SAFETY EVALUATION REPORT

FOR THE HI-STAR 100 CASK SYSTEM

CERTIFICATE OF COMPLIANCE NO. 1008

RENEWAL

DOCKET NO. 72-1008

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

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CONTENTS

TABLES

Page

INTRODUCTION

By letter dated December 7, 2018, as supplemented on June 28, 2019, October 10, 2019, December 12, 2019, June 1, 2020, June 11, 2020, November 13, 2020, and November 24, 2020, the Certificate of Compliance (CoC) holder, Holtec International (Holtec or the applicant) applied for renewal of CoC No. 1008 for the HI-STAR 100 Cask System, for an additional 40 years beyond the initial certificate period (the “period of extended operation”) (Holtec 2018, 2019a, 2019b, 2019c, 2020b, 2020c, 2020d, 2020e). This safety evaluation report (SER) refers to this application, as supplemented, as the “renewal application.” Any specific references to sections of the renewal application are to Revision 1.D of the renewal application, which was included in the applicant’s submittals dated November 13, 2020, and November 24, 2020 (Holtec 2020d, 2020e).

The applicant submitted the renewal application in accordance with 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 structures, systems, 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-STAR 100 Cask System for storage and issued CoC No. 1008 for 20 years, with an expiration date of October 4, 2019. In accordance with 10 CFR Part 72, Subpart K, “General license for storage of spent fuel at power reactor sites,” the HI-STAR 100 Cask System under CoC No. 1008 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 licenses pursuant to 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-STAR 100 Cask System is a canister-based dry storage system for the storage of spent nuclear fuel composed of two discrete components: the multi-purpose canister (MPC) and the overpack. Other auxiliaries, including lifting and handling systems, welding equipment, drying system, and transporter, are used to deploy the HI-STAR 100 Cask System for storage.

The HI-STAR 100 MPC provides the confinement boundary for the stored fuel. The MPCs are seal-welded cylindrical structures largely constructed of stainless steel. Each MPC is an assembly consisting of a fuel basket, a baseplate, canister shell, a lid, and a closure ring. Three principal types of MPCs are authorized for storage. The MPC-24 and MPC-32 can store up to 24 and 32 pressurized-water reactor fuel assemblies, respectively. The MPC-68 can store up to 68 boiling-water reactor assemblies and includes an “MPC-68 E/F” variant that can accommodate the storage of damaged fuel and fuel debris within damaged fuel containers. All MPCs have identical exterior dimensions, while the interior fuel basket characteristics vary to accommodate the different fuel types.

The HI-STAR 100 overpack is a heavy-walled steel cylindrical vessel that provides the helium retention boundary, gamma and neutron radiation shielding, and heat rejection capability. A

single overpack design can store each type of MPC. The inner surfaces of the overpack form an internal cylindrical cavity for housing the MPC. The exposed external steel surfaces of the overpack are coated with paint to prevent corrosion.

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-STAR 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 assure 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 the safe operation of the HI-STAR 100 Cask System for an additional 40 years beyond the current CoC term of 20 years. This SER summarizes the results of the staff’s review and conclusions for compliance with 10 CFR 72.240. In its review of the application and development of the SER, the staff used the guidance in (1) NUREG-1927, Revision 1, “Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel,” issued June 2016 (NRC 2016), and (2) NUREG-2214, “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. In its comparison review, the staff ensured that the design features, environmental conditions, and operating experience for the HI-STAR 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 of the dry storage system. Section 2 provides the staff’s review of the scoping evaluation performed for determining which SSCs are within the scope of renewal. Section 3 provides the staff’s evaluation of the aging management review for assessment of aging effects and aging management activities for SSCs within the scope of renewal. Section 4 documents the additions and changes to the CoC conditions and technical specifications being made to the initial CoC and associated amendments as part of this 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

By letter dated December 7, 2018, as supplemented on June 28, 2019, October 10, 2019, December 12, 2019, June 1, 2020, June 11, 2020, November 13, 2020, and November 24, 2020, Holtec International (Holtec or the applicant) submitted an application to renew Certificate of Compliance (CoC) No. 1008 for the HI-STAR 100 Cask System, under the provisions of 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-STAR 100 CoC and Amendments 1, 2, and 3 to the CoC. The U.S. Nuclear Regulatory Commission (NRC) issued the initial CoC (Amendment 0) for the HI-STAR 100 Cask System on October 4, 1999. Subsequently, the NRC issued three amendments to the HI-STAR 100 CoC. Table 1.3-1 of the application provides general descriptions of the changes in each amendment, the date of issuance of the initial CoC and CoC amendments, identification of the corresponding HI-STAR 100 Cask System final safety analysis report (FSAR) revision that defines the design bases for each amendment, and a reference to where the aging management programs (AMPs) for each amendment are located in the application.

1.2 Safety Review

The objective of this safety review is to determine whether there is reasonable assurance that the dry storage system will continue to meet the requirements of 10 CFR Part 72 during the period of extended operation. The NRC staff safety review assesses the technical aspects of the HI-STAR 100 Cask System renewal application. In accordance with 10 CFR 72.240(c)(2) and 10 CFR 72.240(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) that demonstrate 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 AMP 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 provided in NUREG-1927, Revision 1, "Standard Review Plan for Renewal of Specific Licenses and Certificates of Compliance for Dry Storage of Spent Nuclear Fuel," issued June 2016 (NRC 2016). The applicant also referenced Nuclear Energy Institute (NEI) 14-03, "Format, Content and Implementation Guidance for Dry Cask Storage Operations-Based Aging Management," Revision 2, issued December 2016 (NEI 2016), and NUREG-2214, "Managing Aging Processes in Storage (MAPS) Report," draft issued October 2017 (NRC 2017). Since submittal of the application, the NRC issued the final version of NUREG-2214 (NRC 2019b).

The applicant performed a scoping evaluation and aging management review to identify all SSCs within the scope of the renewal and pertinent aging mechanisms and effects, respectively. The applicant developed AMPs and evaluated TLAAs to ensure that the in-scope SSCs will continue to perform their intended functions during the period of extended operation.

This review documents the staff's evaluation of the applicant's scoping analysis, aging management review, and supporting AMPs and TLAAs.

