SAFETY EVALUATION REPORT

FOR THE TROJAN SITE-SPECIFIC

INDEPENDENT SPENT FUEL STORAGE INSTALLATION

SPECIFIC LICENSE NO. SNM-2509 RENEWAL

DOCKET NO. 72-17

Office of Nuclear Material Safety and Safeguards
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ABBREVIATIONS AND ACRONYMS

ACI	American Concrete Institute
ADAMS	Agencywide Documents Access and Management System
AMP	aging management program
AMR	aging management review
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BPA	Bonneville Power Administration
C	Celsius
CAP	Corrective Action Program
CFR	*Code of Federal Regulations*
CISF	consolidated interim storage facility
DCE	decommissioning cost estimate
DFP	decommissioning funding plan
DOE	U.S. Department of Energy
EWEB	Eugene Water and Electric Board
F	Fahrenheit
HAC	hypothetical accident conditions
ISFSI	independent spent fuel storage installation
ISG	interim staff guidance
ITS	important to safety
LRA	license renewal application
MIT	Massachusetts Institute of Technology
mm	millimeter
MPC	multipurpose canister
n/cm^2	neutrons per square centimeter
$n/in.^2$	neutrons per square inch
n/m^2	neutrons per square meter
NRC	U.S. Nuclear Regulatory Commission
NWTRB	Nuclear Waste Technical Review Board
OPUC	Oregon Public Utility Commission
PGE	Portland General Electric Company
PWR	pressurized-water reactor

QA	quality assurance
SAR	safety analysis report
SCC	stress-corrosion cracking
SER	safety evaluation report
SNM	special nuclear material
SSC	structure, system, and component
TLAA	time-limited aging analysis

INTRODUCTION

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," the U.S. Nuclear Regulatory Commission (NRC) issued a specific license for the independent spent fuel storage installation (ISFSI) at the Trojan Nuclear Plant, Special Nuclear Material (SNM) License No. SNM-2509, for 20 years, with an expiration date of March 31, 2019. SNM-2509 authorizes Portland General Electric Company (PGE) with Eugene Water and Electric Board (EWEB) and PacifiCorp (together, the "licensee" or "applicant") to receive, possess, transfer, and store spent fuel from the Trojan Nuclear Plant in the Trojan ISFSI. The Trojan site is located in Columbia County, OR, approximately 68 kilometers [42 miles] north of Portland, in northwest Oregon. The former Trojan Nuclear Plant site occupies approximately 12 hectares [30 acres] within a PGE property comprising 257 hectares [634 acres]. The ISFSI occupies less than 0.4 hectares [1 acre] within the northeastern portion of the Trojan Nuclear Plant site.

By letter dated March 23, 2017 (PGE, 2017), supplemented on January 23, 2019 (PGE, 2019a), February 21, 2019 (PGE, 2019b), and June 10, 2019 (PGE, 2019c), PGE, on behalf of itself, EWEB, and PacifiCorp, submitted an application to the NRC for renewal of SNM-2509 for an additional 40 years beyond the initial license term. The license renewal, if approved, would authorize the applicant to continue storing spent fuel in the Trojan ISFSI until March 31, 2059. The applicant submitted the license renewal application (LRA) in accordance with the regulatory requirements of 10 CFR 72.42, "Duration of License; Renewal." Because PGE submitted the LRA more than 2 years before the license expiration date, pursuant to 10 CFR 72.42(b) and (c), the application constitutes a timely renewal.

The Trojan ISFSI uses British Nuclear Fuel Limited Fuel Solutions TranStor™ concrete casks, which are a vertical ventilated-type cask, loaded with seal-welded, stainless steel Holtec International multipurpose canisters (MPCs) (type MPC-24E or MPC-24EF). The MPC-24E is designed to accommodate up to 24 pressurized-water reactor (PWR) fuel assemblies. Up to four of the fuel assemblies in any one MPC-24E may be classified as damaged fuel and the balance must be intact fuel. The MPC-24EF is also designed for 24 PWR fuel assemblies, with up to four assemblies classified as damaged or fuel debris. The 34 MPCs stored in the Trojan ISFSI ranged in heat load at time of loading from 4.1 kilowatts to 14.3 kilowatts and were moved to the ISFSI pad between January and September 2003.

The ISFSI consists of a reinforced concrete storage pad supporting 34 Trojan storage systems, each made up of the TranStor™ concrete cask and stored MPC. In addition to these primary components, the ISFSI also requires a transfer cask, transfer station, and ISFSI-related security equipment.

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

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

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

1 GENERAL INFORMATION

1.1 Specific License Holder Information

The license renewal application (LRA) includes general information on the specific license holders, Portland General Electric Company (PGE) with Eugene Water and Electric Board (EWEB) and PacifiCorp. The LRA includes the names and addresses of the applicants; a description of the business of the applicants and the State in which it is incorporated and does business; and the organization and management of the applicants, including the names, addresses, and citizenship of the directors and principal officers.

According to the applicant, the Trojan independent spent fuel storage installation (ISFSI) is jointly owned by PGE (67.5 percent), the City of Eugene through EWEB (30 percent), and PacifiCorp (2.5 percent).[1] As the majority owner, PGE has responsibility for operating and maintaining the Trojan ISFSI. PGE is an investor-owned utility, incorporated in the State of Oregon, which provides electricity to more than 848,000 retail electricity customers.

The U.S. Nuclear Regulatory Commission (NRC) staff finds that the applicant provided the information required in Title 10 of the *Code of Federal Regulations* (10 CFR) 72.22 (a)–(d).

1.2 Financial Qualifications

The regulation at 10 CFR 72.22(e) “Contents of application: General and Financial Information,” states:

> Except for DOE, information sufficient to demonstrate to the Commission the financial qualifications of the applicant to carry out, in accordance with the regulations in this chapter, the activities for which the license is sought. The information must state the place at which the activity is to be performed, the general plan for carrying out the activity, and the period of time for which the license is requested. The information must show that the applicant either possesses the necessary funds, or that the applicant has reasonable assurance of obtaining the necessary funds or that by a combination of the two, the applicant will have the necessary funds available to cover the following:
>
> (1) Estimated construction costs;
>
> (2) Estimated operating costs over the planned life of the ISFSI; and
>
> (3) Estimated decommissioning costs, and the necessary financial arrangements to provide reasonable assurance before licensing, that decommissioning will be carried out after the removal of spent fuel, high-level radioactive waste, and/or reactor-related GTCC waste from storage.

1 The Bonneville Power Administration is obligated through net billing agreements to pay radiological decommissioning costs associated with EWEB’s share of the Trojan ISFSI.

1.2.1 ISFSI Construction Cost Estimate

The Trojan ISFSI consists principally of concrete storage and service pads, a steel fuel transfer station, concrete casks that hold multi-purpose canisters (MPCs), and a transfer cask. According to the Trojan ISFSI safety analysis report (SAR), the applicant does not expect contamination on the concrete cask or significant activation of the concrete and steel.

Because the Trojan ISFSI is already constructed and plans for expansion do not exist at this time, with the exception of a short roadway between the Trojan ISFSI pad to a rail spur, staff review of construction costs is not warranted at license renewal.

1.2.2 ISFSI Operating Cost Estimate

PGE's application, as supplemented by PGE's responses to NRC requests for additional information (RAIs),[2] conservatively estimated annual operating cost is $5.8 million in 2015 dollars for the Trojan ISFSI. The cost estimate for the Trojan ISFSI considers factors found in the decommissioning cost analyses, including costs associated with ISFSI security, project management, cask maintenance, equipment surveillances, and the new Aging Management Program (AMP) annual costs during the extended license period.

In order to evaluate the reasonableness of this Trojan estimate, staff reviewed estimated ISFSI operations costs cited in a 2001 Massachusetts Institute of Technology (MIT) report; two U.S. Government Accountability Office (GAO) reports that provide estimates of annual operations and maintenance costs for a centralized storage facility (2009), and safety and security system and annual operational costs for dry storage at a shutdown reactor site (2014); a 2016 U.S. Department of Energy (DOE) report; and actual costs from three ISFSIs with decommissioned reactors.

The 2001 MIT report, "Interim Storage of Spent Fuel in the United States (Macfarlane, 2001)," estimates ISFSI operating costs at a shutdown reactor, with all spent fuel in dry storage, to be approximately $4 million per year. Accounting for inflation through 2017, the cost estimate would be approximately $5.7 million annually. The 2009 GAO report, entitled "Nuclear Waste Management; Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," provides estimates for the cost of annual operations and maintenance for a centralized storage facility (or centralized interim storage facility (CISF). Because the CISF envisioned in the study has approximately 200 times the spent nuclear fuel than the Trojan ISFSI, the staff considers the study a high-end estimate when evaluating the reasonableness of operational cost data provided by PGE for a spent fuel storage facility. GAO (2009) GAO publication (page 54) estimates $8.8 million in operations costs for a CISF. Accounting for inflation through 2017, the cost estimate would be approximately $10 million. , The report, "Spent Nuclear Fuel Management; Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability," (GAO 2014) provides estimates of $2.5 to $6.5 million in annual operations and other related costs at a shutdown reactor site (page 52). Inflation from 2014 through 2015 is negligible, at approximately 2% during that time period. The U.S. Department of Energy (DOE) report "Cost Implications of an Interim Storage

[2] The NRC requested additional information from PGE to support its technical review of the license renewal application related to 10 CFR 72.22(e). PGE's responses to those RAIs, dated February 21 and June 10, 2019, can be found at ADAMS Accession No. ML19057A148 and ML19164A182, respectively.

Facility in Waste Management System," (DOE 2016), assumes annual maintenance, security and monitoring costs for an ISFSI located at a shutdown reactor site of $10 million.

Finally, for comparison, publicly available information from Connecticut Yankee, Maine Yankee, and Yankee Rowe decommissioned facilities indicate that the annual cost to operate each of the three ISFSIs was approximately $10 million (see http://www.connyankee.com, http://www.maineyankee.com, and http://www.yankeerowe.com).

Based on estimates provided in the MIT, GAO, and DOE reports, and based on operating costs from operating ISFSIs, $2.5 million to $10 million is a reasonable range for annual costs to operate an ISFSI at a shutdown reactor. Based on expenditures provided in Table 1-0-1 in PGE's response to NRC's RAI (ML19164A182), the annual operating cost for the Trojan ISFSI was approximately $4 million per year (2004-2016). This time period provides a reasonable approximation of future operating costs because it is after facility construction is complete, and prior to renewal licensing activities. Accordingly, the staff finds the annual operating cost estimate for the Trojan ISFI of $5.8 million (in 2015 dollars) over the requested period of extended operation, to be reasonable.

1.2.3 ISFSI Operating Funds Availability

To determine if PGE has reasonable assurance to cover its estimated annual operating costs of approximately $5.8 million for the Trojan ISFSI, the NRC staff reviewed the information in PGE's RAI responses. The response noted PGE and PacifiCorp are public utilities that recover a portion of Trojan ISFSI costs through rates approved by the Oregon Public Utility Commission (OPUC). PGE's rate recovery was $3.5 million in year 2018. In OPUC Order Number 07-015, the OPUC approved the continuation of collections until completion of decommissioning of the Trojan Facility. In addition, pursuant to the DOE's approved settlement[3], the U.S. Department of Justice reviews the Trojan ISFSI's annual expenditures and makes an annual settlement payment to the Trojan co-owners. Pursuant to this process, the DOE has reimbursed the Plaintiffs $85 million for costs incurred through 2016, which is an average of approximately $4.7 million per year. Because these two arrangements provide approximately $8.2 million per year on average, staff find that the applicant can reasonable cover the estimated annual operating cost of $5.8 million per year.

1.2.4 Decommissioning Funding Assurance

Pursuant to 10 CFR 72.30(c), each holder of, or applicant for, a license 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," must submit for NRC review and approval a decommissioning funding plan (DFP) containing information on how reasonable assurance will be provided that funds will be available to decommission its ISFSI. At time of license renewal and at intervals not to exceed 3 years, the licensee must submit the DFP with adjustments as necessary to account for changes in decommissioning costs and the extent of contamination. The DFP must update the information submitted with the original or previously approved plan under 10 CFR 72.30(b). In addition, the DFP must also specifically consider the effect of the following events on decommissioning costs: (1) spills of radioactive

[3] In 2004, the co-owners of Trojan filed a complaint against the USDOE for failure to accept spent nuclear fuel by January 31, 1998. PGE had contracted with the USDOE for the permanent disposal of spent nuclear fuel in order to allow the final decommissioning of Trojan. The Plaintiffs paid for permanent disposal services during the period of plant operation and have met all other conditions precedent.

material producing additional residual radioactivity in onsite subsurface material, (2) facility modifications, (3) changes in authorized possession limits, and (4) actual remediation costs that exceed the previous cost estimate. The DFP must contain a detailed decommissioning cost estimate (DCE) in an amount reflecting (1) the cost of an independent contractor to perform all decommissioning activities, (2) an adequate contingency factor, and (3) the cost of meeting the unrestricted use criteria in 10 CFR 20.1402, “Radiological Criteria for Unrestricted Use” (or the cost of meeting the 10 CFR 20.1403, “Criteria for License Termination under Restricted Conditions,” restricted use criteria, provided the licensee can demonstrate its ability to meet these criteria). The licensee’s DFP must also identify and justify using the key assumptions contained in the DCE. Further, the DFP must describe the method of assuring funds for ISFSI decommissioning, including the means for adjusting cost estimates and associated funding levels periodically over the life of the ISFSI. Finally, the DFP must specify the volume of onsite subsurface material containing residual radioactivity that will require remediation to meet the criteria for license termination, and the DFP must contain a certification that financial assurance for ISFSI decommissioning has been provided in the amount of the DCE.

The applicant provided its original DFP for review and approval on December 13, 2012 (PGE, 2012). Pursuant to 10 CFR 72.30(c), Trojan updated its DFP, including the DCE for the Trojan ISFSI, as part of the LRA.[4] PGE estimated the cost to decommission the Trojan ISFSI for unrestricted use to be $5.9 million (in 2015 dollars), which included a 25-percent contingency factor. The staff’s review of PGE’s updated DFP considered guidance in NUREG-1757, “Consolidated Decommissioning Guidance—Financial Assurance, Recordkeeping, and Timeliness,” Volume 3, Revision 1, issued February 2012 (NRC, 2012a). In this regard, the staff concluded that the DCE (1) appears to be based on reasonable costs, (2) includes an adequate contingency factor of 25 percent, and (3) is considered reasonable based on documented assumptions described in detail within the licensee’s submittal.

PGE currently relies on an external trust fund as financial assurance for its ISFSI decommissioning, a method authorized by 10 CFR 72.30 (e)(5). The City of Eugene, Oregon, relies on a Statement of Intent from the EWEB as financial assurance for ISFSI decommissioning, a method authorized by 10 CFR 72.30(e). The EWEB is a government agency with a contractual agreement with Bonneville Power Administration (BPA), a power marketing agency under the U.S. Department of Energy (DOE), obligating BPA to pay costs associated with EWEB’s share of Trojan, including decommissioning costs.

As a part of LRA, PGE provided decommissioning funding assurance in the form of a trust for the Trojan ISFSI. These reports include total funds in the trusts (as of December 31, 2015) allocated for radiological decommissioning. The staff notes that PGE clearly delineated the funds designated for radiological decommissioning expenses and that the aggregate amount exceeds the ISFSI decommissioning cost estimate of $1.59 million. Based on the amount of funds, the staff finds that the applicant has demonstrated decommissioning funding assurance for the Trojan ISFSI.

Based on the review of the application and all associated documentation, the NRC staff finds that the applicant has provided a reasonable cost estimate for the radiological decommissioning of the Trojan ISFSI and has provided reasonable assurance that funds will be available for radiological decommissioning of the ISFSI at the time of license termination.

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[4] Section 1.3.7 of the application provides an update to the 2015 triennial update to the decommissioning funding plan (ADAMS Accession Nos. ML15349A939 and ML16021A491).

1.2.5 Conclusion

Based on an independent analysis of the information in the application, the NRC staff finds that there is reasonable assurance that PGE is financially qualified to engage in the proposed activities with regard to the Trojan ISFSI, as described in the LRA, for the additional 40-year period and that PGE has successfully demonstrated decommissioning funding assurance, meeting the requirements in 10 CFR 72.22(e) and 10 CFR 72.30(c).

1.3 Environmental Review

Regulations in 10 CFR 72.34, “Environmental Report,” require that each application for an ISFSI license under this part must include an environmental report that meets the requirements of 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” Subpart A, “National Environmental Policy Act—Regulations Implementing Section 102(2).” The applicant submitted an environmental report supplement as part of the LRA. The environmental report contained sufficient information to aid the staff in its independent analysis. In July 2019, the staff issued an environmental assessment (NRC, 2019) for Trojan ISFSI license renewal.

1.4 Safety Review

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

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

- a description of the AMP for management of issues associated with aging that could adversely affect ITS SSCs

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

1.5 Application Content

The applicant’s LRA, as supplemented, includes the following information:

- General and financial information
- Renewal scoping

- Aging Management Reviews
- Aging Management Programs
- Time-Limited Aging Analyses
- Tollgates (procedures requiring periodic effectiveness reviews of aging management approach)
- Preapplication/baseline inspections
- Environmental report supplement
- Proposed license and technical specification changes
- Proposed SAR changes
- Decommissioning funding plan update

In particular, the applicant's SAR supplement provides changes and additions to the Trojan SAR (PGE, 2017) to document the results of the AMR, TLAAs, and AMPs. The applicant updated the proposed Trojan ISFSI SAR in accordance with 10 CFR 72.70(b) and (c).

1.6 Safety Review Evaluation Findings

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

F1.1 The information presented in the LRA satisfies the requirements of 10 CFR 72.2, "Scope"; 10 CFR 72.22, "Contents of Application: General and Financial Information"; 10 CFR 72.30, "Financial Assurance and Recordkeeping for Decommissioning"; 10 CFR 72.34; and 10 CFR 72.42, "Duration of License; Renewal."

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

2 SCOPING EVALUATION

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

(1) SSCs that are classified as ITS, as they are relied on to do one of the following functions:
   - Maintain the conditions required by the regulations, specific license, or Certificate of Compliance to store spent fuel safely.
   - Prevent damage to the spent fuel during handling and storage.
   - 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* ITS but, according to the design bases, whose failure could prevent fulfillment of a function that is ITS

After the determination of in-scope SSCs, subcomponents of the SSCs are screened to identify which have intended functions that support the ITS SSCs.

2.1 Scoping and Screening Methodology

In LRA Section 2, the applicant provided the following information from its scoping evaluation:

- a description of the scoping and screening methodology for the inclusion of SSCs and SSC subcomponents in the renewal scope
- a list of sources of information used for the scoping evaluation
- descriptions of the SSCs
- a list of the SSCs identified as 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 application. The section below discusses the staff's review and findings with regard to the applicant's scoping evaluation.

2.1.1 Scoping Process

In LRA Section 2.1, the applicant reviewed the following design-basis documents to identify SSCs with safety functions meeting either scoping criterion 1 or 2, as defined above:

- Trojan ISFSI Safety Analysis Report (PGE-1069), Revision 14
- Special Nuclear Material (SNM) License No. 2509, Amendment 6
- Trojan ISFSI Technical Specifications, Amendment 5
- Trojan ISFSI Safety Evaluation Report (SER) (SNM-2509, Amendment 6)
- HI-STORM 100 Safety Analysis Report, HI-2002444 (referenced in the Trojan SAR)
- NUREG-1927, Revision 1, Section 2.4.2

Table 2-1 lists the SSCs included and excluded from the scope of renewal review and identifies the scoping criterion met by each in-scope SSC.

Table 2-1 SSCs Within and Outside Scope of Renewal Review

SSCs	**Criterion 1**[a]	**Criterion 2**[b]	**In Scope**
MPC[c]	Yes	N/A	Yes
Transfer cask	Yes	N/A	Yes
Concrete cask	Yes	N/A	Yes
Spent fuel assemblies	Yes[d]	N/A	Yes
ISFSI pad (includes storage pad and service pad subcomponents)	No	Yes	Yes
ISFSI security equipment	No	No	No
Transfer station (including structure, pad, and impact limiter)	Yes	N/A	Yes
Fuel transfer and auxiliary equipment	No	No	No

[a] SSC is ITS.
[b] SSC is not ITS, but its failure could prevent an ITS function from being fulfilled.
[c] Includes damaged fuel container, failed fuel can, and fuel debris process can capsule.
[d] Fuel pellets not included.
N/A = not applicable.

