PRELIMINARY SAFETY EVALUATION REPORT

FOR THE HI-STORM 100 CASK SYSTEM

CERTIFICATE OF COMPLIANCE NO. 1014

RENEWAL

DOCKET NO. 72-1014

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

DATE

CONTENTS

INTRODUCTION

By letter dated January 31, 2020, as supplemented on October 16, 2020, October 29, 2020, April 19, 2021, and April 23, 2021, the Certificate of Compliance (CoC) holder, Holtec International (Holtec or the applicant) applied for renewal of CoC No. 1014 for the HI-STORM 100 Cask System, for an additional 40 years beyond the initial certificate period (the “period of extended operation”) (Holtec 2020a, 2020f, 2020g, 2021a, 2021b). The staff generally refers to this application, as supplemented, as the “renewal application” in this safety evaluation report (SER). Any specific references to sections of the renewal application are to Revision 1, which the applicant included in submittals dated April 19, 2021, and April 23, 2021 (Holtec 2021a, 2021b).

The applicant submitted the renewal application in accordance with the regulatory requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) 72.240, “Conditions for spent fuel storage cask renewal.” Because the renewal application was submitted more than 30 days before the CoC expiration date, under 10 CFR 72.240(b), this application constitutes a timely renewal. In the application, the applicant documented the technical bases for renewal of the CoC and proposed actions for managing the potential aging effects of the systems, structures, and components (SSCs) of the dry storage system to ensure that these SSCs will maintain their intended functions during the period of extended operation.

Under 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,” Subpart L, “Approval of Spent Fuel Storage Casks,” the U.S. Nuclear Regulatory Commission (NRC) approved the HI-STORM 100 Cask System and issued CoC No. 1014 for 20 years, with an expiration date of May 31, 2020. In accordance with 10 CFR Part 72, Subpart K, “General license for storage of spent fuel at power reactor sites,” the HI-STORM 100 Cask System under CoC No. 1014 can be used for storage of spent nuclear fuel in an independent spent fuel storage installation at power reactor sites to persons authorized to possess or operate nuclear power reactors under 10 CFR Part 50, “Domestic licensing of production and utilization facilities,” and 10 CFR Part 52, “Licenses, certifications, and approvals for nuclear power plants.”

The HI-STORM 100 Cask System consists of (1) interchangeable multi-purpose canisters (MPCs), which contain the fuel, (2) a storage overpack (HI-STORM), which contains the MPC during storage, and (3) a transfer cask (HI-TRAC), which contains the MPC during loading, unloading, and transfer operations. The cask stores up to 32 pressurized-water reactor fuel assemblies or 68 boiling-water reactor fuel assemblies.

The MPC provides the confinement boundary for the stored fuel. The MPC is a welded, cylindrical canister with a fuel basket, a baseplate, a lid, a closure ring, and the canister shell. This cask system has twelve types of MPCs: the MPC-24, MPC-24E, MPC-24EF, MPC-32, MPC-32F, MPC-32 Version 1, MPC 32-M, MPC-68, MPC-68 Version 1, MPC-68F, MPC-68FF, and MPC-68M. The number suffix indicates the maximum number of fuel assemblies permitted to be loaded in the MPC. All nine MPC models have the same external diameter. Each of the MPCs has different internals (baskets) to accommodate distinct fuel characteristics. The basket, which contains neutron-absorbing material, provides criticality control. All confinement boundary components are made entirely of stainless steel alloy materials.

The HI-STORM 100 dry storage system includes an aboveground system and an underground system. For the aboveground systems, the HI-STORM 100 or 100S storage overpack provides shielding and structural protection of the MPC during storage. The HI-STORM 100S is a variation of the HI-STORM 100 overpack design that includes a modified lid that incorporates the air outlet ducts, allowing the overpack body to be shortened. The overpack is a heavy-walled steel and concrete cylindrical vessel. Its side wall consists of plain (unreinforced) concrete that is enclosed between inner and outer carbon steel shells. The overpack has air inlets at the bottom and at the top to allow air to circulate naturally through the cavity to cool the MPC inside. The inner shell has supports attached to its interior surface to guide the MPC during insertion and removal, provide a medium to absorb impact loads, and allow cooling air to circulate through the overpack. A loaded MPC is stored within the HI-STORM 100 or 100S storage overpack in a vertical orientation. The HI-STORM 100A and 100SA are variants of the HI-STORM 100 overpack and are outfitted with an extended baseplate and gussets to enable the overpack to be anchored to the concrete storage pad in high-seismic applications.

The HI-STORM 100U system is an underground storage system within the HI-STORM 100 Cask System. The HI-STORM 100U storage vertical ventilated module (VVM) uses an air-cooled vault or caisson storage design. The HI-STORM 100U storage VVM relies on vertical ventilation instead of conduction through the soil, as it is essentially a below-grade storage cavity. Air inlets and outlets allow air to circulate naturally through the cavity to cool the MPC inside. The subterranean steel structure is seal welded to prevent ingress of any groundwater from the surrounding subgrade, and it is mounted on a stiff foundation. The surrounding subgrade and a top surface pad provide radiation shielding. A loaded MPC is stored within the HI-STORM 100U storage VVM in the vertical orientation.

The HI-TRAC transfer cask provides shielding and structural protection of the MPC during loading, unloading, and movement of the MPC from the spent fuel pool to the storage overpack. The transfer cask is a multiwalled (carbon steel/lead/carbon steel) cylindrical vessel with a neutron shield jacket attached to the exterior. The HI-TRAC design variants used with the HI-STORM 100 system include the HI-TRAC-100, -125, -100D, -125D, and HI-TRAC MS. All transfer cask sizes have identical cavity diameters. The higher weight HI-TRAC transfer casks have thicker shielding and larger outer dimensions than the lighter HI-TRAC transfer casks.

In the renewal application, the applicant documented the technical bases for renewal of the CoC and proposed actions for managing potential aging effects on the HI-STORM 100 SSCs that are within the scope of CoC renewal to ensure that these SSCs will maintain their intended functions during the period of extended operation. The applicant presented general information about the dry storage system design and a scoping evaluation to determine the SSCs within the scope of 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 subcomponent with an identified aging effect, the applicant proposed an aging management program or provided a time-limited aging analysis to provide assurance 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 HI-STORM 100 system for an additional 40 years beyond the current CoC term of 20 years. This SER summarizes the results of the staff’s review for compliance with 10 CFR 72.240. In its review of the application and development of the SER, the staff used the guidance in NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC 2016), and

NUREG-2214, Revision 0, “Managing Aging Processes In Storage (MAPS) Report,” issued July 2019 (NRC 2019b). NUREG-2214 establishes a generic technical basis for the safety review of storage renewal applications, in terms of the evaluation of (1) aging mechanisms and effects that could affect the ability of 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 HI-STORM 100 Cask System 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 information about the dry storage system. Section 2 presents the staff’s review of the applicant’s scoping evaluation to determine which SSCs are within the scope of renewal. Section 3 provides the staff’s evaluation of the applicant’s aging management review to assess aging effects and aging management activities for SSCs within the scope of renewal. Section 4 documents the NRC’s additions and changes to the conditions and technical specifications of the initial CoC and associated amendments due to renewal. Section 5 presents the staff’s conclusions of the safety review. Section 6 lists the references supporting the staff’s review and technical determinations.

1 GENERAL INFORMATION

1.1 Certificate of Compliance and Certificate of Compliance Holder Information

On January 31, 2020, as supplemented on October 16, 2020, October 29, 2020, April 19, 2021, and April 23, 2021 (Holtec 2020a, 2020f, 2020g, 2021a, 2021b), Holtec International (Holtec or the applicant) submitted an application to renew Certificate of Compliance (CoC) No. 1014 for the HI-STORM 100 Cask System, 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,” Subpart L, “Approval of Spent Fuel Storage Casks.”

The applicant requested renewal of the initial HI-STORM 100 CoC and Amendments 1–15. The U.S. Nuclear Regulatory Commission (NRC) issued the initial CoC (Amendment 0) for the HI-STORM 100 Cask System on May 31, 2000. Subsequently, the NRC issued 15 amendments to the HI-STORM 100 CoC. Table 1.2-1 of the application gives general descriptions of the changes in each amendment, the date of issuance of the initial CoC and CoC amendments, the corresponding final safety analysis report (FSAR) revision that defines the design bases for each amendment, and the location in the application of the aging management programs (AMPs) for each amendment.

1.2 Safety Review

The objective of this safety review is to determine whether the dry storage system will continue to meet the requirements of 10 CFR Part 72 for an additional 40 years beyond the initial certificate period (“the period of extended operation”). The NRC staff safety review is a detailed and in-depth assessment of the technical aspects of the HI-STORM 100 Cask System renewal application. Under 10 CFR 72.240(c)(2) and (c)(3), an application for renewal of a CoC must be accompanied by a safety analysis report that includes (1) time-limited aging analyses (TLAAs) demonstrating that structures, systems, and components (SSCs) important to safety will continue to perform their intended functions for the requested period of extended operation and (2) a description of the AMPs for management of issues associated with aging that could adversely affect SSCs important to safety.

The applicant stated that the renewal application includes the information required by 10 CFR 72.240(c) and that the application content is based on the guidance in NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC 2016). The applicant also referenced Nuclear Energy Institute (NEI) 14-03, Revision 1, “Format, Content and Implementation Guidance for Dry Cask Storage Operations-Based Aging Management,” issued September 2015 (NEI 2015), and NUREG-2214, “Managing Aging Processes in Storage (MAPS) Report,” issued July 2019 (NRC 2019b).

The applicant performed (1) a scoping evaluation to identify all SSCs within the scope of the renewal (“in-scope SSCs”) and (2) an aging management review (AMR) to identify pertinent aging mechanisms and effects. The applicant developed AMPs and evaluated TLAAs to ensure that the SSCs identified as within the scope of renewal will continue to perform their intended functions during the period of extended operation. This safety review documents the staff’s evaluation of the applicant’s scoping analysis, AMR, and supporting AMPs and TLAAs.