1.3 Application Content

The renewal application provides the following information:

- general information
- scoping evaluation
- aging management reviews
- aging management tollgates
- AMPs
- TLAAs
- operating experience from prior multi-purpose canister (MPC) inspections
- proposed FSAR changes (FSAR supplement)
- proposed CoC and technical specification changes

Table 1.3-1 of the renewal application identifies the corresponding HI-STAR 100 FSAR revision that applies to each CoC amendment. Three separate revisions of the FSAR—Revision 0, Revision 3, and Revision 4—define the design bases for each CoC amendment (Holtec 2001, 2013, 2020a). The staff considered these FSAR revisions in its review of the renewal application and the applicant's scoping evaluation and aging management review. The applicant referenced Revision 3 of the FSAR (Holtec 2013) in the renewal application, as this was the latest revision of the FSAR in existence at the time of the initial submittal of the renewal application. Therefore, when referring to "the FSAR," this safety evaluation report (SER) is generally referring to Revision 3 of the FSAR.

The applicant included a proposed FSAR supplement in Appendix D to the renewal application, which includes proposed changes and additions to the design-basis FSARs to document the aging management information associated with the CoC renewal. The applicant also provided a supporting report as an attachment to the renewal application, HI-2188307, Revision 0, "Change Document Evaluation in Support of HI-STAR 100 License Renewal" (Holtec 2018), which documents the review of supplier manufacturing deviation reports, engineering change orders, and evaluations performed in accordance with 10 CFR 72.48, "Changes, tests, and experiments," in support of the renewal application. The applicant evaluated whether these changes 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 NUREG-1927. Based on its review, the staff determined that the applicant provided sufficient information with adequate details to support the renewal application, with the following findings:

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

F1.2 The applicant 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, the scoping evaluation identifies the SSCs requiring an aging management review. The objective of this scoping evaluation is to identify SSCs meeting the following criteria:

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

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

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

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

2. SSCs 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 intended functions.

2.1 Scoping and Screening

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

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

- a list of sources of information used for the scoping evaluation

- descriptions of the SSCs

- a list of the SSCs (and their subcomponents) identified to be within and outside the scope of renewal review and the basis for the scope determination

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

2.1.1 Scoping Process

In Section 2.1 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 above:

- HI-STAR 100 FSAR

- CoC No. 1008 for the original certificate and the approved amendments

    - Original certificate effective date: October 4, 1999 (NRC 1999)

- Amendment No. 1 effective date: December 26, 2000 (NRC 2000)
- Amendment No. 2 effective date: May 29, 2001 (NRC 2001)
- Amendment No. 3 effective date: November 5, 2019 (NRC 2019c)

The applicant's scoping process identified SSCs as being either scoped into the review under scoping criteria 1 and 2 described above 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 within 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

SSC	Criterion 1	Criterion 2	In-Scope
MPC	Yes	N/A	Yes
HI-STAR 100 overpack	Yes	N/A	Yes
Spent fuel assembly	Yes	N/A	Yes
Independent spent fuel storage installation (ISFSI) Pad	No	Yes	Yes
Fuel transfer and auxiliary equipment	No	No	No

The staff reviewed the scoping results to determine whether the applicant's conclusions about the out-of-scope SSCs accurately reflect the design-basis documentation in the HI-STAR 100 FSAR and CoCs.

The applicant stated that the fuel transfer and auxiliary equipment are not included as part of the HI-STAR 100 Cask System and, as such, are not described in detail in the HI-STAR 100 FSAR and are not within scope for aging management. The staff reviewed the applicant's conclusion and noted that the HI-STAR 100 CoC states that the HI-STAR 100 Cask System consists only of the MPC and the overpack. The CoC also states that the cask system reviewed under 10 CFR Part 72 does not include the fuel transfer and auxiliary equipment necessary for ISFSI operation (such as lifting devices, transfer equipment, and vacuum drying equipment). The staff notes that general licensees are responsible for the maintenance of these systems, and these activities are outside the requirements of the CoC. Therefore, the staff finds the applicant's conclusion to exclude these components from the scope of renewal 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 intended functions. SER Sections 2.1.3 and 2.1.4 describe the SSC subcomponents within and outside the scope of renewal review.

2.1.3 Subcomponents Within the Scope of Renewal Review

As discussed above, the applicant identified four SSCs as within the scope of renewal review: the MPC, HI-STAR 100 overpack, spent fuel assemblies, and the ISFSI pad. Tables 2.1-1–2.1-6 of the application tabulate the subcomponents that the applicant determined to support the intended functions of these SSCs and are thus subject to an aging management review. SER Table 2.1-2 summarizes these subcomponents.

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 HI-STAR 100 FSAR. The staff's review also considered NUREG-2214 and NUREG/CR-6407, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," issued February 1996 (McConnell et al. 1996). 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.

2.1.4 Subcomponents Not Within the Scope of Renewal Review

The applicant reviewed the in-scope SSCs to identify any subcomponents that do not support the SSC intended functions and thus do not require an aging management review. SER Table 2.1-3 tabulates the subcomponents that are not within the scope of renewal review.

The staff reviewed the applicant's screening of the out-of-scope SSCs. The staff's review considered the intended function of the subcomponent, its safety classification or basis for exclusion in the scope of renewal review, and design-basis information in the HI-STAR 100 FSAR.

<u>Heat Conduction Elements</u>

In Table 2.1-3 of the renewal application, the applicant stated that the aluminum "optional heat conduction elements" within the MPC basket do not have a function in the period of extended operation. As a result, the applicant did not include these subcomponents within the scope of the aging management review. In its review of the applicant's scoping conclusion, the staff noted that HI-STAR 100 FSAR Table 2.2.6 identifies a heat transfer function for the elements. In its response to an NRC request for additional information (RAI) (Holtec 2020b), the applicant stated that the elements are not credited for heat transfer, and their reference in the FSAR reflects a time early in the initial HI-STAR 100 Cask System licensing process when it was unclear whether the NRC would approve the use of the convection heat transfer mechanism in the applicant's thermal analysis. The applicant stated that, since the HI-STAR 100 CoC was ultimately issued with the crediting of the convection mechanism, use of the heat conduction elements became optional. The staff reviewed the applicant's statements and the thermal analysis in the FSAR and finds the applicant's scoping evaluation for these subcomponents to be acceptable.