The following describes the staff's review of the applicant's scoping results in LRA Section 2.2 to determine whether the applicant's conclusions about the out-of-scope components accurately reflect the design-basis documentation.

The applicant stated that security equipment is not part of the Trojan storage system as approved by the Trojan ISFSI license, and the Trojan ISFSI SAR does not describe it in detail. The staff notes that, consistent with guidance in NUREG-1927, Revision 1 (NRC, 2016), failure of the ISFSI security equipment would not prevent fulfilment of a safety function. Therefore, the staff finds the applicant's conclusion that the security equipment does not meet the scoping criteria to be acceptable. The staff notes that, regardless of this determination, the Trojan ISFSI has programs and procedures to ensure that ISFSI security equipment requirements are met. In accordance with 10 CFR 73.51, "Requirements for the physical protection of stored spent nuclear fuel and high-level radioactive waste," applicants must maintain the performance of security equipment at all times (not just during the renewal period of extended operation).

The applicant stated that the fuel transfer equipment and auxiliary equipment previously used for loading MPCs and moving casks (e.g., drying system, air pad system, welding equipment) are not included as part of the Trojan ISFSI license and are not described in detail in the ISFSI SAR. Therefore, the applicant concluded that the fuel transfer equipment and auxiliary equipment are outside the scope of the 10 CFR Part 72 license renewal. Section 4.3 of the Trojan ISFSI SAR states that no components of the fuel transfer and auxiliary equipment have an ITS function. The staff finds the applicant's determination that the fuel transfer and auxiliary equipment are not in scope to be acceptable based on the design-basis documentation clearly describing these components as not ITS and the documentation showing that failure of the fuel transfer and auxiliary equipment would not affect the safety functions of the storage casks.

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

2.1.2 Subcomponents Within the Scope of the Renewal Review

Based on the scoping process discussed in Section 2.1 of the renewal application, the applicant identified six SSCs as within the scope of renewal review. These SSCs consist of several subcomponents, not all of which support an intended function and need to be considered in the AMR. The applicant screened the six in-scope SSCs to identify the subcomponents that support an intended function. Table 2-2 describes the subcomponents of each of the in-scope SSCs that the applicant identified as supporting an intended function, and Table 2-3 describes the subcomponents that the applicant identified as not supporting an intended function.

The staff reviewed the applicant's screening of the in-scope SSCs to identify subcomponents that support an intended function and require an AMR, as recommended in NUREG-1927, Revision 1. The staff's review considered the intended function of the SSCs, the SSCs' safety classification or basis for inclusion in the scope of renewal review, and the design-basis information in the Trojan ISFSI SAR (including the design drawings for each of the SSCs) and the portions of the HI-STORM 100 SAR referenced in the Trojan ISFSI SAR. Based on this review, the staff finds that the applicant screened in the SSC subcomponents that support a safety function and are within the scope of renewal in a manner consistent with NUREG-1927, Revision 1. Therefore, the staff finds the screening results to identify the in-scope SSC subcomponents to be acceptable.

Table 2-2 SSC Subcomponents Within the Scope of the Renewal Review

MPC	Transfer Cask	Concrete Cask	Transfer Station
			Structure
Shell	Radial lead shield	Cask lid	Fastener
Baseplate	Top lid shielding	Cask liner shell	Transfer cask restraint
Lid	Lead fill plug	Tile	Hex nuts
Closure ring	Outer shell	Bottom plate assembly	Hardened flat washers
Port cover plates	Inner shell	Reinforcement bar	Shim plate
Basket center column	Water jacket end plate	Concrete shell	Inside upper restraint
Basket cell plates	Top flange	Shield ring	Upper restraints
Short cell spacer plates	Water jacket shell	Inlet air assembly	Cross braces
Flux gap cover	Water jacket bottom ring	Outlet air assembly	Quadrapod weldments
Flux gap plate	Water jacket top plates	**Spent Fuel Assembly**	Adaptor ring (storage cask)
Basket cover angle	Water jacket trunnion plate	Fuel cladding	Adaptor ring (transport cask)
Basket cell angle	Water jacket cap plate	Spacer grid assemblies	Shield ring
Basket cell channel	Top lid outer ring	Upper end fitting	Main deck structure
Neutron absorber	Top lid inner ring	Lower end fitting	Cylinder bracket
Drain and vent shield block	Top lid top plate	Guide tubes	Alignment stop
Upper fuel spacer pipe	Top lid bottom plate	**ISFSI Pad** (storage and service pads)	**Pad**
Sheathing	Lifting trunnion block	Concrete	Threaded rod
Shims	Lifting trunnion		Plate
Upper fuel spacer bolt	Top lid lifting block		Hex jam nut
Upper fuel spacer end plate	Top lid stud (top lid bolt)		Hex nut
Lower fuel spacer column	Top lid nut (top lid washer)		Hardened washer
Lower fuel spacer end plate	Rib plates		Concrete
Vent shield block spacer	Door lip		Rebar or equivalent
Damaged fuel container[a]	Door top plate		**Impact Limiter**
Failed fuel cans[b]	Door beam		Plate
Fuel debris process can capsule	Door top		Polyurethane foam
	Door bottom		

[a] Damaged Fuel Container provides an enclosure for a fuel assembly classified as damaged fuel to constrain this assembly within its MPC storage location.

[b] Failed Fuel Cans provide an enclosure for damaged fuel assemblies, fuel debris Process Can Capsules, non-fuel bearing components, and fuel debris in Process Cans to constrain these assemblies and components within their MPC storage locations.

Table 2-3 SSC Subcomponents Not Within the Scope of the Renewal Review

MPC	Transfer Cask	Concrete Cask	Transfer Station
Basket cell spacer block Plugs for drilled holes Lift lug Lift lug baseplate Vent and drain tube Vent and drain cap Vent and drain cap seal washer Vent and drain cap screw Port cover plate set screw Coupling Drain line Drain tube plate Drain line guide tube	Door pins Drain pipes Couplings, valves and vent plug Water jacket port cover plate, Gasket and screws Rail bolt Door top plate clevis Door stop plate Door hex bolt Door slide plate	Transfer cask alignment plates Screen **Fuel Assembly** Fuel pellets Hold-down spring and upper end plugs Control components **ISFSI Storage Pad** (storage and service pads) Rebar Engineered fill Conduit and electrical connectors	**Transfer Station Structure** Deck plates Angle Bar Fastener Concrete stud anchor Hydraulic system assembly Kick plate Hex nut Hardened flat washer Hydraulic cylinder Ladders Upper deck Handrails **Transfer Station Pad** Grout **Impact Limiter** Sheet metal Angle iron Threaded plug

2.1.3 Evaluation Findings

The NRC staff reviewed the scoping evaluation in the LRA and supplemental documentation. The staff performed its review following the guidance in NUREG-1927, Revision 1 (NRC, 2016). The staff also used the information in NUREG/CR-6407, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” issued February 1996 (McConnell, et al., 1996), in its review as a reference for classifying components as ITS to determine the accuracy and completeness of the scoping evaluation. Based on its review, the staff determined that the applicant provided sufficient information with adequate details to support the LRA with the follow findings:

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

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

3 AGING MANAGEMENT REVIEW

3.1 <u>Review Objective</u>

The objective of the staff's evaluation of the applicant's AMR is to determine whether the applicant has adequately performed a review of 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 the associated subcomponents to perform their intended functions during the period of extended operation.

3.2 <u>Aging Management Review Process</u>

In LRA Section 3.1, the applicant described its AMR process as consisting of three steps following the scoping review:

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

The applicant stated that the AMR identified the aging mechanisms and effects applicable to each SSC subcomponent based on the combination of materials and environments and a review of known literature, industry operating experience, and maintenance and inspection records. Finally, for each identified aging mechanism and effect, the applicant identified an AMP or TLAA to ensure that the intended function of the SSC would be maintained during the period of extended operation.

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

3.3 <u>Aging Management Review Results: Materials, Service Environment, Aging Effects, and Aging Management Programs</u>

The applicant's AMR results are provided in LRA Tables 3-1 through 3-6, which are summarized below in SER Tables 3-1 through 3-5. These tables identify, for each subcomponent, the aging mechanisms and effects that could affect a safety function, and they identify the aging management activities (AMPs or TLAAs) that are credited to manage aging. The staff notes that the summarized AMR results below do not include the ISFSI pad. The results for the pad subcomponents are absent because the applicant determined that there were no aging effects that would negatively impact the safety functions of the pad, and thus no pad subcomponents require an aging management activity.

Section 3.3.1 through Section 3.3.6 of this SER provide the staff's review of the applicant's AMR for the in-scope SSCs and subcomponents. The staff's evaluation findings summarizing these reviews are provided in Section 3.3.7.

Table 3-1 AMR Results—Multipurpose Canister

Subcomponent	Intended Function	Materials	Environment [a,b]	Aging Effects Requiring Management	Aging Mechanism	Aging Management Activities
Shell	Confinement, structural integrity, shielding, heat removal	Stainless steel	Inert gas	Cracking	Fatigue	MPC Fatigue TLAA
			Sheltered	Loss of material	Corrosion	MPC AMP
				Cracking	Stress-corrosion cracking	
				Loss of material	Pitting and crevice corrosion	
				Cracking	Fatigue	MPC Fatigue TLAA
Baseplate	Confinement, structural integrity, shielding, heat removal	Stainless steel	Inert gas	Cracking	Fatigue	MPC Fatigue TLAA
			Sheltered	Loss of material	Corrosion	MPC AMP
				Cracking	Stress-corrosion cracking	
				Loss of material	Pitting and crevice corrosion	
				Cracking	Fatigue	MPC Fatigue TLAA
Lid	Confinement, structural integrity, shielding, heat removal	Stainless Steel	Inert gas	Cracking	Fatigue	MPC Fatigue TLAA
			Sheltered	Loss of material	Corrosion	MPC AMP
				Cracking	Stress-corrosion cracking	
				Loss of material	Pitting and crevice corrosion	
				Cracking	Fatigue	MPC Fatigue TLAA
Closure ring	Confinement	Stainless steel	Sheltered	Loss of material	Corrosion	MPC AMP
				Cracking	Stress-corrosion cracking	
				Loss of material	Pitting and crevice corrosion	
Neutron absorber	Criticality control	Boral	Inert gas	Loss of material properties	Radiation	TLAA—neutron absorber depletion evaluation

[a] Where more than one environment is listed, the subcomponent is exposed to one environment on the inside and a second environment on the outside.

[b] The inert gas environment refers to the interior of the helium-filled, sealed MPC. The sheltered environment refers to the interior of the concrete cask.

Table 3-2 AMR Results—Transfer Cask

Subcomponent	Intended Function	Materials[a]	Environment[b]	Aging Effect(s) Requiring Management	Aging Mechanism	Aging Management Activities
Lead fill plug	Shielding	Carbon steel	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Outer shell	Structural integrity, shielding, heat removal	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Inner shell	Structural integrity, shielding, heat removal	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket end plate	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top flange	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket shell	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket bottom ring	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket top plates	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket trunnion plate	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Water jacket cap plate	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid outer ring	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid inner ring	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid top plate	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP

Subcomponent	Intended Function	Materials[a]	Environment[b]	Aging Effect(s) Requiring Management	Aging Mechanism	Aging Management Activities
Top lid bottom plate	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Lifting trunnion block	Structural integrity, shielding	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid lifting block	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid stud (top lid bolt)	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Top lid nut (top lid washer)	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Door lip	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Door top plate	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Door beam	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Door top	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP
Door bottom	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion, pitting and crevice corrosion	Transfer Cask AMP

[a] The applicant takes no credit for coatings, which are used only to mitigate corrosion. The AMPs allow for coating defects; however, when found, the underlying base metal must be assessed.
[b] The listed environment is the long-term extended storage environment. During future MPC movements at the transfer station, the environment will be exposed.

Table 3-3 AMR Results—Concrete Cask

Subcomponent	Intended Function	Materials[a]	Environment[b]	Aging Effect(s) Requiring Management	Aging Mechanism	Aging Management Activities
Cask lid	Radiation shielding, structural integrity	Carbon steel with coating	Exposed/ sheltered	Loss of material	Corrosion	Concrete Cask AMP
Cask liner shell	Radiation shielding, structural integrity	Carbon steel with coating	Exposed/ sheltered	Loss of material	Corrosion	Concrete Cask AMP
Bottom plate assembly	Structural integrity	Carbon steel with coating	Sheltered	Loss of material	Corrosion	Concrete Cask AMP
Reinforcement bar	Structural integrity	Carbon Steel	Embedded	Loss of material	Corrosion	Concrete Cask AMP
Concrete shell	Radiation shielding, structural integrity	Concrete	Exposed	Loss of strength, spalling, cracking, scaling	Alkali-silica reaction CaOH leaching freeze/thaw	Concrete Cask AMP
					Reinforcement bar corrosion	Concrete Cask AMP
					Radiation	Radiation analysis, see Section 3.8.3
Shield ring	Radiation shielding	Carbon steel with coating	Sheltered	Loss of Material	Corrosion	Concrete Cask AMP
Inlet air assembly	Heat transfer	Carbon steel with coating	Sheltered	N/A, Airflow Path Only	N/A, Airflow Path Only	Concrete Cask AMP
Outlet air assembly	Heat transfer	Carbon steel with coating	Sheltered	N/A, Airflow Path Only	N/A, Airflow Path Only	Concrete Cask AMP

[a] The applicant takes no credit for coatings, which are used only to mitigate corrosion. The AMPs allow for coating defects; however, when found, the underlying base metal must be assessed.
[b] The listed environment is the long-term extended storage environment. During future MPC movements at the transfer station, the environment will be exposed.

Table 3-4 AMR Results—Spent Fuel Assembly

Subcomponent	Intended Function	Materials	Environment[a]	Aging Effect/ Mechanism	Aging Mechanism	Aging Management Activities
Fuel cladding	Criticality control, confinement, structural integrity	Zircaloy	Inert gas	Change in material property	Thermal fatigue	TLAA—cladding integrity evaluation

[a] The inert gas environment refers to the interior of the helium-filled, sealed MPC.

Table 3-5 AMR Results—Transfer Station

Subcomponent	Intended Function	Materials[a]	Environment	Aging Effect(s) Requiring Management	Aging Mechanism	Aging Management Activities
Transfer Station Structure						
Fastener	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Fastener	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Fastener	Shielding, retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Transfer cask restraint	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Hex nut	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Hex nut	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Hardened flat washer	Structural Integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Hardened flat washer	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Hardened flat washer	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Shim plate	Structural integrity	Carbon steel with coating	Exposed	Loss of Material	Corrosion	Transfer Station AMP
Inside upper restraint	Structural integrity	Carbon steel with coating	Exposed	Loss of Material	Corrosion	Transfer Station AMP
Upper restraints	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Cross brace, left hand	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Cross brace, right hand	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Quadrapod weldment, right side	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Quadrapod weldment, left side	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Quadrapod weldment, back	Structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP

Subcomponent	Intended Function	Materials[a]	Environment	Aging Effect(s) Requiring Management	Aging Mechanism	Aging Management Activities
Adaptor ring, storage cask	Shielding, retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Adaptor ring, transport cask	Shielding, retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Shield ring	Shielding	Carbon steel	Exposed	Loss of material	Corrosion	Transfer Station AMP
Main deck structure	Shielding, structural integrity	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Cylinder bracket	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Alignment stop	Retrievability	Carbon steel with coating	Exposed	Loss of material	Corrosion	Transfer Station AMP
Transfer Station Pad						
Threaded rod	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Plate	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Hex jam nut	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Hex nut	Structural integrity	Carbon steel (some with coating	Exposed (coated), embedded	Loss of material	Corrosion	Transfer Station AMP
Hardened washer	Structural integrity	Carbon steel (some with coating	Exposed (coated), embedded	Loss of material	Corrosion	Transfer Station AMP
Concrete	Structural integrity	Concrete	Exposed	Loss of strength, spalling, cracking, scaling	Alkali-silica reaction, CaOH leaching, freeze-thaw, rebar corrosion	Transfer Station AMP
Rebar or equivalent	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Plate	Structural integrity	Carbon steel with coating	Exposed, embedded	Loss of material	Corrosion	Transfer Station AMP
Plate	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Rebar	Structural integrity	Carbon steel	Embedded	Loss of material	Corrosion	Transfer Station AMP
Impact Limiter						
Plate	Structural integrity (under HAC[b])	Carbon steel with coating	Sheltered, embedded	Loss of material	Corrosion	Transfer Station AMP

Subcomponent	**Intended Function**	**Materials[a]**	**Environment**	**Aging Effect(s) Requiring Management**	**Aging Mechanism**	**Aging Management Activities**
Polyurethane foam	Structural integrity (under HAC[b])	General plastics FR-3708	Embedded	Change in dynamic crush strength	Chemical changes	Transfer Station AMP

[a] The applicant takes no credit for coatings, which are used only to mitigate corrosion. The AMPs allow for coating defects; however, when found, the underlying base metal must be assessed.

[b] Hypothetical Accident Conditions (HAC)

3.3.1 Multipurpose Canister

The applicant described the two MPC versions (MPC-24E and MPC-24EF) in LRA Sections 2.2.1.1 and 3.2.1. The applicant stated that the major components of the MPC assemblies include the honeycombed fuel basket, a baseplate, canister shell, a lid, and a closure ring. The confinement boundary is defined by the baseplate, shell, lid, port covers, and closure ring. The MPC-24E is designed to accommodate up to 24 pressurized-water reactor (PWR) fuel assembles, where one assembly may be classified as damaged fuel. The MPC-24EF is also designed for 24 PWR fuel assembles, but up to four assemblies may be classified as damaged fuel or fuel debris.

3.3.1.1 Materials and Environments

The applicant stated that the MPC subcomponents are fabricated from American Society of Mechanical Engineers (ASME) SA-240 Type 304 stainless steel. Within each MPC enclosure vessel is a honeycombed fuel basket fabricated from ASME SA-240 Type 304 stainless steel, which contains spent nuclear fuel assemblies. Boral neutron absorber panels provide criticality control. The panels are completely enclosed in stainless steel sheathing that is stitch-welded to the MPC basket cell walls along their entire periphery. The failed fuel cans and damaged fuel container are fabricated from stainless steel. The fuel debris process can capsule, described in LRA Sections 3.2.1.3 and 3.2.1.4, is a container that provides a confinement boundary for processed fuel debris and it is placed within the MPC. It is constructed of Type 304 stainless steel for corrosion resistance and is inerted with helium.

The applicant stated that the internal subcomponents of the MPCs are all exposed to the inert gas (helium) environment inside the MPC. The applicant stated that there is very limited oxygen or moisture within the MPC as a result of the vacuum-drying process. Additionally, the internal MPC components are exposed to elevated gamma and neutron radiation, as discussed LRA Section 3.8.3 and evaluated below in the staff's review of radiation effects for the MPC and concrete cask.

The applicant stated that each MPC is stored in a vertical, ventilated concrete cask. Based on this, the external surface of each MPC is exposed to the same environment as the inside of the concrete cask, which is a sheltered environment protected from precipitation and wetting. This sheltered environment includes ambient air but not direct sunlight, rain, or wind exposure. The ambient air may contain some moisture and contaminants. The normal operating temperature of the outside MPC surface is highest at the top. These maximum surface temperatures are assumed to continue into the license renewal period.

The staff reviewed the applicant's description of the materials and environments for the MPCs and associated subcomponents and compared it to the information in the Trojan ISFSI SAR, including the general description of the system, the general description of the installation, the site characteristics, and specific details of the MPC designs and design drawings (construction materials and specifications). The staff finds that the applicant adequately defined the materials and environments for the Trojan MPC and associated subcomponents.