1.3 Application Content

The renewal application provided the following information:

- general information
- scoping evaluation
- AMR
- aging management tollgates
- AMPs
- TLAAs
- system inspections
- proposed FSAR changes (FSAR supplement)
- proposed CoC and technical specification changes

Table 1.2-1 of the renewal application identifies the HI-STORM 100 FSAR revision that applies to each CoC amendment. The applicant referenced Revision 18 of the FSAR (Holtec 2019) in the renewal application, as this was the latest revision of the FSAR in existence at the time of initial submittal of the renewal application. Therefore, when referring to “the FSAR,” this safety evaluation report (SER) is referring to Revision 18 of the FSAR unless otherwise specified.

During the staff’s review of the renewal application, the applicant submitted Revisions 19 and 20 to the FSAR (Holtec 2020d, 2020e). These FSAR revisions include the changes made through Amendment No. 14 to the CoC and additional changes the applicant made under 10 CFR 72.48, “Changes, tests, and experiments.” The staff considered FSAR Revisions 19 and 20 in its review of the applicant’s renewal application, scoping evaluation, and AMR. During the staff’s review of the renewal application, the staff also considered the changes proposed in Amendment No. 15 to the CoC, which was undergoing concurrent NRC staff review and became effective on June 14, 2021.

The applicant included a proposed FSAR supplement in Appendix D to the renewal application, which provides proposed changes and additions to the design-basis FSARs to document the aging management information described in the renewal application. The applicant also submitted supporting reports as attachments to the renewal application, HI-2188453, Revision 0, “Aging Management Review of SMDRs [Supplier Manufacturing Deviation Reports] for HI-STORM 100” (Holtec 2020b), and HI-2188468, Revision 0, “ECO [Engineering Change Orders] Review in Support of the HI-STORM 100 Renewal Application” (Holtec 2020c), which document the review of supplier manufacturing deviation reports, engineering change orders, and evaluations performed in accordance with 10 CFR 72.48, in support of the renewal application. The applicant evaluated whether these deviations have any impact on the aging of the system in the period of extended operation.

1.4 Evaluation Findings

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

F1.1 The information in the renewal application satisfies the requirements of 10 CFR 72.240, “Conditions for spent fuel storage cask renewal.”

F1.2 The applicant has provided a tabulation of all supporting information and docketed material incorporated by reference, in compliance with 10 CFR 72.240.

2 SCOPING EVALUATION

As described in NUREG-1927, a scoping evaluation is necessary to identify the SSCs requiring an AMR. The objective of this scoping evaluation is to identify SSCs meeting the following criteria:

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

- maintain the conditions required by the regulations or CoC to store spent fuel safely;
- prevent damage to the spent fuel during handling and storage; or
- provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to public health and safety

(2) SSCs that are classified as not important to safety but, according to the design bases, the failure of which 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's intended functions.

2.1 Scoping and Screening Methodology

Section 2 of the renewal application describes the applicant's scoping evaluation, including 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 in the renewal application, which included a review of the supplier manufacturing deviation reports, engineering change orders, and 10 CFR 72.48 evaluations to determine the impact, if any, to the scoping results. The following sections discuss the staff's review and findings about the applicant's scoping evaluation.

2.1.1 Scoping Process

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

- HI-STORM 100 FSAR
- CoC 72-1014 for the original certificate and the approved amendments (NRC 2000–2021):
  - HI-STORM 100 CoC 72-1014, Amendment 0, dated May 31, 2000
  - HI-STORM 100 CoC 72-1014, Amendment 1, dated July 15, 2002
  - HI-STORM 100 CoC 72-1014, Amendment 2, dated June 7, 2005
  - HI-STORM 100 CoC 72-1014, Amendment 3, dated May 29, 2007
  - HI-STORM 100 CoC 72-1014, Amendment 4, dated January 8, 2008
  - HI-STORM 100 CoC 72-1014, Amendment 5, dated July 14, 2008
  - HI-STORM 100 CoC 72-1014, Amendment 6, dated August 17, 2009
  - HI-STORM 100 CoC 72-1014, Amendment 7, dated December 28, 2009
  - HI-STORM 100 CoC 72-1014, Amendment 8, dated November 16, 2012 (corrected, then superseded by Revision 1)
  - HI-STORM 100 CoC 72-1014, Amendment 8R1, dated February 16, 2016
  - HI-STORM 100 CoC 72-1014, Amendment 9, dated March 11, 2014 (then superseded by Revision 1)
  - HI-STORM 100 CoC 72-1014, Amendment 9R1, dated March 21, 2016 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 10, dated May 31, 2016 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 11, dated February 25, 2019 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 12, dated February 25, 2019 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 13, dated May 13, 2019 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 14, dated December 17, 2019 (corrected)
  - HI-STORM 100 CoC 72-1014, Amendment 15, dated June 14, 2021

The applicant’s scoping process identified SSCs as being either scoped into the review under scoping criteria 1 and 2 or not scoped into the review for items not important to safety that did not meet scoping criterion 2.

The staff reviewed the applicant's scoping process and determined that the process was acceptable because the applicant evaluated the scope of items in the renewal review in a manner that is consistent with NUREG-1927, Section 2.4.

2.1.2 Scoping Results

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

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

SSCs	Criterion 1[1]	Criterion 2[2]	In Scope
MPC	Yes	N/A	Yes
HI-STORM 100 overpack	Yes	N/A	Yes
HI-TRAC transfer cask	Yes	N/A	Yes
Fuel assembly[3]	Yes	N/A	Yes
ISFSI pad	No	No	No
ISFSI security equipment	No	No	No
Fuel transfer and auxiliary equipment	No	No	No

[1] SSC is important to safety.
[2] SSC is not important to safety, but its failure could prevent an important-to-safety function from being fulfilled.
[3] Fuel pellets are not included, in accordance with NUREG-1927.

The staff reviewed the scoping results to determine whether the applicant included all SSCs in the approved design bases and whether the conclusions on the out-of-scope SSCs accurately reflect the design-basis documentation. The staff made the following conclusions on the SSCs excluded from the scope of renewal review:

- Independent Spent Fuel Storage Installation (ISFSI) Pad

  The applicant stated that the ISFSI pad is defined as not important to safety in the FSAR and is not included in the list of components in the HI-STORM 100 CoC. The staff reviewed the applicant's design-basis documentation and verified that Section 2.0.4.1 of the FSAR identifies the ISFSI pad as not important to safety and that the CoC only identifies the interchangeable multi-purpose canister (MPC), transfer cask, and storage overpack as components of the storage system. The staff also evaluated the implications of the failure of the ISFSI pad and finds that it would not affect any important-to-safety function. Therefore, the staff finds the applicant's determination that the ISFSI pad is not in scope to be acceptable.

- ISFSI Security Equipment

  The applicant stated that the security equipment is not described in detail in the FSAR and is not part of the HI-STORM 100 CoC. The applicant also stated that the failure of the security equipment would not prevent the storage casks from fulfilling their important-to-safety functions. The staff reviewed the applicant's design-basis documentation and verified that that the design bases of the storage system do not include ISFSI security equipment. The staff also evaluated the implications of the failure of the security equipment and did not identify any means by which such failure could affect an important-to-safety function of the storage system. Exclusion of SSCs associated with physical protection of the ISFSI or dry storage system from the scope of the renewal review is consistent with the guidance in NUREG-1927. Therefore, based on the staff's review of the applicant's design-basis documentation, the staff finds the applicant's determination that the security equipment is not in scope to be acceptable.

- Fuel Transfer and Auxiliary Equipment

  The applicant stated that the auxiliary equipment used to load the MPCs (e.g., closure welding and drying equipment) and move the overpack (e.g., cask transporter, mating devices, lifting devices) is not described in detail in the FSAR and is not part of the HI-STORM 100 CoC. The applicant noted that this determination is consistent with NUREG-1927, which states that equipment associated with cask loading and unloading is generally considered to be out of scope of renewal, provided that the equipment does not affect an important-to-safety function. The staff reviewed the applicant's design-basis documentation and notes that FSAR Table 8.1.6 defines the fuel transfer and auxiliary equipment as not important to safety. In addition, the staff evaluated the implications of the failure of the equipment and did not identify any means by which the equipment failure could affect an important-to-safety function of the storage system (e.g., the applicant's structural analysis demonstrated that the storage system could maintain its intended functions if dropped from the allowable lift height during cask transport). Therefore, based on the staff's review of the applicant's design-basis documentation, the staff finds the applicant's determination that the fuel transfer and auxiliary equipment is not in scope to be acceptable.

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

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

As discussed in Section 2.1.2, the applicant identified the MPC, HI-STORM 100 overpack, HI-TRAC transfer cask, and fuel assembly to be within the scope of renewal review. These SSCs consist of several subcomponents, not all of which support an intended function and need be considered in the AMR.

The staff reviewed the applicant's screening of the in-scope SSCs to identify subcomponents within the scope of renewal review. The staff's review considered the intended function of the subcomponent, its safety classification or basis for inclusion in the scope of renewal review, and design-basis information in the FSAR.

Based on this review, the staff finds that the applicant screened the in-scope SSCs in a manner consistent with NUREG-1927; therefore, the staff finds the screening results for in-scope SSC subcomponents to be acceptable. SER Tables 2.1-2 and 2.1-3 tabulate the results of the applicant's screening evaluation to identify each of the in-scope and out-of-scope SSC subcomponents, respectively.