Damaged Fuel Container

In Table 2.1-3 of the renewal application, the applicant stated that the stainless steel damaged fuel container within the MPC basket does not have a function in the period of extended operation. As a result, the applicant did not include this subcomponent within the scope of the aging management review. In its review of the applicant's scoping conclusion, the staff noted that HI-STAR 100 FSAR Table 2.2.6 identifies only an "operations" function for the damaged fuel container. However, the staff also noted that the safety analyses in the FSAR appear to credit the container to maintain the configuration of damaged fuel to a specific location. The applicant confirmed that the safety analyses rely on the damaged fuel container to maintain fuel configuration (NRC 2020d). Notwithstanding this role in the safety analyses, the staff notes that there are no credible aging mechanisms for the damaged fuel container that would prevent it from continuing to maintain the fuel configuration in the period of extended operation. As documented in NUREG-2214 and SER Table 3.3-2, stainless steel does not have any credible aging mechanisms within the MPC internal helium environment. Therefore, based on the staff's confirmation that no aging management activities are required to maintain the function of the damaged fuel container, the staff finds the applicant's scoping evaluation for this subcomponent to be acceptable.

Thermal Expansion Foam

In Table 2.1-4 of the renewal application, the applicant stated that the thermal expansion foam in the HI-STAR 100 overpack does not have a function in the period of extended operation. As a result, the applicant did not include this subcomponent within the scope of the aging management review. In its review of the applicant's scoping conclusion, the staff noted that HI-STAR 100 FSAR Table 2.2.6 states that the foam is not important to safety; however, HI-STAR 100 FSAR Section 1.2.1.2 states that the foam may be required to alleviate thermal stresses in the overpack enclosure shell from thermal expansion of the neutron absorber material. The staff issued a request for clarification to the applicant on September 30, 2020 (NRC 2020c). In its response (Holtec 2020d), the applicant stated that, as described in HI-STAR 100 FSAR Section 3.4.4.3.2.6, the foam was demonstrated to be unnecessary to minimize stresses on the overpack enclosure shell in the worst case thermal loading conditions. As a result, the applicant stated that a failure of the foam (e.g., due to aging) does not prevent the fulfillment of an important-to-safety function in the period of extended operation. The staff reviewed the applicant's statements and the structural and thermal analyses in the FSAR for the enclosure shell and finds the applicant's scoping evaluation for these subcomponents to be acceptable.

Based on the staff's review of the out-of-scope subcomponents described above, the staff finds that the applicant screened the out-of-scope SSCs in a manner consistent with NUREG-1927; therefore, the staff finds the screening results to be acceptable.

2.2 Evaluation Findings

The NRC staff reviewed the scoping evaluation provided in the renewal application and supplemental documentation. The staff performed its review following NUREG-1927. Based on its review, the staff finds the following:

F2.1 The applicant identified all SSCs important to safety and all SSCs whose failure could prevent an SSC from fulfilling its safety function, in accordance with 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.

Table 2.1-2 Subcomponents Within the Scope of Renewal Review

MPC	**HI-STAR 100 Overpack**
Enclosure Vessel	Inner shell
Shell	Bottom plate
Baseplate	Top flange
Lid	Closure plate
Closure ring	Closure plate bolt
Vent/drain port cover plate	Port plug
Vent/drain shield block	Port plug seal
Plugs for drilled holes	Closure plate seal
Bottom portion of two-piece lid	Port cover seal
Lift lug	Intermediate shell
Lift lug baseplate	Neutron shield
Upper fuel spacer column	Plugs for drilled holes
Upper fuel spacer bolt	Removable shear ring
Upper fuel spacer end plate	Radial channel
Lower fuel spacer column	Lifting trunnion
Lower fuel spacer end plate	Pocket trunnion plug plate
Vent shield block spacer	Pocket trunnion
Vent/drain tube	Relief device
Vent/drain port cap	Relief device plate
Vent/drain cap seal washer	Removable shear ring bolt
Vent/drain cap seal washer bolt	Closure bolt washer
Vent and drain tube, optional	Enclosure shell panel
Threaded disc, plug adjustment	Enclosure shell return
Vent and drain plug	Port cover
Thread shield cap	Port cover bolt
Retaining ring	
	Spent Fuel Assembly
Basket	Fuel cladding
Basket cell plate	Spacer grid assemblies
Neutron absorber	Upper end fitting
Sheathing	Lower end fitting
Shim	Guide tubes
Basket support (angled plate)	
Basket support (flat plate)	**ISFSI Pad**
	Pad

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

MPC	HI-STAR 100 Overpack
Enclosure Vessel	Thermal expansion foam
Reducer	Trunnion end cap
Drain line	Trunnion end cap bolt
Drain line guide tube	Lifting trunnion locking pad
Support plate (for drain line)	Trunnion locking pad bolt
	Nameplate
Basket	
Heat conduction elements	**Spent Fuel Assembly**
Damaged fuel container	Fuel pellets
	Holddown spring and upper end plugs
	Control components
	ISFSI Pad
	N/A

3 AGING MANAGEMENT REVIEW

3.1 Review Objective

The objective of the staff's evaluation of the applicant's aging management review 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 aging management review addresses aging mechanisms and effects that could adversely affect the ability of the SSCs and associated subcomponents to perform their intended functions during the period of extended operation.

3.2 Aging Management Review Process

The applicant stated that its aging management review process consisted of the following 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 aging management review process, including a description of the review process and the design-basis references. Based on its review, the staff finds that the applicant's aging management review 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 renewal review.

3.3 Aging Management Review Results

The staff evaluated the applicant's technical basis for its aging management review by comparing it to the generic technical basis in NUREG-2214. In this evaluation, the staff verified that the NUREG-2214 evaluation bounds the design features, environmental conditions, and operating experience for the HI-STAR 100 Cask System.

In Table 3.1-2 of the renewal application, the applicant defined the SSC service environments. SER Table 3.3-1 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 the applicant's analysis of the HI-STAR 100 Cask System.

Service Environment for Overpack Annulus

The applicant defined the service environment for the annular space between the MPC and the overpack as an inert helium environment. The staff issued an RAI on April 10, 2020 (NRC

2020a), to understand if that helium environment is equivalent to that evaluated in NUREG-2214. In its response dated June 1, 2020 (Holtec 2020b), the applicant provided more detail on the helium environment within the annular space. The overpacks are leak tested to a leakage rate acceptance criterion of 4.3×10^{-6} atm·cm^3/s, which differs from the “leaktight” criterion defined in American National Standards Institute (ANSI) N14.5, “Radioactive Materials—Leakage Tests on Packages for Shipment” (ANSI 2014), and used for the MPC confinement boundary. The applicant provided an analysis that showed that the overpack may lose approximately 11 percent of its helium over the 60-year period of extended operation.