3.3.1.2 Aging Effects and Mechanisms for the MPC During the Period of Extended Operation

In LRA Section 3.2.5, the applicant stated that, based on the MPC materials of construction and the environments experienced during the period of extended storage at the ISFSI, the following aging effects require management by an AMP:

- loss of material due to corrosion, pitting, and crevice corrosion of the external stainless steel MPC surfaces

- cracking due to stress-corrosion cracking (SCC) of the external stainless steel MPC surfaces

The staff notes that the applicant identified the following aging effects that require TLAAs:

- loss of fracture toughness due to radiation effects on the stainless steel MPC subcomponents

- loss of neutron absorbing capacity due to boron depletion of Boral

In LRA Section 3.1.6.1, the applicant summarized operating experience at Trojan to support the above conclusions. The applicant stated that periodic internal inspections of one concrete cask included opportunistic visual inspection of the MPC surface. Two inspections in 2008 and 2013 showed no evidence of aging degradation on the exterior of the MPC.

The staff reviewed the applicant's identification of aging mechanisms and effects for the Trojan MPC-24E/EF and associated subcomponents. In its review, the staff considered NRC guidance (NRC, 2010, 2016), the technical literature, and operating experience from nuclear and nonnuclear applications. A summary of the staff's evaluation of the identified aging effects and mechanisms follows.

<u>General Corrosion</u>

The applicant stated that several measures are taken to provide corrosion protection for the MPC. The MPC shell and fuel basket are constructed of stainless steel material. To avoid contact of dissimilar materials, ceramic tiles separate the bottom of the MPC from the steel bottom plate of the concrete cask liner. As the MPC cavity was sealed, dried, and backfilled with helium during initial cask-loading operations, the MPC internals were maintained in an inert environment during long-term storage to further protect from corrosion. Finally, the surrounding concrete cask protects the MPC from the environment.

The staff reviewed the applicant's evaluation of the potential effects of general corrosion on stainless steel MPC components in the sheltered environment. The staff notes that stainless steels form a protective passive oxide layer on their surfaces that effectively prevents uniform corrosion (Grubb et al., 2005; Kaufman, 2005). Therefore, the staff finds the applicant's evaluation of general corrosion to be acceptable because the applicant has appropriately excluded the consideration of general corrosion for stainless steels, given the passivity of these alloys in the sheltered environment.

Pitting and Crevice Corrosion

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

Stress-Corrosion Cracking

The applicant has concluded that the welded stainless steel MPC materials of construction exposed to the sheltered environment inside the concrete cask may be susceptible to SCC.

The staff finds that the applicant's assessment is consistent with reactor operational experience, such as that summarized in NRC Information Notice 2012-20, "Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters," dated November 14, 2012 (NRC, 2012b), and the results of NRC-sponsored research (He et al., 2014) showing that SCC of stainless steel components has been observed when exposed to atmospheric conditions where chloride-containing species are present. The applicant's assessment is also consistent with recent industry-sponsored reviews of aging mechanisms for the welded stainless steel (Gorman et al., 2014; Fuhr et al., 2013). Therefore, the staff finds the applicant's assessment that aging management is required to manage the effects of SCC to be acceptable.

Embrittlement due to Neutron Radiation Exposure

The applicant did not identify any aging effects associated with radiation exposure of the stainless steel MPC components. In LRA Section 3.8.3.1 and Table 3-8, the applicant summarized its calculation of the radiation exposures at the MPC basket, which the applicant stated is the most conservative location for all the stainless steel in the Trojan storage system. The applicant estimated the accumulated neutron flux over 60 years at 1.3×10^{15} neutrons per square centimeter (n/cm^2), a level the applicant stated is not sufficient to cause embrittlement.

The staff notes that for stainless steels, neutron irradiation can cause changes in stainless steel mechanical properties, such as loss of ductility, fracture toughness, and resistance to cracking (Was et al., 2006). Gamble (2006) found that neutron fluence levels greater than 1×10^{20} n/cm^2 (6.5×10^{20} neutrons per square inch (n/in.^{2})) are required to produce measurable degradation of the mechanical properties. Caskey et al. (1990) also indicate that neutron fluence levels of up to 2×10^{21} n/cm^2 (1×10^{22} n/in.^{2}) were not found to enhance susceptibility. Because the applicant's estimated cumulative neutron fluence is four orders of magnitude below levels that would be expected to degrade stainless steels, the staff finds the applicant's determination not to manage this aging effect to be acceptable.

No Aging Mechanisms and Effects Identified in Helium and Enclosed Environments

The staff notes that the applicant did not identify aging effects for the stainless steel MPC and associated subcomponents as a result of exposure to the MPC internal helium backfilled environment. The staff notes that, as there is expected to be very little residual moisture in the internal cask environment following drying and backfilling with helium, corrosion of the stainless steel components in the MPC internal helium environment will be limited. Therefore, because stainless steel degradation is not expected to occur in the MPC internal helium environment, the staff finds the applicant's decision not to manage aging to be acceptable.

3.3.1.3 Proposed Aging Management Activities

The applicant developed the MPC AMP to manage loss of material due to corrosion (pitting/crevice) and cracking due to SCC for stainless steel components as described above. Based on the staff's review of the information in the LRA and NUREG-1927, Revision 1, which states that the use of an AMP is an acceptable approach to addressing aging degradation issues, the staff finds the applicant's use of an AMP to manage the aging effects to be acceptable.

3.3.2 Transfer Cask

In LRA Section 3.3.1, the applicant stated that the transfer cask was required for initial cask loading and will be required at the transfer station for transferring the MPC from the concrete cask into the transportation cask. The functions of the transfer cask are shielding and structural integrity. The transfer cask uses lead for gamma radiation shielding and a water-filled jacket for neutron shielding. The transfer cask is designed for use in conjunction with the transfer station at the ISFSI to temporarily hold the MPC during transfer into and out of concrete casks or transportation casks. The transfer cask is no longer used as a lifting device.

The applicant stated that the trunnions are not used for transfer now that the canisters have been loaded and stored. The trunnions are only used to lift an empty transfer cask when installing it in, or removing it from, the transfer station. This procedure never takes place over a loaded MPC, and thus the trunnions no longer have an ITS function.

3.3.2.1 Materials and Environments

In LRA Section 3.3, the applicant stated that the transfer cask structure is primarily fabricated from ASME SA-516 Grade 70 carbon steel. Radiation shielding materials include Holtite-A polymer (in the top lid for neutron shielding) and an elemental lead alloy (in the cask wall for gamma shielding). The Holtite-A and lead shielding materials are completely enclosed by the top lid and cask wall, respectively. Therefore, the applicant stated there will be no significant galvanic or chemical reactions between these shielding materials and the environment.

The applicant stated that the internal and external steel surfaces of the transfer cask (except threaded plugs and holes, seal areas, the inner surface of gap flush line, and trunnions) are sandblasted and coated with an epoxy-based coating system to preclude surface oxidation. The coatings are the following epoxy-based material suitable for borated water service (for initial loading):

- primer—Keeler & Long, 6548/7107 White Epoxy Primer
- top coat—Keeler & Long, E-1-7155 Epoxy Enamel

The applicant stated that the exterior of the transfer cask was exposed to borated water during fuel loading (while the transfer cask was in the spent fuel pool) and to demineralized water in the annulus between the MPC and inner cavity wall of the transfer cask when cleaned. The transfer cask water jacket cavity was exposed to potable (nonborated) water during fuel-loading operations. Following fuel loading of the MPC, the transfer cask was removed from the spent fuel pool. The external surfaces were then decontaminated and rinsed with demineralized water. The annulus water was removed following welding of the lid to the MPC, purging of the water in the MPC, drying, and backfilling with helium. The water jacket water drained into a temporary storage container for reuse with the next MPC. During transfer to and loading operations at the ISFSI, the transfer cask was briefly exposed to outside ambient conditions.

The applicant stated that the prior brief exposure of the transfer cask to borated, demineralized, and potable water while in the auxiliary building, and to the outside environment during transfer and loading operations, does not contribute to the aging of the transfer cask materials during the renewal period. The applicant stated that it is the prolonged or frequently recurring exposure to environmental conditions and stresses that must be evaluated for aging effects, such as those encountered during storage or staging before use for MPC transfers.

The applicant stated that the transfer cask is exposed to a sheltered environment in the ISFSI utility building during storage and staging before and between infrequent use for MPC transfers. The building provides protection from direct sunlight, rain, and wind. However, the air in the buildings is not conditioned by heating, ventilation, and air conditioning equipment. The transfer cask water jacket cavity is exposed to an inert argon gas environment during long-term storage in the utility building. The water jacket cavity will be exposed to an embedded environment (intermittent periods filled with water and with air) during future MPC transfers.

The staff reviewed the applicant’s description of the environment for the transfer cask and associated subcomponents and compared it to the information in the Trojan ISFSI SAR, including the general description of the system, the general description of the installation, the site characteristics, specific details of the transfer cask designs, and design drawings (construction materials and specifications), as well as the information in the LRA. Based on staff’s familiarity with the site (e.g., through inspections, weather records), the staff determined that the applicant adequately defined the materials and environments for the Trojan transfer cask and associated subcomponents.

3.3.2.2 Aging Effects and Mechanisms for the Transfer Cask During the Period of Extended Storage

In LRA Section 3.3.5, the applicant identified the following aging effects for the transfer cask that require aging management:

- loss of material due to general corrosion (carbon steel and carbon steel with coating)
- loss of material due to pitting and crevice corrosion (carbon steel, and carbon steel with coating)

The staff reviewed the applicant’s evaluation of aging mechanisms and effects for the transfer cask and associated subcomponents. In its review, the staff considered NRC guidance (NRC, 2016), the technical literature, and operating experience from nuclear and nonnuclear applications (NRC, 2014, 2010; Chopra et al., 2014; Hanson et al., 2011; Sindelar et al., 2011;

NWTRB, 2010). A summary of the staff's evaluation of the identified aging effects and mechanisms follows.

General Corrosion

The applicant identified general corrosion as an aging mechanism requiring management but noted that the transfer cask coating prevents corrosion and aids in surface decontamination. Sealing surfaces, wear surfaces, gap flush supply line inner surfaces, threaded holes, plugs, and seals are not coated as the coating could affect their ability to perform their design functions.

The staff reviewed the applicant's evaluation of the potential effects of general corrosion on carbon steel and coated carbon steel transfer cask components. The staff notes that general, or uniform, corrosion of carbon steels in moisture-bearing atmospheres is a well-known aging mechanism. The rate of material loss depends on a number of factors, including humidity, time of wetness, atmospheric contaminants, and oxidizing species (Fontana, 1986). The potential impacts of general corrosion on carbon steel are well understood. Therefore, the staff finds the applicant's determination that general corrosion is an aging mechanism requiring management to be acceptable.

Pitting and Crevice Corrosion

The applicant identified general corrosion as an aging mechanism requiring management. The staff reviewed the applicant's evaluation of the potential effects of pitting and crevice corrosion on carbon steel and coated carbon steel transfer cask subcomponents. The staff notes that moisture may be present on transfer cask external surfaces because of direct exposure to the sheltered environment during the extended license period. The staff also notes that the outside atmosphere can transport contaminants to transfer cask surfaces. Thus, the conditions necessary for pitting and crevice corrosion may be present for carbon steels (Revie, 2000) and stainless steels (Grubb et al., 2005). Therefore, the staff finds the applicant's evaluation of pitting and crevice corrosion to be acceptable because the applicant's management of these aging mechanisms is consistent with their known occurrence in contaminated, moisture-bearing environments.

Galvanic Corrosion

The applicant did not identify galvanic corrosion as a potential aging effect for transfer cask components. The staff notes that galvanic corrosion occurs when two dissimilar metals or conductive materials are in physical contact in the presence of a conducting solution. The less noble of the two materials oxidizes and can experience a loss of material. The staff notes that galvanic corrosion will not occur in the absence of an aqueous electrolyte to sustain the corrosion reaction (Baboian, 2003). The staff reviewed the Trojan ISFSI SAR, including the transfer cask drawings, and verified that there are no dissimilar metal contacts in the presence of an electrolyte during normal conditions. Therefore, because there is not an aqueous electrolyte present to sustain a corrosion reaction at the locations of dissimilar metal contacts in the transfer cask designs, the staff finds the applicant's conclusion not to manage this aging mechanism to be acceptable.

Loss of Shielding

The applicant did not identify loss of shielding as an aging effect requiring management for the lead and Holtite-A polymeric shielding materials. The staff reviewed the transfer cask drawings and confirmed that the lead and the Holtite-A are fully encased in metal and thus are not exposed to water or atmospheric contaminants that may cause degradation. Lead is well known to be resistant to corrosion in a variety of environments (Alhasan, 2005) and is not susceptible to thermal or irradiation-induced material property changes under the exposures in the transfer cask application.

In addition, the Holtite is subjected to elevated temperatures and radiation only during the relatively brief periods when the MPC is being transported from the spent fuel pool to the storage pad. The time of thermal and radiation exposure is minimal compared to the continuous exposures in which the Holtite operates in other NRC-approved Holtec storage systems. Therefore, the staff finds the applicant's conclusion, that loss of shielding is not an aging effect requiring management, to be acceptable based on the isolation of the shielding materials from the environment by the encasing steel shells and the limited thermal and radiation exposures.

Holtite-A utilizes Aluminum Trihydrate (ATH) as the principal source of hydrogen dispersed in an epoxy compound (Holtec, 2003, and Holtec 2002). A mixing machine is used to pour the Holtite slurry into the cask's cavities. The shielding material cures to solid form in-situ, ensuring that no gaps or voids will exist. Holtite-A was subjected to extensive studies of its critical characteristics (radiation resistance, physical stability at service temperature and homogeneity) during its evaluation and validation program (Holtec, 2003, and Holtec 2002), which led to its regulatory approval in the HI-STAR 100 Docket (certificate of compliance 71-9261) (NRC 2002b) and subsequent use in the manufactured HI-STAR 100 overpacks.

Thermal Aging

The applicant did not identify thermal aging as an aging effect requiring management for the transfer cask. The staff notes that the microstructures of most steels will change, given sufficient time at elevated temperature, and these changes may alter the material's strength and fracture toughness.

The staff reviewed the transfer cask materials in proximity to the MPC with respect to potential thermally induced changes in material properties. The staff notes that the transfer cask is primarily manufactured of carbon steel, ASME SA-516, Grade 70, material with a typical thermal embrittlement cycle at 350–575 degrees Celsius (C) [700–1,070 degrees Fahrenheit (F)]. These temperature thresholds of known embrittlement changes are well above the temperatures associated with the transfer cask inner shell described in the Trojan ISFSI SAR. The staff notes that this grade of material is allowed up to 350°C [700°F] (ASME B&PV Code Section II, Part D) and in agreement with the SAR. Therefore, the staff finds the applicant's conclusion not to manage thermal aging to be acceptable because the temperature exposure during MPC transport is not sufficient to cause a degradation of material properties.

Irradiation Embrittlement

The applicant did not identify irradiation embrittlement as an aging effect requiring management for the transfer cask. Neutron radiation (rather than gamma radiation) has the greatest potential to cause this phenomenon.

The staff reviewed the applicant's evaluation of the potential effects of neutron irradiation on carbon and low-alloy steels. For carbon and alloy steels, the staff notes that neutron irradiation has the potential to increase the tensile and yield strength and decrease the toughness (Nikolaev et al., 2002). Neutron fluence levels greater than 1×10^{19} n/cm^2 [6.45×10^{19} n/in.^{2}] are required to produce measurable degradation of mechanical properties (Nikolaev et al., 2002; Odette and Lucas, 2001). As discussed in Section 3.3.1.2 of this SER, the applicant estimated that the accumulated neutron fluence over 60 years for the MPC basket was 1.3×10^{15} n/cm^2 [8.4×10^{15} n/in.^{2}], which is approximately four orders of magnitude less than would be needed to begin to produce measurable degradation of mechanical properties. Further, transfer casks do not experience continuous radiation exposure. Rather, they are only exposed for brief periods during MPC transfer operations. Therefore, because the neutron exposure experienced by the transfer cask is significantly lower than that required to alter mechanical properties, the staff finds the applicant's conclusion not to manage irradiation embrittlement to be acceptable.

3.3.2.3 Proposed Aging Management Activities

The applicant developed the transfer cask AMP to address loss of material due to general corrosion, pitting corrosion, and crevice corrosion, as described above. NUREG-1927, Revision 1 states that the use of an AMP is an acceptable approach to addressing aging degradation issues; therefore, the staff finds the applicant's use of an AMP to manage the effects of loss of material of transfer cask and subcomponents to be acceptable.

3.3.3 Concrete Cask

The applicant stated that the British Nuclear Fuel Limited Fuel Solutions TranStor™ concrete cask is a reinforced concrete cylinder designed to the requirements of American Concrete Institute (ACI) 349/American National Standards Institute (ANSI) N57.9 and constructed in accordance with ACI 318, "Building Code Requirements for Structural Concrete and Commentary." The concrete cask provides structural support, shielding, and natural circulation cooling for the MPC. The concrete cask is ventilated by internal air flow paths that allow the decay heat to be removed by natural circulation around the metal MPC wall. The carbon steel cask liner is coated to promote radiant heat dissipation and to minimize corrosion. The air inlet and outlet vents are steel-lined penetrations that take nonplanar paths to minimize radiation streaming. A shield ring is provided over the MPC liner annulus to reduce the dose rate at the top of the concrete cask.

3.3.3.1 Materials and Environment

The applicant stated that the concrete cask is a reinforced concrete cylinder and its steel subcomponents are fabricated primarily from American Society for Testing and Materials (ASTM) A36, structural carbon steel, unless otherwise stated throughout this discussion. The concrete shell is fabricated from Type II Portland cement (145 pounds per cubic foot, or 4,000 pounds per square inch concrete). The concrete mix used to fabricate the concrete cask is intended to allow satisfactory, long-term temperature exposure that bounds the calculated values for the Trojan ISFSI. Vertical hook bars and horizontal ring bars form outer and inner reinforcement bar cages, constructed of ASTM A615 Grade 60 steel. A coated steel liner and bottom plate form the internal cavity of the concrete cask. Carbon steel surfaces on the cask that would otherwise be exposed to ambient conditions (such as the cask liner, lid) have been coated with Carboline Carbozinc 11 VOC, an inorganic zinc-rich coating that provides galvanic protection against corrosion. The lid is fabricated from a carbon-steel plate, which provides additional shielding to reduce the sky-shine radiation. The lid also provides a cover and seal to protect the MPC from the environment and postulated tornado missiles. The lid is bolted in place and provided with a locking wire with a lead seal. The bottom of the concrete cask is covered with a carbon-steel plate, which minimizes loss of cask concrete during a bottom drop accident. To avoid contact of dissimilar materials, ceramic tiles separate the stainless steel bottom of the MPC from the carbon steel bottom plate of the concrete cask liner.

The applicant stated that the term "exposed environment" is used for exterior surfaces that are exposed to direct sunlight, wind, rain, and other weather aspects. The Trojan ISFSI concrete casks are in the exposed environment. The exposed environment has temperature ranges equivalent to the Trojan site ambient temperature ranges, as described in the Trojan ISFSI SAR, Section 3.2. The term "sheltered environment" refers to environments that may include ambient air but are shielded from sunlight, rain, or wind exposure. One sheltered environment at the Trojan ISFSI is the annular space between the concrete cask and the MPC. The ambient air contains moisture, salinity, or other contaminants typical for the Trojan site. The temperature of the sheltered environment is within the range of the air temperature passing through the annular space. Finally, the term "embedded environment" applies to materials that are embedded or sealed inside another material. Items in this environment include the internal metal items of the concrete cask.

The applicant stated that the concrete casks are located outdoors at the Trojan ISFSI. The environment for the concrete casks is bounded by the extreme winter and summer conditions at the site. The interior components of the concrete cask (inner liner, bottom plate, inlet air assembly, outlet air assembly, shield ring, and tile) are exposed to a sheltered environment. No stainless steel surfaces in the cask, other than small nonstructural fasteners, are in direct contact with carbon steel parts.

The applicant stated that the metal components of the concrete cask that are in contact with concrete, such as the outer surfaces of the liner shell, bottom surface of the bottom plate, concrete side surfaces of the inlet and outlet air assemblies, and the rebar in the concrete, are considered to be in an embedded environment. The primary concern for embedded environments is the potential chemical reaction between the two materials. Additionally, the concrete cask is exposed to radiation from the stored MPC.

The staff reviewed the information in the Trojan ISFSI SAR, including the general description of the system, the general description of the installation, the site characteristics, specific details of the transfer cask designs, and design drawings (construction materials and specifications), as well as the information in the LRA. The staff determined that the applicant adequately defined the materials and environments for the transfer cask and associated subcomponents.

