FINAL SAFETY EVALUATION REPORT

VENTILATED STORAGE CASK (VSC-24) SYSTEM

CERTIFICATE OF COMPLIANCE NO. 1007

RENEWAL

DOCKET NO. 72-1007

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

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INTRODUCTION

By letter dated October 12, 2012 (ML12290A139), as supplemented February 14, 2013 (ML130500219), April 4, 2014 (ML14099A192), October 24, 2014 (ML14301A283), and June 26, 2015 (ML15182A163), Energy*Solutions* (hereafter the "CoC holder"), applied for renewal of Certificate of Compliance (CoC) No. 1007 for the Ventilated Storage Cask System (VSC-24), for a period of 40 years beyond the initial certificate term. The CoC holder submitted the renewal application in accordance with the regulatory requirements of 10 CFR 72.240, "Conditions for spent fuel storage cask renewal." Because the renewal application was submitted more than 30 days before the Certificate's expiration date, pursuant to 10 CFR 72.240(b), this application constitutes a timely renewal. In the application, the CoC holder documented the technical bases for renewal of the certificate and the required actions for managing the potential aging effects of the systems, structures, and components (SSCs) of the dry storage system to ensure that these SSCs will maintain their intended functions during the period of extended operation.

The VSC-24 was approved under 10 CFR 72, Subpart L, "Approval of Spent Fuel Storage Casks." Approved spent fuel storage casks, or systems, are used under the general license granted under 10 CFR 72, Subpart K for the storage of spent nuclear fuel (SNF) in an independent spent fuel storage installation (ISFSI) at power reactor sites to persons authorized to possess or operate nuclear power reactors under 10 CFR 50 or 10 CFR 52. The VSC-24 storage system is a canister-based dry cask spent fuel storage system comprised of three principal components, the canister (i.e., multi-assembly sealed basket (MSB) assembly), the ventilated concrete cask (VCC) assembly, and the transfer cask (i.e., MSB transfer cask (MTC) assembly). The MTC assembly is used for canister loading and unloading operations that are conducted in the spent fuel building at the reactor site.

In the renewal application, the CoC holder presented general information about the storage system design and a scoping analysis to determine the SSCs that are in-scope of the renewal review and subject to an aging management review (AMR). The CoC holder further screened the in-scope SSCs to identify and describe the subcomponents that support the in-scope SSCs' intended function(s). For each in-scope SSC subcomponent, the CoC holder proposed either a time-limited aging analysis (TLAA) or an aging management program (AMP) to ensure that the SSC will maintain its intended functions during the period of extended operation.

The NRC staff (staff) reviewed the technical bases for safe operation of the dry storage system for an additional 40 years beyond the length of the term certified by the cask's current certificate. This safety evaluation report (SER) summarizes the results of the staff's review for compliance with 10 CFR 72.240. In its review of the application and development of the SER, the staff followed the guidance provided in NUREG–1927, "Standard Review Plan for Renewal of Spent Fuel Dry Cask Storage System Licenses and Certificates of Compliance," dated March 2011 ([65]).

This SER is organized in four sections: Section 1 provides the staff's review of the general information of the dry storage system. Sections 2 and 3 document the staff's evaluation of the application and issues considered during the review of the application. Section 4 describes the additions and changes to the CoC conditions, including the technical specifications, being made to the CoC (the initial CoC and the CoC amendments), as a result of this review and in accordance with 10 CFR 72.240(e). Section 5 provides the staff's conclusions for this review.

Appendix A of this SER includes the AMPs, as submitted and revised by the CoC holder through the review process. Appendix B provides a bibliography of the references supporting the staff's review and technical determinations.

1 GENERAL INFORMATION

1.1 CoC and CoC Holder Information

Energy*Solutions*, as the Certificate of Compliance (CoC) holder of the VSC-24 storage system, submitted a renewal application on October 12, 2012 (ML12290A139), as supplemented February 14, 2013 (ML130500219), April 4, 2014 (ML14099A192), October 24, 2014 (ML14301A283), and June 26, 2015 (ML15182A163), for CoC No. 1007 for a term of 40 years in accordance with 10 CFR 72.240(a). The CoC holder requested renewal of the initial VSC-24 storage system CoC and amendments 1 through 6. The initial CoC was issued on May 7, 1993, corresponding to Revision 0 of the VSC-24 storage system Final Safety Analysis Report (FSAR). Subsequently, six (6) amendments have been issued to the VSC-24 storage system CoC. The CoC holder provided a description of the certification basis for the VSC-24 storage system CoC initial issue and general descriptions of the changes and reasons for each amendment, including the dates of the applications and associated supplements, the dates of CoC and CoC amendments issuance, and the corresponding FSAR revisions in which the changes were incorporated.

Section 1.2.1 of the currently approved technical specifications (TS) (Attachment A to the initial CoC and the CoC for Amendments 1 through 6) describes the characteristics of the spent fuel to be stored in the VSC-24 storage system. The initial CoC and all CoC amendments authorize storage of up to twenty-four (24) intact (i.e., fuel with no known or suspected gross cladding failures), unconsolidated, zircaloy clad pressurized water reactor (PWR) spent nuclear fuel (SNF) assemblies. The post-irradiation time is 5 years or more, and the maximum initial enrichment is limited to 4.2 weight percent (wt %) uranium-235 (U-235). The maximum design basis heat load is 1 kW per assembly, for a cask maximum of 24 kW.

The initial CoC and Amendments 1, 2, and 3 permit storage of SNF with a maximum assembly average burnup of ≤ 51.8 GWd/MTU. The maximum assembly average burnup was reduced to ≤ 45 GWd/MTU for Amendments 4 through 6. The initial CoC and all CoC amendments authorize a maximum design basis heat load of 1 kW per assembly, for a cask maximum of 24 kW.

1.2 Safety Review

The objective of this safety review is to determine that there is reasonable assurance that the spent fuel storage cask will continue to meet the requirements of 10 CFR part 72 during the period of operation that extends beyond the length of the term of the current certificate (referred to hereafter as the period of extended operation or extended storage). The NRC staff's safety review is a detailed and in-depth assessment of the technical aspects of the VSC-24 renewal application. Pursuant to 10 CFR 72.240(c)(2) and 72.240(c)(3), an application for renewal of a spent fuel storage cask CoC must include the following: (i) time-limited aging analyses (TLAAs) that demonstrate SSCs that are important to safety (ITS) will continue to perform their intended function(s) for the requested period of extended operation and (ii) a description of the aging management programs (AMPs) for management of issues associated with aging that could adversely affect SSCs ITS. The CoC holder stated that the renewal application is consistent with guidance provided in NUREG–1927 ([65]). The CoC holder provided both TLAAs and AMPs to assure that the SSCs within the scope of renewal will continue to perform their intended function(s) during the period of extended operation. This SER documents the staff's evaluation of the CoC holder's scoping and screening evaluation, aging management review (AMR), and supporting AMPs and TLAAs.

1.3 Application Content

The renewal application provided the following information:

- General Information
- Scoping Evaluation
- Aging Management Reviews
- Time-Limited Aging Analyses
- Aging Management Programs
- Final Safety Analysis Report Changes
- Proposed certificate conditions or TSs

The CoC holder also provided the FSAR revisions for all CoC amendments, which incorporated all changes to the VSC-24 storage system, including those made in accordance with 10 CFR 72.48. The application includes a listing of all changes made to the storage system by the CoC holder and the general licensees using the 10 CFR 72.48 process. The staff reviewed the changes made under the 10 CFR 72.48 process only to determine their effects, if any, on the renewal of the CoC and the SSCs' performance during extended operation. The relevant changes (e.g., removal of MTC middle shell between the lead and neutron shielding) were considered in the staff's review of the applicant's scoping evaluation and aging management review. Appendix A of the renewal application describes the Final Safety Analysis Report (FSAR) changes to which the CoC holder has committed.

1.4 Interim Staff Guidance

The staff, industry, and other interested stakeholders gain experience and develop lessons learned from operating spent fuel dry storage systems and ISFSIs and from each renewal review. The lessons learned address issues related to the goals of maintaining safety, improving effectiveness and efficiency, reducing regulatory burden, and increasing public confidence. The staff develops Interim Staff Guidance (ISG) to clarify or to address issues not addressed in standard review plans, including NUREG–1927. These ISGs are to be used by the staff, industry, and other interested stakeholders until incorporated into staff guidance documents such as regulatory guides and standard review plans. Table 1.4-1 lists the ISGs relevant to this CoC renewal.

1.5 Evaluation Findings

The staff reviewed the general information provided in Chapter 1 of the renewal application and supplemental documentation. The staff performed its review following the guidance provided in NUREG–1927 ([65]) and the ISGs identified in Table 1.4-1. Based on its review, the staff finds:

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

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

Table 1.4-1. Existing Interim Staff Guidance Relevant to CoC Renewal

Interim Staff Guidance Number	Interim Staff Guidance Title
SFST-ISG-1, Rev. 2	Damaged Fuel
SFST-ISG-2, Rev. 1	Fuel Retrievability
SFST-ISG-5	Revision 1 Confinement Evaluation
SFST-ISG-9, Rev. 1	Storage of Components Associated with Fuel Assemblies
SFST-ISG-10, Rev. 1	Alternatives to the ASME Code
SFST-ISG-11, Rev. 3	Cladding Considerations for the Transportation and Storage of Spent Fuel
SFST-ISG-15	Materials Evaluation
SFST-ISG-21	Use of Computational Modeling Software
SFST-ISG-22	Potential Rod Splitting Due to Exposure to an Oxidizing Atmosphere During Short-Term Cask Loading Operations in LWR or Other Uranium Oxide Based Fuel
SFST-ISG-24	Use of a Demonstration Program as a Surveillance Tool for Confirmation of Integrity for Continued Storage of High Burnup Fuel Beyond 20 Years
SFST-ISG-25	Pressure Test and Helium Leakage Test of the Confinement Boundary for Spent Fuel Storage Canister

2 SCOPING EVALUATION

10 CFR 72.240(c)(2) and (3) require~~s~~ a CoC renewal application to include TLAAs that demonstrate that SSCs ITS will continue to perform their intended function for the requested period of extended operation and a description of AMPs for management of issues associated with aging that could adversely affect SSCs ITS. In addition, 10 CFR 72.236(m) states that to the extent practicable in the design of spent fuel storage casks, consideration should be given to compatibility with removal of the stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy.

