperatures and longer period of extended operation assumed in the Standardized NUHOMS® CoC renewal application.

The staff reviewed the methodology, assumptions, and conclusions of this TLAA and finds them acceptable since the fatigue evaluation discussed in Appendix 3B to the Standardized NUHOMS® CoC renewal application was done in accordance with the provisions of ASME NC-3219.2, and it was demonstrated that there is no need for a fatigue analysis of the OS197 TC (i.e., all six criteria in NC-3219.2 were met to exempt the transfer cask from a detailed fatigue analysis). Further, the applicant's approach is also consistent with the technical basis in NUREG-2214.

3.4.4 Evaluation Findings

The staff reviewed the license 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, Revision 1, and NUREG-2214.

Based on its review of the license 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 had the potential to involve TLAAs. Therefore, the applicant's evaluation provides reasonable assurance that the SSCs will maintain their intended functions for the period of extended operation, require no further aging management activities, and meet the requirements in 10 CFR 72.42(a)(1).

3.5 Aging Management Programs

Under 10 CFR 72.42(a)(2) requirements, the applicant must provide a description of AMPs for management of issues associated with aging that could adversely affect SSCs important to safety. The applicant provided the following AMPs in the license renewal application:

(1) DSC AMP
(2) HSM AMP
(3) Transfer Cask AMP

The staff conducted the safety review of the proposed AMPs in the license renewal application per the guidance in NUREG-1927, Revision 1. The staff also evaluated the proposed AMPs and compared them to the generically acceptable example AMPs in NUREG-2214, as applicable. SER Tables 3.5-1 and 3.5-2 provide the staff's conclusions regarding consistency of the proposed AMPs with the applicable example AMPs in NUREG-2214. If the staff identified inconsistencies, a discussion is provided on the staff's review of the applicant's justification.

- The TMI-2 ISFSI DSC AMP was compared to the NUREG-2214 (Table 6-4) example AMP for monitoring metallic surfaces (see SER Table 3.5-1).

- The TMI-2 HSM AMP was compared to the NUREG-2214 (Table 6-3) example AMP for reinforced concrete structures, for the concrete subcomponents of the HSM (see SER Table 3.5-2). For the nonconcrete subcomponents of the HSM, the staff's evaluation and conclusions pertaining to the adequacy of the HSM AMP is provided in SER Section 3.5.1. The staff also evaluated the adequacy of the HSM AMP, in terms of whether the acceptance criteria are sufficient to ensure the shielding function of the HSM concrete, in SER Section 3.5.2.

- NUREG-2214 does not provide example AMPs applicable to the OS197 TC. Therefore, SER Section 3.5.3 provides discussion of the staff’s evaluation and conclusions pertaining to the adequacy of the OS197 TC AMP for implementation at the TMI-2 ISFSI.

Table 3.5-1 Aging Management Program Review Results—DSC AMP

AMP Element	Staff's assessment on consistency with the example AMP for monitoring metallic surfaces
1. Scope of Program	Consistent.
2. Preventive Actions	As a preventive measure for all DSC SSCs, existing radiation monitoring SRs provide an indirect indicator of possible adverse premature degradation. This includes LCO 3.2.2 that requires the surface dose rate of each HSM rear access door and the purge/vent filter housings to be surveyed on an annual basis. This is confirmed by statements outlined in the TS bases, "If the radiation field at the vent approaches the limits specified, the cause will be evaluated and corrective action taken." Therefore, the associated SR 3.2.2.1 provides data representative of potential increased dose measurements indirectly indicative of adverse degradation. An engineering evaluation as indicated in Section A1.4.4 of the DSC AMP is conducted on the raw radiation measurement data. In addition, the hydrogen levels are monitored and tracked as part of the existing LCO 3.2.3. Monitoring these levels is an indirect indicator of corrosion occurring within the internal DSC environment. As a defense-in-depth enhancement of the DSC AMP, the gas concentration levels will be tracked and monitored to ensure monitored gas production and consumption trends remain within expected values. An engineering evaluation as indicated in Section A1.4.4 of the DSC AMP is conducted on the raw gas measurement data. Consistent otherwise.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Per Table A-1 of the renewal application, the applicant adequately defined the timing of all baseline AMP inspections and the intervals (frequency) of all subsequent inspections of normally nonaccessible, accessible, and inaccessible areas. The applicant justified the inspection interval of 10 years for normally nonaccessible areas to be consistent with ASME, BPVC Section XI, Subarticle IWA-2430 optional inspection program B (Paragraph IWA-2432). The applicant also identified a ±2-year grace period for flexibility in the inspection frequency of normally nonaccessible areas to account for contractor's inspection planning and potential limited availability of vendor remote visual equipment. The staff considers the justification to be reasonable and acceptable. Consistent otherwise.