In its review of the applicant’s aging management review, the staff considered whether the conclusions in NUREG-2214 are applicable to the HI-STAR 100 Cask System, considering the loss of helium from the overpack. Specifically, the staff considered aging implications due to increased component temperatures (as a result of a decrease in heat transfer performance) and a potentially less chemically inert environment in the annular space between the MPC and overpack. With regard to the thermal performance, the staff determined that the aging conclusions in NUREG-2214 remain applicable because that report conservatively evaluated the aging of components at their hottest temperature (immediately after fuel loading). Although a loss of 11 percent of helium over 60 years would be expected to reduce heat transfer from the overpack, it is compensated by the concurrent decrease in the decay heat of the fuel. Similarly, for the potentially less chemically inert environment, the staff determined that the aging conclusions in NUREG-2214 remain applicable because the change in gas composition in the overpack annulus is considered to have a negligible impact on the corrosion performance of the storage system materials. Even with a loss of 11 percent of the helium, the environment within the overpack annulus remains predominantly an inert gas. In addition, the overpack lid seal is expected to prevent an ingress of any external contaminants (e.g., salts) that could degrade the steel and stainless steel storage system SSCs. Therefore, the staff finds that the aging conclusions in NUREG-2214 for components within the overpack annular space are applicable to the HI-STAR 100 Cask System.

Table 3.3-1 Aging Management Review—Environments

Renewal Application Environment	Description	Equivalent Environment in NUREG-2214
Helium	Environments that have been dried and backfilled with inert helium gas; the inside of the MPC and overpack annular space	Helium
Embedded	Instances where materials are in contact with another material	Embedded in concrete Embedded in metal Embedded in neutron shielding
Air—outdoor	Exposure to direct sunlight, wind, rain, and other weather aspects	Air—outdoor

SER Tables 3.3-2–3.3-5 summarize the results of the applicant’s aging management review. These tables identify whether the applicant’s conclusion on the credibility of each aging effect is consistent with the generic technical bases and conclusions 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, or (2) there is a separate

technical basis or supporting analysis that justifies 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: Enclosure Vessel and Fuel Basket

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Stainless steel (welded and non-welded)	Helium	Corrosion—general, pitting, crevice, galvanic, and microbiologically influenced	Loss of Material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.4)
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
Aluminum	Helium	Thermal aging	Loss of strength	No	Yes	AMP/TLAA not necessary
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Corrosion—general, pitting, crevice, galvanic, and microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Neutron absorber (Metamic® or Boral™)	Helium	Boron depletion	Reduction of neutron-absorbing capacity	Yes	Yes	TLAA (see SER Section 3.4.1)
		Thermal aging	Loss of strength	No	Yes	AMP/TLAA not necessary
		Corrosion—general and galvanic (Metamic)	Loss of material	No	Yes	AMP/TLAA not necessary
		Wet corrosion and blistering (Boral)	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary

Table 3.3-3 Aging Management Review Results—HI-STAR 100 Overpack

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Carbon steel and alloy steel	Air—outdoor	Corrosion—general, pitting, crevice, and galvanic	Loss of material	Yes	Yes	Overpack Exterior AMP (see SER Table 3.5-1)
		Corrosion—microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.4)
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
	Embedded (in concrete)	Corrosion—general, pitting, crevice, and microbiologically influenced	Loss of material	Yes	Yes	Overpack Exterior AMP (see SER Table 3.5-1)
	Embedded (in metal and neutron shielding)	Corrosion—general, pitting, crevice, and microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Carbon steel and alloy steel	Helium	Corrosion—general, pitting, crevice, and microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.4)
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
Stainless steel (non-welded)	Air-outdoor	Corrosion—general, pitting, and crevice	Loss of material	Yes	No[a]	Overpack Exterior AMP (see SER Section 3.3.1.1)
		Corrosion—galvanic and microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
Stainless steel (welded and non-welded)	Embedded (in metal)	Corrosion—general, pitting, crevice, and microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary (see SER Section 3.3.1.2)
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Stainless steel (welded and non-welded)	Embedded (in metal)	Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Thermal aging	Loss of fracture toughness and loss of ductility	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
Nickel alloy	Air-outdoor	Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Not evaluated in NUREG-2214	AMP/TLAA not necessary (see SER Section 3.4)
		Corrosion—microbiologically influenced	Loss of material	No	Yes	AMP/TLAA not necessary
		Corrosion—pitting and crevice	Loss of material	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
		Stress relaxation	Loss of preload	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Cracking	No	Yes	AMP/TLAA not necessary
Neutron shielding (Holtite-A™)	Embedded (steel)	Radiation embrittlement	Cracking	Yes	Yes	Overpack Exterior AMP (see SER Table 3.5-1)
		Thermal aging	Loss of fracture toughness and loss of ductility	Yes	Yes	Overpack Exterior AMP (see SER Table 3.5-1)
		Boron depletion	Loss of shielding	Yes	Yes	Overpack Exterior AMP (see SER Table 3.5-1)

a. The application stated that general, pitting, and crevice corrosion are credible for the stainless steel closure bolt washer. The application did not identify these aging mechanisms as credible for other non-welded stainless steel overpack components. NUREG-2214 does not identify these aging mechanisms as credible.

Table 3.3-4 Aging Management Review Results—Spent Fuel Assemblies

Material	Environment	Aging Mechanism[a]	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Zirconium-based alloy Stainless steel[c] (Fuel cladding)[d]	Helium	Hydride reorientation[b]	Loss of ductility	No	Yes	AMP/TLAA not necessary
		Delayed hydride cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Thermal creep[b]	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Low-temperature creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Mechanical overload	Cracking	No	Yes	AMP/TLAA not necessary
		Oxidation	Loss of load-bearing capacity	No	Yes	AMP/TLAA not necessary
		Pitting corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Galvanic corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Loss of ductility	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Yes	AMP/TLAA not necessary
Zirconium-based, Inconel®, and stainless steel alloy (Assembly hardware materials)	Helium	Creep	Change in dimensions	No	Yes	AMP/TLAA not necessary
		Hydriding	Loss of ductility	No	Yes	AMP/TLAA not necessary
		General corrosion	Loss of material	No	Yes	AMP/TLAA not necessary
		Stress corrosion cracking	Cracking	No	Yes	AMP/TLAA not necessary
		Radiation embrittlement	Loss of ductility	No	Yes	AMP/TLAA not necessary
		Fatigue	Cracking	No	Yes	AMP/TLAA not necessary

a. The application stated that there are no aging effects for the fuel assembly materials that require management. The listed aging mechanisms and effects in this table represent those analyzed in NUREG-2214; the NRC staff used NUREG-2214 to evaluate the applicant's conclusion.

b. NUREG-2214 identifies hydride reorientation and thermal creep as credible aging mechanisms only for zirconium alloy cladding with high burnup fuel; the HI-STAR 100 Cask System is not authorized to store high burnup fuel.

c. SER Section 3.3.1.3 further discusses the consistency of the stainless steel cladding results with NUREG-2214.

d. The HI-STAR 100 Cask System is authorized to store both uranium oxide and mixed uranium-plutonium oxide fuel. The aging conclusions in NUREG-2214 are considered applicable to cladding that contains both types of fuel pellets.