A scoping evaluation is necessary to identify the SSCs subject to an AMR. More specifically, the scoping evaluation is used to identify SSCs meeting any of the following criteria:

1. SSCs that are classified as important to safety (ITS), as they are relied on to do one of the following functions:
   a. Maintain the conditions required by the regulations or CoC to store spent fuel safely.
   b. Prevent damage to the spent fuel during handling and storage.
   c. Provide reasonable assurance that spent fuel can be received, handled, packaged, stored, and retrieved without undue risk to the health and safety of the public.
2. SSCs that are classified as <u>not</u> important to safety but according to the design bases, their failure could prevent fulfillment of a function that is important to safety.

The CoC holder performed a scoping evaluation consistent with the above criteria and provided the following information:

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

- A list of the SSCs and SSC subcomponents identified to be within the scope of renewal review and subject to an AMR, including their intended function(s), and safety classification or basis for inclusion in the renewal review scope;

- A list of sources of information used; and

- Any discussion and drawings needed to clarify the process, SSC designations, or sources of information used.

The following section discusses the staff's review of and findings regarding the CoC holder's scoping study.

2.1 Scoping and Screening Methodology

Chapter 2 of the renewal application (Energy*Solutions* Spent Fuel Division Inc., 2015 [45]), Scoping Evaluation, describes the methodology for identifying SSCs within the scope of renewal review and subject to an AMR. The CoC holder followed a scoping evaluation process in accordance with NUREG–1927 ([65]). The CoC holder's scoping and screening methodology reviewed the design bases information as identified in the following documents:

- VSC-24 FSAR:
    - Revision 0, October 1991
    - Revision 1, May 2000
    - Revision 2, March 2001
    - Revision 3, September 2001
    - Revision 4, April 2002
    - Revision 5, March 2003
    - Revision 6, August 2006
    - Revision 7, April 2007
    - Revision 8, April 2009
- VSC-24 SER
    - Initial Certificate Effective Date: May 7, 1993
    - Amendment Number 1 Effective Date: May 30, 2000
    - Amendment Number 2 Effective Date: September 5, 2000
    - Amendment Number 3 Effective Date: May 21, 2001
    - Amendment Number 4 Effective Date: February 3, 2003
    - Amendment Number 5 Effective Date: September 13, 2005
    - Amendment Number 6 Effective Date: June 5, 2006

The CoC conditions and TS govern the transfer of irradiated nuclear fuel from the spent fuel pool and storage at the ISFSI pad, including cask handling, loading, movement, surveillance, and maintenance of the loaded casks.

2.1.1 Scoping Process

The CoC holder reviewed the VSC-24 design bases documents listed in Section 2.1 of this SER to identify SSCs with safety functions meeting either scoping criterion 1 or 2, as defined in Section 2.1. Table 2.1-1 lists the SSCs included and excluded from the scope of renewal review and identifies the scoping criterion met by each in-scope SSC.

Table 2.1-1. SSCs Within and Outside Scope of Renewal Review*

Structures, Systems and Components	Criterion 1	Criterion 2	In-Scope
SNF Assemblies	Yes(1)	N/A	Yes
MSB Assembly	Yes(2)	N/A	Yes
VCC Assembly	Yes(2)	N/A	Yes
MTC Assembly	Yes(2)	N/A	Yes
Fuel Transfer and Auxiliary Equipment(3)	No	No	No
ISFSI Storage Pad	No	No	No
ISFSI Security Equipment(4)	No	No	No

*Energy*Solutions* Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 4, ML15182A163, June 26, 2015.

[1] The CoC holder stated that fuel pellets are not within the scope of the renewal.

[2] Energy*Solutions* Spent Fuel Division, Inc., "Final Safety Analysis Report for the VSC-24 Ventilated Storage Cask System," Docket No. 72-1007, Revision 8, April 2009 indicates that the MSB Assembly, MTC Assembly, and the VCC Assembly are the only VSC-24 ITS SSCs.

[3] The CoC holder stated the fuel transfer and auxiliary equipment include: transfer cask lifting yoke, hydraulic roller skid, air pallets, heavy haul trailer and the engineered cask transporter.

[4] The CoC holder stated that the security equipment includes ISFSI security fences and gates, lighting, communications, and monitoring equipment.

The SSCs identified in Table 2.1-1 to be within the scope of renewal review include:

- SNF Assemblies
- Multi-assembly Sealed Basket (MSB)
- Ventilated Concrete Cask (VCC)
- MSB Transfer Cask (MTC)

The CoC holder stated these SSCs were found to meet scoping criterion 1 as defined in Section 2.1 of this SER, and hence were subject to an AMR. The staff reviewed Chapter 1 of the VSC-24 FSAR[1], which indicates that the MTC Assembly, the MSB Assembly and the VCC Assembly are the only ITS SSCs.

Although the design basis in the FSAR did not identify SNF assemblies as important to safety, in its renewal application, the CoC holder stated the SFA subcomponents have intended functions of criticality control, radiation shielding, confinement, and structural support. Therefore, the SFAs were identified to be within the scope of renewal review. The staff reviewed the design bases in the FSAR, which do not identify the SFAs as important to safety, and the information in the renewal application, which did identify the SFAs as important to safety.

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[1] Except for instances where a specific revision number is stated, the term FSAR refers to all FSAR revisions. Thus, in this instance, the staff review included Chapter 1 of each revision of the FSAR. For its review, the staff considered or reviewed the information in all the revisions of the FSAR since each CoC amendment is associated with a different FSAR revision.

Pursuant to 10 CFR 72.236, the design bases and design criteria for the storage system must be provided for structures, systems, and components important to safety (10 CFR 72.236(b)); the spent fuel storage cask must be designed and fabricated so that the spent fuel is maintained in a subcritical condition under credible conditions (10 CFR 72.236(c)); the spent fuel storage cask must be compatible with wet or dry spent fuel loading and unloading facilities (10 CFR 72.236(h)); and to the extent practicable in the design of spent fuel storage casks, consideration should be given to compatibility with removal of the stored spent fuel from a reactor site, transportation, and ultimate disposition by the Department of Energy (10 CFR 72.236(m)). In ISG-2 Revision 1 (NRC, 2010 [64]), the NRC staff stated a fuel assembly is considered to be "readily retrievable" if it remains structurally sound (i.e., no gross degradation) and could be handled by normal means (i.e., does not pose operational safety problems during removal). Therefore, the CoC holder stated that both the assembly hardware and cladding meet criterion (1)(iii) identified in NUREG-1927, Section 2.4.2 and are therefore considered important to safety. In addition, since the radiation shielding and heat transfer and criticality controls were not analyzed for normal conditions with the fuel in a disrupted state, the applicant identified the SNF assembly hardware and cladding subcomponents (and hence the SNF assemblies) as being relied on for these safety functions. Therefore, the applicant stated that these SNF assembly subcomponents are in scope since their degradation can change the thermal and radiation source terms and affect the criticality safety of the storage system. Consistent with the guidance in NUREG-1927, the applicant determined the fuel pellets to be out of scope.

Because assembly hardware and cladding support retrievability of the spent fuel, as well as criticality control and radiation shielding, by maintaining the fuel geometry that is relied upon in the safety analyses for those functions, the staff finds that the CoC holder has correctly identified the SNF assembly subcomponents to be within the scope of renewal review. The staff also concludes that the fuel pellet is not considered to be within the scope of renewal review because its behavior is not considered in the original safety analyses, and it is not relied on to meet retrievability or confinement functions or the other safety functions. This is consistent with the renewal guidance in NUREG-1927.

The CoC holder stated that the fuel transfer and auxiliary equipment necessary for ISFSI operations are not included as part of the VSC-24 design approved in the CoC. The CoC holder further stated that the VCC, MSB, and MTC assemblies are designed to withstand potential failure of the fuel transfer equipment. Thus, failure of the fuel transfer equipment would not prevent the VCC, MSB, or MTC assemblies from fulfilling their intended functions. Therefore, the applicant stated that fuel transfer equipment does not meet scoping criterion 2 and is not within the scope of renewal. The staff reviewed Chapter 1 of the FSAR and the renewal application to determine whether the fuel transfer and auxiliary equipment are within the scope of the renewal review.

The staff reviewed the FSAR to identify the intended functions of the fuel transfer and auxiliary equipment. The staff confirmed that the design bases of the VSC-24 do not include the lifting yoke. The FSAR states that the handling equipment, including the transfer cask lifting yoke, is addressed on a site-specific basis in site safety reviews. The FSAR further states that additional handling equipment (such as trailers, skids, portable cranes, or cask transporters) are not important to safety as the VSC-24 system is designed to withstand the failure of any of these components.

According to the applicant, the VSC-24 handling system employs a hydraulic roller skid and a heavy haul trailer (or alternatively, an engineered cask transporter, as described in Appendix B of the FSAR). Section 1.2.1.4 of the FSAR states that the skid is composed of two steel forks, which ride on eight 50-ton Hilman® rollers and lift the cask two inches above the floor. In this position, the skid and the cask can be towed or pushed with a heavy haul truck (or other suitable vehicle). Appendix B of the FSAR further states that the engineered cask transporter is an alternative to the trailer and skid for movement of the VSC-24 to the storage pad. The transporter is designed to lift the VCC from 6 to 18 inches off the ground so that the transporter and cask can be moved to the storage location. Section B.1.2.14 of the FSAR provides the bases for the first part of TS 1.2.14, which states that drops up to 60 inches, of the MSB inside the VCC, can be sustained without breaching the confinement boundary, preventing removal of the spent fuel assemblies, or causing a criticality accident. This part of the TS ensures that handling height limits (60 inches) will not be exceeded in transit to, or at the storage pad. The applicant showed in FSAR tables 11.2-1 and 11.2-2 that ASME code limit stresses are not exceeded for a 60-inch drop. That analysis shows that the MSB will not result in breach of confinement, or loss of criticality or retrievability functions. Accordingly, the TS 1.2.14 states that the VCC with the MSB shall not be handled at a height of greater than 60 inches to prevent the possibility of an unanalyzed condition. Since the VCC is analyzed for drops of up to 60 inches, or a tip-over, and the VCC is lifted less than 60 inches using either the skid or engineered cask transporter, the staff also finds it acceptable for the applicant to state that the fuel transfer auxiliary equipment is not important to safety and its failure will not prevent fulfillment of a function that is important to safety.

After reviewing the information, and consistent with guidance in NUREG-1927, the staff concludes that fuel transfer and active auxiliary equipment (e.g., vacuum drying and helium back-fill system with a helium sniffer for leak detection, welding equipment) is not within the scope of renewal review, as it is not important to safety and does not prevent fulfilment of a safety function.