3.3.3.2 Aging Effects and Mechanisms for the Concrete Cask During the Period of Extended Storage

In LRA Section 3.4.5, the applicant evaluated a range of possible aging mechanisms and effects to identify those that could, if left unmanaged, result in a loss of component intended function. The applicant identified the following aging effects for the concrete cask that require aging management:

- loss of material due to corrosion (carbon steel and carbon steel with coating)

- loss of strength, spalling, cracking, and scaling due to corrosion of embedded reinforcing steel, freeze-thaw cycles, alkali-silica reaction, or calcium hydroxide leaching (concrete), or a combination of these

In LRA Section 3.1.6.1, the applicant summarized operating experience at Trojan to support the above conclusions. The Trojan ISFSI SAR requires a concrete cask interior inspection every 5 years. The first three inspections were performed in 2008, 2013, and 2018 on the concrete cask storing the first MPC loaded at Trojan. The inspections did not identify any degradation mechanisms affecting system performance that were not identified in the SAR.

The staff reviewed these degradation mechanisms against those described in the recommended example AMP for reinforced concrete structures in Appendix B to NUREG-1927, Revision 1. A summary of the staff's evaluation of the identified aging mechanisms follows.

Freeze-Thaw

The applicant identified freeze-thaw cycles as a potential aging mechanism requiring management for the concrete cask. Because water expands when freezing, fully or partially saturated concrete will experience internal stresses from the expanding ice that can cause concrete cracking or scaling (NRC, 1995, 2012). The applicant indicated that degradation of the concrete cask, caused by this mechanism, could affect its ability to provide the following: MPC support, radiation shielding, missile shielding, and/or a path for heat transfer. The applicant states that regional temperatures are for the most part, mild throughout the year. For example, the average temperature for the summer season is 18°C [65°F] and for the winter season 4°C [40°F] and there have been no major hail storms within a 97-km [60-mile] radius of the site. The applicant also stated that Trojan operating experience has not noted any cracking due to freeze-thaw cycles. The staff reviewed the applicant's evaluation of the potential effects of freeze-thaw for the concrete cask in the outdoor atmosphere environment. Therefore, the staff finds the applicant's evaluation of freeze-thaw to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in water-saturated concrete.

Reaction with Aggregates (Alkali-Silica Reaction)

The applicant identified alkali-silica reaction as a potential aging mechanism requiring management for the concrete cask. The applicant indicated that degradation of the concrete cask, caused by this mechanism too, could affect its ability to provide the following: MPC support, radiation shielding, missile shielding, and/or a path for heat transfer. The staff notes that reactions can occur between the concrete aggregate and alkaline components within the cement or from outside sources such as deicing salts and ground water.sources of moisture. The reaction products (e.g., alkali-silica gel in the case of alkali-silica reactions) can swell with the absorption of water, exerting expansive pressures within the concrete, leading to cracking (ACI, 2008). Such degradation has occurred in nuclear power plant concrete structures. Therefore, the staff finds the applicant's assessment evaluation of alkali-silica reaction to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in water-saturated concrete

Leaching of Calcium Hydroxide

The applicant identified leaching of calcium hydroxide as a potential aging mechanism and noted this could lead to a change in the concrete material properties. The applicant indicated that inspecting to the level of detail in the concrete cask AMP ensures that degradation will be detected before it impairs the ability of the concrete cask to perform its intended functions. The staff reviewed the applicant's evaluation of the potential effects of leaching of calcium hydroxide for the concrete cask in the outdoor atmosphere environment and notes that a flux of water through a concrete surface can result in the removal, or leaching, of calcium hydroxide (Hanson et al., 2011). This can cause a loss of concrete strength, an increase in the concrete porosity and permeability, and a reduction in pH. Therefore, the staff finds the applicant's evaluation of leaching of calcium hydroxide to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in concrete foundation structures exposed to a constant or intermittent flow of water.

Corrosion of Reinforcing Steel

The applicant identified corrosion of reinforcing steel as a potential aging mechanism leading to concrete degradation. The applicant noted that the Trojan ISFSI is located where the ISFSI components are not exposed to significant concentrations of air pollutants or close to roadways using deicers, or close to saltwater, both containing chlorides. The applicant indicated that though concrete degradation due to chloride corrosion of reinforcing steel is not expected, it has been included as a mechanism of concrete shell degradation due to corrosion of the concrete cask reinforcement bars. The staff notes that chloride attack of the reinforcing steels within concrete structures is a well-known phenomenon (Cheung et al., 2009). The alkaline environment of the concrete typically results in a metal-adherent oxide film on the reinforcing steel bar surface, which passivates the steel. However, chloride ions can break down the passive layer, triggering corrosion that leads to cracking and spalling of the concrete. Therefore, the staff finds the applicant's evaluation of concrete degradation by corrosion of reinforcing steel to be acceptable because the applicant's management of this aging mechanism is consistent with its known occurrence in moisture-bearing environments.

Corrosion of Steel Structures (Other than Concrete Reinforcing Steel)

The applicant identified corrosion as an aging mechanism requiring management for the carbon steel subcomponents in the concrete cask. The applicant indicated that degradation could affect the ability of the concrete steel structures to provide support to the MPCs, to provide radiation shielding, to provide missile shielding, or to provide a path for heat transfer. The staff notes that moisture may be present on steel surfaces as a result of exposure to the sheltered and outside environments during the extended license period. Thus, the conditions necessary for general pitting and crevice corrosion may be present for carbon steels. Therefore, the staff finds the applicant's evaluation of corrosion to be acceptable because the applicant's management of this aging mechanism is consistent with its known occurrence in moisture-bearing environments.

Irradiation Embrittlement

The applicant did not identify irradiation embrittlement as an aging effect requiring management for the concrete cask. The applicant provided a radiation effects analysis in LRA Section 3.8.3. The applicant stated that neutron radiation has little effect on shielding or thermal properties of concrete, but it can impact its structural properties starting at levels as low as 1×10^{18} n/cm^2. The applicant indicated further that gamma radiation doses as low as 1×10^7 Gy [1×10^9 rads] may affect the structural properties of concrete. The applicant stated that both levels for neutron and gamma radiation are well above the calculated value for the Trojan concrete casks over

60 years, as described in LRA Table 3-8, and, therefore, there is no impact to the structural properties of the concrete from radiation.

The staff reviewed the applicant's analysis of the potential effects of cumulative neutron and gamma irradiation on concrete in LRA Section 3.8.3. The staff notes that ACI 349.3R-02, "Evaluation of Existing Nuclear Safety-Related Concrete Structures," states that the critical, cumulative neutron fluence and gamma dose levels from historical testing results are 1×10^{25} n/square meter (m^2) (1×10^{21} n/cm^2) and 1×10^{8} Gy [1×10^{10} rad], respectively, and a neutron fluence limit of 1×10^{17} n/m^2 (1×10^{13} n/cm^2) is recommended for preventing any lifetime radiation-related degradation. Thus, the expected gamma radiation dose of 1×10^{8} rads is below the critical gamma dose level in ACI 349.3R, and the estimated neutron fluence is orders of magnitude less than the critical, cumulative fluence level required for concrete degradation from historical testing identified in ACI 349.3R.

Therefore, the staff determined that aging of the concrete from radiation exposure would not result in significant degradation of the concrete shielding or mechanical properties because both the gamma radiation dose and the neutron fluence are significantly below those required for radiation-induced degradation. The staff finds the applicant's radiation analysis adequate to evaluate the aging effects resulting from irradiation of the concrete and demonstrates that the aging effect will not result in a loss of the concrete cask functions during the period of extended operation.

Aggressive Chemical Attack

The applicant did not evaluate the potential effects of aggressive chemical attack of the concrete cask. The staff notes that, when aggressive ions or acids intrude into the pore network of the concrete, the consequent chemical attack can cause several degradation phenomena. The aggressive chemical attack typically originates from an external source of sulfate (Poe, 1998; Nuclear Waste Technical Review Board (NWTRB), 2010) or magnesium ions as well as from acidic environmental conditions (Gutt and Harrison, 1997; Mehta, 1986). Depending on the type of aggressive chemical, the degradation of concrete can manifest in the form of cracking, loss of strength, concrete spalling and scaling, and reduction of pH.

Although the applicant did not specifically address this aging mechanism, the staff notes that the applicant can identify the aging effects associated with aggressive chemical attack (e.g., cracking, loss of strength, loss of material) when it conducts the inspections for the other aging mechanisms (e.g., freeze-thaw, reaction with aggregates). As a result, the staff finds the applicant's decision not to address this specific aging mechanism to be acceptable because the applicant can identify chemical attack during the planned inspections for other mechanisms in the Concrete Cask AMP discussed below.

Microbiological Degradation

The applicant did not evaluate the potential effects of microbiological degradation of the concrete cask. The staff notes that microbiological degradation can occur in the presence of moisture, causing an increase in concrete porosity/permeability and loss of material by spalling or scaling; however, the staff has determined that this is not a credible aging effect for the concrete cask. First, the conditions for moisture exposure of the concrete cask are intermittent, and microbiological degradation is typically associated with continuous moisture exposure. In addition, no industry operating experience has been identified with concrete degradation as a result of this mechanism in an aboveground environment. Therefore, the staff finds the applicant's decision not to manage this aging mechanism to be acceptable.

3.3.3.3 Proposed Aging Management Activities

The applicant developed the Concrete Cask AMP to manage loss of material due to corrosion to carbon steel and coated carbon steel and loss of concrete strength, spalling, cracking, and scaling due to corrosion of embedded reinforcing steel, freeze-thaw cycles, alkali-silica reaction, or calcium hydroxide leaching, or a combination of these, as described above. NUREG-1927, Revision 1, states that the use of an AMP is an acceptable approach to addressing these concrete aging degradation issues; therefore, the staff finds the applicant's use of an AMP to manage the effects of loss of material of an MPC and subcomponents to be acceptable.

3.3.4 Spent Fuel Assemblies

The applicant stated that the intended functions of the fuel assemblies include criticality control, radiation shielding, confinement, and structural integrity. The geometry of the fuel assembly is a factor in the criticality model. The fuel rod, or cladding, contains the fuel pellets and provides a confinement barrier. Its structural integrity is necessary to maintain a favorable geometry and to support potential retrieval. After fuel loading and MPC drying, the fuel assemblies are not moderated, assuring subcriticality during subsequent operations and configurations. The fuel assembly principal function during dry storage is to maintain proper geometry and position of radioactive material through confinement.

3.3.4.1 Materials and Environment

In LRA Section 2.2.1.4, the applicant stated that the Trojan storage system is designed to accommodate up to 24 PWR fuel assemblies, and, depending on the MPC design, these assemblies may be classified as damaged fuel or fuel debris and stored in damaged fuel containers. The PWR fuel is a 17×17 design by Westinghouse and Babcock & Wilcox. Table 3.1-1 of the Trojan ISFSI SAR describes the detailed characteristics of the fuel. The maximum initial enrichment is limited to 3.09 weight percent uranium-235, and the maximum assembly average burnup level is 42,000 megawatt-days per metric ton uranium. The maximum decay heat per assembly is 0.725 kilowatts.

The applicant stated that the fuel assembly subcomponents included in the AMR are made from zirconium alloys (trade name Zircaloy), stainless steel, or Inconel materials, or any combination of these. LRA Table 3-4 identifies the material type of each fuel assembly subcomponent (i.e., fuel cladding, spacer grid assembly, upper and lower end fitting, and guide tubes).

The applicant stated that the fuel assembly environment refers to the internal MPC atmosphere. The MPC is dried and backfilled with helium gas, according to the Trojan ISFSI technical specifications. During initial cask loading, the long-term temperature of the fuel cladding was limited to 342°C [647°F], with short-term temperature limits of 570°C [1058°F]. The environment for each subcomponent of the fuel assembly is given in LRA Table 3-4.

The staff reviewed the applicant's description of the materials and environments for the spent fuel assemblies and associated subcomponents. The staff also reviewed information in the Trojan ISFSI SAR, including the general description of the system, the general description of the installation, the site characteristics, specific details of the fuel assembly designs, and design drawings (construction materials and specifications), as well as the information in the LRA. The staff determined that the applicant adequately defined the materials and environments for the Trojan fuel assemblies and associated subcomponents.

3.3.4.2 Aging Effects and Mechanisms for the Spent Fuel Assemblies During the Period of Extended Storage

In LRA Section 3.1.6.2, the applicant stated that the fuel assemblies are in an inert gas environment, and, therefore, there are very few credible aging effects for the fuel assembly subcomponents. Additionally, the Trojan ISFSI does not store any high burnup fuel, and, therefore, the cladding is not susceptible to hydrogen embrittlement and radial hydride formation aging mechanisms, as discussed in NRC Interim Staff Guidance (ISG)-11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel," dated November 17, 2003. However, the applicant stated that a TLAA for the integrity of the fuel cladding is required, as discussed in LRA Appendix B, Section B.4.

The staff reviewed the applicant's conclusion that identified no aging mechanisms or effects for the spent fuel assemblies. The staff based its review on NUREG-1927, Revision 1, and ISG-11, Revision 3, which state that low burnup fuel (less than 45 gigawatt-days per metric ton uranium) is expected to maintain its integrity in the period of extended operation, provided that the maximum cladding temperature limits cited in ISG-11 are followed. The discussion below summarizes the basis for that position, considering the aging mechanisms that could have the potential to affect the intended functions of fuel assemblies.

<u>Creep</u>

The applicant indicated that potential degradation mechanisms identified for the spent nuclear fuel assemblies included cladding creep. Creep is the time-dependent deformation that takes place at an elevated temperature and constant stress. The applicant noted that the rate of creep in fuel cladding is a function of the cladding temperature and hoop stress; however, creep will not cause gross rupture if the cladding temperatures do not exceed 400°C [752°F] during loading or storage. The applicant added, cladding creep is not likely to be a significant effect over the period of extended storage as cladding temperatures occurring after 20 years in dry storage are relatively low and continuing to decrease.

As described in ISG-11, relatively high temperatures, differential pressures, and corresponding hoop stress on the cladding will result in permanent creep deformation of the cladding over time. Excessive creep of the cladding during dry storage could lead to thinning, hairline cracks, or gross ruptures. The rate of creep in fuel cladding is a function of the cladding temperature and hoop stress, with creep exceeding 1.0-percent strain potentially causing gross rupture.

In ISG-11, the staff concluded that creep is not expected to lead to gross ruptures in low burnup spent fuel assemblies, provided that the maximum cladding temperature limits cited in the ISG are followed. The staff notes that the Trojan ISFSI SAR states that the maximum predicted fuel cladding allowable temperature limit for normal steady-state conditions was determined to be 342°C [647°F] for a Westinghouse 17 x 17 fuel assembly and a minimum cooling time of nine years. The applicant indicated that the 342°C [647°F] limit was determined to bound the B&W 17 x 17 fuel assemblies, which will also be stored at the Trojan ISFSI. The applicant noted that a short-term temperature limit of 570°C [1058°F] is established for off-normal and accident limits. the staff notes that 342°C [647°F] is below the allowable fuel cladding temperature limit of 400°C [752°F] cited in ISG-11. In addition, the data and analyses in ISG-11 demonstrate that (1) deformation caused by creep will proceed slowly over time and will decrease the rod pressure, (2) the decreasing cladding temperature with time also decreases the hoop stress, and this too will slow the creep rate, and (3) in the unlikely event that a breach of the cladding due to creep occurs, it is believed that this will not result in gross rupture

NUREG/CR-6745, "Dry Cask Storage Characterization Project—Phase 1: CASTOR V/21 Cask Opening and Examination," issued September 2001 (Bare and Torgerson, 2001), and NUREG/CR-6831, "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage," issued September 2003 (Einziger et al., 2003), provide the experimental confirmatory basis, which states that creep will not impact the ability of low-burnup fuel to remain in its analyzed configuration during the period of extended operation. This research demonstrated that low burnup fuel cladding and other cask internals had no deleterious effects after 15 years of storage. As a result, the staff finds the applicant's decision not to manage creep to be acceptable.

Hydride Reorientation

The applicant indicated that potential degradation mechanisms identified for the spent nuclear fuel assemblies included hydride reorientation within the cladding. The applicant noted that hydride reorientation can occur in cladding during high temperature, high hoop stress scenarios such as vacuum drying, adversely affecting material properties. However significant hydride re-orientation is not expected to occur in low burnup fuel assemblies. Further, Section 4.2.6.1 of the Trojan ISFSI SAR limits fuel cladding temperatures to approximately 342°C [647°F] for normal conditions and 570°C [1058°F] for off-normal and accident limits.

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

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

Oxidation

The applicant indicated that potential degradation mechanisms identified for the spent nuclear fuel assemblies included oxidation. The applicant notes that oxidation of the Zircaloy fuel cladding and the irradiated fuel pellets can occur if the fuel is exposed to air, causing the pellets to swell and potentially impact the fuel cladding. In addition, excessive oxidation of the fuel cladding, combined with internal stress, could cause a fuel cladding breach. The applicant cited that for low-burnup fuel assemblies, such as those stored in the Trojan ISFSI, NUREG/CR-6831 (Reference 3.1.3) suggests that degradation of the fuel cladding will not occur during initial storage and will not occur during extended storage if the inert atmosphere is maintained. The applicant concluded that the integrity of the MPC containment boundary maintains the inert environment and prevents oxidation of the fuel. The applicant decided that oxidation is therefore, not considered a credible degradation mechanism.

The staff determined that no aging management activity is necessary for the oxidation of Zircaloy cladding because the MPC loading procedures required the use of an inert environment that will prevent the oxidation of the Zircaloy cladding and prevent oxidation of any fuel pellet surface exposed through pinholes or hairline cracks in the Zircaloy cladding. The staff's conclusion is also based upon available data that show that even if the inert environment is not maintained the oxidation rate of the Zircaloy cladding and the fuel pellets are strongly temperature dependent. Because the temperature of the cladding and the fuel will decrease with time in storage, significant oxidation of the fuel and the cladding will not occur even if the inert environment is not fully maintained in the period of extended operation. As a result, the staff finds the applicant's decision not to manage oxidation to be acceptable.

<u>Corrosion</u>

The applicant identified corrosion as a potential degradation mechanisms for the spent nuclear fuel assemblies . The applicant notes that corrosion of the fuel assembly components can only occur if they are exposed to moisture during the storage period. Residual water within the MPC is limited to very low levels through the vacuum drying process required in the technical specifications. The applicant stated that, because of the drying process, no significant amount of moisture will be within the MPC cavity during extended storage. Additionally, water ingress is considered not to be credible because of the MPC confinement boundary, which is managed for aging with the MPC AMP, as described in Section 3.5.1 below. Thus, the applicant concluded that corrosion is not a credible degradation mechanism of the fuel assembly subcomponents.

The staff reviewed the applicant's assessment of corrosion degradation mechanisms for the spent fuel assemblies by reviewing the corrosion resistance of the Zircaloy material from which the spent fuel cladding and other fuel assembly component are made. Zircaloy alloys form protective passivating oxide films. The staff notes that as long as the protective oxide films are maintained, the corrosion rate of these alloys is very low. However, localized corrosion of these alloys can occur if the passive oxide film is damaged or cannot be maintained. The staff concludes that no aging management activities are necessary for the corrosion degradation of the spent fuel assembly subcomponents comprised of Zircaloy material because the loading procedures require the removal of water and the use of an inert environment in the MPC cavity, both of which will significantly decrease the potential for corrosion of the spent fuel assembly materials. The staff's conclusion is also based upon the fact that any residual water that is not removed in the drying process will have concentrations of reduced sulfur species and halides such as fluoride and chloride that will be insufficient to damage the protective oxide films on the Zircaloy material. As a result, the staff finds the applicant's decision not to manage corrosion to be acceptable.

3.3.4.3 Proposed Aging Management Activities

The applicant did not identify any aging effects and mechanisms for low-burnup fuel in the helium environment, as described above. Section 3.4 of this SER documents the evaluation of a TLAA for fuel cladding integrity.

3.3.5 ISFSI Pads (Storage and Service Pads)

The applicant stated that the reinforced concrete storage pad on which the concrete casks rest (storage pad) and the adjacent reinforced concrete service pad that supports cask movement operations (service pad) are at-grade structures. The concrete pads are located on approximately 61 centimeters [24 inches] of engineered fill founded on competent rock.