Table 3.3-5 Aging Management Review Results—ISFSI Pad

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Concrete (reinforced)	Air—outdoor	Leaching of calcium hydroxide	Change in material properties[a]	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Reaction with aggregates		No	No	AMP/TLAA not necessary (see SER Section 3.3.1.4)
		Freeze and thaw	Cracking	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Differential settlement		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Reaction with aggregates		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack	Loss of material (spalling, scaling)	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Freeze and thaw		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Salt scaling		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
	Embedded (in soil)	Leaching of calcium hydroxide	Change in material properties[a]	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Microbiological degradation		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Corrosion of reinforced steel		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Reaction with aggregates		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)

Material	Environment	Aging Mechanism	Aging Effect	Applicant Defined as Credible	Consistent with Conclusion of NUREG-2214	Disposition
Concrete (reinforced)	Embedded (in soil)	Freeze-thaw	Cracking	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Differential settlement		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Reaction with aggregates		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Corrosion of reinforced steel		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Aggressive chemical attack	Loss of material	Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Freeze and thaw		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Salt scaling		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Microbiological degradation		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)
		Corrosion of reinforced steel		Yes	Yes	ISFSI Pad AMP (see SER Table 3.5-2)

a. Change in material properties includes (1) loss of strength, (2) reduction of concrete pH, (3) increase in porosity and permeability, and (4) loss of concrete steel bond.

The staff reviewed the applicant's aging management review 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 NUREG-2214, the staff considered the results acceptable and provided no additional discussion in this SER. The following section addresses 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 aging management review conclusions that were either inconsistent with NUREG-2214 or warranted additional explanation.

3.3.1.1 Loss of Material due to General, Pitting, and Crevice Corrosion of the HI-STAR 100 Overpack Closure Bolt Washer

The applicant identified general, pitting, and crevice corrosion as credible aging mechanisms for the stainless steel closure bolt washer in the HI-STAR 100 overpack, which is exposed to outdoor air. The applicant proposed these aging mechanisms to be managed by the Overpack Exterior AMP.

The staff notes that NUREG-2214 does not identify general, pitting, and crevice corrosion as credible aging mechanisms for stainless steel exposed to outdoor air because of stainless steel's negligible general (uniform) corrosion rate in this service environment, and neither pitting nor crevice corrosion is expected to produce significant degradation to the stainless steel washer. However, the staff finds the applicant's proposal to manage this aging effect to be acceptable because the applicant's conservative approach to identify and manage these corrosion mechanisms (through visual inspections in the AMP) provides additional assurance of the performance of the closure bolt washer in the period of extended operation.

3.3.1.2 Cracking due to Stress Corrosion Cracking and Localized Corrosion of HI-STAR 100 Overpack Pocket Trunnion and Plug Plate

The applicant did not identify any aging mechanisms that require management for the stainless steel pocket trunnion and pocket trunnion plug plate in the HI-STAR 100 overpack. The applicant identified the environment for these subcomponents as outdoor air. The staff notes that NUREG-2214 identifies stress corrosion cracking, pitting corrosion, and crevice corrosion as credible aging mechanisms for stainless steel components that are welded when the weld is directly or indirectly exposed to outdoor air. The staff reviewed the drawings and confirmed that the subcomponents either do not contain a weld (pocket trunnion plug plate) or the structural weld is not exposed to outdoor air (pocket trunnion). Therefore, the staff finds the applicant's conclusion to be acceptable.

3.3.1.3 Aging Mechanisms for Stainless Steel Fuel Cladding

The applicant provided aging management review results for stainless steel fuel assembly components, concluding that there are no credible aging mechanisms. This conclusion is consistent with NUREG-2214. The staff notes, however, that NUREG-2214 does not provide a specific analysis of the aging of stainless steel fuel cladding. As a result, the staff's review considered potential aging phenomena unique to stainless steel cladding.

As detailed in Electric Power Research Institute (EPRI) Technical Report (TR)-106440, “Evaluation of Expected Behavior of LWR Stainless Steel-Clad Fuel in Long-Term Dry Storage,” issued 1996 (EPRI 1996), there are no known aging degradation mechanisms for stainless steel cladding in dry storage, provided that the cladding is not allowed to exceed temperatures that could lead to creep deformation and sensitization to stress corrosion cracking. In the staff’s original issuance of the HI-STAR 100 CoC, the staff verified that the allowable cladding temperatures in FSAR Table 4.3.1 are sufficiently conservative to preclude those aging mechanisms. In addition, the staff notes that extending the storage term to 60 years does not introduce any additional aging considerations, as the stainless steel is not subject to corrosive aging mechanisms in the helium inert environment, nor is it susceptible to the hydrogen-related embrittlement phenomena that may affect the performance of zirconium cladding alloys. Based on its independent evaluation of the aging of stainless steel cladding, the staff finds the applicant’s conclusion for all stainless steel fuel assembly components to be acceptable for the cladding as well.

3.3.1.4 Loss of Strength due to Reactions with Aggregates in the Independent Spent Fuel Storage Installation Concrete Pad

Table 3.3-5 of the renewal application does not include loss of strength due to reaction with aggregates as a credible aging mechanism/effect combination for the ISFSI pad exposed to outdoor air. This conclusion is inconsistent with NUREG-2214, Table 4-24, “Concrete Pad.”

The staff notes that chemical reactions between alkali hydroxides in portland cement and certain types of aggregates can induce swelling and cracking of the concrete and, thus, reduce mechanical properties. However, the staff also notes that the applicant did not identify the specific aging mechanism/effect combination of loss of strength due to reactions with aggregates; instead, the applicant identified cracking due to reactions with aggregates as credible. As recommended in NUREG-2214, the applicant will manage all concrete aging mechanisms and effects following the inspection guidance in American Concrete Institute (ACI) 349.3R-02, “Evaluation of Existing Nuclear Safety-Related Concrete Structures,” issued 2010 (ACI 2010).