The CoC holder also stated that the ISFSI concrete storage pad is not important to safety and not part of the approved CoC design. The storage pad provides freestanding support of the VSC-24 casks. The CoC holder further stated that the VCC and MSB assemblies are designed to withstand potential failure of the storage pad. The CoC holder’s assessment is consistent with the guidance in NUREG-1927 which states that the ISFSI concrete pad is generally not within scope unless the pad provides a safety function (e.g., during a seismic event) The staff reviewed the information provided and determined that the ISFSI storage pad does not meet either scoping criterion. Therefore, the staff concludes that the ISFSI storage pad is not within the scope or renewal review.

The CoC holder stated that the ISFSI security equipment is not ITS and not part of the design approved in the CoC. Consistent with guidance provided in NUREG-1927, the CoC holder further stated that failure of the ISFSI security equipment would not prevent fulfilment of a safety function. The staff reviewed the information provided and determined that the ISFSI security equipment does not meet either scoping criterion; therefore, the staff concludes the ISFSI security equipment is not within the scope of renewal review.

The CoC holder screened the in-scope SSCs to identify and describe the subcomponents that support the SSC intended function(s). The CoC holder identified those SSC subcomponents and associated intended functions based on the design basis documents listed in Section 2.1 of this SER. The SSC subcomponents within the scope of the renewal review are described in Section 2.1.2 and the SSC subcomponents not within the scope of the renewal review are described in in Section 2.1.3.

2.1.2 Structures, Systems, and Components Within Scope of Renewal Review

Based on the scoping process discussed in Section 2.1 of the renewal application (Energy*Solutions* Spent Fuel Division Inc., 2015 [45]), the CoC holder identified four SSCs of the VSC-24 design to be within the scope of renewal review. Tables 2.1-2 and 2.1-3 describe the subcomponents that support the intended functions of the SSCs that are within the scope of renewal review.

Table 2.1-2. SSC Subcomponents Within Scope of Renewal Review*
(Spent Nuclear Fuel -SNF Assemblies , Multi-assembly Sealed Basket – MSB)

SNF Assemblies	MSB
Fuel Cladding	Shell
Spacer Grid Assemblies	Bottom Plate
Upper End Fitting including nozzle	Shield Lid Support Ring
Lower End Fitting including nozzle	Lifting Lug
Guide Tubes	Structural Lid
	Shim
	Shield Lid Top Plate
	Shield Lid Bottom Plate
	Shield Lid Side Ring
	Shield Lid Neutron Shield
	Structural Lid Valve/Port Covers
	Shield Lid Support Plate
	Storage Sleeve
	Basket Edge Structure
	Coating(1)

*Energy*Solutions* Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 4, Energy*Solutions* Spent Fuel Division Inc., 2015, ML15182A163, June 26, 2015.

[1] Coating on the MSB structural lid and structural lid closure weld is within scope as a criterion 2 item. Coating on the MSB shell and MSB bottom is NITS and conservatively ignored in the analysis and is therefore out of scope.

Table 2.1-3. SSC Subcomponents Within Scope of Renewal Review*
(Ventilated Concrete Cask – VCC, MSB Transfer Cask – MTC)

VCC	**MTC**
Concrete Shell	Outer Shell
Rebar	Inner Shell
Cask Liner Shell	Middle Shell(1)
Cask Liner Bottom	Top Ring
Liner Flange	Bottom Ring
Cask Lid	Neutron Absorber Shield
Lid Bolts, Nuts, Lockwashers	Lead Shield
Shielding Ring Plates (Liner Assembly)	Angle, Heat Transfer
Shielding Ring Plates (Shield Ring)	Trunnion
Air Inlet Assembly	Trunnion Inner & Outer Plate(1)
Air Outlet Weldment	Trunnion Lead/ Neutron Shields(1)
Air Inlet Screen/Hardware	MTC Lid
Air Outlet Screen/Hardware	Lid Bolts
Bottom Plate Assembly	Shim/ Flange
	Rail Shield
Coating(2)	Rail Lower Plate
	Shield Door
	Light MTC Shield Door Lead Plug
	Coating(2)

*Energy Solutions Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 4, Energy*Solutions* Spent Fuel Division Inc., 2015, ML15182A163, June 26, 2015.

[1] The CoC holder stated that these subcomponents were removed by the general licensees in accordance with 10 CFR 72.48 and the change was subsequently adopted in CoC amendment 4 and incorporated in FSAR Revision 5. The CoC holder further stated that all current and any future MTCs do not and will not include removed subcomponents because Amendments 4 through 6 do not authorize the use of these subcomponents, and because the initial CoC and Amendments 1 through 3 will include, upon renewal, a condition that precludes the fabrication and use of these subcomponents in new and existing MTCs. (See Section 4 of this SER for the conditions to be added to the CoC.)

[2] Coating on the VCC, the MSB structural lid, structural lid closure weld, structural lid valve covers, and structural lid valve cover welds, and the MTC is within scope as a criterion 2 item.

The staff reviewed the CoC holder’s screening of the SSCs to identify subcomponents within the scope of renewal review. The staff’s review considered the intended function of the subcomponent, its safety classification or basis for inclusion in the scope of renewal review, and design basis information in the FSAR. Based on this review, the staff finds the CoC holder’s screening evaluation results are consistent with NUREG-1927, and therefore acceptable. The staff additionally notes that the welds of the in-scope SSC subcomponents (e.g., MSB structural lid closure weld, MSB shell-to-base plate weld, MSB shell longitudinal welds) are also within the scope of the renewal review. Further discussions in this SER of the in-scope SSC subcomponents implicitly include these welds.

2.1.3 Structures, Systems, and Components NOT Within Scope of Renewal Review

The CoC holder reviewed the in-scope SSCs to identify and describe any subcomponents that do not support the SSC intended function(s). Tables 2.1-4 and 2.1-5 tabulate these subcomponents, as identified by the CoC holder.

Table 2.1-4. SSC Subcomponents NOT Within Scope of Renewal Review*

(Spent Nuclear Fuel - SNF Assemblies , Multi-assembly Sealed Basket – MSB)

SNF Assembly	MSB
Fuel Pellets	Closure Weld Backing Ring
Hold down Spring & Upper End Plugs	Shield Lid Pipe & Flex Tubing
Control Components(1)	Swagelok Quick Connect

*Energy*Solutions* Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 4, Energy*Solutions* Spent Fuel Division Inc., 2015, ML15182A163, June 26, 2015.

[1] The CoC holder stated that the VSC-24 criticality analysis does not account for negative reactivity effects of control components. Therefore, the control components do not have a criticality control function.

Table 2.1-5. SSC Subcomponents NOT Within Scope of Renewal Review*

(Ventilated Concrete Cask – VCC, MSB Transfer Cask – MTC)

VCC	MTC
Locking Wire with Lead Seal	Drain Pipe
Lid Gasket	Trunnion Cylinder/ End Covers
Tile (MSB support)	Rail Alignment Plate/ Door Bolt
MTC Alignment Plates	Door Top Cover
VCC Lifting Lugs	Door hydraulics/ Brackets/ Attachment Hardware
	Hydraulic Cylinder Assembly

*Energy Solutions Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 4, EnergySolutions Spent Fuel Division Inc., 2015, ML15182A163, June 26, 2015.

The staff reviewed the CoC holder’s screening of the SSCs, which identified subcomponents not within the scope of renewal review. The staff’s review considered the intended function of the subcomponent, its safety classification or basis for exclusion from the renewal review scope, and design information in the FSAR. Based on this review, the staff finds the CoC holder’s screening evaluation results are consistent with NUREG-1927 and therefore, acceptable.

2.2 Evaluation Findings

The staff reviewed the scoping evaluation provided in Chapter 2 of the renewal application and supplemental documentation. The staff performed its review following the guidance provided in NUREG–1927 (NRC, 2011 [65]) and the ISGs identified in Table 1.4-1. Consistent with the guidance in NUREG-1927, the staff also used the information provided in NUREG/CR–6407, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety” (NRC, 1996 [57]), in its review as a reference for classification of components as ITS to determine the accuracy and completeness of the CoC holder’s scoping evaluation. Based on its review, the staff finds:

F2.1 The CoC holder has identified all SSCs ITS and SSCs the failure of which could prevent a SSC ITS from performing its intended safety function per the requirements of 10 CFR 72.3, “Definitions”, and 72.236, “Specific requirements for spent fuel storage cask approval and fabrication.”

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

3 AGING MANAGEMENT REVIEW

3.1 Review Objective

The objective of the staff's review of the aging management review (AMR) is to assess the proposed aging management activities (AMAs) for systems, structures and components (SSCs) determined to be within the scope of renewal review. The AMR addressed aging mechanisms and effects that could adversely affect the ability of the SSCs (and associated subcomponents) to perform their intended functions during the period of renewal.

3.2 AMR Process

The CoC holder described its AMR process to be consistent with guidance provided in Chapter 3, "Aging Management Review" of NUREG-1927 (NRC, 2011 [65]). The AMR identified the aging mechanisms and effects applicable to each SSC subcomponent based on its material of construction and service environment during normal storage conditions. For each aging mechanism/effect, the CoC holder further identified either a TLAA or AMP to ensure the intended function of the SSC would be maintained during the period of extended operation.

The CoC holder stated in the renewal application that the materials of construction of the SSC subcomponents were identified through a review of pertinent design basis documents and general arrangement drawings in the references listed in Section 2.1 of this SER. The CoC holder stated that the review was also performed to identify the environmental conditions to which the SSCs are normally exposed. The CoC holder clarified that these environmental conditions are based on a review of the original FSAR and all revisions to the FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001 [70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; Energy Solutions Spent Fuel Division, 2006 [34]; 2007 [35]; 2009 [36]) and plant records.

The CoC holder proposed that the initial CoC and Amendments 1, 2, and 3 of the VSC-24 storage system CoC be conditioned to require that all new VSC-24 storage system SSCs be constructed in accordance with Amendment 4 of the VSC-24 storage system CoC or subsequent CoC amendments. The purpose of the proposed condition is to preclude the continuance of fuel loading and closure welding operations and design issues that arose during the use of the VSC-24 system under the initial CoC and Amendments 1 through 3, and resolved in the subsequent CoC amendments and limit the maximum assembly average burnup on any future loading to 45 GWd/MTU. The intent of this condition is that no new SSCs or subcomponents of SSCs may be constructed or put into service under the initial CoC or Amendments 1 through 3; however, systems may continue to be operated and maintenance and repairs of SSCs and subcomponents may continue to be done per the CoC amendment under which they were put into service. Based on the CoC holder's proposal and the staff's review, the staff has added an appropriate condition to the affected CoC amendments. The CoC conditions are included in Section 4 of this SER.

The staff reviewed the CoC holder's AMR process, including a description of the review process, the design basis references, and the discussion needed to clarify the AMR. The staff's review considered the intended function of the subcomponent, its safety classification or basis for inclusion in the scope of renewal, and design basis information in the FSAR. Based on its review, the staff finds the CoC holder's AMR process acceptable.