AMP Element	Staff's assessment on consistency with the example AMP for monitoring metallic surfaces
5. Monitoring and Trending	Per Table A-1 of the renewal application, if the preceding inspection's acceptance criteria have been exceeded, and it is unclear what the trend from previous inspections indicates, the applicant defined reductions in the interval between inspections. The staff considers the proposed revised frequency to be adequate. Consistent otherwise.
6. Acceptance Criteria	Consistent.
7. Corrective Actions	Consistent.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent.
10. Operating Experience	Consistent. The applicant provided an extensive discussion on pre-application inspections (Section 3.3 of the license renewal application) and relevant industry operating experience (Section 3.4 of the license renewal application). The staff recognizes that pre-application inspections are not required per 10 CFR Part 72 regulations. However, consistent with the guidance in NUREG-1927, Revision 1, the staff reviewed the scope, methods, and acceptance criteria of the pre-application inspections in support of the AMPs. Further, the staff reviewed the applicant's discussion pertaining to initiated corrective actions (including results from actions to verify extent of condition) due to adverse conditions identified during the pre-application inspections. Based on this review, the staff considers that the applicant provided an adequate discussion of pre-application inspections and relevant operating experience in support of the applicant's AMR and AMPs. The staff has also reviewed proposed actions to ensure that the AMP remains adequate during the period of extended operation upon review of new operating experience (including the implementation of periodic tollgate assessments); see SER Section 3.5.4.

Table 3.5-2 Aging Management Program Review Results—HSM AMP

AMP Element	Staff's assessment on consistency with the example AMP for reinforced concrete structures in NUREG-2214
1. Scope of Program	Differences in aging mechanisms and effects, as justified per the safety review in SER Section 3.3.1. Consistent otherwise.
2. Preventive Actions	Per TMI-2 ISFSI operational experience, inspections of the HSM roof protective bolt cover assemblies are a preventive action to preclude any future freeze-thaw cracking of HSM concrete subcomponents (per the method discussed in Section A2.4.3 of the license renewal application). The staff considers the justification to be acceptable. Consistent otherwise.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Per Table A-2 of the renewal application, the applicant adequately defined the timing of all baseline AMP inspections and the intervals (frequency) of all subsequent inspections of normally accessible and nonaccessible areas. The applicant justified the inspection interval of 10 years for normally nonaccessible areas to be consistent with ASME, BPVC Section XI, Subarticle IWA-2430, optional inspection program B (paragraph IWA-2432). The applicant identified a ±1-year grace period for flexibility in the inspection frequency of normally accessible areas to allow the inspections to be spaced out instead of performing two inspections in the same year and to reduce workload at the TMI-2 ISFSI, as an additional HSM is included in the inspection from the outset and not because of any adverse findings or applicable operating experience. The applicant also identified a ±2-year grace period for flexibility in the inspection frequency of normally nonaccessible areas to account for contractor's inspection planning and potential limited availability of vendor remote visual equipment. The staff considers the justification to be reasonable and acceptable. Consistent otherwise.
5. Monitoring and Trending	Per Table A-2 of the renewal application, if preceding inspection's acceptance criteria have been exceeded and it is unclear what the trend from previous inspections indicates, the applicant defined reductions in the interval between inspections. The staff considers that the proposed revised frequency to be adequate. Consistent otherwise.