Because the staff considers this ACI guidance an acceptable approach to manage all credible concrete aging mechanisms and effects identified in NUREG-2214, the staff finds the applicant’s ISFSI pad aging management review conclusions to be acceptable.

3.3.2 Evaluation Findings

The staff considered the aging management review provided in the renewal application to verify that it adequately identified the materials, environments, and aging effects of the in-scope SSCs. The staff performed its evaluation following NUREG-1927 and NUREG-2214. Based on its review of the renewal application, the staff finds the following:

F3.1 The applicant’s aging management review 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 summarized the information in the renewal application, including the proposed FSAR supplement.

F3.2 The applicant’s aging management review 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 a summary of the information in the renewal application, including the proposed FSAR supplement.

3.4 Time-Limited Aging Analyses

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

(1) neutron absorber depletion
(2) fuel cladding integrity

In addition, the staff noted that the applicant did not identify a TLAA associated with fatigue, even though the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (ASME Code) to which the HI-STAR 100 Cask System was designed includes provisions for evaluating fatigue due to cyclic loading. As a result, the staff evaluated the applicant's basis for not identifying a fatigue TLAA and found it to be acceptable, as documented in SER Section 3.4.3.

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

3.4.1 Neutron Absorber Depletion

In Section B.2 of the renewal application, the applicant provided the TLAA for boron depletion of the neutron absorber (poison) plates. The HI-STAR 100 Cask System uses Metamic and Boral as neutron poison materials within the MPC. The original analysis determined that boron depletion over 50 years of storage was negligible. To address the period of extended operation, the applicant referenced HI-STAR 100 FSAR Section 6.3.2 and a proprietary shielding analysis to demonstrate that the total depletion of boron-10 atoms in Boral is negligible in 500 years, based on a calculation that conservatively assumed a constant neutron source equal to the initial source for design-basis fuel. The applicant concluded that boron depletion in the neutron absorber was not credible for the period of extended operation.

The staff reviewed the boron carbide loading data for Metamic and Boral (EPRI 2009) and notes that the boron concentrations in these two materials are similar. Therefore, the negligible boron-10 depletion rates in Boral that were calculated in the applicant's TLAA is considered to also apply to boron-10 depletion rates in Metamic. The staff reviewed the analysis methodology, assumptions, and conclusions of this TLAA and finds them acceptable and consistent with the generic technical basis in NUREG-2214, which also concluded that boron depletion of neutron poison materials is not credible in the period of extended operation.

3.4.2 Fuel Cladding Integrity

In Section B.3 of the renewal application, the applicant provided the TLAA for fuel cladding integrity. The applicant stated that HI-STAR 100 FSAR Section 4.3 provides an analysis of the integrity of the fuel to be stored, which includes a time-based assumption, and could be considered a TLAA. However, for the period of extended operation, the applicant proposed not to update the original analysis for 60 years but rather demonstrate fuel integrity by following the guidance for fuel drying in NRC Interim Staff Guidance (ISG)-11, "Cladding Considerations for

the Transportation and Storage of Spent Fuel," Revision 3, issued 2003 (NRC 2003), which was issued shortly after the original HI-STAR 100 CoC was issued. The staff notes that, following the applicant's submittal of the renewal application, ISG-11 was retired and its guidance was fully incorporated into NUREG-2215, "Standard Review Plan for Spent Fuel Dry Storage Systems and Facilities," issued 2020 (NRC 2020b).

The applicant cited ISG-11, Revision 3, to show that the fuel cladding temperatures of the HI-STAR 100 Cask System in FSAR Table 2.2.3 meet the temperature limits for storage of spent fuel that were established to minimize potential aging mechanisms of cladding creep and hydride reorientation. ISG-11 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 Celsius (752 degrees Fahrenheit) 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 Celsius (1,058 degrees Fahrenheit).

Therefore, the applicant concluded that it is not necessary to extend the original fuel cladding integrity analysis for the period of extended operation because meeting the temperature limits during the drying operations ensures cladding integrity with no time-based assumption.

The staff reviewed the applicant's assessment of the fuel cladding integrity. The staff determined that the fuel cladding temperatures of the HI-STAR 100 system documented in FSAR Table 2.2.3 meet the temperature criteria in ISG-11, Revision 3, which has been incorporated into the current guidance in NUREG-2215. Therefore, the staff finds the applicant's approach to be acceptable to ensure cladding integrity for the period of extended operation.

3.4.3 Fatigue Analysis of the HI-STAR 100 Cask System

As discussed above, the applicant did not identify a TLAA associated with fatigue. The staff notes that the original design of the MPC confinement boundary, fuel basket, and overpack helium retention boundary included an evaluation of fatigue, per the criteria in ASME Code, Section III, Division 1, NB and NG-3222.4.

The staff issued a request for supplemental information to the applicant on May 14, 2019 (NRC 2019a). In its response dated June 28, 2019 (Holtec 2019a), the applicant stated that its original design-basis fatigue assessment of the HI-STAR 100 Cask System did not involve any time-based parameters. The applicant explained that it had originally concluded that fatigue was not a concern because of the insignificance of the applied stress in the design of the system and not because of any time-based assessment. The applicant referred to HI-STAR 100 FSAR Section 3.4.11, which states that the MPC is not subject to structural fatigue due to the low stress in relation to the material's fatigue endurance limit.

The staff reviewed the applicant's basis for not including a TLAA for fatigue and finds it to be acceptable because the design-basis assessment for fatigue in the HI-STAR 100 Cask System was not based on time or loading cycles. The proposed extended storage term does not

introduce any time-based fatigue degradation mechanism that is not already considered in the original design bases.

3.4.4 Evaluation Findings

The staff reviewed the TLAAs provided in the renewal application. The staff performed its review following 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 determined that the applicant provided sufficient information with adequate details to support the renewal application, with the following finding:

F3.3 The applicant identified all pertinent 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. Therefore, the applicant's TLAAs provide reasonable assurance that the SSCs will maintain their intended functions for the period of extended operation, require no further aging management activities, and meet the requirements in 10 CFR 72.240(c)(2).