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

Tables 3.3-1 through 3.3-4 provide the results of the CoC holder’s AMR and the TLAAs or AMPs credited for the identified aging mechanisms and effects for SSC subcomponents within the scope of renewal review, as provided in the CoC renewal application dated June 26, 2015 (EnergySolutions Spent Fuel Division Inc., 2015 [45]).

Table 3.3-1. Aging Management Review Results—SNF Assembly

Item No.	Subcomponent	In Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	TLAA/AMP SER Section
SNF-1	Fuel Cladding	1	Zircaloy	Inert Gas[1]	Change in dimensions (Cladding creep)	3.3.1	3.4.5
SNF-2	Spacer Grid Assemblies	1	Zircaloy; Stainless Steel	Inert Gas[1]	None Identified	3.3.1	N/A
SNF-3	Upper end Fitting including nozzle	1	Stainless Steel; Inconel	Inert Gas[1]	None Identified	3.3.1	N/A
SNF-4	Lower End Fitting including nozzle	1	Stainless Steel; Inconel	Inert Gas[1]	None Identified	3.3.1	N/A
SNF-5	Guide Tubes	1	Zircaloy	inert Gas[1]	None Identified	3.3.1	N/A

[1] The CoC holder defined 'Inert Gas' as the environment inside the MSB cavity that ranges in temperature from ambient to 371 °C [700 °F]. The gas composition is helium at approximately 1 atmosphere pressure. The presence of oxygen or moisture within the MSB cavity is limited to very low levels.

Table 3.3-2. Aging Management Review Results—Multi-assembly Sealed Basket (MSB)

Item No.	Subcomponent[1]	In Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	TLAA/AMP SER Section
MSB-1	MSB Shell	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-2	MSB Shell	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-3	MSB Shell	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-4	MSB Shell	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-5	MSB Shell	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of material (Corrosion)	3.3.2	3.4.3; 3.5.2; 3.5.3; 3.5.5
MSB-6	Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-7	Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-8	Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-9	Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-10	Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of material (corrosion)	3.3.2	3.4.3
MSB-11	Shield Lid Support Ring	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4

Table 3.3-2. Aging Management Review Results—Multi-assembly Sealed Basket (MSB)

Item No.	Subcomponent[1]	In Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	TLAA/AMP SER Section
MSB-12	Lifting Lug	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-13	Structural Lid	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sealed air-filled	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-14	Structural Lid	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sealed, Air-Filled	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-15	Structural Lid	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of material (corrosion)	3.3.2	3.5.3; 3.5.5
MSB-16	Structural Lid	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-17	Structural Lid	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-18	Shim	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	None Identified	3.3.2	None
MSB-19	Shield Lid Top Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sealed air-filled	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-20	Shield Lid Bottom Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-21	Shield Lid Side Ring	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-22	Shield Lid Neutron Shield	1	RX-277	Embedded	Loss of shielding effectiveness (Radiation)	3.3.2	3.4.4; 3.4.7

Table 3.3-2. Aging Management Review Results—Multi-assembly Sealed Basket (MSB)							
Item No.	**Subcomponent[1]**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**
MSB-23	Structural Lid Valve Covers	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sealed air-filled	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-24	Structural Lid Valve Covers	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sealed air-filled	Loss of fracture toughness (radiation)	3.3.2	3.4.4
MSB-25	Structural Lid Valve Covers	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of material (corrosion)	3.3.2	3.5.3; 3.5.5
MSB-26	Structural Lid Valve Covers	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Crack growth (Fatigue)	3.3.2	3.4.2; 3.4.6
MSB-27	Structural Lid Valve Covers	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Sheltered	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-28	Shield Lid Support Plate	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-29	Storage Sleeve	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-30	Basket Edge Structure	1	SA 516 Grade 70 with Dimetcote 6 or CarboZinc 11	Inert Gas	Loss of fracture toughness (Radiation)	3.3.2	3.4.4
MSB-31	Coating on Structural Lid and Closure Weld	2	Dimetcote 6 or CarboZinc 11	Sheltered	Loss of Coating	3.3.2	3.5.3; 3.5.5

Table 3.3-3. Aging Management Review Results—Ventilated Concrete Cask (VCC)							
Item No.	**Subcomponent**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**
VCC-1	Concrete Shell	1	Reinforced Concrete	Exposed	Loss of strength (ASR)	3.3.3	3.5.1
VCC-2	Concrete Shell	1	Reinforced Concrete	Exposed	Loss of strength (CaOH leaching)	3.3.3	3.5.1
VCC-3	Concrete Shell	1	Reinforced Concrete	Exposed	Loss of strength (Radiation)	3.3.3	3.4.4
VCC-4	Concrete Shell	1	Reinforced Concrete	Exposed	Scaling, Cracking, Spalling (Freeze-Thaw)	3.3.3	3.5.1
VCC-5	Concrete Shell	1	Reinforced Concrete	Exposed	Scaling, Cracking, Spalling (ASR)	3.3.3	3.5.1
VCC-6	Concrete Shell	1	Reinforced Concrete	Exposed	Scaling, Cracking, Spalling (Corrosion of rebar)	3.3.3	3.5.1
VCC-7	Concrete Shell	1	Reinforced Concrete	Exposed	Thermal Fatigue	3.3.3	3.4.8
VCC-8	Rebar	1	A 615 Grade 60	Embedded	Loss of material (corrosion)	3.3.3	3.5.1
VCC-9	Rebar	1	A 615 Grade 60	Embedded	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-10	Rebar	1	A 615 Grade 60	Embedded	Thermal Fatigue	3.3.3	3.4.8
VCC-11	Cask Liner Shell	1	A36 Steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.2; 3.5.5
VCC-12	Cask Liner Shell	1	A36 Steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-13	Cask Liner Shell	1	A36 Steel	Embedded	Loss of fracture toughness (radiation)	3.3.3	3.4.4

Table 3.3-3. Aging Management Review Results—Ventilated Concrete Cask (VCC)							
Item No.	**Subcomponent**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**
VCC-14	Cask Liner Bottom	1	A36 Steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.2; 3.5.5
VCC-15	Cask Liner Bottom	1	A36 Steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-16	Cask Liner Bottom	1	A36 Steel	Embedded	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-17	Liner Flange	1	A36 steel with Dimetcote 6 coating or equivalent	Exposed	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5
VCC-18	Liner Flange	1	A36 steel with Dimetcote 6 coating or equivalent	Exposed	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-19	Liner Flange	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5
VCC-20	Liner Flange	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-21	Liner Flange	1	A36 steel	Embedded	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-22	Cask Lid	1	A36 steel with Dimetcote 6 coating or equivalent	Exposed	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5

Table 3.3-3. Aging Management Review Results—Ventilated Concrete Cask (VCC)

Item No.	Subcomponent	In Scope Classification Criterion 1 or 2	Materials	Environment	Aging Effect/ Mechanism	AMR SER Section	TLAA/AMP SER Section
VCC-23	Cask Lid	1	A36 steel with Dimetcote 6 coating or equivalent	Exposed	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-24	Cask Lid	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5
VCC-25	Cask Lid	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.3	3.4.4
VCC-26	Lid Bolts, Nuts, Lockwashers	1	A307 steel with Zinc coating	Exposed	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5
VCC-27	Shielding Ring Plates (Liner Assy.)	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.2; 3.5.3; 3.5.5
VCC-28	Shielding Ring Plates (Shield Ring)	1	A36 Steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.2; 3.5.3; 3.5.5
VCC-29	Air Inlet Assembly	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.3; 3.5.5
VCC-30	Air Inlet Assembly	1	A 36 Steel	Embedded	None Identified	3.3.3	N/A
VCC-31	Air Outlet Weldment	1	A36 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.3	3.5.2; 3.5.3; 3.5.5
VCC-32	Air Outlet Weldment	1	A36 Steel	Embedded	None Identified	3.3.3	N/A

Table 3.3-3. Aging Management Review Results—Ventilated Concrete Cask (VCC)							
Item No.	**Subcomponent**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**
VCC-33	Air Inlet Screen/ Hardware	1	Carbon steel ; Galvanized steel; Zinc plated steel	Exposed	Loss of material (corrosion)	3.3.3	3.5.1
VCC-34	Air Outlet Screen/ Hardware	1	Stainless Steel; Galvanized steel;	Exposed	Loss of material (corrosion)	3.3.3	3.5.1
VCC-35	Coating on Steel surfaces	1	Carbon steel	Exposed	Loss of material (corrosion)	3.3.3	3.5.4; 3.5.5
VCC-36	Bottom Plate Assembly	1	A36 Steel	Embedded	None Identified	3.3.3	N/A
VCC-37	Bottom Plate Assembly	1	A36 Steel	Exposed	Loss of material (corrosion)	3.3.3	3.5.1
VCC-38	Coating on steel surfaces	2	Dimetcote 6 or equivalent	Sheltered	Loss of coating	3.3.3	3.5.2; 3.5.3; 3.5.5

Table 3.3-4. Aging Management Review Results—MSB Transfer Cask (MTC)

Item No.	Subcomponent	In Scope Classification Criterion 1 or 2	Materials	Environment[1, 2]	Aging Effect/ Mechanism	AMR SER Section	TLAA/AMP SER Section
MTC-1	Outer Shell	1	A588 Grade A or B steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-2	Outer Shell	1	A588 Grade A or B steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-3	Outer Shell	1	A588 Grade A or B steel	Embedded	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-4	Inner Shell	1	A588 Grade A or B steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-5	Inner Shell	1	A588 Grade A or B steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-6	Inner Shell	1	A588 Grade A or B steel	Embedded	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-7	Top Ring	1	A516 Grade 70 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-8	Top Ring	1	A516 Grade 70 steel	Embedded	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-9	Bottom Ring	1	A516 Grade 70 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4

Table 3.3-4. Aging Management Review Results—MSB Transfer Cask (MTC)

Item No.	**Subcomponent**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment[1, 2]**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**
MTC-10	Bottom Ring	1	A516 Grade 70 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-11	Bottom Ring	1	A516 Grade 70 steel	Embedded	Loss of fracture toughness (radiation)	3.3.4	3.4.4
MTC-12	Neutron Absorber Shield	1	RX-277	Embedded	Loss of shielding effectiveness (radiation)	3.3.4	3.4.4
MTC-13	Lead Shield	1	Lead	Embedded	None Identified	3.3.4	N/A
MTC-14	Angle, Heat Transfer	1	A36 Steel	Embedded	None Identified	3.3.4	N/A
MTC-15	Trunnion	1	A516 Grade 70 steel	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-16	MTC Lid	1	A516 Grade 70 steel with Dimetcote 6 coating or equivalent	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-17	Lid Bolts	1	A325 Steel	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-18	Shim/Flange	1	A36 Steel	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-19	Rail Shield	1	A36 Steel with coating[1]	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-20	Rail Lower Plate	1	A36 Steel with coating[1]	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-21	Shield Door	1	A36 Steel with coating[1]	Sheltered	Loss of material (corrosion)	3.3.4	3.5.4
MTC-22	Light MTC Shield Door Lead Plug	1	Lead	Sheltered	None Identified	3.3.4	N/A
MTC-23	Coating on steel surfaces	2	Dimetcote 6 or equivalent	Sheltered	Loss of coating	3.3.4	3.5.4

Table 3.3-4. Aging Management Review Results—MSB Transfer Cask (MTC)

Item No.	**Subcomponent**	**In Scope Classification Criterion 1 or 2**	**Materials**	**Environment[1, 2]**	**Aging Effect/ Mechanism**	**AMR SER Section**	**TLAA/AMP SER Section**

[1] The CoC holder stated that the exposed surfaces of the Rail Shield, Rail lower plate, and Shield door are coated with Dimetcote 6 or equivalent and the sliding surfaces of these components are lubricated with Everlube 823 or equivalent.