The applicant stated that the ISFSI pads meet the requirements of ACI standard 318 (ACI, 1982) and are capable of supporting the loads associated with the array of concrete casks and transfer equipment. The ISFSI pads are classified as not ITS. The reinforced concrete ISFSI pads provide a supporting surface for the concrete casks and the transportation cask. The ISFSI pads also provide a smooth, level surface to allow operation of the air pad system.

3.3.5.1 Materials and Environments

In LRA Section 3.7, the applicant stated that the ISFSI pads are constructed of reinforced concrete founded on engineered fill placed on competent bedrock. The pad includes embedded, rigid electrical conduits and connectors made of galvanized steel for the concrete cask temperature monitoring system.

The applicant stated that the ISFSI pad is located outdoors at the Trojan ISFSI site. The environment for the ISFSI pad is bounded by the extreme winter and summer conditions (see Table 2.7-1 in the Trojan ISFSI SAR). The ISFSI pad is exposed to weather-related effects, including sunlight, wind, rain, snow, ice, and ambient air, and is thus considered to be in an exposed environment. The only exceptions are the materials (reinforcement and rigid conduits) that are embedded in the ISFSI pad.

The staff reviewed the applicant's description of the materials and environments for the ISFSI pad and associated subcomponents. The staff also reviewed the general description of the system, the general description of the installation, the site characteristics, specific details of the pad design, and design drawings (construction materials and specifications), as well as the information in the LRA. The staff determined that the applicant adequately defined the materials and environments for the ISFSI pad and associated subcomponents.

3.3.5.2 Aging Effects and Mechanisms for the ISFSI Pads (Storage and Service) During the Period of Extended Storage

In LRA Section 3.7.5, the applicant stated that, based on a review of the role played by the ISFSI pads in supporting retrievability and the environments experienced during the period of extended storage at the ISFSI, no aging effects require management. The applicant acknowledged that potential aging effects include concrete spalling, cracking, and scaling. However, the applicant concluded that these aging effects would not prevent the ISFSI pads from supporting retrievability using standard methods (air pads and sheet metal to cover surface defects) to move a Trojan storage system from its position on the ISFSI pads to a position underneath the transfer station.

In its review of the applicant's determination that no aging effects are required to be managed, the staff noted that an additional aging effect that could produce gross vertical offsets in the ISFSI pads would be differential settlement, which is caused by the uneven deformation of the support soil. However, the ISFSI pads are placed on 61 cm [24 inches] of compacted engineered fill, which, in turn, is placed on top of bedrock. As a result, because the ISFSI pads are on a foundation of compacted fill and bedrock, which is considered to prevent gross pad settlement that is considered capable of interfering with the cask retrieval system, the staff finds the applicant's determination not to manage aging of the ISFSI pads to be acceptable. The staff also notes that, for more minor concrete degradation, the applicant has the ability to span pad defects with sheet metal and, if necessary, perform any concrete repairs to provide the sheet metal with a competent supporting surface.

3.3.5.3 Proposed Aging Management Activities

The applicant did not identify any aging effects and mechanisms for the concrete pad, as described above; therefore, there are no aging management activities.

3.3.6 Transfer Station

The applicant stated that the transfer station is utilized for MPC transfer operations at the ISFSI site. The applicant stated that the transfer station is ITS, is designed for seismic requirements, and has a stationary lateral and vertical restraint. The transfer station allows a concrete cask or transportation cask to be positioned under the transfer cask for MPC transfers. The subcomponents are the transfer station pad (which supports the transfer station), the steel structure of the transfer station, and the foam impact limiter, which is encased in a thin stainless steel shell and includes a thick top plate. The role of the impact limiter is to provide defense-in-depth protection of the MPC to minimize the consequences should the MPC drop in an accident.

3.3.6.1 Materials and Environment

The applicant stated that the structural components of the transfer station are fabricated from structural carbon steel and carbon steel pipe (e.g., ASTM A36 and A53, respectively). The transfer station pad is made of 21 MPa [3,000 psi] concrete reinforced with ASTM A615 Grade 60 carbon steel bar. The impact limiter, embedded in the transfer station foundation mat, includes a 7.6 cm [3 inch-] thick carbon steel top plate, impact (polyurethane) foam, and a surrounding thin stainless steel shell. Table 3-5 in the LRA identifies the material type of each transfer station subcomponent.

The applicant stated that the transfer station is located outdoors at the Trojan ISFSI site. The environment for the transfer station is bounded by the extreme winter and summer conditions (see Table 2.7-1 in the Trojan ISFSI SAR). The entirety of the transfer station is exposed to weather-related effects, including sunlight, wind, rain, snow, ice, and ambient air, and is thus considered to be in an exposed environment. The only exceptions are the impact limiter, which is stored inside a building on site, and the support footings, which are embedded in the transfer station pad.

The applicant stated that the transfer station is not exposed to any significant radiation levels during the period of extended storage, as the MPC, transfer cask, and concrete cask are only present at the transfer station during the short time of moving the MPC between the transfer cask, concrete cask, and a transportation cask.

The staff reviewed the applicant's description of the materials and environments for the transfer station and associated subcomponents. The staff also reviewed information in the Trojan ISFSI SAR, including the general description of the system, the general description of the installation, the site characteristics, specific details of the transfer station design, and design drawings (construction materials and specifications), as well as the information in the LRA. The staff determined that the applicant adequately defined the materials and environments for the Trojan transfer station and associated subcomponents.

3.3.6.2 Aging Effects and Mechanisms for the Transfer Station During the Period of Extended Storage

The applicant stated that the transfer station is only used for the short duration of MPC transfer between the three components that may house the MPC: the transfer cask that is used to support the MPC during transfer station operations, the concrete cask in which the MPC is stored, and the transportation cask that will ultimately be used to move the MPC off site. Based on a review of the transfer station materials of construction and the environments experienced during the period of extended storage at the ISFSI, the transfer station structure has the following aging effect requiring management:

- loss of material due to corrosion (carbon steel with coating)

The transfer station pad concrete has the following aging effects requiring management:

- loss of strength, spalling, cracking, and scaling due to freeze-thaw cycles, alkali-silica reaction, and calcium hydroxide leaching (concrete)
- embedded reinforcing steel corrosion (carbon steel with and without coating)
- cracking and distortion due to differential movement (concrete)

The impact limiter top plate has the following aging effect requiring management:

- loss of material due to corrosion (carbon steel with coating)

The impact limiter foam has the following aging effect requiring management:

- change in dynamic crush strength due to chemical changes

The staff reviewed these degradation mechanisms against those described in the recommended example AMP for reinforced concrete structures in NUREG-1927, Revision 1, Appendix B. A summary of the staff's evaluation of the identified aging mechanisms follows.

<u>Corrosion of Steel Structures</u>

The applicant identified corrosion as an aging mechanism requiring management for the carbon steel subcomponents in the transfer station. The applicant indicated that degradation of the transfer station structural steel, caused by this mechanism, could affect the ability to provide lateral and vertical support of the loaded transfer cask during transfer operations. The staff notes that moisture may be present on exposed steel surfaces due to exposure to the sheltered and outside environments during the extended license period. Thus, the conditions necessary for general, pitting, and crevice corrosion may be present for carbon steels. Therefore, the staff finds the applicant's evaluation of corrosion to be acceptable because the applicant's management of this aging mechanism is consistent with its known occurrence in moisture-bearing environments.

Freeze-Thaw

The applicant identified freeze-thaw cycles as a potential aging mechanism requiring management for the transfer station concrete pad. The applicant indicated that degradation of the transfer station concrete pad, caused by this mechanism, could affect its ability to perform it's intended functions such as successful transfer of the MPC. However, the applicant stated that the Trojan operating experience has not noted any cracking due to freeze-thaw cycles. The applicant states that regional temperatures are for the most part, mild throughout the year. For example, the average temperature for the summer season is 18°C [65°F] and for the winter season 4.4°C [40°F] and there have been no major hail storms within a 97-kilometer [60-mile] radius of the site. The staff reviewed the applicant's evaluation of the potential effects of freeze-thaw for the transfer station concrete pad in the outdoor atmosphere environment and notes that, because water expands when freezing, fully or partially saturated concrete will experience internal stresses from the expanding ice that can cause concrete cracking or scaling (NRC, 1995, 2012). Therefore, the staff finds the applicant's evaluation of freeze-thaw to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in water-saturated concrete.

Reaction with Aggregates (Alkali-Silica Reaction)

The applicant identified alkali-silica reaction as a potential aging mechanism requiring management for the concrete cask. The applicant indicated that degradation of the transfer station concrete pad, also caused by this mechanism , could affect its ability to perform intended functions such as successful transfer of the MPC. The staff notes that reactions can occur between the concrete aggregate and alkaline components within the cement or from outside sources such as deicing salts and sources of moisture. The reaction products (e.g., alkali-silica gel in the case of alkali-silica reactions) can swell with the absorption of water, exerting expansive pressures within the concrete and leading to cracking (ACI, 2008). Such degradation has been identified in nuclear power plant concrete structures. Therefore, the staff finds the applicant's assessment evaluation of alkali-silica reaction to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in water-saturated concrete.

Leaching of Calcium Hydroxide

The applicant identified leaching of calcium hydroxide as a potential aging mechanism and noted this could lead to a change in the concrete material properties. The applicant indicated that inspecting for this mechanism ensures that degradation will be detected before it impairs the ability of the transfer station concrete pad to perform its intended functions. The staff notes that a flux of water through a concrete surface can result in the removal, or leaching, of calcium hydroxide (Hanson et al., 2011). This can cause a loss of concrete strength, an increase in the concrete porosity and permeability, and a reduction in pH. Therefore, the staff finds the applicant's evaluation of leaching of calcium hydroxide to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in concrete foundation structures exposed to a constant or intermittent flow of water.

Corrosion of Concrete Reinforcing Steel

The applicant identified corrosion of reinforcing steel within the concrete as a potential aging mechanism leading to concrete degradation. The applicant noted that the Trojan ISFSI is located where the ISFSI components are not exposed to significant concentrations of air pollutants or close to roadways using deicers, or close to saltwater, both containing chlorides. The staff notes that chloride attack of the reinforcing steels within concrete structures is a well-known phenomenon (Cheung et al., 2009). In addition, the alkaline environment of the concrete typically results in a metal-adherent oxide film on the reinforcing steel bar surface, which passivates the steel. Chloride ions can break down the passive layer, triggering corrosion that leads to cracking and spalling of the concrete. Therefore, the staff finds the applicant's evaluation of concrete degradation by corrosion of reinforcing steel to be acceptable because the applicant's management of this aging mechanism is consistent with its known occurrence in moisture-bearing environments.

Differential Movement

The staff reviewed the applicant's evaluation of the potential effects of differential movement for the transfer station concrete pad in the outdoor atmosphere and soil environments. The applicant indicated that inspecting the level of detail required by the AMP for defects and irregularities ensures that degradation will be detected and addressed before it impairs the ability of the transfer station concrete pad to perform its intended functions. The staff notes that differential movement is the uneven deformation of the supporting foundation soil (Das, 1999; NAVFAC, 1986). In addition, its occurrence depends on the type of soil, thickness of soil layers, water-table level, depth of the foundation material below the ground surface, liquefaction during seismic events, and the mechanical loading. Operating experience has shown that differential movement has occurred in nuclear power plant concrete structures (NRC, 1995). The applicant also identified settlement as a potential aging mechanism and noted this could lead to cracking of the concrete. The staff notes that differential movement could affect the transfer station's ability to successfully transfer the MPC. Therefore, the staff finds the applicant's evaluation of differential movement to be acceptable because the applicant's determination that this aging mechanism requires management is consistent with its known occurrence in concrete foundation structures.

Change in Material Properties (Crush Strength of Impact Limiter Foam)

The applicant identified a change in crush properties as an aging mechanism requiring management for the impact limiter foam due to changes in dynamic crush strength due to chemical changes. The applicant indicated that degradation of the transfer station impact limiter, caused by this mechanism, could affect the ability of the transfer station impact limiter to mitigate a possible drop during MPC transfer. The staff notes that the transfer station impact limiter includes a 7.6-cm [3-inch] thick carbon steel top plate and impact foam surrounded by a thin stainless steel shell. In addition, the foam is constructed of General Plastics FR-3708 polyurethane. The staff notes that polyurethane can be subject to a change in properties (e.g., shrinkage, embrittlement), particularly when exposed to elevated temperatures, radiation, and ultraviolet light from chemical changes. Although the foam is not normally exposed to these environments, the staff finds the applicant's evaluation to be acceptable because the management of this aging mechanism will ensure that the foam will continue to be capable of performing its intended function during the period of extended operation.

Aggressive Chemical Attack

The applicant did not evaluate the potential effects of aggressive chemical attack of the concrete transfer station concrete pad. When aggressive ions or acids intrude into the pore network of the concrete, the consequent chemical attack can cause several degradation phenomena. The aggressive chemical attack typically originates from an external source of sulfate (Poe, 1998; NWTRB, 2010) or magnesium ions, as well as acidic environmental conditions (Gutt and Harrison, 1997; Mehta, 1986). Depending on the type of aggressive chemical, the degradation of concrete can manifest in the form of cracking, loss of strength, concrete spalling and scaling, and reduction of pH.

Although the applicant did not specifically address this aging mechanism, the staff notes that the applicant can identify aging effects associated with aggressive chemical attack (e.g., cracking, loss of strength, loss of material) when it conducts inspections for the other aging mechanisms (e.g., freeze-thaw, reaction with aggregates). As a result, because the chemical attack nevertheless can be identified during the planned inspections for other mechanisms in the Concrete Cask AMP discussed below, the staff finds the applicant's decision not to address this specific aging mechanism to be acceptable.

Microbiological Degradation

The applicant did not evaluate the potential effects of microbiological degradation of the concrete transfer station pad. Microbiological degradation can occur in the presence of moisture; however, the conditions for moisture exposure of the transfer station pad are intermittent. Also, there is no industry operating experience with concrete degradation as a result of this mechanism in an aboveground environment. Therefore, the staff finds the applicant's decision not to manage this aging mechanism to be acceptable.

3.3.6.3 Proposed Aging Management Activities

The applicant stated that, based on the AMR of the transfer station subcomponents documented in LRA Table 3-5, the Transfer Station AMP provides the aging management activities required for the transfer station, transfer station pad, and the impact limiter's top plate and foam. NUREG-1927, Revision 1, states that the use of an AMP is an acceptable approach to addressing aging degradation issues; therefore, the staff find the applicant's use of an AMP to manage the effects of loss of material of the transfer station and subcomponents to be acceptable.

3.3.7 Evaluation Findings

The staff reviewed the AMR in the renewal application and supplemental documentation. The NRC staff performed its review following the guidance in NUREG-1927, Revision 1, and relevant ISGs. Based on its review, the staff determined that the applicant provided sufficient information with adequate details to support the LRA with the following findings:

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 summarized the information in the application.

F3.2 The applicant's AMR process is comprehensive in identifying all pertinent aging mechanisms and effects applicable to the in-scope SSCs, and the applicant summarized the information in the renewal application with changes to be incorporated into the Trojan ISFSI SAR.

3.4 Time-Limited Aging Analyses

3.4.1 Time-Limited Aging Analysis Identification Criteria

In LRA Section 3.8.1, the applicant stated that it used the following criteria defined in NUREG-1927, Revision 1, to identify the analyses that can be considered a TLAA for existing SSCs with a time-dependent operating life:

- involves ITS SSCs within the scope of license or Certificate of Compliance renewal
- considers the effects of aging
- involves time-limited assumptions defined by the current operating term
- licensee determined it to be relevant in making a safety determination
- involves conclusions or provides the basis for conclusions related to the capability of the SSCs to perform their intended safety functions
- is contained or incorporated by reference in the design basis

The applicant stated that it reviewed the design documents for the Trojan ISFSI against the TLAA identification criteria discussed in LRA Section 3.8.1. These included the license, SER, technical specifications, and site-specific calculations and evaluations. The applicant identified the following four TLAAs as the time-based calculations that exist in the current licensing basis; these calculations required further evaluation and disposition for the period of extended operation:

(1) MPC fatigue evaluation
(2) neutron absorber depletion evaluation
(3) transfer cask fatigue evaluation
(4) fuel cladding integrity evaluation

LRA Appendix B describes each of those TLAAs.

Based on its review of the design-bases documents, the staff confirmed that the applicant identified all calculations and analyses meeting all six criteria in 10 CFR 72.3; therefore, the staff concludes that the applicant adequately identified all TLAAs. The staff's review of the identified TLAAs follows.

B.1 MPC Fatigue Evaluation

LRA Appendix B.1 to the LRA noted the discussion of MPC fatigue evaluation in Section 4.2.5.3.6 of the Trojan ISFSI SAR. In performing a TLAA for a 60-year MPC service life, the evaluation continued to recognize the current licensing bases of the low-stress, high-cycle conditions of ambient temperature and sunlight cycling during normal dry storage conditions. However, the applicant also considered it possible that repeated lifting of the MPC might cause increased stresses and therefore lower the fatigue life of the MPC.

To determine the maximum allowable number of lifting and handling cycles for the MPC components, the applicant selected lifting points for the MPC for evaluation. The evaluation considered stress allowables associated with NUREG-0612, “Control of Heavy Loads at Nuclear Power Plants: Resolution of Generic Technical Activity A-36,” issued July 1980 (NRC, 1980), ANSI N14.6, “American National Standard for Special Lifting Devices for Shipping Containers Weighing 10000 pounds (4500 kg) or More for Nuclear Materials,” and NRC 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). As detailed in LRA Reference B.1.1, “HI-2012787R22, Structural Calculation Package for MPC,” the applicant also considered stress allowables from the ASME Boiler and Pressure Vessel Code (ASME Code), Section III, “Rules for Construction of Nuclear Facility Components,” Subsection NB, for other MPC components. The fatigue life evaluation resulted in 6,750 cycles as the allowable number of lifting without incurring fatigue failure to the MPC.

The applicant noted that lifts of MPCs are only expected to be necessary for offsite transport, and each MPC is expected to undergo less than a few lifts, which is much below the allowable number of lifting cycles. The staff reviewed the applicant’s assessment of the expected number of the MPC lifts in Reference B.1.1 and determined that the evaluation was done appropriately and results to be acceptable. Therefore, the staff finds the TLAA evaluation acceptable for demonstrating adequate MPC fatigue performance during the extended storage period.

B.2 Neutron Absorber Depletion Evaluation

The applicant performed a TLAA for the potential loss of B-10 in the neutron poison plates inside the MPC and its impact on the criticality safety of the Trojan ISFSI system during the period of extended operation. The applicant presented its TLAA for B-10 loss in LRA Appendix B Reference B.2.1. The result shows that it would take approximately 2×10^{10} years to deplete all the B-10 in the poison plates at the neutron flux level when the casks were loaded. Based on this result, the applicant concluded that the total loss of B-10 in poison plates over a 500-year period is negligible (less than 1 part per million of total B-10 atoms would be depleted).

The staff reviewed the applicant’s TLAA for loss of B-10 in the poison plates inside the cask. The staff also performed independent calculations to estimate the loss of B-10 in a cask as a result of irradiation by the neutrons emitted from the spent fuel. The staff finds that the applicant’s result is consistent with the staff’s independent calculations. Therefore, the initial criticality safety analysis for the ISFSI remains valid for the requested extended period of operation of the ISFSI because the loss of B-10 is negligible.

Based on its review, the staff finds that the applicant’s analysis is acceptable because the applicant’s assumptions for the neutron flux and material data are conservative. The analysis is rigorous and meets the acceptance criteria of NUREG-1927, Revision 1. On these bases, the staff determined that the applicant’s TLAA for loss of B-10 in the poison plates is consistent with the acceptance criteria, and there is a reasonable assurance that the Trojan ISFSI loaded with Trojan reactor fuel in the MPC casks will continue to meet the criticality safety requirement of 10 CFR 72.124(a) without a need for an AMP to manage the loss of B-10 in poison plates as a component of the MPC used in the Trojan ISFSI.