3.5 <u>Aging Management Programs</u>

Under 10 CFR 72.240(c)(3) requirements, the applicant must describe AMPs for managing aging issues that could adversely affect SSCs important to safety. The applicant proposed the following two AMPs in the renewal application:

(1) Overpack Exterior AMP
(2) ISFSI Pad AMP

The staff conducted the safety review of the proposed AMPs in the renewal application in accordance with NUREG-1927. The staff also compared the proposed AMPs with the generically acceptable example AMPs in NUREG-2214, as follows:

- The staff compared the Overpack Exterior AMP to the NUREG-2214 example AMP, "Monitoring of Metallic Surfaces" (see SER Table 3.5-1).

- The staff compared the ISFSI Pad AMP to the NUREG-2214 example AMP, "Reinforced Concrete Structures" (see SER Table 3.5-2).

SER Tables 3.5-1 and 3.5-2 provide the staff's conclusions on the consistency of the proposed AMPs with the applicable example AMPs in NUREG-2214. The tables address the staff's evaluation for those elements for which the staff identified inconsistencies.

Table 3.5-1 Aging Management Program Review Results—Overpack Exterior AMP

AMP Element	Staff's Assessment on Consistency with the NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
1. Scope of Program	Consistent The applicant defined the scope as those HI-STAR 100 overpack components in Table 3.3-3 of the renewal application identified as requiring the overpack AMP. This includes metallic components exposed to the outdoor air environment (e.g., bottom plate, outer enclosure shell, plugs for drilled holes) and polymeric neutron shielding encased within the outer enclosure shell.
2. Preventive Actions	Consistent
3. Parameters Monitored or Inspected	Consistent
4. Detection of Aging Effects	Consistent, in part <u>Readily (Normally) Accessible Surfaces</u>: Consistent The staff notes that the applicant's proposal to conduct ASME Code VT-3 visual examinations every 5 years on all normally accessible surfaces is consistent with NUREG-2214. In addition, the applicant proposed to also continue the annual non-ASME Code visual inspections of all readily accessible surfaces in accordance with HI-STAR 100 FSAR Table 9.2.1. <u>Normally Inaccessible Surfaces</u>: Inconsistent NUREG-2214 recommends that inaccessible surfaces be inspected on a justified frequency to monitor for corrosion; however, the applicant proposed to manage the aging of the normally inaccessible overpack bottom plates by monitoring the condition of adjacent accessible surfaces. Specifically, the Overpack Exterior AMP includes visual inspections of the accessible portions of the bottom plate adjacent to the pad. The AMP also includes acceptance criteria to verify that absence of any signs of rust staining on the concrete in the area adjacent to the casks. The staff finds the applicant's proposal to be acceptable because monitoring the condition of the accessible bottom plate surfaces and examining for evidence of rust stains on the concrete are considered to be capable of identifying any corrosion of the thick base plate before degradation could affect an intended function. <u>Shielding Effectiveness</u>: No Guidance in NUREG-2214 The applicant proposed to continue conducting the neutron and gamma dose surveys of all casks every 5 years, consistent with the current practice in accordance with HI-STAR 100 FSAR Table 9.2.1. In these surveys, measurements are taken at three vertical cross-section planes and four circumferential positions on each plane. Four measurements are also taken at the top of the overpack closure plate.

AMP Element	Staff's Assessment on Consistency with the NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
	The staff reviewed the applicant's shielding effectiveness surveys and finds them to be acceptable because the use of gamma and neutron dose measurements at several vertical and circumferential positions on the exterior of each cask is considered to be capable of identifying cracking of the Holtite-A neutron-shielding materials. Also, as the 5-year surveys conducted to date have not identified Holtite-A degradation in any cask, the staff finds that the continuation of this inspection interval provides reasonable assurance of identifying degradation before loss of intended function. The staff notes that the most severe radiation and temperature exposures for the neutron shield occurred early in the initial storage term, and any potential effects of this exposure are expected to decrease as the spent fuel decays in the period of extended operation.
5. Monitoring and Trending	Consistent
6. Acceptance Criteria	Consistent, in part The applicant included additional criteria for (1) evidence of corrosion related to the bottom plate, and (2) shielding effectiveness (see AMP Element 4 above). To address the bottom plate corrosion, the AMP includes acceptance criteria for no evidence of corrosion of the accessible metal surfaces and no evidence of rust on the ISFSI pad adjacent to the cask. The staff considers the absence of corrosion to be sufficient criteria to ensure that any degradation of the cask bottom will be evaluated by the licensee in a timely manner to verify that the bottom plate can continue to perform its intended function. Therefore, the staff finds the acceptance criteria related to the bottom plate to be acceptable. To address neutron shield effectiveness, the AMP includes acceptance criteria for the radiation survey measurements to meet the dose rates specified in the technical specifications. The staff reviewed the applicant's acceptance criteria for the radiation surveys and finds them to be acceptable because they are consistent with the guidance in NUREG-1927, which states that criteria may be taken directly from the technical specifications. The staff also notes that the monitoring and trending program element states that the AMP will compare the survey results against previous inspections in order to monitor the progression of aging effects over time.
7. Corrective Actions	Consistent The AMP relies on the corrective action program to address degradation that does not meet the acceptance criteria (consistent with NUREG-2214); the AMP also contains an additional potential corrective action of directly inspecting the overpack bottom plate if corrosion is found in adjacent readily accessible surfaces.

AMP Element	Staff's Assessment on Consistency with the NUREG-2214 Example AMP, "Monitoring of Metallic Surfaces"
8. Confirmation Process	Consistent
9. Administrative Controls	Consistent, with additional discussion on the use of tollgates for program assessment (see SER Section 3.5.1)
10. Operating Experience	Consistent The applicant stated that the periodic visual inspections and shielding effectiveness tests conducted to date have not identified any aging-related degradation of the HI-STAR 100 systems. As discussed in SER Section 3.5.1, 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 and inform the assessment of AMP effectiveness.