Table 2.1-2. Subcomponents Within the Scope of Renewal Review

MPC	
Shell	Upper Fuel Spacer Column
Baseplate	Upper Fuel Spacer Pipe
Lid	Sheathing
Closure Ring	Shims
Port Cover Plates	Basket Supports (Angled Plates and Parallel Plates with connecting end shims)
Basket Cell Spacer Block	Basket Supports (Angled Plates and Parallel Plates, if Basket Shims are not used)
Basket Center Column	Upper Fuel Spacer Bolt
Basket Center Plates	Upper Fuel Spacer End Plate
Flux Gap Cover	Lower Fuel Spacer Column
Flux Gap Plate	Lower Fuel Spacer End Plate
Basket Cover Angle	Vent Shield Block Spacer
Basket Cell Angle	Damaged Fuel Container
Basket Cell Channel	Basket Sub-Panel
Neutron Absorber	Basket Shims
Drain and Vent Shield Block	Solid Shims
Plugs for Drilled Holes	Damaged Fuel Isolator
Heat Conduction Elements (Optional)	Drain Line Guide Tube
Lifting Hole Plug (Optional)	Vent and Drain Tube, Optional
Vent and Drain Tube	Threaded Disc, Plug Adjustment
Vent and Drain Cap	Retaining Ring
Vent and Drain Plug	
Thread Shield Cap	
HI-STORM 100 Overpack	
Radial Shield	Lug Support Ring
Shield Block Ring & Shell	Gusset
Pedestal Shield	Stud with Nut
Lid Shield	Bottom Plate
Shield Shell	Spacer Block
Shield Block	Top Place
Gamma Shield Cross Plates & Tabs	MPC Support
Baseplate	Shield Concrete
Outer Shell	Lid Outer Ring
Inner Shell	Lid Inner Ring
Pedestal Shell	Lid Lift Block
Pedestal Baseplate	Lid Vent Shield
Lid Bottom Plate	Lid Shield Concrete
Lid Shell	Lid Stud

Inlet Vent Vertical & Horizontal Plates Exit Inlet Vent Vertical & Horizontal Plates Top Plate Lid Top Plate Lid Shield Ring Lid Vent Side Plate Lid Shield Block Radial Plate Lid Stud Lid Stud Nut Bolt Anchor Block Channel or Guide Tube Pedestal Platform Shear Ring Channel Mounts Radial Weld Plate Heat Shield Heat Shield Ring 100S Lid Washer 100S Version B Base Shield Block Lid Stud Washer	Lid Closure Bolt Lid Hex Nut Cask Radial Gusset Radial Rib Closure Lid Concrete Closure Lid Steel Container Shell Bottom Plate Container Flange Divider Shell and Divider Shell Restraints Upper and Lower MPC Guides MPC Bearing Pads Insulation Reinforced Concrete; VVM Interface Pad, Top Surface Pad Retaining Wall, Support Foundation Pad Lid Rib MPC Bottom Support Guides Subgrade
Fuel Assembly	
Fuel Cladding Spacer Grid Assemblies Upper End Fitting	Lower End Fitting Guide Tubes
HI-TRAC	
Radial Lead Shield Pool Lid Lead Shielding Top Lid Shielding Outer Shell Inner Shell Enclosure Shell Panels Water Jacket End Plate Top Flange Lower Water Jacket Shell Water Jacket Bottom Ring Water Jacket Top Plates Bottom Flange Pool Lid Outer Ring Pool Lid Top Plate Top Lid Outer Ring Top Lid Inner Ring Top Lid Top Plate Top Lid Bottom Plate Pool Lid Bolt Lifting Trunnion Block Lifting Trunnion and End Cap Pocket Trunnion	Top Lid Lifting Block Top Lid Stud/Bolt Top Lid Nut/Washer Transfer Lid Side Lead Shield Transfer Lid Door Shield Transfer Lid Door Shielding Transfer Lid Top Plate Transfer Lid Bottom Plate Transfer Lid Intermediate Plate Transfer Lid Lead Cover Plate Transfer Lid Lead Cover Side Plate Transfer Lid Door Top Plate Transfer Lid Door Middle Plate Transfer Lid Door Bottom Plate Transfer Lid Door Wheel Housing Transfer Lid Door Interface Plate Transfer Lid Side Plate Transfer Lid Wheel Shaft Transfer Lid Shaft Cover Plate Transfer Lid Housing Stiffener Transfer Lid Door Lock Bolt Transfer Lid Door End Plate

Dowel Pins	Transfer Lid Lifting Lug and Pad
Water Jacket Bottom Plate	Short Rib
Pool Lid Bottom Plate	Extended Rib
Bottom Flange Gussets	Transfer Lid Door Stop Block
Fill Port Caps	Transfer Lid Door Stop Block Bolt
Transfer Lid Wheel Track	

Table 2.1-3. Subcomponents Not Within the Scope of Renewal Review

MPC Short Cell Spacer Plates Lift Lug Lift Lug Baseplate Vent and Drain Cap Seal Washer Vent and Drain Cap Seal Washer Bolt Vent and Drain Cap Lock Washer Reducer/Coupling Drain Line Shims **HI-TRAC** Bottom Flange Washer Thermal Expansion Foam Pool Lid Gasket End Cap Bolts Drain Pipes Drain Bolt Lifting Trunnion Pad Bolt Couplings, Valves, and Vent Plug Transfer Lid Door Handle Transfer Lid Door Wheels Hydraulic System **Spent Fuel Assembly** Fuel Pellets Hold-down Springs & Upper End Plugs Control Components Channels for boiling-water reactor fuel	**HI-STORM 100 Overpack** Storage Marking Nameplate Exit Vent Screen Sheet Drain Pipe Exit & Inlet Screen Frame Stud Tube Screens Screen Bolts Compression Fitting, Protection Head, Bushing, Coupling, and Hex Nipple for Thermocouple Conduit Connection Screws for Screen Fit-Up 100 Lid Washer Pedestal Shims Screen Bar Vent Frames Strap Block (Grounding Lugs) Washer Base and Lid Screen Mounts Base and Lid Lift Plug MPC Guide Lid Stud Pipe Lid Stud Spacer Lid Stud Ring Lid Lift Ring Lid Bolt Handle Lid Stud Cap Lid Vent Seal Lid Shim

2.2 Evaluation Findings

The NRC staff reviewed the scoping evaluation in the renewal application. The staff performed its review following the guidance in NUREG-1927. 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,” and 10 CFR 72.236, “Specific requirements for spent fuel storage cask approval and fabrication.”

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 whether the applicant has adequately reviewed applicable materials, environments, and aging mechanisms and effects and has 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

Following the scoping review, the applicant's AMR process consisted of three steps:

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

The applicant identified the materials of construction and their service environments for each SSC and associated subcomponents within the scope of renewal. The applicant then determined the aging effects and associated aging mechanisms that could cause degradation resulting in a loss of intended function. Finally, for each aging effect requiring management, the applicant determined the required aging management activities—either a TLAA or an AMP—to ensure that the intended function of the SSC would be maintained during the renewed certification period.

The staff reviewed the applicant's AMR process, which included a review of the supplier manufacturing deviation reports, engineering change orders, and 10 CFR 72.48 evaluations to determine the impact, if any, to the AMR results. The staff finds that the applicant's AMR process is acceptable because it is consistent with the methodology recommended in NUREG-1927 and is adequate for identifying credible aging effects for the SSCs within the scope of the renewal review.

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 verified that the design features, environmental conditions, and operating experience for the HI-STORM 100 Cask System are bounded by those evaluated in NUREG-2214.

The applicant defined the SSC service environments in Section 3.2.2 of the renewal application. Table 3.3-1 of this SER summarizes these environments and compares them to the environments evaluated in NUREG-2214. The staff considered this comparison in its determination of whether the conclusions in NUREG-2214 are applicable to applicant's analysis of the HI-STORM 100 Cask System.

Table 3.3-1. Aging Management Review—Environments

Environment in Renewal Application	Description	Equivalent Environment in NUREG-2214
Helium	Environment inside the MPC that is backfilled with inert helium gas and has negligible amounts of oxygen or moisture.	Helium
Sheltered	Environment that may include ambient air, but is shielded from sunlight, rain, or wind exposure. The ambient air contains moisture, salinity, or other contaminants typical for the site where it is stored. Additionally, the term refers to the interior of a storage building, which may not be conditioned by heating, ventilation, and air conditioning equipment.	Sheltered
Embedded	Environment applicable to materials that are embedded or sealed inside another material and are exposed to the temperatures of the components in which they are embedded.	Embedded in concrete Embedded in metal Embedded in neutron shielding Fully encased or lined
Air–outdoor	Environment for exterior surfaces that are exposed to direct sunlight, wind, rain, and other weather aspects and has temperature ranges equivalent to the site ambient temperature ranges.	Air–outdoor

SER Tables 3.3-2 through 3.3-5 summarize 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 about the credibility of each aging effect is consistent with the generic technical bases and conclusions 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 analysis that justifies 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 3.3-2. Aging Management Review Results—MPC

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Stainless steel (austenitic or duplex)	Helium	Fatigue	Cracking	Yes	Yes	MPC Fatigue TLAA (see SER Section 3.4.3)
	Sheltered	Pitting and crevice corrosion	Loss of material	Yes[1]	Yes[1]	MPC AMP
		Stress corrosion cracking	Cracking	Yes[1]	Yes[1]	MPC AMP
		Radiation	Loss of fracture toughness	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	Yes	Yes	MPC Fatigue TLAA (see SER Section 3.4.3)
		Microbiologically influenced corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
	Embedded	Radiation	Loss of fracture toughness	No	Yes	AMP/TLAA not necessary
Aluminum	Helium	None	None	No	Yes[2]	AMP/TLAA not necessary (see SER Section 3.3.1.3)
Steel	Helium	None	None	No	Yes	AMP/TLAA not necessary
	Embedded	None	None	No	Yes	AMP/TLAA not necessary
Neutron absorber (Metamic™, Metamic-HT™, or Boral™)	Helium	Radiation	Loss of material properties	Yes	Yes	Neutron Absorber Depletion TLAA (see SER Section 3.4.1)

[1] The applicant identified corrosion (as a precursor to stress corrosion cracking) and stress corrosion cracking as credible aging mechanisms only for welded components where sufficient residual stress exists to promote cracking, consistent with NUREG-2214. These mechanisms are not identified for non-welded components.

[2] NUREG-2214 did not identify credible aging effects for aluminum in a helium environment but states that an analysis for thermal aging effects on mechanical properties may be required on a case-specific basis. SER Section 3.3.1.3 documents the staff's review of this aging mechanism.