B.3 Transfer Cask Fatigue Evaluation

LRA Appendix B.3, Section 4.8, describes the evaluation of transfer cask that summarizes a cyclic loading fatigue evaluation of the transfer cask. The evaluation concludes that stresses in the lifting trunnions are well below the material endurance limit. The evaluation noted that following placement of MPCs into concrete casks, the transfer cask is no longer used to lift loaded MPCs and trunnion fatigue is not an issue during the extended license period.

In LRA Appendix B.3, the applicant also noted that, in the MPC transfer station handling operation, potential fatigue issues existed in the transfer cask trunnions. As detailed in LRA Reference B.3.1, "HI-2012785, Structural Calculation Package for HI-TRAC," the applicant considered the primary stress limit with a stress concentration factor as applicable to the NUREG-0612 stress acceptance criteria in prescribing an alternating stress amplitude for evaluating the trunnion fatigue life. For all other HI-TRAC components governed by the ASME Code, Section III, Subsection NF, the applicant calculated the maximum allowable number of lifting cycles using a stress range equal to the material ultimate strength. The fatigue life evaluation resulted in 3,730 cycles, as an allowable number of lifts without incurring fatigue failure to the transfer cask. The applicant noted that the allowable number of lifting cycles far exceeds the number of lifts and MPC support cycles of the transfer cask that will be needed.

The staff reviewed the Reference B.3.1 calculation and determined that the evaluation was done appropriately and the results are acceptable.

The applicant noted that the allowable number of lifting cycles far exceeds the needed number of lifts and MPC support cycles of the transfer cask. The staff reviewed the applicant's assessment of the expected number of transfer cask lifts and MPC support cycles and determined it to be a reasonable estimate. The staff reviewed the Appendix B.3.1 calculation and determined that the evaluation was done appropriately and results are acceptable. Therefore, the staff finds the TLAA evaluation acceptable for demonstrating adequate transfer cask fatigue performance during the extended storage period.

B.4 Fuel Cladding Integrity Evaluation

In LRA Section B.4, the applicant stated that Section 4.2.6.1 of the Trojan ISFSI SAR describes a calculation for the fuel cladding temperature limit, which is a function of temperature versus time as well as internal rod pressurization. The original fuel cladding temperature limit was established to keep the probability of cladding breach less than 0.5 percent per fuel rod over a 40-year storage term.

The applicant stated that the renewed license will allow for storage of fuel over 60 years; therefore, the original calculation for 40 years was reviewed. The TLAA analyzes the peak fuel rod cumulative cladding damage to ensure that the probability of cladding breach is less than 0.5 percent, consistent with the original analysis. The applicant calculated the life usage fraction of the fuel cladding, based on normal storage peak cladding temperature, and the results are shown in LRA Table B-2. The calculated life usage fraction is significantly below a value of 1, so the applicant concluded that the evaluation supports the conclusion that cladding integrity is assured under 60-year fuel storage at the Trojan ISFSI. The applicant stated that this evaluation, in conjunction with its aging management review in LRA Section 3.1.6.2, supports the conclusion that no additional aging management plan is needed for the fuel cladding stored at the Trojan ISFSI.

The staff reviewed the TLAA that evaluates cumulative cladding damage during the period of extended storage. The staff notes that the cladding life fraction calculation is based on the time required to fracture cladding under constant temperature and stress conditions. The staff reviewed the TLAA and confirmed that the analysis includes several conservative assumptions to bound the calculated cumulative cladding damage. Based on the staff's confirmation that the applicant appropriately updated the original design basis calculation to show that 60 years of storage uses just 6 percent of the cladding life, the staff finds the TLAA acceptable for demonstrating that the cladding damage will not result in a loss of safety functions during the period of extended operation.

3.4.2 Evaluation Findings

The staff reviewed the renewal application and design-basis documentation to confirm that the applicant did not omit any TLAAs that were part of its approved design basis. The staff performed its review following the guidance in NUREG-1927, Revision 1. The staff finds the applicant's determination, which did not identify a TLAA, to be acceptable. Based on its review, the staff determined that the applicant provided sufficient information with adequate details to support the LRA with the follow finding:

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

3.5 Aging Management Programs

Based on the reviews described in the above sections, the applicant named the AMPs that are needed during the Trojan ISFSI renewed storage period. In accordance with 10 CFR 72.42(a)(2), the applicant must describe AMPs for the management of issues associated with aging that could adversely affect ITS SSCs. The applicant proposed four AMPs:

(1) MPC AMP
(2) Transfer Cask AMP
(3) Concrete Cask AMP
(4) Transfer Station AMP

LRA Appendix A contains the full details of these AMPs. LRA Appendix G gives the proposed changes to the Trojan ISFSI SAR, including the AMP summaries. As specified in the new license condition in Section 4 of this SER, the AMPs summarized in SAR Appendix G will be incorporated in the Trojan ISFSI SAR after issuance of the renewed license.

3.5.1 Multipurpose Canister Aging Management Program

As identified in LRA Section 3.2.5, the applicant stated that effects requiring management for the MPC are loss of material due to corrosion, pitting and crevice corrosion, and cracking due to SCC on the external MPC surfaces. The discussion below identifies the main elements of the MPC AMP needed to manage the effects of these aging mechanisms during the extended storage period.

The staff reviewed each of the elements of the AMP with respect to the guidance in NUREG-1927, Revision 1, Table B-1, "Example AMP for Localized Corrosion and Stress Corrosion Cracking of Welded Stainless Steel Dry Storage Systems," to ensure that the program is capable of adequately managing the effects of aging.

1. Scope of Program

The applicant stated that the program covers the Trojan MPCs and subcomponents identified in LRA Table 3-1, which require the MPC AMP.

The staff reviewed the scope of the program to verify that the applicant adequately applied the process and methodology of scoping components covered under the program, as recommended in NUREG-1927, Revision 1. The staff notes that the applicant will evaluate the MPCs and subcomponents to the extent described throughout the remaining elements of this AMP. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that the MPC AMP uses condition monitoring to manage aging effects. Preventive actions to minimize corrosion and SCC were taken during fabrication; for example, stainless steel material was used to provide corrosion resistance. The applicant stated that these preventive actions minimize the likelihood of aging effects, but they do not replace the need for condition monitoring during the extended storage period. This AMP does not include any new preventive actions.

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

3. Parameters Monitored or Inspected

The applicant stated that the MPC AMP uses inspections to look for visual evidence of discontinuities and imperfections, such as localized corrosion, including pitting corrosion and SCC of the accessible canister welds and weld-heat-affected zones. The inspections also look for the appearance and location of deposits on the canister surfaces.

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

The staff finds the applicant's parameters monitored or inspected program element to be acceptable because the proposed visual inspections are capable of identifying the initiation and progression of corrosion of the MPC external surfaces, and the presence of pitting corrosion is considered to be a precursor to the formation of stress-corrosion cracks.

4. Detection of Aging Effects

The applicant stated that an ASME VT-3 visual inspection will be performed on one canister every 5 years. The inspection will be performed on the first cask placed in service at the Trojan ISFSI, unless there is a specific, technically justified reason to select a different cask or canister.

The selected cask is the cask previously inspected as part of the Concrete Cask Interior Inspection Program, which will allow for the best continued monitoring and trending. This cask is also the oldest cask and has the lowest heat load of the casks at the Trojan ISFSI.

The applicant stated that, for the visual inspection, the concrete cask lid will be removed, and the shield ring will be lifted or removed to provide access to the top end concrete cask interior space above the MPC. A visual inspection of the MPC lid and closure ring will be performed using a borescope (or equivalent). In addition, a visual inspection of the MPC surfaces below the shield ring will be performed using a borescope (or equivalent) run through each outlet vent. The boroscope (or equivalent) will be run through one or more of the vents to the bottom of the annulus to provide coverage of this area.

The applicant stated that, at the discretion of the inspector and the Trojan ISFSI manager, the inspection of selected areas on the MPC may be upgraded to the ASME VT-1 standard or a volumetric technique.

The Trojan ISFSI SAR requires a concrete cask interior inspection every 5 years. The first three inspections were performed in 2008, 2013, and 2018 on the concrete cask storing the first MPC loaded at Trojan. The inspections will continue on a 5-year basis, with the next serving as the Baseline Inspection for this AMP. Staff note that the MPC AMP inspections will be concurrent with these concrete cask inspections.

The staff reviewed the detection of aging effects program element to confirm that the applicant adequately described the inspection details, including the methods used, inspection frequency, and inspection timing. The staff finds the detection of aging effects program element to be acceptable because the performance of the ASME Code visual examinations on at least one canister on a minimum 5-year frequency is consistent with the guidance in NUREG-1927, Revision 1, for canister inspections and is considered capable of identifying degradation before a loss of function. In addition, the applicant’s proposal to follow up, if necessary, with ASME VT-1 or volumetric inspections is considered capable of determining whether the identified corrosion is indicative of the formation of stress-corrosion cracks.

5. Monitoring and Trending

The applicant stated that monitoring and trending methods are in accordance with the evaluation criteria in ASME Code, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” Article IWA-2200, evaluation criteria. The documented inspection results should provide the ability to monitor and trend the condition of the canister, with the inspection video retained for comparison in subsequent examinations. The applicant should identify and document changes to the size and location of any areas of discoloration, localized corrosion, or SCC for subsequent inspections.

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

6. Acceptance Criteria

The applicant stated that the acceptance criteria for the MPC surface are no indication of localized corrosion pits, etching, SCC, or red-orange-colored corrosion products in the vicinity of accessible canister fabrication welds and closure welds.

The following indications of interest are subject to additional examination and disposition through the Corrective Action Program (CAP):

- localized corrosion pits, SCC, etching, deposits, or corrosion products
- discrete red-orange-colored corrosion products that are 1 millimeter (mm) [0.04 inch] in diameter or larger, especially those adjacent to fabrication welds, closure welds, and accessible locations where temporary attachments may have been welded to and subsequently removed from the MPC and the weld-heat-affected zones of these areas
- linear appearance of any color of corrosion products of any size parallel to or traversing fabrication welds, closure welds, and the weld-heat-affected zones of these areas
- red-orange-colored corrosion products greater than 1 mm [0.04 inch] in diameter combined with deposit accumulations in any location of the stainless steel canister
- red-orange-colored corrosion tubercles of any size

The applicant also stated that the CAP evaluation may include removal of the deposits and rust stains in accessible locations that reveal undamaged welds (i.e., absence of pits, cracking, localized attack, or etching) and the original machining or grinding marks on the stainless steel base metal, including weld-heat-affected zones, to confirm that localized corrosion or SCC has not begun. In addition, this process may result in an engineering evaluation to determine the extent and impact of the condition on the ability of the MPC to perform its intended function.

The staff reviewed the applicant’s acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended function. The staff notes that the criteria are consistent with those recommended in the NUREG-1927, Revision 1, example AMP for canisters. The staff also notes that the criteria are consistent with the parameters monitored, and compliance with the criteria can be determined using the inspection methods detailed in the detection of aging effects program element. Therefore, the staff finds that the acceptance criteria program element provides reasonable assurance that the effects of aging will be adequately managed.

7. Corrective Actions

The applicant stated that the corrective actions performed based on unacceptable aging effects are in accordance with the Trojan ISFSI Quality Assurance (QA) Program. The QA Program ensures that corrective actions are completed within the Trojan ISFSI CAP. The Trojan ISFSI SAR states that the Trojan QA Program applies to the activities covered by 10 CFR Part 72, Subpart G, “Quality Assurance.”

The staff reviewed the CAP element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of the CAP approved under 10 CFR Part 72, Subpart G. NUREG-1927, Revision 1, also states that all conditions that do not meet AMP acceptance criteria should be entered into the CAP. Therefore, the staff finds the CAP element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered into the CAP, and the QA requirements provide reasonable assurance that corrective actions will be adequate for managing the MPC.

8. Confirmation Process

The applicant stated that the confirmation process will be commensurate with the Trojan ISFSI QA Program. The QA Program ensures that inspections, evaluations, and corrective actions are completed in accordance with the Trojan ISFSI CAP.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach to ensure that the effectiveness of corrective actions are verified and that adverse trends will be monitored to address potential degradation before a loss of function. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the Trojan ISFSI implementing procedure for this AMP will address instrument calibration and maintenance, inspector requirements, record retention requirements, and document control.

The applicant also stated that the AMP will be updated, as necessary, based on the periodic tollgate assessments (5-year intervals) described in LRA Appendix C and new SAR Section 9.7.8.5. Inspection results will be documented and made available for NRC inspectors to view upon request.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach for providing adequate review, approval, and fulfillment of activities that ensure SSCs will continue to perform satisfactorily in service. Performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

The applicant stated that no cases of chloride-induced SCC for stainless steel dry storage canisters have been reported; however, it determined that some amount of chloride-containing salts were present at other ISFSIs and identified corrosion products believed to be related to iron contamination.

The applicant stated that the Trojan ISFSI has had a requirement for a 5-year periodic inspection of the concrete cask interior. Although the inspection focuses on the concrete cask inner liner, a portion of the inspection has looked at the MPC exterior surface. In these past inspections, the visible MPC surfaces showed no signs of degradation. LRA Appendix D describes these past inspections.

The staff reviewed the operating experience program element to ensure that the applicant appropriately considered past operating experience and that the program includes provisions to conduct future reviews of operating experience to confirm the program’s continued effectiveness. The staff notes that the degradation at other ISFSIs described in the applicant’s operating experience review was minor and is considered to be effectively addressed by the applicant's proposed AMP activities. The staff also notes that the applicant's proposal to share operating experience with the industry and conduct periodic AMP effectiveness reviews through the proposed tollgate process in LRA Appendix C is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to ensure continued effectiveness. Appendix C1 states that, on a 5-year interval, the effectiveness of each AMP will be assessed against performance criteria for each element, as described in LRA Table C-2. AMPs are either concluded to be effective or corrective actions are initiated to address ineffective program elements.

Therefore, the staff finds the operating experience program element to be acceptable because the applicant provided sufficient previous operating experience to support the effectiveness of AMP activities and gave a framework for future operating experience reviews to ensure that AMPs will be adjusted as knowledge becomes available from new analyses, experiments, and inspection activities.

Conclusion

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

3.5.2 Transfer Cask Aging Management Program

In LRA Section 3.3.5, the applicant stated that the aging effect requiring management for the transfer cask is loss of material due to general, pitting, and crevice corrosion.

The staff reviewed each of the elements of the Transfer Cask AMP with respect to the guidance in NUREG-1927, Revision 1, to ensure that the program is capable of adequately managing the effects of aging.

1. Scope of Program

The applicant stated that the program covers the Trojan Transfer Cask, and subcomponents identified in LRA Table 3-2, which require the Transfer Cask AMP.

The staff reviewed the scope of the program to verify that the applicant adequately applied the process and methodology of scoping components covered under the program, as recommended in NUREG-1927, Revision 1. The staff notes that the applicant will evaluate the Transfer Cask and subcomponents to the extent described throughout the remaining elements of this AMP. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that the Transfer Cask AMP uses inspections (condition monitoring) to ensure that the equipment maintains its intended function during the extended storage period. However, preventive actions to minimize corrosion were taken during fabrication. For example, carbon steel material, where applicable, was coated to provide corrosion resistance. The staff notes that these preventive actions minimize the likelihood of aging effects, but do not replace the need for inspections during the period of extended storage.

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

3. Parameters Monitored or Inspected

The applicant stated that the Transfer Cask AMP uses visual inspections to find evidence of degradation of accessible surfaces of the transfer cask. Degradation of the transfer cask surfaces will be detected by identification of defects and irregularities. Defects are defined as water jacket leakage; chipped, cracked, blistered or missing coating that exposes base metal; and corrosion products showing through the coating. Irregularities are defined as degradation that is noted but is less severe than a defect.

The staff reviewed the parameters monitored or inspected to confirm that the parameters will be capable of identifying degradation before a loss of intended function and provide a clear link to the loss of material aging effect identified in the scope of the program. The staff finds the applicant's parameters monitored or inspected to be acceptable because the proposed visual inspections are capable of identifying the initiation and progression of corrosion of the transfer cask surfaces.

4. Detection of Aging Effects

The applicant stated that the Transfer Cask AMP will use visual inspections, which will be implemented through detailed inspection procedures and conducted by qualified individuals, for the following:

- All accessible coated surfaces, including MPC cavity surfaces, will be inspected for defects and irregularities.
- The water jacket will be inspected for leaks.

This inspection will be performed before the use of the transfer cask and, at a minimum, once a year while in use.

The staff reviewed the detection of aging effects program element to confirm that the applicant adequately described the inspection details, including the methods used, inspection frequency, and inspection timing, in a manner consistent with the recommendations in NUREG-1927, Revision 1. The staff notes that, as detailed above, the performance of visual inspections once a year while the transfer cask is in use is capable of identifying corrosion degradation before a loss of function. Therefore, the staff finds that the detection of aging effects program element provides reasonable assurance that the effects of aging will be adequately managed.

5. Monitoring and Trending

The applicant stated that visual inspections will determine the existence of loss of material on the external surfaces of the transfer cask, and observations about the material condition will be recorded in accordance with inspection procedures. Concerns about condition will be corrected or evaluated as satisfactory before use of the transfer cask. Inspection results are compared to those obtained during previous inspections, so that the progression of degradation can be evaluated and predicted.

The applicant also stated that evaluation of this information during the preparations for MPC retrieval and transfers provides adequate predictability and allows for corrective action, if necessary, before the need to perform the intended function of the component.

The staff reviewed the applicant's monitoring and trending activities to ensure that they provide for an evaluation of the extent of aging and the need for timely corrective or mitigative actions, as recommended in NUREG-1927, Revision 1. The staff notes that the performance of a baseline inspection during use of the transfer cask at the transfer station and trending future inspection results against that baseline are capable of effectively evaluating and responding to any identified effects of aging. Thus, activities will be in place to ensure that evidence of degradation will be adequately evaluated such that future inspections will be performed, or components will be repaired, before a loss of function. Therefore, the staff finds that the monitoring and trending program element provides reasonable assurance that the effects of aging will be adequately managed.

6. Acceptance Criteria

The following are the acceptance criteria for transfer cask subcomponents:

- no corrosion, dents, cracks, scratches, or gouges in base metal that exceeds 1/8 inch in depth (defects in the protective coating are acceptable provided the underlying base metal meets the above criteria)

- no leakage of water from the water jacket

The applicant also stated that the Trojan ISFSI manager evaluates the inspection results and if s water jacket leakage or degradation of material is detected on any of the identified subcomponents within the transfer cask that exceeds the above acceptance criteria, the issue will be entered into the Trojan CAP. Acceptance criteria of this AMP is based upon Response to Request for Technical Information (RRTI) 2536-002R2 as specified in the LRA, Appendix A, Transfer Cask AMP, Note (2).

The staff reviewed the applicant's acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended function. The staff notes that the criteria are consistent with the parameters monitored, and compliance with the criteria can be determined using the inspection methods detailed in the detection of aging effects program element. Therefore, the staff finds that the acceptance criteria program element provides reasonable assurance that the effects of aging will be adequately managed.

7. Corrective Actions

The applicant stated that, as applicable in accordance with the CAP, Trojan staff will perform cause evaluations, address the extent of condition, determine any necessary actions to prevent recurrence, identify any changes to the existing AMP, and determine whether the condition is reportable. In addition, this process may result in an engineering evaluation to determine the extent and impact of the condition on the ability of the transfer cask to perform its intended function, or it may result in supplemental inspections, such as nondestructive examinations.

The applicant stated that corrective actions will also identify actions needed for increased scope or frequency of inspections, as necessary, based on any detected aging effects.

The staff reviewed the corrective actions program element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of the CAP approved under 10 CFR Part 72, Subpart G. NUREG-1927, Revision 1, also states that all conditions that do not meet AMP acceptance criteria should be entered into the CAP. As a result, the staff finds the corrective actions program element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered into the CAP, and the QA requirements in Trojan's Nuclear Quality Assurance QA Program provide reasonable assurance that corrective actions will be adequate for managing the aging transfer cask.

8. Confirmation Process

The applicant stated that the confirmation process will be commensurate with the Trojan ISFSI QA Program. The QA Program ensures that inspections, evaluations, and corrective actions are completed in accordance with the Trojan ISFSI CAP.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach to ensure that the effectiveness of corrective actions are verified and that adverse trends will be monitored to address potential degradation before a loss of function. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the Trojan ISFSI implementing procedure for this AMP will address instrument calibration and maintenance, inspector requirements, record retention requirements, and document control.