AMP Element	Staff's assessment on consistency with the example AMP for reinforced concrete structures in NUREG-2214
6. Acceptance Criteria	The staff has reviewed the acceptability of the ACI 349.3R for ensuring that it is adequate for radiation shielding of the HSM concrete; see SER Section 3.5.2. Consistent otherwise.
7. Corrective Actions	Consistent.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent.
10. Operating Experience	Consistent. The applicant provided an extensive discussion on pre-application inspections (Section 3.3 of the license renewal application) and relevant industry operating experience (Section 3.4 of the license renewal application). The staff recognizes that pre-application inspections are not required per 10 CFR Part 72 regulations. However, consistent with the guidance in NUREG-1927, Revision 1, the staff reviewed the scope, methods, and acceptance criteria of the pre-application inspections in support of the AMPs. Further, the staff reviewed the applicant's discussion pertaining to initiated corrective actions (including results from actions to verify extent of condition) due to adverse conditions identified during the pre-application inspections. Based on this review, the staff considers that the applicant provided an adequate discussion of pre-application inspections and relevant operating experience in support of the applicant's AMR and AMPs. The staff has also reviewed proposed actions to ensure that the AMP remains adequate during the period of extended operation upon review of new operating experience (including the implementation of periodic tollgate assessments); see SER Section 3.5.4.

3.5.1 Evaluation of Nonconcrete Subcomponents in the HSM AMP

The staff reviewed Appendix A2 and Table A-2 of the license renewal application on the nonconcrete subcomponents under the aegis of the HSM AMP. The review included the scope of SSC subcomponents, timing of baseline inspections, intervals (frequency) between inspections, acceptance criteria and any predefined corrective actions (including the decrease of inspection frequency if adverse degradation of an SSC subcomponent was identified during a prior inspection).

Per this review, the staff considers the defense-in-depth activities related to the zinc-rich coatings of steel subcomponents to be consistent with the staff expectations under the example AMP for monitoring metallic surfaces in NUREG-2214. The staff also considers the activities related to the steel subcomponents to be consistent with the staff expectations under the example AMP for monitoring metallic surfaces in NUREG-2214.

The staff further considers that activities related to the normally nonaccessible nonconcrete subcomponents (i.e., protective bolt covers and polyurethane gasket and filler and surrounding concrete; attachment bolt, nut, and washer plate) and activities related to inaccessible areas (including the HSM seismic retainer, backside of HSM shield door, and HSM shield door opening) provide reasonable assurance that aging effects of these subcomponents will be adequately managed before a loss of intended functions.

The staff, therefore, has reasonable assurance that activities related to nonconcrete subcomponents in the HSM AMP (as defined in Table A-2 of the renewal application and to be incorporated into the UFSAR per SER Section 4.1) are adequate to demonstrate these subcomponents will continue to perform as intended during the period of extended operation.

3.5.2 Evaluation of ACI 349.3R Tier 2 Criteria for the HSM AMP

The licensee’s proposed AMP for managing the aging of the HSM’s reinforced concrete uses the Tier II evaluation criteria in ACI 349.3R as acceptance criteria for the HSM AMP. These criteria are based on ensuring the structural performance of reinforced concrete structures rather than on an intent to ensure any shielding function is adequately managed, or maintained, for these structures. The licensee’s proposed AMP does not include any monitoring or acceptance criteria that are explicitly focused on maintaining the shielding function of the reinforced concrete of the HSM.

The staff performed some simple shielding analyses to determine whether such monitoring and acceptance criteria were needed. The staff’s evaluation considered the extent of degradation that the ACI 349.3R Tier II criteria would allow before action needs to be taken to address the degradation in the licensee’s corrective action program. The staff’s evaluation also considered the decay of the source term for the 20 years of the initial storage period. The staff calculated dose rates for the design-bases fuel neutron and gamma source terms for the as-designed HSM and dose rates for the degraded HSM reinforced concrete with the design-bases fuel neutron and gamma source terms decayed for 20 years to account for the initial storage period. The degraded HSM model assumed that concrete on the external surface up to the depth of the concrete cover was lost (i.e., concrete to the thickness of the cover concrete was treated as void). The total dose rates for the degraded configuration increased a little above the dose rates for the as-designed, design-bases configuration. In actuality, the cover concrete for degraded concrete would still be present, though with degraded properties. So, the staff analyzed a configuration where the cover concrete was present at half its design density to represent degraded concrete. The total dose rate decreased noticeably versus the design-bases configuration. The fuel neutron dose rate increased in both cases; however, it contributed negligibly to the total dose rates.