Table 3.3-3. Aging Management Review Results—Overpack

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Concrete	Embedded (metal)	Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
	Air–outdoor	Aggressive chemical attack	Cracking/loss of strength/loss of material/reduction of concrete pH	Yes	Yes	100U Concrete AMP
		Freeze and thaw	Cracking/loss of material (spalling, scaling)	Yes	Yes	100U Concrete AMP
		Reaction with aggregates	Cracking/loss of strength	Yes	Yes	100U Concrete AMP
		Salt scaling	Loss of material	Yes	Yes	100U Concrete AMP
		Leaching of calcium hydroxide	Loss of strength/increase in porosity and permeability/ reduction of concrete pH	Yes	Yes	100U Concrete AMP
	Embedded (soil)	Aggressive chemical attack	Cracking/loss of strength/loss of material/reduction of concrete pH	Yes	Yes	100U Concrete AMP
		Differential settlement	Cracking	Yes	Yes	100U Concrete AMP
		Freeze and thaw	Cracking/loss of material	Yes	Yes	100U Concrete AMP

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Microbiological degradation	Loss of strength/loss of material/increase in porosity and permeability/ reduction of concrete pH	Yes	Yes	100U Concrete AMP
		Reaction with aggregates	Cracking/loss of strength	Yes	Yes	100U Concrete AMP
		Salt scaling	Loss of material	Yes	Yes	100U Concrete AMP
		Leaching of calcium hydroxide	Loss of strength/increase in porosity and permeability/ reduction of concrete pH	Yes	Yes	100U Concrete AMP
	Sheltered	Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
Steel	Air–outdoor	General, pitting, and crevice corrosion	Loss of material	Yes	Yes	Overpack AMP
		Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
	Sheltered	General, pitting, crevice, and galvanic[1] corrosion	Loss of material	Yes	Yes	Overpack AMP
		Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
	Embedded[2]	None	None	No	Yes	AMP/TLAA not necessary
	Embedded (concrete)	General, pitting, and crevice corrosion	Loss of material	Yes	Yes	Overpack AMP

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
		Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
Stainless steel	Sheltered	Pitting and crevice corrosion	Loss of material	Yes	Yes	Overpack AMP
		Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
Insulator material (e.g., Kaowool®)	Embedded	None	None	No	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.3.1.1)
Subgrade	Embedded (soil)	Erosion	Loss of material	Yes	Not evaluated in NUREG-2214	100U Concrete AMP (see SER Section 3.3.1.4)
		Settlement	Loss of form	Yes	Not evaluated in NUREG-2214	100U Concrete AMP (see SER Section 3.3.1.4)
		Desiccation	Loss of material properties	Yes	Not evaluated in NUREG-2214	100U Concrete AMP (see SER Section 3.3.1.4)

[1] The applicant identified galvanic corrosion as a credible aging mechanism for steel components that have dissimilar metal contacts (e.g., MPC bearing pads).
[2] The applicant identified the lid vent shield as important to safety in Section 2 of the application; however, the staff noted that a corresponding AMR was not included in AMR Table 3.3-2 of the application. The staff noted that per FSAR Section 3.4.8.1, including associated design drawings, the steel lid vent shield is embedded in concrete; thus, consistent with NUREG-2214, there are no credible aging effects requiring management during the period of extended operation.

Table 3.3-4. Aging Management Review Results—Fuel Assembly

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Zircaloy (fuel cladding)	Helium	Hydride reorientation (high-burnup fuel only)	Embrittlement (high-burnup fuel only)	Yes	Yes	High Burnup Fuel Assembly AMP
		Thermal creep (high-burnup fuel only)	Changes in dimension (high-burnup fuel only)	Yes	Yes	High Burnup Fuel Assembly AMP
Stainless steel	Helium	None	None	No	Yes	AMP/TLAA not necessary
Inconel	Helium	None	None	No	Yes	AMP/TLAA not necessary
Zircaloy (except fuel cladding)	Helium	None	None	No	Yes	AMP/TLAA not necessary

Table 3.3-5. Aging Management Review Results—HI-TRAC

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Steel	Air	General, pitting, and crevice corrosion	Loss of material	Yes	Yes	Transfer Cask AMP[1]
	Embedded	Radiation	Loss of material properties	No	Yes	AMP/TLAA not necessary
	Water (when water jacket filled—may have contained glycol)	General, pitting, and crevice corrosion	Loss of material	Yes	Yes	Transfer Cask AMP
Holtite-A™	Embedded	Radiation embrittlement	Cracking	No[2]	Yes	AMP/TLAA not necessary (see SER Section 3.3.1.2)
		Thermal aging	Loss of ductility and fracture toughness	No[2]	Yes	AMP/TLAA not necessary (see SER Section 3.3.1.2)
		Boron depletion	Loss of shielding	No[2]	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.3.1.2)
Stainless steel/nickel alloy (lifting trunnions)	Air	Wear	Loss of material	Yes	Yes	Transfer Cask AMP
Stainless steel (non-welded)	Air	None	None	No	Yes	AMP/TLAA not necessary
Lead (including ASTM B29)	Embedded	None	None	No	Yes	AMP/TLAA not necessary

[1] The applicant used inconsistent terminology to describe the AMP for the transfer cask. In the application, the AMR Table 3.3-4 refers to the “HI-TRAC AMP,” while the AMP descriptions in Appendices A and D are titled “Transfer Cask AMP.”

[2] The applicant’s AMR Table 3.3-4 lists radiation embrittlement, thermal aging, and boron depletion as aging effects requiring management; however, the applicant concluded in Section 3.3.4.5 of the application that these aging effects will not cause the material to suffer damage or a change in properties. Therefore, the applicant did not propose an AMP or TLAA.

The staff reviewed the applicant's AMR results for consistency with the technical bases for aging mechanisms and effects in NUREG-2214. If the staff determined that the applicant's conclusions were consistent with expected aging management activities in accordance with NUREG-2214, the staff considered the results acceptable and provides no additional discussion in this SER. The following sections address the applicant's conclusions on aging mechanisms and effects for which the staff was not able to verify consistency with NUREG-2214 or for which the staff considered additional explanation of its review to be warranted.

3.3.1 Supplemental Analyses

The following assessments document the staff's review for those AMR conclusions that were either inconsistent with NUREG-2214 or warranted additional explanation.

3.3.1.1 Cracking Due to Radiation Embrittlement of HI-STORM 100 Overpack Insulation Subcomponents

The applicant indicated that the insulation for the HI-STORM 100U system is not subject to any credible aging effects requiring management during the renewal period. However, Section 3.5.2.1 of NUREG-2214 states that a review of the radiation effects on the insulation material should be performed on a case-by-case basis and that the application should address cracking due to radiation embrittlement. The renewal application does not give a basis for the determination that the insulation material for the HI-STORM 100U system does not require aging management during the renewal period. The staff noted that fibrous insulation (e.g., Kaowool®) was tested to ensure the insulation maintains a tight fit to prevent gaps in "A Survey Of The Materials And Design Of Insulation For Prestressed-Concrete Vessels For Gas-Cooled Reactors," issued May 1971 (Holcomb 1971). The effects of irradiation on the compression characteristics were investigated by exposing samples of Kaowool® and other fibrous materials to a neutron fluence (E > 1 mega-electron volt) of up to 1.8×10^{18} neutrons per square centimeter (n/cm^2) at temperatures of 66 degrees Celsius (C) (150 degrees Fahrenheit (F)) and 399 degrees C (750 degrees F). The results from this study demonstrate that irradiation of Kaowool® ceramic fiber insulation had a negligible impact on the dimensional stability of the material. NUREG-2214 calculated a conservative estimate of the accumulated neutron fluence for any component after 100 years of storage to be 2.63×10^{16} n/cm^2, which is two orders of magnitude less than the test conditions described by Holcomb (1971). Based on the testing of Kaowool®, the staff finds that radiation embrittlement of the Kaowool® ceramic fiber insulation is not credible during the period of extended operation. Therefore, the staff finds the applicant's determination to be acceptable.

3.3.1.2 Aging Management of HI-TRAC Holtite-A™ Subcomponents

The applicant indicated that the Holtite-A™ neutron shielding material in the transfer cask top lid and transfer lid door is not subject to any credible aging effects requiring management during the renewal period. However, Sections 3.3.1.2 and 3.3.1.3 of NUREG-2214 state that thermal and radiation embrittlement are credible aging mechanisms for polymer-based neutron shielding materials. The staff issued a request for additional information to the applicant on August 17, 2020 (NRC 2020b) and a request for clarification on February 18, 2021 (NRC 2021b). In its response (Holtec 2020f, 2020g, 2021a), the applicant provided a thermal and shielding evaluation to demonstrate that subcomponents of the HI-TRAC fabricated from Holtite-A™ do not require aging management during the period of extended operation.

Specifically, for its thermal evaluation, the applicant used a Holtite-A™ weight loss calculation that was parameterized by temperature and exposure time based on testing data from measurements of weight loss at differing temperatures. The applicant investigated the operational history usage for the HI-TRAC to determine the amount of exposure time that one HI-TRAC unit could experience during a 60-year period during all loading and subsequent unloading operations. The staff reviewed the applicant's assumed exposure time for one HI-TRAC unit during a 60-year period at a dual reactor unit site and determined that the number of loading and unloading operations on the ISFSI are reasonable and generally account for worst case scenarios. The applicant calculated the weight loss of the Holtite-A™ material due to thermal effects to show that the amount of potential weight loss during the period of extended operation is well within the design bases of the HI-STORM 100 Cask System (see HI-STORM 100 FSAR Sections 1 and 5 and Table 8.1.8). The staff noted that the potential weight loss due to thermal effects during the period of extended operation of the Holtite-A™ material is less than the conservative potential weight loss in the design bases of the HI-STORM 100 Cask System.

Additionally, for the shielding evaluation, the staff noted that the applicant assumed the following when calculating how much time the neutron shielding material would be exposed to radiation:

- The HI-TRAC is used at a dual reactor unit site.
- All loading operations take 7 days (compared to the typical 3-day process).
- Normal loading operations are continuous over 60 years (i.e., two loadings per year per reactor unit).
- Offloading of the fuel from the spent fuel pool into dry casks is performed after final reactor defueling operations (i.e., the final fuel is to be off-loaded from the pool into dry casks as part of the decommissioning effort).
- All loaded casks are subsequently unloaded during the 60-year period.

The staff noted that the assumptions used to estimate the radiation exposure time in the shielding evaluation are reasonable and generally account for worst case scenarios during a 60-year period. With regard to the assumption related to the defueling operations, the staff noted that the applicant used an average number of loadings for the transfer cask, while the staff would have typically expected an assumption based on the maximum number of loadings for the transfer cask. However, the staff noted that any potential nonconservatism in the estimate of the exposure time related specifically to the defueling operations is considered to be compensated by the large margins incorporated into other aspects of the exposure calculations. As described in HI-2002396, Revision 5, "Holtite-A: Development History and Thermal Performance Data," issued June 2017 (Holtec 2017), irradiation testing subjected the Holtite-A™ samples to a neutron fluence approximately 110 times, and to a gamma dose almost 80 times, the total expected exposure of the HI-TRAC over a 60-year period. The post-irradiation analysis of the samples (see HI-2002396, Revision 5) demonstrated that the irradiation tests did not result in any change in the appearance of the Holtite-A™ samples. In addition, the samples showed negligible change in dimensions, weight, and density; had essentially no depletion of boron-10 post-irradiation; and retained the hydrogen content following exposures to high neutron and gamma radiation. Consequently, the staff finds that there is significant margin available between the test results of the Holtite-A™ material and the expected exposure of the HI-TRAC over a 60-year period.