Table 3.5-2 Aging Management Program Review Results—ISFSI Pad AMP

AMP Element	Staff's Assessment on Consistency with NUREG-2214 Example AMP, "Reinforced Concrete Structures"
1. Scope of Program	Consistent The applicant defined the scope as the ISFSI pad.
2. Preventive Actions	Consistent
3. Parameters Monitored or Inspected	Consistent The AMP states that exposed surfaces of the ISFSI pad are visually examined for cracking, loss of material (spalling, scaling), loss of bond, and increased porosity and permeability. The staff notes that the above criteria are consistent with the aging effects NUREG-2214 recommends for inspection. However, the NUREG-2214 example AMP also provides additional detail on the concrete characteristics associated with the above aging effects (e.g., popouts, voids, honeycombing) that the applicant did not discuss in AMP Element 3. Nevertheless, the staff finds that the applicant's proposal is consistent with the recommendation in NUREG-2214 because the detailed inspection parameters in the AMP are defined through the use of ACI 349.3R-02 in AMP Element 6. The use of ACI 349.3R-02 to define inspection parameters and acceptance criteria will ensure that the specific concrete characteristics evaluated by the AMP will be consistent with NUREG-2214.
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, with additional discussion on the use of tollgates for program assessment (see SER Section 3.5.1)
10. Operating Experience	Consistent The applicant stated that a survey of Holtec storage systems identified very minor signs of degradation of the ISFSI pad, such as minor local spalling, that demonstrate that the AMP will be sufficient to detect aging effects. As discussed in SER Section 3.5.1, the applicant also stated that it will use AMID to share operating experience with others and inform the assessment of AMP effectiveness.

3.5.1 Aging Management Tollgates

The applicant included periodic tollgate assessments in the renewal application, as recommended in NEI 14-03, Revision 2. The applicant included the schedule for these tollgate

assessments in Table 4-1 of the renewal application and in the proposed FSAR supplement (as FSAR Table 9.2.4).

These tollgate assessments will evaluate information from the following sources:

- results of research and development programs focused specifically on aging-related degradation mechanisms identified as potentially affecting the HI-STAR 100 systems 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 tollgate process will continue on a routine 5-year basis throughout the period of extended operation to ensure that the AMPs continue to effectively manage the identified aging effects. The applicant stated that a written assessment of the aggregate impact of the information obtained from periodic tollgate assessments will be performed, including trends, corrective actions required, and the effectiveness of the associated Overpack Exterior and ISFSI Pad AMPs.

To prepare the tollgate assessments effectively, the applicant stated that the ISFSI sites 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. 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. ISFSI sites will continue to follow existing processes for addressing emergent issues, including the use of the site corrective action programs.

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 AMID, in addition to other periodic operating experience reviews consistent with the site quality assurance program, provide reasonable assurance that the Overpack Exterior and ISFSI Pad AMPs will remain adequate during the period of extended operation.

3.5.2 Evaluation Findings

The staff reviewed the AMPs provided in the renewal application. The staff performed its review following NUREG-1927 and NUREG-2214. The staff evaluated the 10 elements of the applicant's Overpack Exterior AMP and ISFSI Pad AMP that address aging mechanisms and effects of potential aging that could adversely affect the ability of the SSCs and the 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. Therefore, the staff finds reasonable assurance that the SSCs will continue to perform their intended functions during the requested period of extended operation.

Based on its review, the staff finds the following:

F3.4 The applicant identified programs that provide reasonable assurance 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 changes to the CoC conditions and technical specifications from the staff's review of the renewal application.

4.1 Final Safety Analysis Report Update

The NRC added the following condition to the initial CoC (Amendment 0) and Amendments 1, 2, and 3:

> FSAR UPDATE FOR RENEWED CoC
>
> The CoC holder shall submit an updated FSAR(s) to the Commission, in accordance with 10 CFR 72.4, within 90 days after the effective date of the renewal. The updated FSAR(s) shall reflect the changes resulting from the review and approval of the CoC renewal, including the HI-STAR 100 FSAR supplement that is documented in Appendix D of the HI-STAR 100 CoC renewal application, Revision 1.D, dated November 24, 2020 (ADAMS Accession No. ML20329A323). The CoC holder shall continue to update the FSAR pursuant to the requirements of 10 CFR 72.248.

The applicant indicated 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.D of the renewal application, Appendix D (Holtec 2020d, 2020e), which reflects the final proposed FSAR supplement to address the aging management activities described in the renewal application. This condition ensures that the 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 added the following condition to the initial CoC (Amendment 0) and Amendments 1, 2, and 3:

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

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 CoC renewal and the NRC Safety Evaluation Report related to the CoC renewal.

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

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

The staff considers it important to ensure that a general licensee's report prepared in response to 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 about operations during the period of extended operation. This includes potential use by general licensees that may use a new HI-STAR 100 Cask System after the CoC has been renewed, whether at a new or 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-STAR 100 Cask System must evaluate it for use at their respective sites. This condition also makes it clear that in order to meet the requirements in 10 CFR 72.212(b)(11), general licensees that currently use a HI-STAR 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 an implementation timeframe and a reference to the NRC SER related to the CoC renewal.

4.3 Future Amendments to the CoC

The NRC added the following condition to the initial CoC (Amendment 0) and Amendments 1, 2, and 3:

> 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 assure 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 Aging Management Program Implementation

The NRC added new Technical Specification 3.5, "Aging Management Program Procedures," associated with the initial CoC (Amendment 0) and Amendments 1, 2, and 3:

> 3.5 Aging Management Program (AMP) Procedures

Each general licensee shall have a program to establish, implement, and maintain written procedures for each 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 one year after the effective date of the CoC renewal, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate HI-STAR 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.

The above technical specification addition is similar in nature to the currently existing CoC conditions and technical specifications with regard 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, and the timeframe is consistent with NUREG-1927. The tollgate assessments in the AMPs assure that the results of those assessments will inform AMP procedures. The staff notes that the applicant proposed the above 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-STAR 100 Cask System.

4.5 Reference to 10 CFR Part 52

The NRC revised the initial CoC (Amendment 0) and Amendments 1, 2, and 3 to address the language change in 10 CFR 72.210, “General license issued,” and other updates to the regulations. This revision was made for consistency with the language currently in 10 CFR 72.210 and other cited regulations and is not pertinent to the safety review conducted for the renewal application. Changes to the text are in bold, which only involves adding new text.

11. AUTHORIZATION

The HI-STAR 100 Cask System, which is authorized by this certificate, is hereby approved for general use by holders of 10 CFR Part 50 **and 10 CFR Part 52** licenses for nuclear reactors at reactor sites under the general license issued pursuant to 10 CFR 72.210, subject to the conditions specified by 10 CFR 72.212, and the attached Appendix A and Appendix B.

The NRC modified any CoC and technical specification language that discusses 10 CFR Part 50 licensees to also include 10 CFR Part 52 licensees. In addition, the NRC

updated the regulation citations referenced in the applicable CoC and technical specifications to reflect citations currently in the regulations.

5 CONCLUSIONS

Pursuant to 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-STAR 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

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

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

10 CFR Part 72, *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."

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