The applicant stated that this AMP will be updated, as necessary, based on the periodic tollgate assessments described in LRA Appendix C and new SAR Section 9.7.8.5. Inspection results will be documented and made available for NRC inspectors to view upon request.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach for providing adequate review, approval, and fulfillment of activities (including implementing procedure development) that ensure SSCs will continue to perform satisfactorily in service. Performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

The applicant stated that it used the transfer cask during the initial loading of the Trojan ISFSI. The transfer cask was inspected before use in accordance with existing operating procedures.

The staff reviewed the operating experience program element to ensure that the applicant appropriately considered past operating experience and that the program includes provisions to conduct future reviews of operating experience to confirm the program's continued effectiveness. The staff notes that the applicant did not identify any operating experience showing transfer cask degradation. The staff also notes that the applicant's proposal to share operating experience with the industry and conduct periodic AMP effectiveness reviews through the proposed tollgate process in LRA Appendix C is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to ensure continued effectiveness. Therefore, the staff finds the operating experience program element to be acceptable because the applicant considered previous operating experience in the development of the AMP and provided a framework for future operating experience reviews to ensure that AMPs will be adjusted as knowledge becomes available from new analyses, experiments, and inspection activities.

Conclusion

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

3.5.3 Concrete Cask Aging Management Program

As identified in LRA Sections 3.4.5 and 3.8.3, the aging effects requiring management for the concrete cask are loss of material (steel) due to corrosion and concrete aging effects (loss of strength, spalling, cracking, and scaling) caused by freeze-thaw cycles, alkali-silica reaction, calcium hydroxide leaching, and corrosion of embedded reinforcing steel. The description below identifies the main elements of the Concrete Cask AMP needed to manage the effects of these aging mechanisms during the extended storage period.

1. Scope of Program

The applicant stated that the program covers the Trojan concrete cask, and subcomponents identified in LRA Table 3-3, which require the Concrete Cask AMP.

The staff reviewed the scope of the program to verify that the applicant adequately applied the process and methodology of scoping components covered under the program, as recommended in NUREG-1927, Revision 1. The staff notes that the applicant will evaluate the concrete cask and subcomponents to the extent described throughout the remaining elements of this AMP. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that this AMP uses condition monitoring to manage aging effects. The applicant stated that the design of the system is intended to minimize aging effects, but this AMP focuses on condition monitoring. This AMP does not include any new preventive actions.

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

3. Parameters Monitored or Inspected

<u>Concrete Cask Exterior</u>

The applicant stated that it uses visual identification of defects to detect the deterioration of the exposed steel and concrete surfaces. Defects associated with the concrete surface are defined as damage or degradation (scabbing, spalling, cracking) larger than 1.3 centimeters [0.5 inch] in diameter or width and with a depth greater than 0.64 centimeters [1/4 inch.]. Defects also include evidence of leachate deposits, staining, or stalactite growth on the concrete surface. The inspections identify defects or irregularities of any form that meet or exceed the above criteria regardless of their cause or origin. An irregularity is damage or degradation to a component that is noted but is less severe and does not meet the definition of a defect.

The applicant stated that contact radiation dose rate measurements are taken at the location of any identified defect in the concrete surface and at an unaffected location adjacent to the defect. The results of these measurements are compared to each other to assess whether the defect has compromised the radiation shielding function of the concrete.

The applicant stated that defects associated with the cask lid are defined as chipped, cracked, blistered, or missing coating that exposes base metal, and corrosion products showing through the coating.

The applicant stated that the defects associated with the inlet and outlet air assemblies are visible signs of blockage in the air flowpath.

<u>Concrete Cask Interior</u>

The applicant stated that the accessible interior steel surfaces of the concrete cask are inspected for visual indications of corrosion. The applicant stated that the heat transfer function of the concrete cask is maintained by the presence of an open airflow channel through the cask. Corrosion of steel surfaces inside the cask does not affect this function unless corrosion products block the flowpath.

The staff reviewed the parameters monitored or inspected program element to confirm that the parameters will be capable of identifying degradation before a loss of intended function and provide a clear link to the loss of material aging effect identified in the scope of the program. The staff finds the applicant's parameters monitored or inspected program element to be acceptable because the use of visual indications of concrete degradation (e.g., spalling, cracking) and steel corrosion are capable of identifying and monitoring the progression of degradation of the concrete cask surfaces.

4. Detection of Aging Effects

Concrete Cask Exterior

The applicant stated that the Concrete Cask AMP includes a visual inspection of the cask exterior to detect any defects and irregularities considered to be aging effects. Qualified individuals conduct this visual inspection annually, and the inspection includes all concrete casks in service at the Trojan ISFSI.

The applicant stated that data from all inspection and monitoring activities, including evidence of degradation and its extent and location, will be recorded on a checklist or inspection form and include descriptions of observed aging effects, supporting sketches, and photographs or video.

Concrete Cask Interior

The applicant stated that a visual inspection of the concrete cask lid, shield ring, and top-end surfaces of the cask liner will be performed using a borescope (or equivalent) after removal of the cask lid and removal or lifting of the shield ring. In addition, a visual inspection of the accessible concrete cask liner surfaces below the shield ring, the annular space, and the interior areas of the vents will be performed using a borescope (or equivalent) run as far as necessary through each outlet vent to cover the full surface of the vent. The boroscope (or equivalent) will be run through one or more vents to the bottom of the annulus to provide coverage of this area. This visual inspection will meet the requirements of a VT-3 examination, as given in the ASME Code, Section XI, Article IWA-2200.

The applicant stated that the inspection will be performed on one concrete cask every 5 years. The inspection is performed on the first concrete cask placed in service at the Trojan ISFSI, which is the cask previously inspected as part of the site’s Concrete Cask Interior Inspection Program, allowing for the best continued monitoring and trending. If aging-related degradation is discovered on the currently selected concrete cask and a second sample concrete cask is determined to be necessary, the new cask should be selected based on the aging mechanism of concern, fabrication history, heat load, and time in service..

The staff reviewed the detection of aging effects program element to confirm that the applicant adequately described in the inspection details, including the methods used, inspection frequency, and inspection timing. The staff notes that the proposed visual inspections are capable of identifying the parameters associated with concrete and steel degradation, and the frequency of inspections (annually for the exterior of all casks and every 5 years for the interior of one cask) are sufficient to provide for timely identification of degradation. The staff also notes that the inspection methods and frequency are consistent with the recommendations for reinforced concrete overpack structures in NUREG-1927, Revision 1. Therefore, the staff concludes that the detection of aging effects program element provides reasonable assurance that the concrete cask subcomponents will maintain their intended functions during the period of extended operation.

5. Monitoring and Trending

The applicant stated that the inspections of the interior and exterior subcomponents of the concrete cask are performed periodically in order to identify areas of degradation. The results will be compared against previous inspections in order to monitor and trend the progression of the aging effects over time. The applicant also stated that the inspection will be documented in accordance with Trojan ISFSI inspection procedures, which require a detailed description of the surface condition and location of areas showing surface degradation. Finally, as stated in the AMP's parameters monitored or inspected program element, all defects and irregularities will be documented in an inspection data sheet and reviewed against previous inspection reports to determine whether the condition has changed.

The Trojan ISFSI SAR requires a concrete cask interior inspection every 5 years. The first three inspections were performed in 2008, 2013, and 2018 on the concrete cask storing the first MPC loaded at Trojan. The inspections did not identify any degradation mechanisms affecting system performance that were not identified in the SAR. The inspections will continue on a 5-year basis, with the next serving as the Baseline Inspection for this AMP.

The staff reviewed the applicant's monitoring and trending activities to ensure that they provide for an evaluation of the extent of aging and the need for timely corrective or mitigative actions, as recommended in NUREG-1927, Revision 1. The staff notes that the periodic monitoring and trending of indications of corrosion and defects and/or irregularities identified by visual inspections provide sufficient opportunity to identify adverse trends such that corrective actions can be implemented before a loss of intended function. Therefore, the staff finds that the monitoring and trending provides reasonable assurance that the concrete cask subcomponents will maintain their intended functions during the period of extended operation.

6. Acceptance Criteria

Concrete Cask Exterior

The following are the acceptance criteria for the concrete shell of the concrete cask:

- no exposed reinforcing steel on the surface of the concrete cask
- no defects in the concrete cask surface result in a contact radiation dose rate of 150 percent or more of the contact radiation dose rate of adjacent unaffected areas of the concrete cask
- no leachate deposits, staining, or stalactite growth on the concrete surface
- no areas of unsound concrete

The following is the acceptance criterion for the exterior surface of the concrete cask lid:

- no corrosion, dents, cracks, scratches, or gouges in base metal that exceeds 3.2 mm [1/8 inch] in depth (defects in the protective coating are acceptable provided the underlying base metal meets the above criteria)

The following are the acceptance criteria for the inlet and outlet air assemblies:

- no more than 180 square centimeters [28 square inches] (cross-sectional area) of visible foreign material blockage on any inlet air assembly vent screen or within the flow channel

- no more than 90 square centimeters [14 square inches] (cross-sectional area) of visible foreign material blockage on any outlet air assembly vent screen or within the flow channel

The applicant stated that inspection results that exceed the above acceptance criteria will be entered into the Trojan CAP.

Concrete Cask Interior

The following is the acceptance criterion for the concrete cask accessible interior:

- no corrosion, dents, cracks, scratches, or gouges in base metal that exceeds 3.2 mm [1/8 inch] in depth (defects in the protective coating are acceptable provided the underlying base metal meets the above criteria)

The applicant stated that the ASME VT-3 or VT-1 inspector evaluates the inspection results, and if degradation of material was detected on any of the identified subcomponents within the concrete cask that exceeds the above acceptance criteria, the issue will be entered into the Trojan CAP.

The staff reviewed the applicant's acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended function. The staff notes that the criteria are consistent with the parameters monitored, and compliance with the criteria can be determined using the inspection methods detailed in the detection of aging effects program element. Therefore, the staff finds that the acceptance criteria program element provides reasonable assurance that the effects of aging will be adequately detected and appropriately addressed before degradation reaches a level where the concrete cask would be challenged in performing its intended function.

7. Corrective Actions

The applicant stated that corrective actions will be performed in accordance with the Trojan ISFSI QA Program, which is approved under 10 CFR Part 72, Subpart G. Under its QA program, Trojan staff will perform cause evaluations, address the extent of condition, determine any necessary actions to prevent recurrence, identify any changes to the existing AMP, and determine whether the condition is reportable. In addition, this process may result in an engineering evaluation to determine the extent and impact of the condition on the ability of the concrete cask to perform its intended function.

The applicant stated that the corrective actions will also identify the actions needed for increased scope or frequency of inspections, as necessary, based on any detected aging effects.

The staff reviewed the corrective actions program element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of the CAP approved under 10 CFR Part 72, Subpart G. NUREG-1927, Revision 1, also states that all conditions that do not meet AMP acceptance criteria should be entered into the CAP. Therefore, the staff finds the corrective actions program element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered into the CAP, and the QA requirements provide reasonable assurance that corrective actions will be adequate for managing the aging concrete cask.

8. Confirmation Process

The applicant stated that the confirmation process will be commensurate with the Trojan ISFSI QA Program. The QA Program ensures that inspections, evaluations, and corrective actions are completed in accordance with the Trojan ISFSI CAP.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach to ensure that the effectiveness of corrective actions are verified and that adverse trends will be monitored to address potential degradation before a loss of function. The Trojan ISFSI QA Program has been approved by the NRC under 10 CFR Part 72, Subpart G. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the Trojan ISFSI implementing procedure for this AMP will address instrument calibration and maintenance, inspector requirements, record retention requirements, and document control.

The applicant stated that this AMP will be updated, as necessary, based on the periodic tollgate assessments described in LRA Appendix C and the SAR Section 9.7.8.5. Inspection results will be documented and made available for NRC inspectors to view upon request.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach for providing adequate review, approval, and fulfillment of activities that ensure SSCs will continue to perform satisfactorily in service. The Trojan ISFSI QA Program has been approved by the NRC under 10 CFR Part 72, Subpart G. Also, performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

The applicant stated that the Trojan ISFSI has used the same concrete casks since they were initially loaded. Both the site’s Structural Inspection Program and Concrete Cask Interior Inspection Program have been followed consistently over that time and have found no degradation of concern. Although the Trojan staff has not noted any cracking due to freeze-thaw cycles, and AMP has factored in those possible concerns. LRA Appendix D summarizes the previous cask inspections.

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

Conclusion

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

3.5.4 Transfer Station Aging Management Program

The transfer station is used for the short duration of MPC transfer between the transfer cask, concrete casks, and transportation cask. LRA Section 3.6.5 states that the aging effect requiring management for the transfer station and impact limiter top plate is loss of material due to corrosion. The aging effect for the impact limiter foam is a change in dynamic crush strength resulting from chemical changes. The aging effect for the transfer station pad is concrete aging (loss of strength, spalling, cracking, scaling) caused by freeze-thaw cycles, alkali-silica reaction, calcium hydroxide leaching, and corrosion of embedded reinforcing steel.

The staff reviewed each of the elements of the AMP with respect to the guidance in NUREG-1927, Revision 1, to ensure that the program is capable of adequately managing the effects of aging.

1. Scope of Program

The applicant stated that the program covers the Trojan transfer station, and subcomponents identified in LRA Table 3-5, which require the Transfer Station AMP to operate during the extended storage period.

The staff reviewed the scope of the program to verify that the applicant adequately applied the process and methodology of scoping components covered under the program, as recommended in NUREG-1927, Revision 1. The staff notes that the applicant will evaluate the transfer station and subcomponents to the extent described throughout the remaining elements of this AMP. Based on the staff's confirmation that the applicant accurately and clearly specified the details of the components addressed under the program, the staff finds the scope of the program to be acceptable.

2. Preventive Actions

The applicant stated that the AMP uses inspections to ensure that the equipment maintains its intended function during the extended storage period. However, preventive actions to minimize corrosion were taken during fabrication, for example, carbon steel material, where applicable, was coated to provide corrosion resistance. The staff notes that these preventive actions minimize the likelihood of aging effects, but do not replace the need for inspections during the period of extended storage. The applicant states that the design and materials of construction of the transfer station were selected to minimize aging effects. No new preventive transfer station actions are included as part of this AMP.

The staff reviewed the preventive actions program element and confirmed that the program does not rely on preventive actions to manage the effects of aging. The staff notes that the program uses visual inspections to manage steel and concrete degradation and crush testing to manage the change in impact limiter properties. The staff finds the applicant's preventive actions program element to be acceptable because, consistent with the recommendations in NUREG-1927, Revision 1, preventive actions do not need to be provided for condition-monitoring programs.

3. Parameters Monitored or Inspected

Transfer Station

The applicant stated that the parameters inspected by the Transfer Station AMP are visual evidence of degradation of accessible external surfaces of the transfer station. Degradation of the transfer station surfaces will be detected by identification of defects or irregularities. Defects are defined as chipped, cracked, blistered, or missing coating that exposes base metal, and corrosion products showing through the coating. An irregularity is defined as damage or degradation to a component that is noted but is less severe and does not meet the definition of a defect.

Transfer Station Pad

The applicant stated that the complete exposed surface of the pad is inspected for defects and irregularities or other signs of damage. Defects are defined as visible signs of movement, or holes or large cracks greater than 1.3 cm [1/2 inch] across or extending into rebar. Defects also include evidence of leachate deposits or staining on the concrete surface. Irregularities are damage or degradation to a component that is noted but is less severe and does not meet the definition of a defect.

Impact Limiter

The applicant stated that the parameters monitored and trended for the impact limiter are static crush-strength values of representative foam samples of the impact limiter foam, and visual evidence of degradation of the external surfaces of the impact limiter top plate.

Staff Review

The staff reviewed the parameters monitored or inspected program element to confirm that the parameters will be capable of identifying degradation before a loss of intended function and provide a clear link to the aging effects identified in the scope of the program, as recommended in NUREG-1927, Revision 1. The staff finds the applicant's parameters monitored or inspected program element to be acceptable because the proposed visual inspections and crush testing are capable of identifying the initiation and progression of degradation of the steel and concrete surfaces and changes in the impact limiter properties.

4. Detection of Aging Effects

Transfer Station

The applicant stated that all accessible coated steel surfaces will be visually inspected for defects and irregularities. The staff notes that, although this visual inspection is based on general inspection criteria, it will be conducted by qualified individuals using inspection procedures. The applicant states that this inspection will be performed before use of the transfer station and at least once a year while in use.

Transfer Station Pad

The applicant states that visual inspections conducted by qualified individuals will be used to detect any aging effects by identifying defects and irregularities of the transfer station pad. using detailed inspection procedures.

The applicant states that this inspection program provides the means to detect and address the aging effects identified in LRA Section 3.6.5, including the following:

- cracking or loss of material (concrete) due to freeze-thaw degradation
- cracking or loss of material (concrete) due to alkali-silica reactions
- cracking or loss of material (concrete) due to corrosion of embedded reinforcing steel
- calcium hydroxide leaching that could cause loss of strength
- cracking and distortion due to differential movement

The applicant stated that inspecting to this level of detail for defects and irregularities ensures that degradation will be detected and addressed before it impairs the ability of the pad to perform its intended function. As stated in LRA Appendix G (proposed changes to the Trojan ISFSI SAR), this inspection will be performed at least once a year while the transfer station is in use.

Impact Limiter

The applicant stated that samples of foam representative of the foam in the impact limiter material shall be tested for static crush strength every 10 years. The applicant stated that, while in storage, the foam samples shall be maintained in environmental conditions similar to those for the impact limiter.

The applicant stated that, as a part of the transfer station visual inspection of coated metal components, the impact limiter top plate will be inspected for chipped, cracked, blistered, or missing coating that exposes base metal and corrosion products showing through the coating.

Staff Review

The staff reviewed the detection of aging effects program element to confirm that the applicant adequately described the inspection details, including the methods used, inspection frequency, and inspection timing. The staff concludes the proposed visual inspections are capable of identifying the parameters associated with concrete and steel degradation, and that the frequency of those inspections is sufficient to provide for timely identification of degradation. The staff bases this conclusion on the use of qualified inspectors utilizing procedures under the

Trojan QA/CAP inspect the readily accessible and infrequently used transfer station and pad which are in and exposed environment. In addition, testing the impact limiter foam at a 10-year frequency (coupled with a review of previous testing since 2000) is sufficient to identify any changes in the foam properties. Therefore, the staff finds the detection of aging effects program element to be acceptable because the AMP uses techniques capable of identifying degradation, and the inspections and testing will be performed at a frequency that supports timely identification of degraded conditions and implementation of corrective actions, consistent with the guidance in NUREG-1927, Revision 1.

5. Monitoring and Trending

Transfer Station

The applicant stated that visual inspections will determine the existence of loss of material on the external surfaces of the transfer station. Observations about the material condition will be recorded in accordance with inspection procedures. Concerns about condition will be corrected or evaluated as satisfactory before use of the transfer station.

Transfer Station Pad

The applicant stated that all noted defects and irregularities on the transfer station pad will be documented on an inspection data sheet and recorded in a defect log. Previously reported defects and irregularities will be reviewed against the defect log and evaluated to determine whether their condition has visibly changed. Areas where new defects are found, or previously identified irregularities or defects have changed, will be examined closely to determine the extent of the damage.

The applicant stated that evaluation of this information during the preparations for MPC retrieval and transfers provides adequate predictability and allows for corrective action, if necessary, before the need for the intended function of the component to be performed.

Impact Limiter

The applicant stated that test results for the impact limiter foam will be compared against limits in the MPC drop analysis at the transfer station to verify that the material properties are adequate for the intended function of structural integrity under hypothetical accident conditions. In addition, visual inspection observations about the material condition will be recorded in accordance with inspection procedures and will be corrected or evaluated as satisfactory before use of the impact limiter.

Staff Review

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

6. Acceptance Criteria

Transfer Station

The applicant stated that the acceptance criteria for transfer station metal subcomponents are no corrosion, dents, cracks, scratches, or gouges in base metal that exceed 3.2 mm [1/8 inch] in depth (defects in the protective coating are acceptable, provided the underlying base metal meets the above criteria). The applicant stated that Trojan ISFSI manager evaluates the inspection results and, if degradation of material on any of the identified subcomponents within the transfer station that exceeds the above acceptance criteria is detected, the issue is entered into the Trojan CAP. The acceptance criterion is based upon Response to Request for Technical Information (RRTI) 2536-002R2 as specified in the LRA, Appendix A, Transfer Station AMP, Note (2).