Based on its review, the staff concludes that the Holtite-A™ will continue to perform its shielding function in the period of extended operation because significant margin exists between the results from the testing of Holtite-A™ and the expected thermal and radiation exposure of the Holtite-A™ in the HI-TRAC over 60 years.

3.3.1.3 Aging Management of Aluminum Subcomponents of the Multi-purpose Canister

The applicant indicated that the aluminum basket shims and solid shims for the MPC-68M/32M are not subject to any credible aging effects requiring management during the renewal period. Table 2.2.2 of the renewal application states that the shims have structural integrity and heat transfer intended functions. The staff noted that Section 3.2.3.7 of NUREG-2214 states that the microstructures and mechanical properties of many aluminum alloys may change given sufficient time at temperature, which is commonly called thermal aging. The effect of thermal aging on mechanical properties will depend on the time at temperature and the microstructure and chemical composition of the aluminum components.

In letters dated October 16, 2020, and April 19, 2021, the applicant provided additional technical bases to justify that the mechanical properties of the thermally aged aluminum shims remain acceptable during the most severe accident conditions (i.e., non-mechanistic cask tipover accident) (Holtec 2020f, 2021a). The applicant referenced information contained in Section 3.III.2 of the HI-STORM 100 FSAR to describe the mechanical properties of alloys used to fabricate these aluminum shims as a function of time at temperature.

The staff notes that it had previously reviewed the thermal aging of the shims during the first 20 years of storage and concluded that the shim material properties are acceptable, as documented in the final SER for Amendment No. 11 to the CoC No. 1014 for the HI-STORM 100 (NRC 2019a). As a result, for the renewal review, the staff evaluated whether the aluminum may undergo additional thermal aging during the period of extended operation that could challenge the shim's intended functions. The staff noted that the shim temperatures will continue to decrease over time, with the initial temperature drop following initial loading being more rapid, due to the dropping decay heat of the spent fuel. Consequently, any thermal aging is considered to be dominated by the thermal exposure in the initial storage period, which the staff had previously concluded to be acceptable. Based on the staff's independent literature review (Aluminum Association 2003) and the information in the FSAR, the staff finds it reasonable that thermal aging of the aluminum shims during the period of extended operation will not impact the component's ability to perform its intended function during accident conditions. Therefore, the staff finds the applicant's determination to be acceptable.

3.3.1.4 Aging Management of the HI-STORM 100U Subgrade

The applicant concluded that the subgrade (soil) surrounding the HI-STORM 100U vertical ventilated module (VVM) is subject to loss of material due to erosion, loss of form due to settlement, and loss of material properties due to desiccation. The applicant proposed to manage these aging effects with the 100U Concrete AMP.

The staff notes that NUREG-2214 does not provide an evaluation of the subgrade. In its review of the identified aging effects, the staff noted that the applicant's conclusions are consistent with the guidance associated with the renewal of power reactors. Both NUREG-1801, Revision 2, "Generic Aging Lessons Learned (GALL) Report," issued December 2010 (NRC 2010), and Electric Power Research Institute (EPRI) Report 1015078, "Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools)," issued 2007 (EPRI 2007), identify aging effects that are applicable for soil structures, which include loss of material due to erosion, loss of form due to settlement or cracking, and change in properties due to loss of moisture (desiccation). Therefore, based on its consistency with NRC and industry guidance on the aging of soil structures, the staff finds the applicant's determination regarding applicable aging effects for the subgrade surrounding the HI-STORM 100U VVM to be appropriate and acceptable.

3.3.2 Evaluation Findings

The staff reviewed the AMR in the 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 in NUREG-1927 and NUREG-2214. Based on its review of the renewal application, the staff finds the following:

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

3.4 Time-Limited Aging Analyses

As discussed in Appendix B to the renewal application, the applicant identified four TLAAs for SSCs within the scope of the renewal review:

(1) Neutron Absorber Depletion
(2) HI-TRAC Trunnion
(3) MPC Fatigue
(4) Fuel Cladding Integrity

Based on its review of the design-basis documents, the staff confirmed that the applicant identified all calculations and analyses that meet all six criteria in 10 CFR 72.3 that define a TLAA. The following sections document the staff's evaluation of the TLAAs. On that basis, the staff concludes that the applicant's TLAAs are appropriate.

As described in additional detail in Section 3.4.2, the applicant's analysis for the HI-TRAC trunnion would not be considered a TLAA in accordance with 10 CFR 72.3 because the original analysis did not have a time-limited assumption. Nevertheless, the applicant provided an assessment for trunnion fatigue, which the staff reviewed to ensure that this potential aging mechanism was adequately evaluated.

3.4.1 Neutron Absorber Depletion

In Section B.2 of the renewal application, the applicant stated that the original design-basis analysis in FSAR Section 6.3.2 demonstrated that the boron depletion of the neutron-absorbing material is negligible over a 50-year duration and that the applicant re-performed this same analysis in support of the renewal application, documented in HI-951322, Revision 24, "HI-STAR 100 Shielding Design and Analysis for Transport and Storage," Appendix 3, issued May 2016 (Holtec 2016). The applicant stated that this analysis concluded that the total depletion of boron-10 in Boral™ over 500 years is negligible (less than 1 part per million of total boron-10 atoms depleted). The applicant stated that the evaluation for Boral bounds the evaluation for the use of Metamic™. Based on this assessment, the applicant determined that the TLAA for neutron absorber depletion shows that the neutron absorber will perform its intended function well beyond the period of extended operation and that no AMP is needed to manage neutron absorber aging.

The staff reviewed the boron carbide loading data for Metamic™ and Boral™ in EPRI's "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications," issued 2009 (EPRI 2009), and noted that the boron concentrations in these two materials are similar. Therefore, the staff finds the applicant's conclusion for boron-10 depletion rates in Boral™ that were calculated in the TLAA is considered to also be applicable to boron-10 depletion rates in Metamic™.

The staff reviewed the analysis methodology, assumptions, and conclusions of this TLAA and finds them acceptable because (1) the applicant's boron depletion analysis demonstrated that the neutron absorber material will perform its intended function well beyond the period of extended operation and (2) the conclusion is consistent with the technical basis in NUREG-2214, which also concluded that boron depletion of neutron-absorbing materials is not credible in the period of extended operation.

3.4.2 HI-TRAC Trunnion

In Section B.3 of the renewal application, the applicant stated that the original design-basis documentation concluded that fatigue is not a concern for the HI-STORM 100 Cask System, including the HI-TRAC. Specifically, the applicant stated that the inspections of the trunnions are performed to ensure damaged components are not used. Based on its assessment and its FSAR, the applicant relies on the Transfer Cask AMP (including trunnion inspections) for managing any aging effects; therefore, the applicant concluded that no further analysis of the trunnions is needed.

During its review of the FSAR to verify the applicant's conclusion and to determine whether a fatigue analysis for the HI-TRAC trunnions was performed as part of the design, the staff noted that FSAR Section 3.4.11.2 described that (1) the HI-TRAC is designed for repeated normal condition handling operations with a high factor of safety, particularly for the lifting trunnions, to ensure structural integrity, and (2) the resulting cyclic loading produces stresses that are well below the endurance limit of the trunnion material and, therefore, will not lead to a fatigue failure in the transfer cask.

The staff notes that, since the original design-basis evaluation of fatigue did not have a time-limited assumption but rather was based on demonstrating that stresses are well below material endurance limits, this analysis for renewal is not a TLAA. The extended service time of the HI-TRAC will not introduce fatigue concerns in the period of extended operation because stresses are not expected to be sufficiently high to cause fatigue. Therefore, the staff finds the applicant's analysis to be acceptable.

3.4.3 Multi-purpose Canister Fatigue

In Section B.4 of the renewal application, the applicant stated that Section 3.1.2.4 of the HI-STORM FSAR describes that the low stress, high-cycle conditions of ambient temperature and insolation cycling during normal dry storage conditions cannot lead to a fatigue failure of the MPC and that the endurance limits of the material are well in excess of 20,000 pounds per square inch. However, the applicant stated that it is possible that repeated lifting of the MPC might cause increased stresses and therefore lower the fatigue life of the MPC.

In order to determine the maximum number of lifting cycles, the applicant evaluated the lifting points against the allowable limits from NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants: Resolution of Generic Technical Activity A-36,” issued July 1980 (NRC 1980); American National Standards Institute (ANSI) N14.6, “Radioactive Materials—Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More,” issued 1993 (ANSI 1993); and Regulatory Guide 3.61, “Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask,” issued February 1989 (NRC 1989). The applicant explained that its analysis set the maximum applicable stress limit for MPC components as the secondary stress limit from the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code Section III, Subsection NB (ASME 2007). The calculation concluded that the allowable number of lifting cycles of the MPC greatly exceeds the amount of lifts of an MPC that would be expected over the 60-year extended storage of the MPC.

The staff noted that the applicant’s assumption for the maximum applicable stress limit for MPC components is conservative because the lifting points are limited to the low stress limits of NUREG-0612 and ANSI N14.6; thus, the maximum stress will not be higher than the secondary stress limit used. The staff reviewed the analysis methodology, assumptions, and conclusions of this TLAA and finds them acceptable because of the conservatism in the analysis, as described above, and the significant margin between the allowable number of lifting cycles of the MPC and the number expected over the 60-year extended storage of the MPC.

3.4.4 Fuel Cladding Integrity

In Section B.5 of the renewal application, the applicant stated that early amendments to CoC No. 1014 for the HI-STORM 100 Cask System provided an analysis of the integrity of the fuel to be stored, which includes a time-based assumption and could be considered a TLAA. The applicant explained that the temperature limits for fuel in Interim Staff Guidance (ISG)-11, Revision 3, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” issued November 2003 (NRC 2003), were incorporated into the design bases for the HI-STORM 100 Cask System after the NRC issued ISG-11, Revision 3. The ISG provides the technical information that supports the storage of fuel in the HI-STORM 100 Cask System. Following this change to the design basis, the performance of the fuel cladding no longer depends on a time-based assumption. Therefore, the applicant did not reperform the original time-based analysis in the early amendments for the period of extended operation. The applicant also described that additional aging management activities for high-burnup fuel are covered under the High Burnup Fuel Assembly AMP. The staff notes that, after the applicant’s submittal of the renewal application, the NRC fully incorporated the guidance in ISG-11 into NUREG-2215, “Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities,” issued April 2020 (NRC 2020a), and withdrew ISG-11.