In the ACI criteria, there is a criterion for depth of scaling. This criterion represents a depth of concrete that could be lost. An appropriate configuration for calculating dose rates for this case would be a model with the concrete thickness reduced by the allowable depth of scaling (1.125 inches) and any remaining depth of cover concrete modeled at half of the design density. The staff did not perform this calculation. However, based upon the results of the degraded configurations it did model, as described above, the staff finds there is reasonable assurance that the dose rates for this third degraded condition would not exceed the dose rates of the design-bases configuration (i.e., the as-designed HSM containing the design-bases source). Thus, the staff finds that the ACI 349.3R Tier II criteria are sufficient to ensure the shielding function of the HSM concrete is adequately managed or maintained and that no additional actions or criteria specific to shielding are needed in the AMP for the HSM.

3.5.3 Transfer Cask AMP

The applicant stated that the TMI-2 ISFSI UFSAR describes the use of a transfer cask to move DSCs into and out of the HSMs. Thus, the transfer cask is required to retrieve a DSC and is within the scope of renewal review. The licensee does not possess an authorized design-bases transfer cask associated with the TMI-2 ISFSI license (i.e., either an MP187 or an OS197 TC).

For the MP187, the applicant proposed a new license condition prohibiting use of an MP187 aged greater than 20 years at the TMI-2 ISFSI, which is discussed in SER Section 4.4. As discussed in SER Section 2.1.3, the staff concludes that an AMR of, and an AMP for, the MP187 is not necessary, per the new license condition.

On the other hand, for an OS197 TC aged greater than 20 years, the applicant proposed to incorporate by reference (into the TMI-2 UFSAR) the portions of renewed Standardized NUHOMS® Horizontal Modular Storage System for Irradiated Nuclear Fuel (NRC Docket No. 72-1004) pertaining to the OS197 TC, as identified in the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016). This reference documents the previously reviewed OS197 TC scoping evaluation (see SER Section 2.1.3), AMR (see SER Section 3.3.1.17), TLAA (see SER Section 3.4.3), and AMP. The applicant includes this reference in its proposed UFSAR supplement (Appendix C to the TMI-2 license renewal application (DOE-ID, 2019b)), including the OS197 TC AMP in Table C-9 of the license renewal application. The applicant provided details regarding OS197 TC maintenance, including implementation of the AMP at the TMI-2 ISFSI.

The applicant clarified that, when an OS197 TC is needed at the TMI-2 ISFSI, the licensee will acquire access via an important-to-safety purchase order. A determination will be made at that time as to the method of obtaining access, but in all cases, it will be developed under a procurement process using the licensee's approved QA program.

The applicant further clarified that a future transfer cask supplier may choose to provide a new OS197 TC or a transfer cask aged less than the 20-year TMI-2 ISFSI initial licensing period, rather than a transfer cask more than 20 years old. Thus, the selected OS197 TC may or may not require any aging management. Because it is unknown until the time of procurement whether the OS197 TC provided under that quality order will require any aging management, those activities, if any are required, will be coordinated with the transfer cask supplier.

Requirements for the supplier to perform all required maintenance, tests, and inspection activities (including AMPs, if applicable) of the OS197 TC before use at the TMI-2 ISFSI will be included in the procurement documents. Further, procedures for operation of the OS197 TC will be developed or revised as appropriate, before use by the entity actually performing DSC transfer operations. The applicant stated that such procedures will comply with all applicable requirements in the TMI-2 license, TS, and UFSAR.