3.3.1 Spent Nuclear Fuel (SNF) Assemblies

The VSC-24 storage system is designed to accommodate up to twenty-four (24) intact, unconsolidated, zircaloy clad Pressurized Water Reactor (PWR) SNF assemblies in each cask. A wide range of PWR SNF assembly types are accommodated by the VSC-24 storage system. The fuel types allowed by the initial CoC include Babcock and Wilcox (B&W) Mark B 15 × 15, Combustion Engineering (CE)/Exxon 15 × 15, CE 16 × 16, Westinghouse PWR 17x 17, Westinghouse PWR 15 × 15, and Westinghouse PWR 14 × 14. Amendment 1 expands the fuel types to include B&W Mark B 15 × 15 with burnable poison rod assemblies (BPRAs). Amendment 4 further expands the fuel types to include B&W Mark B 15 × 15 with thimble plug assemblies (TPAs), CE/Exxon 15 × 15 fuel with poison clusters or plugging clusters, Westinghouse PWR 17 × I 7 with BPRAs and TPAs, and Westinghouse PWR 14 × 14 with BPRAs and TPAs. The VSC-24 storage system components are provided in three different lengths to accommodate the fuel assemblies allowed for storage.

In the initial CoC and Amendments 1, 2, and 3, the maximum assembly average burnup level is limited to ≤51.8 GWd/MTU. In Amendment 4 and subsequent amendments, the maximum assembly average burnup level is limited to ≤45 GWd/MTU. The maximum heat load for casks loaded under the initial CoC or any of the amendments is 24 kW (1kW per assembly).

However, as described in Section 1.1.2 of the CoC renewal application, the maximum heat load for each of the 58 casks loaded to date under the initial CoC or any of the Amendments is 14.7 kW; and no fuel assemblies with burnups exceeding 45 GWd/MTU have been loaded into any VSC-24 casks.

In the renewal application, the CoC holder chose not to address the unique issues related to the storage of high burnup fuel (fuel with assembly average burnups exceeding 45 GWd/MTU). The applicant based this decision, in part, on the fact that no currently loaded VSC-24 systems contain spent fuel having assembly average burnups exceeding 45 GWd/MTU. Rather than address the issues associated with HBF, the CoC holder proposed a CoC condition to limit the storage of spent fuel assemblies having assembly average burnups that exceed 45 GWd/MTU in a VSC-24 cask to 20 years. The CoC holder proposed, and the staff is adding, a new CoC condition (see Section 4 of the SER) that precludes fabrication of and placing into service new VSC-24 cask system SSCs under the initial CoC and Amendments 1 through 3. The new condition's purpose is, in part, to preclude the use of features of the VSC-24 that the CoC holder did not address in the renewal application. Since high burnup fuel is only approved contents for these amendments to the CoC, the condition effectively limits all future loadings, if any, of VSC-24 casks to SNF assemblies with burnups no greater than 45 GWd/MTU. Given this new CoC condition, the staff finds the applicant's decision to not address high burnup fuel in its renewal application to be acceptable and a specific condition to limit storage of high burnup fuel to 20 years to be unnecessary.

The CoC holder also proposed a CoC condition to limit the total decay heat to 15 kW for all casks loaded under the renewed CoC. The CoC holder contends that the proposed CoC condition limiting the cask heat load to 15 kW and SNF assembly decay heat to 0.625 kW provides margin for aging mechanisms for temperature-related aging effects, including cladding temperatures, and that it ensures that the analyses in the renewal application will remain applicable to future loadings, if any, of VSC-24 casks. Based on the CoC holder's thermal analyses in the renewal application and its proposed condition on SNF assembly decay heat limits, the staff modified the specifications in the CoC to limit SNF assembly decay heat to a maximum of 0.625 kW/SNF assembly and the maximum heat load for any future VSC-24 loading to 15 kW (0.625 kW/SNF assembly × 24 SNF assemblies /cask = 15 kW/cask).

The CoC holder identified the following SNF assembly subcomponents in Section 2.2.2 and Table 8 of the CoC renewal application to be within the scope of the renewal review:

- Fuel Cladding
- Spacer Grid Assemblies
- Upper end Fitting
- Lower End Fitting
- Guide Tubes

The CoC holder identified the following SNF assembly subcomponents in CoC renewal application Section 2.2.2 and Table 8 as not important to safety and not within the scope of the renewal review:

- Fuel Pellets
- Hold down Spring & Upper End Plugs
- Control Components

The staff verified the SNF contents that are approved for storage in the VSC-24 as identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001[70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; EnergySolutions Spent Fuel Division Inc., 2006 [34]; 2007 [35]; 2009 [36]) and TS 1.2.1 are consistent with those identified in the CoC renewal application. Per TS 1.2.1, only intact, unconsolidated SNF assemblies may be stored in the VSC-24 system including:

- B&W Mark B 15 × 15 with and without BPRAs or TPAs
- CE/Exxon 15 × 15 with and without poison clusters or plugging clusters
- CE 16 × 16
- Westinghouse PWR 17 × 17 with and without BPRAs or TPAs
- Westinghouse PWR 15 × 15
- Westinghouse PWR 14 × 14 with and without BPRAs or TPAs

Staff also verified the description of the fuel assembly characteristics, including initial enrichment, maximum burnup and maximum decay power per assembly.

3.3.1.1 Materials and Environments

Materials

The CoC holder provided additional information on the materials and environments for the SNF assembly subcomponents that were identified as within the scope of the renewal review.

- Fuel Cladding

  The CoC holder specified that the fuel cladding was made of zircaloy (a zirconium-based alloy).

- Spacer Grid Assemblies

The CoC holder specified that the spacer grid assemblies are made of either stainless steel or zircaloy.

- Upper and Lower End Fittings

  The CoC holder specified that the upper and lower end fittings are made of either stainless steel or Inconel (a nickel base alloy).

- Guide Tubes

  The CoC holder specified that the guide tubes are made of zircaloy.

- Insert materials

  The CoC holder stated that the SNF assemblies may also include various assembly control components, such as burnable poison rod assemblies, thimble plug assemblies and control rod assemblies. The insert materials include zircaloy or stainless steel cladding, stainless steel or Inconel top fittings, and neutron absorbing materials such as boron carbide, borosilicate glass or silver-indium-cadmium.

The staff reviewed the description of the SNF assembly materials provided in the CoC renewal application. The staff also reviewed the information contained in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001 [70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; EnergySolutions Spent Fuel Division Inc., 2006 [34]; 2007 [35]; 2009 [36]) and TS 1.2.1. The staff verified that the description of the SNF materials of construction is accurate and complete.

Environments

The SNF assemblies stored in the MSB cavity are exposed to inert gas (helium). The CoC holder has stated that the presence of oxygen or moisture within the MSB cavity is limited to very low levels due to the vacuum drying process, and that this avoids deleterious chemical changes in the fuel cladding. SNF subcomponents exposed to the environments inside the MSB cavity include the outer surface of the zircaloy fuel cladding, the top and bottom end nozzle structures, guide tubes, and the outer surfaces of the zircaloy or stainless steel cladding of the insert materials. The CoC holder stated the gas pressure inside the MSB cavity is close to one atmosphere.

The CoC holder provided the results of thermal analyses of the VSC-24 cask for the vacuum drying condition. Based on a maximum canister heat load of 24 kW and steady-state conditions, the CoC holder calculated a peak cladding temperature of 424°C [796°F], which is slightly higher than the 400°C [752 °F] temperature limit recommended by ISG-11 Revision 3 (NRC, 2003 [62]). However, the CoC holder has indicated that the highest initial heat generation level for all currently-loaded MSBs is less than 15 kW, so the actual peak cladding temperatures experienced during the vacuum drying process are well below 400°C [752°F]. The CoC holder has also proposed a CoC condition that will limit the initial total heat load to 15 kW for all casks loaded under the renewed CoC. The CoC holder indicated that during storage the maximum temperature of the gas in contact with the SNF assembles can range from the ambient air temperature for zero decay heat to as high as 371°C [700°F] for the maximum canister heat load of 24 kW. The CoC holder stated that temperatures of the cladding and the gas inside the MSB decrease with time.

The staff reviewed the accuracy of the service environments for the SNF assemblies with the VSC-24 design bases referenced in the CoC renewal application. The staff also reviewed the MSB loading procedures described in Chapter 8 of the FSAR and confirmed that the procedures include removal of water, vacuum drying and helium backfill for all loaded MSBs, with appropriate criteria, also included in the technical specifications, to ensure residual water is adequately minimized (i.e., the MSB is effectively dry). The staff reviewed the information on past MSB loadings supplied in the CoC renewal application. Based upon the information provided by the CoC holder, all fuel loaded in the VSC-24 systems consists of low burnup fuel and the maximum initial cask heat load was 14.75 kW (EnergySolutions Spent Fuel Division Inc., 2015 [45]). The staff confirmed that the maximum initial temperature of the cladding for this maximum initial heat load would be less than 400°C [752°F] (EnergySolutions Spent Fuel Division Inc., 2015 [45]). Based on its review, the staff concludes that the CoC holder adequately identified the service environment for the SNF assemblies.

3.3.1.2 Aging Effects/Mechanisms for the Spent Nuclear Fuel Assemblies During the Period of Extended Storage

The CoC holder stated in Section 3.2.1.3 of the CoC renewal application that the potential degradation mechanisms for the SNF assemblies include oxidation, corrosion, cladding creep, cladding annealing, and hydride redistribution and reorientation within the cladding.