FSAR Tables 2.0.1 and 4.3.1 cite ISG-11, Revision 3, to demonstrate that the fuel cladding temperatures of the HI-STORM 100 Cask System meet the temperature limits for storage of spent fuel that were established to minimize potential aging mechanisms of cladding creep and hydride reorientation. Specifically, ISG-11, Revision 3, states that the following temperature criteria should be met to ensure integrity of the cladding material:

- For all fuel burnups (low and high), the maximum calculated fuel cladding temperature should not exceed 400 degrees C (752 degrees F) for normal conditions of storage and short-term loading operations (e.g., drying, backfilling with inert gas, and transfer of the cask to the storage pad).
- For off-normal and accident conditions, the maximum cladding temperature should not exceed 570 degrees C (1,058 degrees F).

The staff reviewed the applicant's assessment of the fuel cladding integrity. The staff determined that the fuel cladding temperatures of the HI-STORM 100 Cask System documented in FSAR Tables 2.0.1 and 4.3.1 meet the temperature criteria in ISG-11, Revision 3. As stated in NUREG-2214, Section 3.6, for fuel assemblies that are dried in accordance with the ISG-11 criteria, no aging mechanisms are considered credible for assemblies with average burnups that do not exceed 45 gigawatt-days per metric ton of uranium.

However, for higher burnup assemblies, NUREG-2214 concluded that cladding creep and hydride reorientation are credible aging mechanisms. The applicant proposed to manage those aging mechanisms with the High Burnup Fuel Assembly AMP, consistent with the recommendation in NUREG-2214. The staff documents its review of the High Burnup Fuel Assembly AMP in SER Section 3.5.

Based on the applicant's use of the ISG-11 drying criteria, and the applicant's proposed aging management activities for high-burnup fuel as discussed in SER Section 3.5, the staff finds the applicant's approach to be consistent with the staff's guidance in ISG-11 and NUREG-2214 to ensure cladding integrity for the period of extended operation. Therefore, the staff finds the applicant's evaluation of this TLAA to be acceptable.

3.4.5 Evaluation Findings

The staff reviewed the TLAAs in the renewal application. The staff performed its review following the guidance in NUREG-1927 and NUREG-2214. The staff verified that the TLAA assumptions, calculations, and analyses were adequate and bound the environment and aging mechanisms or aging effects for the pertinent SSCs. Based on its review of the renewal application, the staff finds the following:

F3.3 The applicant identified all aging mechanisms and effects pertinent to SSCs within the scope of renewal that involve TLAAs. The methods and values of the input parameters for the applicant's TLAAs are adequate. The applicant's TLAAs require no further aging management activities and meet the requirements in 10 CFR 72.240(c)(2). Therefore, there is reasonable assurance that the SSCs will maintain their intended functions for the period of extended operation.

3.5 Aging Management Programs

Under 10 CFR 72.240(c)(3), the applicant must provide a description of AMPs for the management of issues associated with aging that could adversely affect SSCs important to safety. The applicant proposed the following five AMPs in the renewal application:

(1) MPC AMP
(2) Overpack AMP

(3) Transfer Cask AMP
(4) High Burnup Fuel Assembly AMP
(5) 100U Concrete AMP

The staff conducted the safety review of the proposed AMPs in the renewal application in accordance with the guidance in NUREG-1927. 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 through 3.5-5 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.

Specifically, the staff compared the following AMPs:

- The staff compared the MPC AMP to the NUREG-2214 example AMP, "Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Canisters" (see SER Table 3.5-1).

- The staff compared the Overpack AMP to the NUREG-2214 example AMP, "Monitoring of Metallic Surfaces" (see SER Table 3.5-2).

- The staff compared the HI-TRAC AMP to the NUREG-2214 example AMP, "Transfer Casks" (see SER Table 3.5-3).

- The staff compared the High Burnup Fuel Assembly AMP to the NUREG-2214 example AMP, "High-Burnup Fuel Monitoring and Assessment" (see SER Table 3.5-4).

- The staff compared the 100U Concrete AMP to the NUREG-2214 example AMP, "Reinforced Concrete Structures" (see SER Table 3.5-5).

Table 3.5-1. AMP Review Results—MPC AMP

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Canisters"
1. Scope of Program	Consistent. The applicant defined the scope as those HI-STORM 100 MPC components in Table 3.3-1 of the renewal application that are identified as requiring the MPC AMP.
2. Preventive Actions	Consistent.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Consistent.
5. Monitoring and Trending	Consistent.
6. Acceptance Criteria	Consistent.
7. Corrective Actions	Consistent.

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Canisters"
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent. The applicant stated the AMP will be updated, as necessary, based on the tollgate assessments. SER Section 3.5.1 documents the staff's evaluation of the use of tollgates for program assessment.
10. Operating Experience	Consistent. The applicant stated that no cases of chloride-induced stress corrosion cracking for stainless steel dry storage canisters have been reported. Further, the applicant stated that no evidence of localized corrosion had been identified, but some amount of chloride-containing salts were present, and corrosion products believed to be related to iron contamination were identified. As discussed in the Administrative Controls AMP element, the applicant also stated that it will use the ISFSI Aging Management Institute of Nuclear Power Operations Database (AMID) to share operating experience with others.

Table 3.5-2. AMP Review Results—Overpack AMP

AMP Element	Staff's Assessment of Consistency with NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
1. Scope of Program	Consistent. The applicant defined the scope as those HI-STORM 100 overpack components in Table 3.3-2 of the renewal application that are identified as requiring the Overpack AMP.
2. Preventive Actions	Consistent.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Consistent, except as noted here. NUREG-2214 recommends that the exterior of the overpack in contact with concrete (e.g., cask bottom) be inspected on a justified frequency. The applicant proposed an alternative approach, in which visual inspections of the ISFSI pad concrete adjacent to the overpack will be performed to identify evidence of steel degradation (such as staining or rust). The applicant stated that these inspections will be used to determine whether normally inaccessible components of the overpack (i.e., container shell bottom plate for the underground 100U system, cask bottom for the aboveground system) need additional inspection. For the aboveground system, the staff finds the visual inspection of adjacent concrete to be acceptable to manage the aging of the cask bottom because it provides an indication of the condition for inaccessible bottom surfaces of the overpack and ensures that timely corrective actions are initiated, without undue burden to lift the overpack. The staff also notes that portions of the bottom plate (vertical exterior surfaces where the plate meets the ground) will be accessible for the annual exterior inspections as part of the AMP, and

AMP Element	Staff's Assessment of Consistency with NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
	these inspections provide an additional opportunity to identify bottom plate corrosion before a loss of intended function. For the underground 100U system, given the design of the container shell bottom plate resting on the below-grade concrete support foundation pad, the staff noted that it is not practical to identify evidence of the plate's degradation on adjacent concrete (such as staining or rust). However, the staff finds that the AMP's inspection of the internal surfaces of the overpack for the 100U system to identity evidence of corrosion are adequate aging management of the container shell bottom plate, consistent with NUREG-2214.
5. Monitoring and Trending	Consistent.
6. Acceptance Criteria	Consistent, except as noted here. The applicant included additional criteria for evidence of corrosion related to the container shell bottom plate and cask bottom. To address corrosion of these inaccessible surfaces, the AMP includes acceptance criteria for no evidence of corrosion, such as rust in the area of ISFSI pad concrete adjacent to the overpack. The staff considers the absence of corrosion indications on the adjacent concrete to be a sufficient criterion to ensure that any degradation of the container shell bottom plate and cask bottom will be evaluated by the licensee in a timely manner to verify that these components can continue to perform their intended function. Therefore, the staff finds the acceptance criteria to be acceptable. The applicant also included acceptance criteria for gouges (e.g., size, number, and proximity) on the external surfaces of the overpack. The staff does not consider the occurrence of gouges on the overpack as a materials aging effect but rather as an operational event caused by cask handling or other site activities. In addition, the applicant did not identify the formation of gouges in its AMR review. As a result, the staff did not review this portion of the program in making the finding of whether overpack aging effects will be adequately managed because gouges, which are considered mechanical damage, on the overpack are not considered a materials aging effect.
7. Corrective Actions	Consistent.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent. The applicant stated the AMP will be updated, as necessary, based on the tollgate assessments. SER Section 3.5.1 documents the staff's evaluation of the use of tollgates for program assessment.
10. Operating Experience	Consistent. The applicant stated that minimal corrosion has been detected to date, mostly limited to small rust spots and coating degradation. Further, the applicant stated that there has been some minor overpack concrete degradation (e.g., shrinkage cracks, minor spalling, surface damage, paint loss, and small scratches).

AMP Element	Staff's Assessment of Consistency with NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
	As discussed in the Administrative Controls AMP element, the applicant also stated that it will use the AMID to share operating experience with others.

Table 3.5-3. AMP Review Results—Transfer Cask AMP

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "Transfer Casks"
1. Scope of Program	Consistent. The applicant defined the scope as those HI-STORM 100 cask transfer components in Table 3.3-4 of the renewal application that are identified as requiring the Transfer Cask AMP.
2. Preventive Actions	Consistent.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Consistent.
5. Monitoring and Trending	Consistent.
6. Acceptance Criteria	Consistent.
7. Corrective Actions	Consistent.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent. The applicant stated the AMP will be updated, as necessary, based on the tollgate assessments. SER Section 3.5.1 documents the staff's evaluation of the use of tollgates for program assessment.
10. Operating Experience	Consistent. The applicant stated that minimal corrosion has been detected to date, mostly limited to coating degradation. As discussed in the Administrative Controls AMP element, the applicant also stated that it will use the AMID to share operating experience with others.