Transfer Station Pad

The following are the acceptance criteria for the transfer station pad:

- no cracks or holes greater than 1.3 cm [1/2 inch] wide or extending to rebar
- no leachate deposits or staining on the concrete surface
- no unsound concrete
- no differential movement greater than 2.5 cm [1 inch] between portions of the pad or between the pad and transfer station footings

The applicant stated that the Trojan ISFSI manager evaluates the inspection results and, if degradation of material or differential movement of the pad that exceeds the above acceptance criteria is detected, the issue is entered into the Trojan CAP.

Impact Limiter

The applicant stated that the results of the periodic materials tests on representative foam samples shall be evaluated to ensure that the impact limiter foam maintains the critical parameters needed for the MPC drop analysis. The AMP lists the specific acceptable ranges for static crush strength of the representative foam samples as a function of strain.

The applicant stated that the acceptance criteria for the impact limiter top plate are no corrosion, dents, cracks, scratches, or gouges in base metal that exceed 3 cm [1/8 inch] (defects in the protective coating are acceptable, provided the underlying base metal meets the above criteria).

The applicant stated that the Trojan ISFSI manager evaluates the inspection results and, if degradation of material that exceeds the above acceptance criteria is detected, the issue is entered into the Trojan CAP.

Staff Review

The staff reviewed the applicant’s acceptance criteria to verify that they provide specific benchmarks to prompt corrective actions before a loss of intended function. The staff notes that the acceptance criteria are consistent with the parameters monitored, and compliance with the criteria can be determined using the inspection methods detailed in the detection of aging effects program element. Also, the criteria provide clear thresholds for entering a condition into the CAP. Therefore, the staff finds that the acceptance criteria program element provides reasonable assurance that the effects of aging will be adequately managed.

7. Corrective Actions

The applicant stated that, in accordance with the CAP, Trojan staff will perform cause evaluations, address the extent of condition, determine any necessary actions to prevent recurrence, identify any changes to the existing AMP, and determine if the condition is reportable. In addition, this process may result in an engineering evaluation to determine the extent and impact of the condition on the transfer station to perform its intended function.

The applicant stated that corrective actions will also identify actions needed for increased scope or frequency of inspections, as necessary, based on any detected aging effects.

The staff reviewed the corrective actions program element and noted that NUREG-1927, Revision 1, states that an applicant may reference the use of a CAP approved under 10 CFR Part 72, Subpart G. NUREG-1927 also states that all conditions that do not meet AMP acceptance criteria should be entered into the CAP. Therefore, the staff finds the corrective action program element to be acceptable because inspection and monitoring results that do not meet acceptance criteria will be entered into the CAP, and the QA requirements provide reasonable assurance that corrective actions will be adequate for managing the aging transfer station.

8. Confirmation Process

The applicant stated that the confirmation process will be commensurate with the Trojan ISFSI QA Program. The QA Program ensures that inspections, evaluations, and corrective actions are completed in accordance with the Trojan ISFSI CAP.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach to ensure that the effectiveness of corrective actions are verified and that adverse trends will be monitored to address potential degradation before a loss of function. The Trojan ISFSI QA Program has been approved by the NRC under 10 CFR Part 72, Subpart G. Therefore, the staff finds the confirmation process program element to be acceptable.

9. Administrative Controls

The applicant stated that the Trojan ISFSI implementing procedure for this AMP will address instrument calibration and maintenance, inspector requirements, record retention requirements, and document control.

The applicant stated that this AMP will be updated, as necessary, based on the periodic tollgate assessments described in LRA Appendix C and new SAR Section 9.7.8.5. Inspection results will be documented and made available for NRC inspectors to view upon request.

NUREG-1927, Revision 1, states that NRC-approved QA programs are an accepted approach for providing adequate review, approval, and fulfillment of activities that ensure SSCs will continue to perform satisfactorily in service. The Trojan ISFSI QA Program has been approved by the NRC under 10 CFR Part 72, Subpart G. Also, performing periodic AMP effectiveness reviews is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to maintain effectiveness. Therefore, the staff finds the administrative controls program element to be acceptable.

10. Operating Experience

The applicant stated that the functionality of the transfer station was demonstrated at the time of initial loading of the Trojan ISFSI by transferring a dummy MPC between the transfer cask and a concrete cask. The transfer station was inspected at that time in accordance with existing operating procedures and has been inspected annually thereafter.

The applicant stated that the transfer station pad has been inspected on an annual basis starting in 1999, in accordance with the Structural Inspection Program identified in the ISFSI SAR. Identified defects and irregularities have been sealed or coated as necessary to preclude further degradation.

The applicant stated that representative foam samples of the transfer station impact limiter have been tested since 2000, and test results have been within the acceptable ranges.

The staff reviewed the operating experience program element to ensure that the applicant had appropriately considered past operating experience and that the program includes provisions to conduct future reviews of operating experience to confirm the program's continued effectiveness. The staff notes that the applicant's operating experience review did not identify any significant degradation of the transfer station, pad, or impact limiter, and the aging effects are considered to be effectively addressed by the proposed AMP activities. The staff also notes that the applicant's proposal to share operating experience with the industry and conduct periodic AMP effectiveness reviews through the tollgate process described in LRA Appendix C is consistent with the guidance in NUREG-1927, Revision 1, which recommends that programs incorporate future reviews of operating experience to ensure continued effectiveness. Therefore, the staff finds the operating experience program element to be acceptable because the applicant provided sufficient previous operating experience to support the effectiveness of AMP activities and gave a framework for future operating experience reviews to ensure that AMPs will be adjusted as knowledge becomes available from new analyses, experiments, and inspection activities.

<u>Conclusion</u>

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

3.5.5 Evaluation Findings

The staff reviewed the AMPs in the LRA and supplemental documentation. The staff performed its review following the guidance in NUREG-1927, Revision 1. Based on its review, the staff determined that the applicant provided sufficient information with adequate details to support the LRA with the follow finding:

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

4 LICENSE CONDITIONS TO ADDRESS RENEWAL

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

4.1 Safety Analysis Report Update

The NRC added the following condition to the license:

> Within 90 days of the issuance of renewed license, the licensee shall submit an updated Trojan ISFSI Safety Analysis Report (SAR) to the Commission and continue to update the SAR pursuant to the requirements in 10 CFR 72.70(b) and (c). The updated SAR shall include the proposed revisions as documented in Appendix G in Enclosure 2 of the January 23, 2019, response to NRC's Request for Additional Information (ADAMS Accession No. ML19028A411). The licensee may make changes to the SAR consistent with 10 CFR 72.48(c).

The applicant indicated that it will change the SAR to address aging management activities resulting from the renewal of the license and provide the SAR as part of the LRA. The applicant submitted a proposed update to the SAR in Appendix G to the March 23, 2017, LRA and Appendix G in Enclosure 2 to the January 23, 2019, response to the NRC's request for additional information to address the aging management activities described in the LRA. This condition ensures that the SAR changes are made in a timely fashion to enable the licensee to develop and implement necessary procedures related to renewal and aging management activities during the period of extended operation.

The SAR Update must also include the following text, to be added to the last paragraph in Section 9.7.8.4 Aging Management Programs:

> "However, for the Transfer Cask AMP and Transfer Station AMP, consistent with the timing stated in the LRA, the licensee must conduct the first inspection prior to the first use of the transfer cask and transfer station, respectively."

The applicant indicated that the first implementation of the AMPs would be completed in calendar years 2022 through 2023 and be considered Baseline Inspections. NRC staff have found that acceptable in this Safety Evaluation Report, assuming that the spent nuclear fuel (SNF) remains onsite. In the event SNF were to be transported offsite prior to 2022, the Baseline Inspections for the Transfer Cask and Transfer Station AMPs would have to be conducted prior to any shipment.

4.2 Procedures for Aging Management Program Implementation

The NRC added the following condition to the license:

> Within one year after the renewed license effective date, the licensee shall revise or create a document that defines the implementation of the Aging Management Program (AMP) as described in the proposed SAR update, as documented in Appendix G in Enclosure 2 of the January 23, 2019, response to NRC's Request for Additional Information. The document shall have sufficient detail to enable the

> development of comprehensive AMP procedures. The document shall contain a reference to the specific AMP provision(s) that the document is intended to implement. The reference shall be maintained even if the document is modified. The licensee shall maintain the document and any specific procedures for implementing the AMP throughout the term of this license.

This condition ensures that operating procedures address AMP activities required for extended storage operations. The timeframe in the condition is to ensure that operating procedures are developed in a timely manner. This timeframe is consistent with the guidance in NUREG-1927, Revision 1.

5 CONCLUSION

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

The NRC staff reviewed the LRA for the Trojan site-specific ISFSI, in accordance with NRC regulations in 10 CFR Part 72. The staff followed the guidance in NUREG-1927, Revision 1, and NUREG-1757, Volume 3, Revision 1. Based on its review of the LRA and the license conditions, the staff determines that the requirements of 10 CFR 72.42(a) and 10 CFR 72.42(b) have been met.

6 REFERENCES

10 CFR Part 51, *U.S. Code of Federal Regulations,* “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” Part 51, 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.”

10 CFR Part 73, *U.S. Code of Federal Regulations*, “Requirements for the physical protection of stored spent nuclear fuel and high-level radioactive waste,” Part 73. Chapter I, Title 10, “Energy.”

ACI 221.1R-98, “State-of-the-Art Report on Alkali-Aggregate Reactivity,” American Concrete Institute, Farmington Hills, MI, reapproved 2008.

ACI 318, “Building Code Requirements for Structural Concrete,” American Concrete Institute, Detroit, MI, 1983.

ACI 349.3R-02, “Evaluation of Existing Nuclear Safety-Related Concrete Structures,” American Concrete Institute, Farmington Hills, MI, 2002.

ANSI N14.6, “American National Standard for Special Lifting Devices for Shipping Containers Weighing 10000 pounds (4500 kg) or More for Nuclear Materials,” American National Standards Institute, Washington, DC.

ASME Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” Subsection NB, Section XI, “Rules for Inservice Inspection of Nuclear Power Plant Components,” Subsection IWL, American Society of Mechanical Engineers, New York, NY, 1995.

ASTM A36/A36M “Standard Specification for Carbon Structural Steel,” ASTM International, West Conshohocken, PA, 2012.

ASTM C150, “Standard Specification for Portland Cement,” ASTM International, West Conshohocken, PA, 2016a (latest version).

ASTM C494, “Standard Specification for Chemical Admixtures for Concrete,” ASTM International, West Conshohocken, PA, 2016b (latest version).

ASTM C33, “Standard Specification for Concrete Aggregates,” ASTM International, West Conshohocken, PA, 2016c (latest version).

ASTM A53/A53M, “Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless,” ASTM International, West Conshohocken, PA, 2018.

ASTM A615/A615M, “Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement,” ASTM International, West Conshohocken, PA, 2018.

Aomi, M., T. Baba, T. Miyashita, K. Kamimura, T. Yasuda, Y. Shinohara, and T. Takeda, “Evaluation of Hydride Reorientation Behavior and Mechanical Property for High-Burnup

Fuel-Cladding Tubes in Interim Dry Storage," *Journal of ASTM International*, Volume 5, pp. 651–673, 2008.

Baboian, R., "Galvanic Corrosion", *Corrosion: Fundamentals, Testing, and Protection,* ASM Handbook, Volume 13A, pp. 210–213, ASM International, 2003.

Bare, W.C., L.D. Torgerson, "Dry Cask Storage Characterization Project—Phase 1: CASTOR V/21 Cask Opening and Examination," NUREG/CR-6745, Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID, 2001, ADAMS Accession No. ML013020363.

Billone, M.C., T.A. Burtseva, Z. Han, and Y.Y. Liu, "Embrittlement and DBTT of High-Burnup PWR Fuel Cladding Alloys," FCRD-UFD-2013-000401, ANL-13/16, Argonne National Laboratory, Lemont, IL, 2013.

Cheung, M.M.S., J. Zhao, and Y.B. Chan, "Service Life Prediction of RC Bridge Structures Exposed to Chloride Environments," *Journal of Bridge Engineering*, Volume 14, pp. 164–178, 2009.

Cota, S.S., V. Vasconcelos, M. Senne, Jr., L.OL. Carvalho, D.B. Rezende, and R.F. Cõrrea, "Changes in Mechanical Properties Due to Gamma Irradiation of High-Density Polyethylene," *Brazilian Journal of Chemical Engineering*, Volume 24, No. 02. pp. 259–265, 2007.

Das, B.J., *Principles of Foundation Engineering*, 4th Edition, Brooks/Cole Publishing Company, Pacific Grove, CA, 1999.

Department of Energy, "Cost Implications of an Interim Storage Facility in the Waste Management System," FCRD-NFST-2015-000648 Rev. 1, 2016.

Einziger, R.E., H. Tsai, M.C. Billone, and B.A. Hilton, "Examination of Spent PWR Fuel Rods after 15 Years in Dry Storage," NUREG/CR-6831, Argonne National Laboratory, Argonne, IL, 2003, ADAMS Accession No. ML032731021.

Fontana, M.G., *Corrosion Engineering*, McGraw-Hill Book Company, New York, NY, 1986.

Government Accountability Office, "Nuclear Waste Management: Key Attributes, Challenges, and Costs for the Yucca Mountain Repository and Two Potential Alternatives," GAO-10-48, 2009.

— — — "Spent Nuclear Fuel Management: Outreach Needed to Help Gain Public Acceptance for Federal Activities That Address Liability," GAO-15-141, 2014.

Grubb, J.F., T. DeBold, and J.D. Fritz, "Corrosion of Wrought Stainless Steels," *Corrosion: Materials*, ASM Handbook, Volume13B, pp. 54–77, ASM International, Materials Park, OH, 2005.

Gutt, W.H. and W.H. Harrison "Chemical Resistance of Concrete," *Concrete*, Volume 11, pp. 35–37, 1997.

Hanson, B., H. Alsaed, C. Stockman, D. Enos, R. Meyer, and K. Sorenson, "Gap Analysis to Support Extended Storage of Used Nuclear Fuel, Rev. 0," FCRD-USED-2011-000136, PNNL-20509, 2011.

Holtec Report HI-2002420, “Holtite-A: Results of Pre-and Post-Irradiation Tests and Measurements.” 2003, Docket No. 72-1014. (This document contains proprietary information and is withheld under 10 CFR 2.390.)

Holtec Report HI-2002396, “Holtite-A: Development History and Thermal Performance Data,” 2002, Docket No. 72-1014.

Kaufman, J.G., “Corrosion of Aluminum and Aluminum Alloys,” *Corrosion: Materials,* ASM Handbook, Volume 13B, pp. 95–124, ASM International, Materials Park, OH, 2005.

Macfarlane, A., “Interim Storage of Spent Fuel in the United States,” Annual Review of Energy and the Environment, Volume 26, pp. 201-235, 2001.

McConnell, J.W., Jr., A.L. Ayers, Jr., and M.J. Tyacke, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” NUREG/CR-6407, Idaho National Engineering Laboratory, Idaho Falls, ID, February 1996, ADAMS Accession No. ML15127A114.

Mehta, P.K, *Concrete, Structure, Properties and Materials*, Prentice-Hall, Inc Upper Saddle River, NJ, 1986.

NAVFAC, “Foundations and Earth Structures,” Design Manual NAVFAC DM-7.02, U.S. Naval Facilities Engineering Command, Alexandria, VA, 1996.

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

— — — Regulatory Guide 3.61, “Standard Format and Content for a Topical Safety Analysis Report for a Spent Fuel Dry Storage Cask,” U.S. Nuclear Regulatory Commission, February 1989, ADAMS Accession No. ML003739511.

— — — NUREG-1522, “Assessment of In-service Conditions of Safety-Related Nuclear Plant Structures,” U.S. Nuclear Regulatory Commission, Washington, DC, 1995, ADAMS Accession No. ML062510407.

— — — “Safety Evaluation Report Related to the Model No. HI-STAR 100 Cask System Certificate of Compliance No. 9261 Revision N. 0.” U.S. Nuclear Regulatory Commission, Washington, DC, 2002, ADAMS Accession No. ML023260089.

— — — Interim Staff Guidance 11, “Cladding Considerations for the Transportation and Storage of Spent Fuel,” Revision 3, U.S. Nuclear Regulatory Commission, Washington, DC, November 17, 2003, ADAMS Accession No. ML033230335.

— — — NUREG-1757, “Consolidated Decommissioning Guidance—Financial Assurance, Recordkeeping, and Timeliness,” Volume 3, Revision 1, U.S. Nuclear Regulatory Commission, Washington, DC, February 2012a, ADAMS Accession No. ML12048A683.

— — — Information Notice 2012-20, “Chloride-Induced Stress Corrosion Cracking of Austenitic Stainless Steel and Maintenance of Dry Cask Storage System Canisters,” U.S. Nuclear

Regulatory Commission, Washington, DC, November 2012b, ADAMS Accession No. ML12319A440.

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

— — — “Final Environmental Assessment for the Proposed Renewal of the U.S. Nuclear Regulatory Commission License SNM-2509 for the Trojan Independent Spent Fuel Storage Installation in Columbia County, Oregon,” U.S. Nuclear Regulatory Commission, Washington, DC, 2019, July 2019, ADAMS Accession No. ML19169A054.

Nikolaev, Yu., A.V. Nikolaeva, and Ya.I. Shtrombakh. “Radiation Embrittlement of Low-Alloy Steels.” *International Journal of Pressure Vessels and Piping*. Vol. 79. pp. 619–636. 2002.

Odette, G.R. and G.E. Lucas. “Embrittlement of Nuclear Reactor Pressure Vessels.” *Journal of Metals*. Vol. 53, Issue 7. pp. 18-22. 2001.

Nuclear Waste Technical Review Board (NWTRB), “Evaluation of the Technical Basis for Extended Dry Storage and Transportation of Used Nuclear Fuel,” Washington, DC, 2010.

Poe, W.L., “Final Long-Term Degradation of Concrete Facilities Presently Used for Storage of Spent Nuclear Fuel and High-Level Waste,” Revision 1, *Degradation Mechanisms for Concrete and Reinforcing Steel*, Tetra Tech NUS, Inc., Aiken, SC, 1998.

PGE, “Trojan Independent Spent Fuel Storage Installation's (ISFSI) Radiological Decommissioning Cost Estimate and Funding Plans,” VPN-007-2012, Portland General Electric Company, December 13, 2012, ADAMS Accession No. ML12355A286.

— — — “Trojan Site-Specific Independent Spent Fuel Storage Installation (ISFSI) License Change Application (LCA), License Renewal,” VPN-004-2017, Portland General Electric Company, March 23, 2017, ADAMS Accession No. ML17086A039.

— — — “Portland General Electric Company—Submittal of Response to NRC’s Request for Additional Information Related to the Trojan ISFSI License Change Application (LCA 72-07) for License Renewal (CAC No. 001028),” VPN-001-2019, Portland General Electric Company, January 23, 2019, ADAMS Accession No. ML19028A411. 2019a.

— — — “Submittal of Response to NRC's Request for Additional Information Related to the Trojan ISFSI License Change Application (LCA 72-07) for License Renewal (CAC No. 001028),” VPN-004-2019, Portland General Electric Company, February 21, 2019, ADAMS Accession No. ML19057A148. 2019b.

— — — “Submittal of Response to NRC's Request for Additional Information Related to the Trojan ISFSI License Change Application (LCA 72-07) for License Renewal (CAC No. 001028),” VPN-009-2019, Portland General Electric Company, June 10, 2019, ADAMS Accession No. ML19164A182. 2019c.

Revie, R.W., *Uhlig’s Corrosion Handbook*, Second Edition, John Wiley and Sons, Hoboken, NJ, 2000.

Sindelar, R.L., A.J. Duncan, M.E. Dupont, P.-S. Lam, M.R. Louthan, Jr., and T.E. Skidmore, "Materials Aging Issues and Aging Management for Extended Storage and Transportation of Spent Nuclear Fuel," NUREG/CR-7116, Savannah River National Laboratory, Aiken, SC, November 2011.