The CoC holder considered the potential for oxidation of the zircaloy fuel cladding and the irradiated UO_2 fuel pellets which could occur if the fuel is exposed to air as described in ASTM C1562 (ASTM, 2010 [20]). The CoC holder stated that oxidation of the fuel pellets can cause swelling which has the potential to split the fuel cladding, and excessive oxidation of the fuel cladding, combined with internal stress, can cause the fuel cladding to breach. The CoC holder stated that both effects could affect the ability to retrieve fuel. The CoC holder cited the results of a demonstration program reported in NUREG/CR-6831 (Einziger et al., 2003 [33]) indicating previous studies show that for low burnup fuel assemblies (i.e., assemblies with an average burnup level less than 45 GWd/MTU), degradation of the fuel cladding will not occur during the initial storage period and should not occur during extended storage if the inert atmosphere is maintained. The CoC holder stated that the MSB confinement boundary is designed, constructed, and tested to assure that confinement and the inert atmosphere in the MSB cavity will be maintained during the storage period. In addition, the CoC holder stated that the peak temperatures of the fuel are much lower than the temperatures required to produce significant oxidation (i.e., generally above 300°C [572°F]). Because of the inert environment and the temperature of the SNF assemblies stored within the MSB cavity, the CoC holder stated that oxidation of the fuel and cladding, even if exposed to air during the period of extended operation, is not considered a credible degradation mechanism.

The staff reviewed the CoC holder's assessment of oxidation of the zircaloy fuel cladding and irradiated UO_2 fuel. The analysis reported in NUREG/CR-6831 (Einziger et al., 2003 [33]) showed that the cladding had measured external oxide thicknesses of 5 to 45 μm which was similar to that expected for Zircaloy-4 cladding with a burnup of 35 GWd/MTU. The staff noted that NUREG/CR-6831 (Einziger et al., 2003 [33]) concluded that no deleterious effects on fuel and cladding were observed after 15-years of dry cask storage and that similar oxide thicknesses (15 to 40 μm) were reported for Zircaloy at 36 GWd/MTU by EPRI (EPRI, 2006 [49]). The staff reviewed the oxidation rate data for Zircaloy-4 including the data in NUREG/CR-

6846 (Natesan and Soppet, 2004 [58]) that showed the oxidation rate of unirradiated cladding is temperature dependent and oxidation in steam and dry air at or below 400°C proceeds slowly. The staff also reviewed UO_2 oxidation data reported by Hanson (Hanson, 1998 [53]) that showed an activation energy of 109 kJ/mol which increased with burnup. The author concluded oxidation of UO_2 to U_3O_8 was strongly temperature dependent and unlikely to occur at low temperatures. The staff reviewed the MSB loading procedures in the FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001 [70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; EnergySolutions Spent Fuel Division Inc., 2006 [34]; 2007 [35]; 2009 [36]) and confirmed that the loading procedures are consistent with the recommendations in ISG-22 (NRC, 2006 [63]) for preventing damage to fuel rods as a result of UO_2 oxidation by exposure to oxidizing conditions at elevated temperatures. The staff determined that no aging management activity is necessary for the oxidation of zircaloy cladding because the MSB loading procedures required the use of an inert environment that will prevent the oxidation of the zircaloy cladding and prevent oxidation of any UO_2 fuel surface exposed through pinholes or hairline cracks in the zircaloy cladding. The staff's conclusion is also based upon available data that shows that even if the inert environment is not maintained the oxidation rate of the zircaloy cladding and the UO_2 fuel 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. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for oxidation of the SNF assemblies to be acceptable.

The CoC holder considered the potential for corrosion degradation mechanisms that could occur in the presence of moisture include pitting, stress corrosion cracking (SCC), and galvanic corrosion of the fuel assembly components (ASTM, 2010 [20]). The CoC holder stated that water ingress into the MSB cavity during storage is not considered to be credible for the double welded closure configuration of the MSB assembly. The CoC holder stated that other potential sources of moisture in the MSB cavity are residual water in the MSB cavity and fuel assemblies following MSB loading operations, including off-gassing of the RX-277 neutron shielding material in the MSB shield lid, which are limited to very low levels through the vacuum drying process. The CoC holder stated that any moisture off-gassed during the vacuum drying process will be evacuated from the MSB cavity and consequently any moisture remaining in the MSB cavity as a result of RX-277 off-gassing will be very small and will not result in any significant amount of corrosion of the zircaloy fuel cladding.

The staff reviewed the CoC holder's assessment of corrosion degradation mechanisms for the SNF assemblies constructed from zircaloy, stainless steel, and Inconel (nickel-based alloy with chromium) materials as described in SER Section 3.3.3.1. The staff reviewed the corrosion resistance of the SNF assembly materials. Zircaloy, stainless steels, and Inconel alloys form protective passivating oxide films. As long as the protective oxide films are maintained, the corrosion rate of these alloys is very low. Localized corrosion of these alloys can occur if the passive oxide film is damaged or cannot be maintained. Zircaloy, and zirconium alloys in general, are susceptible to localized corrosion in halide containing solutions, and accelerated corrosion rates are known to occur in fluoride containing solutions (Yau and Webster, 1987 [80]). Stainless steels and Inconel are known to be susceptible to localized corrosion in chloride containing solutions (Davison et al., 1987 [31]; Asphahani et al., 1987 [18]). Reduced sulfur species are also aggressive to iron-chromium and nickel-chromium alloys such as stainless steels and Inconel. Contaminants such as fluoride, chloride and sulfur containing species are strictly controlled in operating reactor coolants (EPRI, 1999 [48]) and spent fuel pools and therefore, are not expected to be present in concentrations required to affect the passivity of the SNF assembly materials of construction. The staff determined the MSB loading procedures and the CoC's technical specifications (see TS 1.2.7 and 1.2.8) (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001 [70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; EnergySolutions Spent Fuel Division Inc., 2006 [34]; 2007 [35]; 2009 [36]) require evacuating the canister under vacuum and backfilling with helium (which is an inert gas) that will significantly reduce the water content and humidity inside the canister and also reduce the oxidizing potential of the environment. The staff concludes that no aging management activities are necessary for the corrosion degradation of the SNF assembly subcomponents comprised of zircaloy, stainless steel, and Inconel materials because the loading procedures require the removal of water and the use of an inert environment in the MSB cavity, both of which will significantly decrease the potential for corrosion of the SNF 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, stainless steel and Inconel materials. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for corrosion of SNF assemblies inside the MSB cavity to be acceptable.

The CoC holder evaluated the potential for annealing of the fuel rod cladding, which may affect structural properties. The CoC holder cited results of a demonstration program where little if any cladding annealing was reported in the examination of low burnup (35.7 GWd/MTU) fuel rods after 15 years of dry storage (Einziger et al., 2003 [33]). The CoC holder stated that because cladding temperatures continue to decrease with time, cladding annealing is not a significant degradation mechanism that needs to be addressed for extended storage for low burnup SNF assemblies.

The staff reviewed the CoC holder's assessment of annealing of the zircaloy fuel cladding. The staff reviewed the information contained in NUREG/CR-6831 (Einziger et al., 2003 [33]) which noted that annealing of irradiation damage is temperature dependent and temperatures above 350°C [662°F] are required for significant annealing to occur in a relatively short period of time. Adamson (Adamson, 1977 [9]) reported that for 12 hour exposures the recovery of irradiation growth and yield strength in zircaloy was less than 10 percent at a temperature of 350°C [662°F] but increased to greater than 60 percent at 400°C [752°F]. The staff notes that all VSC-24 systems loaded to date had initial thermal loads less than 15 kW and the CoC holder has proposed a condition to limit any future loadings to 15 kW or less. The staff determined that no aging management activities are necessary for the annealing of zircaloy cladding because the MSB loading procedures and storage conditions will maintain the peak cladding temperature during loading and storage below the temperature required for annealing to occur. The staff's conclusion is also based upon the condition proposed by the CoC holder to limit any future loading to a maximum cask heat load of 15 kW or less which will assure that cladding temperatures during loading and storage will not result in significant annealing of the zircaloy fuel cladding. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for annealing of the fuel cladding to be acceptable.

The CoC holder considered the potential for hydride reorientation of the SNF assembly cladding which can adversely affect the structural properties of the cladding. The CoC holder stated that high cladding temperatures and hoop stresses that can occur during the cask loading process (e.g., vacuum drying) might result in hydrogen within cladding forming a solid solution that precipitates into radially oriented hydrides when the cladding cools after vacuum drying and during storage. The significance of this effect is primarily a function of the fuel assembly burnup, the fuel rod pressure and hoop stress, and the peak temperature reached during the cask loading process. The CoC holder cited ISG-11 Revision 3 (NRC, 2003 [62]), which indicates significant hydride re-orientation is not expected to occur in low burnup SNF assemblies. In addition, the CoC holder indicated that ISG-11 Revision 3 (NRC, 2003 [62]) states that the structural integrity of SNF assemblies is assured for low burnup fuel if the peak cladding temperature during the cask loading process remains under 400°C [752°F] and that the 570°C [1058°F] criterion specified in older licenses for low burnup fuel (e.g., the VSC-24 CoC) is acceptable and that no technical specification changes are required. The CoC holder also cited previous work on the examination of low burnup fuel (i.e., 35.7 GWd/MTU and 46 GWd/MTU) after an initial storage period of 15 years, which shows no evidence of radial hydrides (Einziger et al., 2003 [33]). The thermal analyses of the VSC-24 cask for the vacuum drying condition, which is based on a maximum canister heat load of 24 kW and steady-state conditions, calculates a peak cladding temperature of 424°C [796°F]. The CoC holder stated that while the results of the thermal analysis indicate the highest cladding temperature during drying is slightly higher than the 400°C [752°F] temperature limit recommended by ISG-11 Revision 3, the highest initial heat generation level for all currently-loaded MSBs is less than 15 kW, so the actual peak cladding temperatures experienced during the vacuum drying process are well below 400°C [752°F]. As a result, the CoC holder concluded that hydride redistribution and reorientation is not a credible aging effect for the SNF assemblies stored in the VSC-24 casks due to the low burnup levels of the fuel and the low peak cladding temperatures maintained during vacuum drying and normal storage operations. To ensure continued applicability of this conclusion to the VSC-24 spent fuel contents, the CoC holder proposed a CoC condition to limit the initial total heat load to 15 kW for all casks loaded under the renewed CoC.