Table 3.5-4. AMP Review Results— High Burnup Fuel Assembly AMP

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "High-Burnup Fuel Monitoring and Assessment"
1. Scope of Program	Consistent. The applicant defined the scope as those HI-STORM 100 fuel assembly components in Table 3.3-3 of the renewal application that are identified as requiring the High Burnup Fuel Assembly AMP.
2. Preventive Actions	Consistent.
3. Parameters Monitored or Inspected	Consistent.

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "High-Burnup Fuel Monitoring and Assessment"
4. Detection of Aging Effects	Consistent.
5. Monitoring and Trending	Consistent.
6. Acceptance Criteria	Consistent.
7. Corrective Actions	Consistent, except as noted here. The applicant stated that corrective actions will be performed in accordance with licensee's corrective action process, which is consistent with the example AMP in NUREG-2214. However, NUREG-2214 also provides additional guidance for the corrective actions, including assessing (1) fuel performance (impacts on fuel and changes to fuel configuration) and (2) the design-basis safety analyses, when considering degraded fuel performance and any changes to fuel configuration. The staff reviewed the applicant's AMP and noted that, while not explicitly stated in the Corrective Actions program element, the AMP clearly identifies the acceptance criteria for allowable moisture and fuel condition. Therefore, the staff finds that the licensee's corrective action process will specifically assess the consequences and identify corrective actions for any indications that do not meet the AMP's performance criteria.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent. The applicant stated the AMP will be updated, as necessary, based on the tollgate assessments. SER Section 3.5.1 documents the staff's evaluation of the use of tollgates for program assessment.
10. Operating Experience	Consistent. As discussed in the Administrative Controls AMP element, the applicant also stated that it will use the AMID to share operating experience with others.

Table 3.5-5. AMP Review Results—100U Concrete AMP

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "Reinforced Concrete Structures"
1. Scope of Program	Consistent. The applicant defined the scope as those components in Table 3.3-2 in the renewal application that are identified as requiring the 100U Concrete AMP.
2. Preventive Actions	Consistent.
3. Parameters Monitored or Inspected	Consistent.
4. Detection of Aging Effects	Consistent. The applicant's AMP stated that visual inspections cover all of the readily accessible surfaces of the ISFSI pad and are conducted every 5 years.
5. Monitoring and Trending	Consistent.

AMP Element	Staff's Assessment of Consistency with the NUREG-2214 Example AMP, "Reinforced Concrete Structures"
6. Acceptance Criteria	Consistent. The applicant's AMP provided additional detail (beyond the generic guidance in NUREG-2214) to describe the acceptance criteria for the concrete shielding performance. For example, the baseline radiation survey measurements shall be lower than the dose measurements taken at the time of cask loading. Furthermore, the dose rate measurements for all subsequent radiation surveys shall be less than the baseline radiation survey dose rate measurement. The staff reviewed the applicant's acceptance criteria for the radiation surveys and finds them to be acceptable and consistent with the guidance in NUREG-2214 because the specified measurement location is consistent with the location surveyed at the time of cask loading (see FSAR Figure 5.I.1), and measurements will ensure that degradation of shielding effectiveness will be identified. The staff also noted that the Monitoring and Trending program element of the AMP provides for comparison of the survey results against previous inspections to monitor the progression of shielding effectiveness over time.
7. Corrective Actions	Consistent.
8. Confirmation Process	Consistent.
9. Administrative Controls	Consistent. The applicant stated the AMP will be updated, as necessary, based on the tollgate assessments. SER Section 3.5.1 documents the staff's evaluation of the use of tollgates for program assessment.
10. Operating Experience	Consistent. The staff noted that no HI-STORM 100U systems have been put into service. However, the applicant stated the ISFSI pad will be inspected before the cavity enclosure container is placed in accordance with existing operating procedures. As discussed in the Administrative Controls AMP element, the applicant also stated that it will use the AMID to share operating experience with others.

3.5.1 Aging Management Tollgates

The applicant incorporated periodic tollgate assessments as requirements in the renewed CoC as recommended in NEI 14-03, Revision 2, issued December 2016 (NEI 2016). The NRC endorsed NEI 14-03, Revision 2, with clarifications, in Regulatory Guide 3.76, Revision 0, "Implementation of Aging Management Requirements for Spent Fuel Storage Renewals," issued July 2021 (NRC 2021c). The schedule for these tollgate assessments will be incorporated into the FSAR as Appendix 9.A.2-1 (the same as Table 4-1 of the renewal application).

The staff noted that the purpose of the tollgate concept is to provide a structured way for licensees to (1) formally assess aggregated aging management feedback at specific points in time during the period of extended operation and (2) perform a safety assessment that confirms the safe storage of spent nuclear fuel.

The applicant's tollgate assessment includes an evaluation of the following information, much of which can be gathered from the AMID:

- results of research and development programs focused specifically on aging-related degradation mechanisms identified as potentially affecting the HI-STORM 100 Cask System and ISFSI site
- relevant results of other domestic and international research
- relevant domestic and international operating experience
- relevant results of domestic and international ISFSI and dry storage system performance monitoring

The staff noted that the tollgate assessment process occurs on a routine and periodic 5-year basis throughout the period of extended operation to ensure that the MPC AMP, Overpack AMP, HI-TRAC AMP, High Burnup Fuel Assembly AMP, and 100U Concrete AMP continue to effectively manage the identified aging effects. The applicant stated that each tollgate assessment will include the following elements, as applicable:

- summary of research findings, operating experience, monitoring data, and inspection results made available since the last assessment
- aggregate impact of findings, including any trends
- consistency of data with the assumptions and inputs in the TLAAs
- effectiveness of AMPs
- corrective actions, including any changes to AMPs

The applicant stated that the general licensees will have access to the industry's AMID to facilitate the aggregation and dissemination of aging-related information for the completion of these tollgate assessments. Further, the applicant noted that the implementation of these tollgates does not infer that general licensees will wait until one of these designated times to evaluate information. General licensees will continue to follow existing processes for addressing emergent issues, including the use of the site corrective actions 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, in addition to other periodic operating experience reviews consistent with the site quality assurance program, provide reasonable assurance that the MPC AMP, Overpack AMP, HI-TRAC AMP, High Burnup Fuel Assembly AMP, and 100U Concrete AMP will remain adequate during the period of extended operation.

3.5.2 Evaluation Findings

The staff reviewed the AMPs in the renewal application. The staff performed its review following the guidance in NUREG-1927 and NUREG-2214. The staff evaluated the 10 elements of the applicant's MPC AMP, Overpack AMP, Transfer Cask AMP, High Burnup Fuel Assembly AMP, and 100U Concrete AMP that address aging mechanisms and the effects of potential aging that could adversely affect the ability of the SSCs and associated subcomponents to perform their intended functions. For each program element, the staff either confirmed consistency with the example AMPs in NUREG-2214 or confirmed that the applicant's alternative approach was adequate to manage all credible aging effects. Based on its review, the staff determined that the SSCs will continue to perform their intended functions during the requested period of extended operation. The staff finds the following:

F3.4 The applicant has identified programs that ensure that aging mechanisms and effects will be managed effectively during the period of extended operation, in accordance with 10 CFR 72.240(c)(3).

4 CHANGES TO CERTIFICATE OF COMPLIANCE AND TECHNICAL SPECIFICATIONS

This section provides a consolidated list of, and the basis for, the changes to the CoC conditions and technical specifications resulting from the staff's review of the renewal application.

4.1 Final Safety Analysis Report Update

The NRC is adding the following condition to the initial CoC (Amendment 0) and Amendments 1–15:

> FSAR UPDATE FOR RENEWED CoC
>
> The CoC holder shall submit an updated FSAR to the Commission, in accordance with 10 CFR 72.4, within 90 days after the effective date of the renewal. The updated FSAR shall reflect the changes resulting from the review and approval of the renewal of the CoC, including the HI-STORM 100 FSAR supplement, as documented in Appendix D of the HI-STORM 100 CoC renewal application, Revision 1, dated April 23, 2021 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21113A203). The CoC holder shall continue to update the FSAR pursuant to the requirements of 10 CFR 72.248.

The applicant stated that it will make changes to the FSAR to address aging management activities resulting from the renewal of the CoC. The applicant submitted the proposed FSAR supplement in Revision 1 of the renewal application, Appendix D (Holtec 2021a, 2021b), which reflects the final proposed FSAR supplement to address the aging management activities described in the renewal application. This condition ensures that FSAR changes are made in a timely fashion to enable general licensees using the storage system during the period of extended operation to develop and implement necessary procedures related to renewal and aging management activities.

4.2 10 CFR 72.212 Evaluations

The NRC is adding the following condition to the initial CoC (Amendment 0) and Amendments 1–15:

> 10 CFR 72.212 EVALUATIONS FOR CoC USE DURING THE PERIOD OF EXTENDED OPERATION
>
> Any general licensee that initiates spent fuel dry storage operations with the HI-STORM 100 Cask System after the effective date of the renewal of the CoC and any general licensee operating a HI-STORM 100 Cask System as of the effective date of the renewal of the CoC, including those that put additional storage systems into service after that date, shall:
>
> a. As part of the evaluations required by 10 CFR 72.212(b)(5), include the evaluations related to the terms, conditions, and specifications of this CoC amendment as modified (i.e., changed or added) as a result of the renewal of the CoC.

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

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

d. Complete this condition prior to entering the period of extended operation or no later than 365 days after the effective date of the renewal of the CoC, whichever is later.

The staff considers it important to ensure that a general licensee's report prepared under 10 CFR 72.212, "Conditions of general license issued under § 72.210," evaluates the appropriate considerations for the period of extended operation. These considerations arise from the analyses and assumptions in the renewal application regarding operations during the period of extended operation. This includes potential use by general licensees that may use a new HI-STORM 100 Cask System after the CoC has been renewed, whether at a new or at an existing general-licensed ISFSI. The renewal of the CoC is based on assumptions and analyses regarding the dry storage system and the sites where it is used. Licensees considering the use of the HI-STORM 100 system must evaluate it for use at their respective sites. This condition also makes it clear that to meet the requirements in 10 CFR 72.212(b)(11), general licensees that currently use a HI-STORM 100 Cask System will need to update their 10 CFR 72.212 reports, even if they do not put additional dry storage systems into service after the renewal's effective date. The staff notes that the applicant proposed the above condition, which the staff modified to include a reference to the NRC SER related to the CoC renewal.