For an OS197 TC aged greater than 20 years, compliance with the Standardized NUHOMS® CoC renewal application (AREVA TN Americas, 2016) pertaining to the OS197 TC will be specified in the procurement requirements. This will include specifying any maintenance and aging management requirements. The applicant stated that such procurement requirements will be consistent with applicable license commitments for the OS197 TC, including the program elements from Appendix 6A (Section 6A.7) of the Standardized NUHOMS® CoC renewal application (incorporated by reference) and verifying that before use, all program elements requiring prior implementation (e.g., inspections, monitoring, and trending activities) have been completed.

The staff reviewed the applicant's approach for the procurement of a transfer cask and considers that the proposed incorporation by reference of the OS197 TC AMP into the proposed UFSAR supplement (that will be added to the TMI-2 UFSAR following the renewal issuance, as discussed in SER Section 4.1) is adequate for ensuring that any OS197 TC aged longer than 20 years will be subject to the previously approved OS197 TC AMP incorporated by reference.

3.5.4 Learning AMPs

The applicant stated that both the DSC and HSM AMP are "learning" AMPs. The applicant clarified that this means that the AMPs will be updated, as necessary, to incorporate new information on degradation due to aging effects identified from TMI-2 ISFSI inspection findings, related industry operating experience, and related industry research. The applicant clarified that future TMI-2 ISFSI and industry operating experience will be captured through a review process, which considers operating experience regarding aging management and aging-related degradation.

The applicant incorporated periodic tollgate assessments as part of the learning AMP process. The schedule for these tollgate assessments will be incorporated into the UFSAR as Table 9.8-6 (the same as Table 3-11 of the license renewal application).

These tollgate assessments include ongoing reviews of both TMI-2 ISFSI-specific and industry operating experience. The tollgate process will continue on a routine basis throughout the period of extended operation, to ensure that both the DSC and HSM AMPs continue to be effective in managing the identified aging effects. The applicant clarified that reviews of operating experience via the tollgate process in the future may identify areas where the DSC and HSM AMPs should be enhanced or new programs developed. If enhancements or new programs are identified during the review of operating experience, then the pertinent procedures for DSC and HSM AMP implementation are revised as necessary to address any lessons learned. The applicant further clarified that the licensee's contractor will maintain the effectiveness of this process under the licensee's ISFSI management QA program, QA procedures, review and approval processes, and administrative controls.

To prepare the tollgate assessments effectively, the applicant stated that the licensee will have access to the industry's Aging Management Institute of Nuclear Power Operations Database

(AMID) via the NUHOMS® vendor, TN Americas. The licensee will review the AMID to obtain and aggregate relevant information to support the preparation of the tollgate assessments and will prepare those assessments as recommended in Nuclear Energy Institute (NEI) 14-03 (NEI, 2016). The licensee will review AMP effectiveness as part of the tollgate assessment process and will make changes, as appropriate, subject to the change controls of 10 CFR 72.48. The licensee will also enter information into AMID as directed by the AMP implementing procedures so that other ISFSI licensees performing tollgate assessments may use the information.

The applicant stated that the licensee intends to use AMID to develop its tollgate assessment but requested flexibility to also use other sources of information in the future to augment AMID with relevant information. In particular, the licensee may use aging-related material degradation information generated elsewhere in DOE's laboratory network that is relevant to the TMI-2 ISFSI materials and environments. Such information may or may not be available in AMID, based on the distribution restrictions applicable to the information.

The applicant also noted that the tollgate process is not a substitute for the other operating experience reviews conducted by the licensee or the licensee's corrective action program. Operating experience and other information or events pertaining to ISFSI aging-related issues that the licensee becomes aware of will be reviewed for relevance to the TMI-2 ISFSI. As a result, actions will be taken in a timeframe commensurate with the safety significance of the issue. Relevant items will be addressed in the DOE-ID corrective action program, as appropriate. The applicant clarified that the preparation of tollgate assessments during the period of extended operation will be administratively controlled using the licensee's commitment management program.

The staff reviewed the applicant's description of actions to ensure that the AMP remains adequate during the period of extended operation upon review of new operating experience. The staff considers that the implementation of periodic tollgate assessments and the use of the AMID database, in addition to other periodic operating experience reviews consistent with the licensee's QA program, provide reasonable assurance the DSC and HSM AMPs will remain adequate during the period of extended operation.