The staff reviewed the CoC holder’s assessment of hydride reorientation of the zircaloy fuel cladding. The staff reviewed the information referenced by the CoC holder and noted that since ISG-11 Revision 3 was published, no additional information has been published or has otherwise been made available that challenges the conclusion that the staff has reasonable assurance that hydride reorientation will be limited and not lead to degradation of the cladding provided that the maximum cladding temperature does not exceed 400°C [752°F]. The staff determined that no aging management is necessary for the hydride reorientation of zircaloy cladding because the MSB loading procedures and storage conditions will maintain the cladding below the temperature necessary for the dissolution of circumferentially oriented hydrides and thus the re-precipitation of significant radial hydrides upon cooling will not occur. Therefore, the staff finds the CoC holder’s assessment that no aging management activity is required for hydride reorientation in the fuel cladding to be acceptable.

3.3.1.3 Proposed Aging Management Activities

The CoC holder stated that the rate of creep in fuel cladding is a function of the cladding temperature and hoop stress, and cladding creep exceeding 1.0% strain could cause gross rupture of the fuel cladding. In CoC renewal application Section 3.3.3.5, the CoC holder evaluated cladding creep using a TLAA. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

3.3.2 Multi-assembly Sealed Basket (MSB)

The SNF assemblies placed in dry storage using the VSC-24 dry storage systems are placed inside the MSB. MSB components identified by the CoC holder to be within the scope of the renewal review are identified in Table 5 of the CoC renewal application and included in this SER in Table 2.1-2.

The CoC holder summarized the AMR results for the MSB in CoC renewal application Table 9. In addition, previous MSB loading operational experiences are summarized in CoC renewal application Section 3.4.3; it is noted that these operational experiences should be considered in any future loading/unloading operations. The staff's evaluation of the AMR results is provided in this section.

The staff verified the MSB components that are within the scope of the renewal review are identified in the descriptions and design drawings contained in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991 [67]; 2000 [68]; 2001 [69]; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001 [70]; 2002 [71]; BNFL Fuel Solutions Corporation, 2003 [25]; EnergySolutions Spent Fuel Division Inc., 2006 [34]; 2007 [35]; 2009 [36]).

3.3.2.1 Materials and Environments

The MSB is comprised of a bottom plate, cylindrical shell, shield lid assembly, shield lid support ring, structural lid, and a MSB storage sleeve assembly that consists of a welded array of 24 storage sleeves, surrounded by three bands formed by support plates and support walls. The MSB assembly is constructed entirely from carbon steel; primarily SA516 Grade 70 (ASME, 2010a [14]), with the exception of the castable neutron shielding material (RX-277) that is sealed within the carbon steel casing plates that form the MSB shield lid. The design drawings include the option to use galvanized steel grate instead of the ceramic tiles to elevate the MSB slightly and prevent direct contact with the VCC interior bottom shell. The CoC holder did not provide an aging management review of this galvanized steel grate noting that none of the currently loaded VSC-24 systems use this grate. The CoC holder instead proposed a CoC condition to preclude the use of this grate in any VSC-24 systems that are loaded under the renewed CoC.

The exposed internal and external surfaces of the MSB shell, bottom plate, top lids and storage sleeve assembly are coated with a radiation-resistant, high-temperature, non-organic coating, such as Dimetcote 6 (PPG Industries, 2009 [73]) or Carbozinc 11 (Carboline Company, 2010 [27]). The CoC holder clarified that the functions of the coating are to protect the pool chemistry during the fuel loading operations and to facilitate decontamination of the MSB assembly exterior surfaces. The coating on the outside of the MSB shell and the MSB bottom plate is not relied on for corrosion protection or any other safety-related function during storage operations. However, the CoC holder identified the coating on the MSB structural lid and the structural lid to shell closure weld as within the scope of review as a NITS Criterion 2 item because the coating is relied on to prevent corrosion of these subcomponents. As discussed in the latest VSC-24 storage system FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]), the MSB relies on soluble boron in the spent fuel pool water for criticality control during fuel loading operations.

The CoC holder stated that the components of the MSB are exposed to four environments: sheltered, embedded, sealed air-filled, and inert gas. The CoC holder stated that during storage the outer surfaces of the MSB assembly are exposed to a sheltered environment. This environment includes ambient air, but not sun, rain or wind exposure. The CoC holder stated that the ambient air may contain moisture and some salinity, but clarified that none of the loaded VSC-24 systems are located in marine environments. The temperature of the ambient air inside the VCC cavity may range from that of the outside air for zero decay heat to nearly 149°C

[300°F] (based on the peak temperature of the MSB shell) for the design-basis canister heat load of 24 kW and extreme hot off-normal ambient conditions.

The CoC holder stated that the RX-277 neutron shield material inside the MSB shield lid is exposed to an embedded environment as it is fully encased in the SA-516 Grade 70 shield lid. Temperatures of the MSB lid RX-277 range up to 66°C [150°F] for normal storage conditions.

The CoC holder stated that the MSB storage sleeve assembly (basket), and the inside (cavity facing) surfaces of the MSB shell assembly are exposed to the inert gas (helium) with the presence of oxygen or moisture limited to very low levels by the vacuum drying process. The CoC holder stated the gas pressure inside the MSB cavity is close to one atmosphere. The CoC holder also indicated the temperature of the gas can range from the ambient air temperature for zero decay heat to as high as 371°C [700°F] for the maximum canister heat load of 24 kW. Further, the CoC holder indicated that the MSB interior components are exposed to significant gamma and neutron radiation.

The CoC holder stated that some MSB subcomponents including the top of the MSB shield lid assembly, the bottom of the MSB structural lid, the MSB structural lid backing plate, and the inner surfaces of the structural lid valve cover plates are exposed to a sealed, air-filled environment. This environment is not inert but has a limited quantity of oxygen and moisture because it is a small volume and physically separated from the sheltered environment of the MSB exterior by the combination of MSB steel subcomponents and welds. Oxygen and any moisture in the sealed air-filled environment will be consumed by the corrosion of the exposed surfaces of the MSB steel subcomponents.

The staff reviewed the description of the MSB subcomponents and the materials of construction identified in the descriptions and design drawings contained in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the description of the MSB subcomponents and the materials of construction in the renewal application are accurate and complete.

The staff reviewed the accuracy of the service environments for the MSB subcomponents based on the description and design drawings for the MSB included in Chapter 1 and Appendix E, as applicable, of the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff also reviewed the MSB loading procedures described in Chapter 8 of the FSAR and confirmed that the procedures include removal of water, vacuum drying and helium backfill for all loaded MSBs, with appropriate criteria, also included in the technical specifications, to ensure residual water in the MSB is adequately minimized (i.e., the MSB is effectively dry) (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the descriptions of the service environments for the MSB subcomponents are accurate and complete.

3.3.2.2 Aging Effects/Mechanisms for the Multi-assembly Basket During the Period of Extended Storage

The CoC holder stated in Section 3.2.1.1 of the CoC renewal application that the potential degradation mechanisms for the MSB subcomponents constructed from carbon steel include loss of material from general corrosion, galvanic corrosion, and crevice corrosion, loss of fracture toughness, and crack growth. The CoC holder indicated in CoC renewal application Section 3.2.1.4 that a potential degradation mechanism for the RX-277 neutron shielding material is loss of shielding effectiveness. Each of these aging effects and the associated degradation mechanisms are discussed in the following paragraphs.

The CoC holder has stated that MSB subcomponents constructed from carbon steel and exposed to the inert gas environment inside the MSB cavity are not susceptible to corrosion during the period of extended operation since it is a non-oxidizing environment. Therefore, the CoC holder has stated that corrosion of the MSB steel components exposed to an inert environment is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment of general corrosion of carbon steel used in internal components of the MSB exposed to an inert environment including the CoC holder's description of the environment as well as documented assessments of atmospheric conditions on the general corrosion of carbon steel. The general corrosion rate of carbon steel in atmospheric exposures is dependent on a number of factors including humidity, time of wetness, atmospheric contaminants and oxidizing species (Pohlman, 1987 [72]; Bryson et al., 1987 [26]; Tullmin and Roberge 2000 [77]). Atmospheric contaminants such as chloride and sulfur species can significantly accelerate general corrosion rates; however, such species are strictly controlled in operating reactor coolants (EPRI, 1999 [48]) and spent fuel pools. The staff determined that no aging management activity is necessary for the corrosion of carbon steel used in the internal components of the MSB because the MSB loading procedures and TS 1.2.7 and 1.2.8 required the MSB cavity to be evacuated under vacuum and backfilled with helium (which is an inert gas) creating a low humidity reducing environment that prevents the corrosion of carbon steel. For this reason, the staff finds the CoC holder's assessment that no aging management activity is required for general corrosion of carbon steel inside the MSB to be acceptable.

The CoC holder has stated that the MSB subcomponents constructed from carbon steel and exposed to the sealed air-filled environment at the top end of the MSB assembly are not susceptible to loss of materials because the available oxygen and moisture are very limited and once consumed, the carbon steel corrosion reactions cease. Based upon the limited volumes of the sealed air-filled cavities at the top end of the MSB assembly, the amount of corrosion that can occur before the oxygen and available moisture are consumed is insignificant for the MSB steel components. Therefore, according to the CoC holder, corrosion of the MSB steel components exposed to a sealed, air-fill environment is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment of general corrosion of carbon steel used in internal components of the MSB exposed to a sealed air-filled environment inside small cavities at the top end of the MSB assembly. Corrosion reactions for iron based alloys such as carbon steels are known to be limited by the available oxidants that can be reduced in cathodic reactions including oxygen and water. The staff determined that no aging management activity is necessary for the corrosion of the carbon steel exposed to sealed air-filled environments because corrosion of the carbon steel will be insignificant and restricted by the small and finite volume of water and oxygen relative to the large available surface area of the MSB subcomponents exposed to the sealed air-filled environment in the cavities located between the top of the MSB shield lid and the bottom of the MSB structural lid. For this reason, the staff finds that the CoC holder's assessment that no aging management activity is required for general corrosion of carbon steel MSB components exposed to sealed, air-filled environments to be acceptable.