4.3 Future Amendments to the Certificate of Compliance

The NRC is adding the following condition to the initial CoC (Amendment 0) and Amendments 1–15:

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

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

4.4 References to Regulations

The NRC is revising the initial CoC (Amendment 0) and Amendments 1–15 to address the language change in 10 CFR 72.210, "General license issued," and other updates to the regulations. The NRC is updating the regulation citations referenced in the applicable CoCs and technical specifications to reflect citations currently in the regulations. The NRC is also modifying the authorization statements in the CoCs and technical specifications to refer to the general license issued under 10 CFR 72.210, rather than repeat the language currently in the 10 CFR 72.210 regulation regarding licensees under 10 CFR Part 50, “Domestic licensing of production and utilization facilities” and 10 CFR Part 52, “Licenses, certifications, and approvals for nuclear power plants.” These changes are not pertinent to the safety review conducted for the renewal application. The CoC and technical specification authorization statements will be revised, as follows.

> 12. AUTHORIZATION
>
> The HI-STORM 100 Cask System, which is authorized by this certificate, is hereby approved for use under the general license issued pursuant to 10 CFR 72.210, subject to the conditions specified by 10 CFR 72.212, this certificate, and the attached Appendices A, B, A-100U, B-100U, C, and D as applicable....
>
> 3.1.1 Site Location
>
> The HI-STORM 100 Cask System is authorized for use at various site locations under the general license provisions of 10 CFR 72, Subpart K.

4.5 <u>Aging Management Program Implementation</u>

The NRC is adding new Technical Specification 5.8/5.4, “Aging Management Program,” associated with the initial CoC (Amendment 0) and Amendments 1–15:

> Aging Management Program
>
> Each general licensee shall have a program to establish, implement, and maintain written procedures for each applicable AMP described in the FSAR. The program shall include provisions for changing AMP elements, as necessary, and within the limitations of the approved design bases to address new information on aging effects based on inspection findings and/or industry operating experience. Each procedure shall contain a reference to the specific aspect of the AMP element implemented by that procedure, and that reference shall be maintained even if the procedure is modified.
>
> The general licensee shall establish and implement these written procedures prior to entering the period of extended operation or no later than 365 days after the effective date of the renewal of the CoC, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate HI-STORM 100 Cask Systems in service for longer than 20 years.
>
> Each general licensee shall perform tollgate assessments as described in Chapter 9 of the FSAR.

This technical specification addition is similar to the current CoC conditions and technical specifications related to operating procedures for loading and operating dry storage systems under this CoC and extends the requirement for operating procedures to address AMP activities. This technical specification ensures that procedures address AMP activities required in the period of extended operation. The timeframe (1 year) in the condition is to ensure operating procedures are developed in a timely manner; this timeframe is consistent with the guidance in NUREG-1927. The tollgate assessments in the AMPs provide assurance that the results of those assessments will inform AMP procedures. The staff notes that the applicant proposed this technical specification, which the staff modified to state that procedures shall include AMP references and procedures should be maintained as long as the general licensee operates the HI-STORM 100 Cask System.

5 CONCLUSION

Under 10 CFR 72.240(d), the design of a spent fuel storage cask will be renewed if (1) the quality assurance requirements in 10 CFR Part 72, Subpart G, “Quality Assurance,” are met, (2) the requirements of 10 CFR 72.236(a) through (i) are met, and (3) the application includes a demonstration that the storage of spent fuel has not, in a significant manner, adversely affected SSCs important to safety. Additionally, 10 CFR 72.240(c) requires that the safety analysis report accompanying the application contain TLAAs and AMPs that demonstrate that the dry storage system SSCs will continue to perform their intended functions for the requested period of extended operation.

The NRC staff reviewed the renewal application for the HI-STORM 100 Cask System in accordance with 10 CFR Part 72. The staff followed the guidance in NUREG-1927 and NUREG-2214. Based on its review of the renewal application and the CoC conditions, the staff determines that the dry storage system has met the requirements of 10 CFR 72.240.

6 REFERENCES

U.S. Code of Federal Regulations, "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter I, Title 10, "Energy."

U.S. Code of Federal Regulations, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter I, Title 10, "Energy."

U.S. Code of Federal Regulations, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," Part 72, Chapter I, Title 10, "Energy."

Aluminum Association. 2003. "Aluminum Standards and Data." Arlington, VA.

American National Standards Institute. 1993. "Radioactive Materials—Special Lifting Devices for Shipping Containers Weighing 10 000 Pounds (4500 kg) or More." ANSI N14.6. New York, NY.

American Society of Mechanical Engineers. 2007. Boiler and Pressure Vessel Code. Section III, "Rules for Construction of Nuclear Facility Components," Division 1, "Metallic Components," Subsection NB, "Class 1 Components." New York, NY.

Electric Power Research Institute (EPRI). 2007. "Plant Support Engineering: Aging Effects for Structures and Structural Components (Structural Tools)." EPRI 1015078. Palo Alto, CA.

_____. 2009. "Handbook of Neutron Absorber Materials for Spent Nuclear Fuel Transportation and Storage Applications." Palo Alto, CA.

Holcomb, R.S. 1971. "A Survey of the Materials and Design of Insulation for Prestressed-Concrete Vessels for Gas-Cooled Reactors." ORNL-TM-2929. May.

Holtec International. 2016. "NRC-2536001 Attachment 5—HI-951322, Rev. 24, Appendix 3, HI-STAR 100 Shielding Design and Analysis for Transport and Storage." May 23. ADAMS Accession No. ML17150A268 (proprietary).

_____. 2017. "Holtite-A: Development History and Thermal Performance Data." Holtec Report HI-2002396, Revision 5. June. ADAMS Accession No. ML20303A256 (proprietary).

_____. 2019. "Final Safety Analysis Report for the HI-STORM 100 Cask System." HI-2002444, Revision 18. May. ADAMS Package Accession Nos. ML19150A396 and ML20098G177. ADAMS Accession No. ML19150A405 (public). ADAMS Accession No. ML20098G187 (proprietary).

_____. 2020a. "Holtec International HI-STORM 100 Storage CoC Renewal Application." Holtec Letter 5014890. January 31. ADAMS Package Accession No. ML20049A081.

_____. 2020b. "Aging Management Review of SMDRs [Supplier Manufacturing Deviation Reports] for HI-STORM 100." HI-2188453, Revision 0. January. ADAMS Accession No. ML20049A086.

_____. 2020c. “ECO [Engineering Change Orders] Review in Support of the HI-STORM 100 Renewal Application.” HI-2188468, Revision 0. January. ADAMS Accession No. ML20049A087.

_____. 2020d. “Final Safety Analysis Report for the HI-STORM 100 Cask System.” HI-2002444, Revision 19. April. ADAMS Package Accession No. ML20121A314. ADAMS Accession No. ML20121A317 (public). ADAMS Accession No. ML20121A316 (proprietary).

_____. 2020e. “Final Safety Analysis Report for the HI-STORM 100 Cask System.” HI-2002444, Revision 20. June. ADAMS Package Accession No. ML20167A015. ADAMS Accession No. ML20167A018 (public). ADAMS Accession No. ML20167A017 (proprietary).

_____. 2020f. “Holtec International, Submittal of RAI Responses on HI-STORM 100 License Renewal.” Holtec Letter 5014911. October 16. ADAMS Package Accession No. ML20290A819.

_____. 2020g. “Holtec International, Submittal of RAI Responses on HI-STORM 100 License Renewal [submittal of report HI-2002396, Revision 5].” Holtec Letter 5014912. October 29. ADAMS Package Accession No. ML20303A254.

_____. 2021a. “Holtec International, Submittal of RAI Clarification Responses on HI-STORM 100 License Renewal.” Holtec Letter 5014922. April 19. ADAMS Package Accession No. ML21109A367.

_____. 2021b. “Holtec International, Submittal of RAI Clarification Responses on HI-STORM 100 License Renewal—Updated Attachment.” Holtec Letter 5014923. April 23. ADAMS Package Accession No. ML21113A201.

Nuclear Energy Institute (NEI). 2015. “Format, Content and Implementation Guidance for Dry Cask Storage Operations-Based Aging Management.” NEI 14-03, Revision 1. Washington, DC. September. ADAMS Accession No. ML15272A329.

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

U.S. Nuclear Regulatory Commission (NRC). 1980. “Control of Heavy Loads at Nuclear Power Plants: Resolution of Generic Technical Activity A-36.” NUREG-0612. Washington, DC. July. ADAMS Accession No. ML070250180.

_____. 1989. “Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask.” Regulatory Guide 3.61. Washington, DC. February. ADAMS Accession No. ML003739511.

_____. 2000–2021. Certificate of Compliance No. 1014 for the HI-STORM 100 Cask System, Amendment Nos. 0–15. https://www.nrc.gov/waste/spent-fuel-storage/designs.html.

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

_____. 2010. "Generic Aging Lessons Learned (GALL) Report." NUREG-1801, Revision 2. Washington, DC. December. ADAMS Accession No. ML103490041.

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

_____. 2019a. "Final Safety Evaluation Report Docket No. 72-1014, Holtec International HI-STORM 100 Multipurpose Canister Storage System, Certificate of Compliance No. 1014 Amendment No. 11." January 29. ADAMS Accession No. ML18355A377.

_____. 2019b. "Managing Aging Processes in Storage (MAPS) Report." Final Report. NUREG-2214. Washington, DC. July. ADAMS Accession No. ML19214A111.

_____. 2020a. "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities." Final Report. NUREG-2215. Washington, DC. April. ADAMS Accession No. ML20121A190.

_____. 2020b. "Request for Additional Information for the Technical Review of the Application for Renewal of the Certificate of Compliance No. 1014 for the HI-STORM 100 Storage Cask System." August 17. ADAMS Accession No. ML20231A290.

_____. 2021a. Conversation Record: Teleconference with Holtec International on January 12, 2021. Washington, DC. ADAMS Accession No. ML21025A332.

_____. 2021b. "Request for Clarification of Response to Request for Additional Information for the Technical Review of the Application for Renewal of the Certificate of Compliance No. 1014 for the HI-STORM 100 Storage Cask System." February 18. ADAMS Accession No. ML21029A107.

_____. 2021c. "Implementation of Aging Management Requirements for Spent Fuel Storage Renewals." Regulatory Guide 3.76, Revision 0. Washington, DC. July. ADAMS Accession No. ML21098A022.