3.5.5 Evaluation Findings

The staff reviewed the AMPs in the license renewal application. The staff performed its review following the guidance provided in NUREG-1927, Revision 1, and NUREG-2214. Based on its review, the staff finds the following:

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

4 LICENSE CONDITIONS TO ADDRESS RENEWAL

This section provides a consolidated list of the changes to the license conditions resulting from the review of the license renewal application, 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 Final Safety Analysis Report Update

The NRC added the following condition to the license:

> Within 90 days after issuance of the renewed license, the licensee shall submit an updated FSAR to the Commission and continue to update the FSAR pursuant to the requirements in 10 CFR 72.70(b) and (c). The updated FSAR shall include the revised TMI-2 ISFSI FSAR Supplement, as documented in Appendix C of the "TMI-2 Independent Spent Fuel Storage Installation Application for 10 CFR 72 Specific License Renewal," Revision 3, dated May 21, 2019 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML19150A336) (hereinafter referred to as the FSAR supplement). The licensee may make changes to the FSAR, including changes to the FSAR supplement, consistent with 10 CFR 72.48(c).

The applicant indicated that it will change the UFSAR to address aging management activities resulting from the renewal of the license. The applicant submitted the proposed UFSAR supplement (in Revision 3 of the license renewal application, Appendix C (DOE ID, 2019b)), which reflects the final proposed UFSAR supplement to address the aging management activities described in the license renewal application. The applicant also proposed a license condition to submit an updated FSAR that includes the information from the proposed UFSAR supplement within 90 days after issuance of the license renewal. This condition ensures that the changes to the UFSAR are made in a timely fashion to enable the licensee to develop and implement necessary procedures related to renewal and aging management activities during the period of extended operation.

4.2 Aging Management Program Implementation

The NRC added the following condition to the license:

> Within one year after the renewed license effective date, the licensee shall document a program for implementing the activities in the Aging Management Programs (AMPs) described in the FSAR supplement. The program document shall contain a reference to the specific AMP provision(s) that the program document is intended to implement, and the reference shall be maintained even if the program document is modified. The licensee shall maintain the program document throughout the term of this license.

The applicant proposed a license condition to revise or create a program document for implementing the AMPs described in the FSAR within 1 year of the renewed license effective date. This condition ensures that programs address AMP activities required for extended storage operations. The timeframe (1 year) in the condition is to ensure that the program document is developed in a timely manner. This timeframe is consistent with the guidance in NUREG-1927, Revision 1.

4.3 Overpack HSM—Extra HSM-15 and its Pre-installed DSC Overpack

The NRC added the following condition to the license:

> Horizontal storage module (HSM)-15 and its pre-installed dry shielded canister (DSC) overpack shall not be used for spent fuel storage operations.

The TMI-2 ISFSI includes an extra unloaded HSM (HSM-15) with a pre-installed DSC overpack (together referred to as the “overpack HSM” in this SER). As discussed in SER Section 2.1.4, the applicant demonstrated that the TMI-2 ISFSI design bases do not rely on the use of the overpack HSM for safe storage operations under normal, off-normal, or credible accident conditions for the TMI-2 ISFSI, and thus, the overpack HSM is excluded from the scope of renewal. The applicant proposed a license condition to preclude the use of the overpack HSM for storage operations during the period of extended operation. This condition ensures that the license accurately reflects the TMI-2 ISFSI design bases.

4.4 NUHOMS®-MP187 Multi-Purpose Cask

The NRC added the following condition to the license:

> The NUHOMS®-MP187 Multi-Purpose Cask described in the FSAR is prohibited for use as a transfer cask at the TMI-2 ISFSI if the NUHOMS®-MP187 Multi-Purpose Cask was fabricated 20 or more years prior to the proposed date of use.
>
> To use a NUHOMS®-MP187 Multi-Purpose Cask aged greater than 20 years, the licensee shall submit a license amendment request which shall include information that will address aging management considerations for the NUHOMS®-MP187 Multi-Purpose Cask.

Two types of transfer casks—the MP187 and OS197 TC—are included in the TMI-2 ISFSI design bases. As discussed in SER Section 2.1.3, DOE-ID does not currently possess a transfer cask associated with the TMI-2 ISFSI license, and a transfer cask is not needed at the TMI-2 ISFSI until future retrieval of the DSCs at the end of storage operations. There is a possibility that a new transfer cask or transfer cask aged less than 20 years may be used in the future for DSC retrieval operations.

Instead of conducting a scoping evaluation, AMR, and any corresponding TLAAs or AMP for the MP187, the applicant proposed a license condition to limit the age of an MP187 that can be used as a transfer cask at the TMI-2 ISFSI to 20 years (the initial licensing term for the TMI-2 ISFSI), thereby preventing the transfer cask from entering its period of extended operation in which aging management considerations would need to be addressed.

If DOE-ID wishes to use an MP187 aged greater than 20 years, DOE-ID would need to request a license amendment to change the license condition to allow for the use of such a transfer cask. An amendment request would follow the form of the current license renewal application, as applicable. In this case, the amendment request would include a scoping evaluation, AMR, and any corresponding TLAAs or AMPs demonstrating that aging effects for the MP187 will be managed so that the MP187 will continue to perform its intended functions in the period of extended operation.

4.5 Transfer Cask Spacers

The NRC added the following condition to the license:

> Transfer cask spacers, if required for DSC retrieval, shall only be used if they are fabricated fewer than 20 years before use.

The transfer cask spacers are included in the TMI-2 ISFSI design bases, as the spacers are credited in the UFSAR shielding analysis for axially positioning the DSC within the transfer cask and its radial shielding. As discussed in Section 2.1.2 of this SER, the transfer cask spacers used during the initial ISFSI loading campaign no longer exist, and new spacers would need to be fabricated if they were needed in the future (e.g., for retrieval operations from storage).

Instead of conducting a scoping evaluation, AMR, and any corresponding TLAAs or AMP for the transfer cask spacers, the applicant proposed a license condition to limit the age of spacers that can be used at the TMI-2 ISFSI to 20 years, thereby establishing a service life for the transfer cask spacers that is less than the initial licensing term for the TMI-2 ISFSI.

4.6 Exemptions

The NRC revised condition 12.b) and deleted condition 12.d) of the license.

The NRC revised license condition no. 12.b), as follows:

> b) Requirements of 10 CFR 20.1501(d) to use NVLAP accredited dosimetry and instead is authorized to use DOELAP dosimetry.

License condition 12.b) included an exemption from the requirement in 10 CFR 20.1501(c) to use NVLAP accredited dosimetry. The exemption allowed DOE-ID to use DOELAP as an alternative. In the 2011 final rule for "Decommissioning Planning," the regulation at 10 CFR 20.1501(c) was redesignated as 10 CFR 20.1501(d) (76 *Federal Register* (FR) 35564). Therefore, an editorial change to this license condition to correctly cite the current regulation in 10 CFR 20.1501(d) ensures regulatory clarity.

The NRC deleted license condition no. 12.d), which included an exemption from the requirements of 10 CFR 72.82(e) that a report of the preoperational test acceptance criteria and test results be submitted at least 30 days before loading the ISFSI. In the 1999 final rule for "Elimination of Reporting Requirement and 30-Day Hold in Loading Spent Fuel After Preoperational Testing of Independent Spent Fuel Storage or Monitored Retrievable Storage Installations," the NRC eliminated the 10 CFR 72.82(e) requirement (69 FR 17512). In addition, the TMI-2 ISFSI is fully loaded, and no additional radioactive material will be added to the ISFSI. Therefore, an administrative change to delete this license condition is appropriate, as the condition and exemption are no longer applicable to the TMI-2 ISFSI.

5 CONCLUSIONS

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

The NRC staff reviewed the license renewal application for the TMI-2 ISFSI, 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 license renewal application and the license conditions, the staff determines that the requirements of 10 CFR 72.42(a) have been met.

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