The CoC holder has indicated that the VSC-24 storage system is less vulnerable to galvanic corrosion than other storage systems since it does not use many dissimilar metals. The MSB shell exterior is all SA-516 Grade 70 carbon steel coated with a radiation-resistant, high-temperature, non-organic coating, such as Dimetcote 6 or Carbozinc 11. In addition, the VCC interior is constructed from A36 (ASTM, 2012 [21]) carbon steel coated with Dimetcote 6 or Carbozinc 11. Because there are no dissimilar metal combinations where the MSB shell would be preferentially anodic, galvanic corrosion of the MSB shell will not occur. Therefore, the CoC holder has stated that galvanic corrosion of the MSB steel components is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment of galvanic corrosion of the MSB shell. The staff reviewed the materials of construction for the MSB shell using information provided in the descriptions and design drawings contained in Chapter 1 and Appendix E, as applicable, of the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that SA-516 Grade 70 was used for the MSB shell and A36 carbon steel was used for the VCC liner and the shielding rings. The staff reviewed the compositions of A36 carbon steel and SA-516 Grade 70 steel and determined that these steels are compositionally similar and will have similar electrochemical behavior (ASTM, 2012 [21]; ASME 2010a [14]). The staff also examined the coating on the MSB shell and the materials used in the construction of the VCC liner and the shielding ring plates. Coatings on the VSC-24 system are zinc-based coatings that would be preferentially anodic to the carbon steel MSB shell (Hack, 1987 [52]). The staff determined that no aging management is necessary for galvanic corrosion of the MSB shell, VCC liner, and the shield rings because these components and subcomponents are constructed from compositionally similar steels and there are no dissimilar metal combinations present, which would be necessary to promote galvanic corrosion. In addition, the MSB shell, VCC liner and shield rings are coated with a zinc based coating that is preferentially anodic to steel and is designed to protect the underlying steel from corrosion. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for galvanic corrosion of the MSB shell to be acceptable.

The CoC holder indicated that locations where the potential for crevice corrosion could occur in the VSC-24 storage system include the outer surface of the MSB bottom plate, which could potentially contact the VCC liner bottom, and the top end of the MSB shell, which could contact the VCC shield ring. These locations are within the sheltered environment of the VCC cavity, which is exposed to moisture in the air, but should not be exposed directly to water. The CoC holder stated that the MSB bottom plate is separated from the VCC bottom plate by ¼-inch thick ceramic tiles specifically to preclude crevice corrosion from occurring between the two surfaces. According to the CoC holder, while the design drawings include the option to use galvanized steel grate instead of the ceramic tiles, none of the currently loaded VSC-24 systems use this grate. Instead of providing an analysis of the aging effects for systems using galvanized steel grate, the CoC holder has proposed a CoC condition to preclude the use of this grate in any VSC-24 systems that are loaded under the renewed CoC. Therefore, according to the CoC holder, crevice corrosion of the MSB bottom plate is not a potential degradation mechanism during the period of extended operation.

The staff also reviewed the CoC holder's assessment that ceramic tiles located between the MSB and the VCC bottom will prevent crevice corrosion of the MSB shell and MSB bottom lid. Positioning ceramic tiles between the MSB and the VCC bottom plate prevents the formation of a metal-to-metal crevice, which can promote crevice corrosion (Dexter et al., 1987 [32]). In addition, the MSB shell, MSB bottom lid, and the VCC inner shell are coated with a zinc primer that is designed to be preferentially anodic to the carbon steel MSB shell and VCC liner. The VCC is also designed to prevent the accumulation of water between the MSB shell and bottom lid and the VCC interior by allowing any water that might enter thought the vents to drain through the lower ventilation ducts. The staff determined that no aging management activity is necessary for the crevice corrosion of the MSB shell and MSB bottom lid because (1) the design of the VSC-24 system does not include a metal-to-metal crevice; (2) the design also prevents the accumulation of water in contact with the bottom of the MSB and the VCC interior; and (3) the carbon steel MSB shell, MSB bottom lid and the VCC liner are all coated with a protective zinc based primer which would protect the MSB and VCC carbon steel surfaces from corrosion. Therefore the staff finds the CoC holder's assessment that no aging management activity is required for crevice corrosion of the MSB shell and bottom lid to be acceptable.

The CoC holder also evaluated hydrogen induced under-bead weld cracking or delayed hydride cracking (DHC) that can occur due to disassociation of water vapor in the weld arc, and subsequent absorption of the hydrogen in the weld metal which could lead to lamellar tearing, particularly in an over-constrained weld joint. The CoC holder indicated that early operating experience of the VSC-24 storage system revealed weld indications due to lamellar tearing that were identified by non-destructive examination (NDE) during the MSB loading process. These defects were repaired at the time of loading and the MSBs were placed into storage. In addition, the CoC holder reported that ultrasonic test (UT) examinations of the closure welds of all previously loaded VSC-24 casks were also performed, which confirmed that no MSB closure welds had experienced DHC-induced failure. The CoC holder indicated that corrective actions were taken that prevented this condition from occurring during subsequent MSB loading operations. Therefore, according to the CoC holder, hydrogen induced cracking of the MSB welds is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's evaluation of hydrogen-induced cracking described in CoC renewal application Section 3.2.1.1 and the operating experience summarized in CoC renewal application Section 3.4.3.2, MSB Closure Weld Cracks. The staff also reviewed the documentation associated with Corrective Action Letter (CAL) 97-7-001 (NRC, 1997 [61]), including the NRC technical evaluation of the response to CAL 97-7-001 which concluded ultrasonic testing (UT) of the VSC-24 MSB closure welds was sufficient to identify any unacceptable conditions requiring evaluation or repair. The staff confirmed that the corrective actions to address hydrogen induced cracking of the MSB closure weld described in CoC renewal application Section 3.4.3.2 are consistent with those identified in the NRC technical evaluation of the response to CAL 97-7-001. The staff determined that no aging management is necessary for hydrogen induced cracking of the MSB shell because hydrogen induced cracking, if it were to occur, would have been identified in the UT examination of all loaded MSBs prior to the issuance of CAL 97-7-001. In addition, changes to the materials used in the construction of the VSC-24 system and the revised welding procedures are sufficient to preclude hydrogen induced cracking in subsequently loaded MSBs. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for hydrogen cracking of the MSB closure wield to be acceptable.

The CoC holder stated that, unlike stainless steels, carbon steel is not susceptible to stress corrosion cracking. Therefore, the CoC holder has stated that stress corrosion cracking of the MSB shell and welds is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment and available information on the stress corrosion cracking susceptibility of carbon steels including SA-516 Grade 70 used in the MSB. The staff found that carbon steels are susceptible to stress corrosion cracking in a variety of environments including chlorides, hydrogen sulfide, nitrates, hydroxides, ammonia, sulfuric acid and carbonates (Ciaraldi, 1992 [28]). Of the environments that may promote stress corrosion cracking of carbon steels, only the aqueous chlorides are relevant for the VSC-24 system. In practice, the yield strength of the material has a marked effect on stress corrosion cracking susceptibility. Prevention and control of stress corrosion cracking of carbon and low alloy steel in an aqueous chloride environment has been accomplished by selecting materials with yield strengths below 689 MPa (100 ksi). The staff confirmed that the SA-516 Grade 70 steel used in the MSB has a specified minimum yield strength of 260 MPa (38 ksi) and a specified tensile strength of 485 to 620 MPa (70-90 ksi) (ASME, 2010a [14]). Because the yield and specified tensile strength of SA-516 Grade 70 in the MSB is well below 689 MPa (100 ksi), the material is not considered susceptible to chloride stress corrosion cracking. All other chemical species that can promote cracking of carbon and low allow steels are considered not credible in the operating environment of the VSC-24 dry cask storage system because of the water chemistry controls in operating PWRs (EPRI, 1999 [48]) and the characteristics of the dry storage environments. The staff determined that no aging management activity is necessary for stress corrosion cracking of the carbon steel MSB components because the SA-516 Grade 70 carbon steel has a yield strength sufficiently low to prevent SCC and the operating environments for the MSB subcomponents do not contain the aggressive species necessary to promote SCC. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for cracking of the MSB SA-516 Grade 70 steel components to be acceptable.

3.3.2.3 Proposed Aging Management Activities

The CoC holder evaluated the potential for the loss of helium inside the MSB cavity using a TLAA described in Section 3.3.3.1 of the renewal application. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder indicated that MSB subcomponents constructed from carbon steel and exposed to the sheltered environment inside the VCC might experience loss of material due to corrosion during the period of extended operation. While these carbon steel surfaces are covered with a coating that is resistant to high-temperature and radiation, the CoC holder indicated that in some cases the coating is not relied upon to prevent corrosion during storage. The CoC holder evaluated the uniform loss of material by atmospheric corrosion of the MSB shell and bottom plate using a TLAA described in Section 3.3.3.3 of the CoC renewal application. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder indicated that carbon steels exposed to high neutron fluence (particularly fast neutrons) can experience a reduction of fracture toughness (i.e., an increase in the nil-ductility temperature). The CoC holder provided a TLAA in Section 3.3.3.4 of the CoC renewal application to evaluate the effects of radiation exposure on steel components. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder stated that crack growth in carbon steel as a result of fatigue due to cyclic loading is a potential degradation mechanism during the period of extended operation. The CoC holder evaluated the potential for fatigue failure of the MSB assembly using a TLAA, as discussed in Section 3.3.3.2 of the CoC renewal application. The CoC holder also evaluated the potential for fatigue crack growth from indications of flaws that were identified in the longitudinal seam weld of Palisades MSB-04 after the MSB was loaded and placed into service. The TLAA in CoC renewal application Section 3.3.3.6 evaluates the fatigue crack growth analysis of Palisades MSB-04 to the end of the 60-year service period. Staff reviews of the TLAAs provided by the CoC holder are included in SER Section 3.4.

The CoC holder considered loss of shielding effectiveness of the RX-277 neutron shielding material as a result of neutron irradiation during the period of extended operation. The effects of neutron irradiation on the RX-277 neutron shielding material are evaluated using a TLAA in Section 3.3.3.4 of the CoC renewal application. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder also stated that crevice corrosion could possibly occur at the top end of the MSB shell near the VCC shield ring. The CoC holder indicated that the “Examination of the VCC Assembly Ventilation Ducts and Annulus” AMP in CoC renewal application Section 3.4.2.2 includes examination of the accessible portions of the MSB shell and the MSB bottom plate as well as the VCC shield ring plates for localized corrosion. In addition, the “Examination of the VSC Top End Steel Components” AMP in CoC renewal application Section 3.4.2.3 also requires examination of the VCC shield ring plates and top end of the MSB for localized corrosion. The AMPs described in the CoC renewal application will be used to manage crevice corrosion during the period of extended operation. Staff reviews of the AMPs provided by the CoC holder are included in SER Section 3.5.

3.3.3 Ventilated Concrete Cask (VCC) Assemblies

The CoC holder stated that the MSB containing the SNF assemblies placed in dry storage using the VSC-24 dry storage systems are placed inside a VCC assembly. The CoC holder stated the intended functions of the VCC assembly include structural support, radiation shielding, and heat transfer. In addition, the CoC holder stated that the VCC assembly protects the MSB assembly from damage due to external events, such as tornado generated winds and missiles. The CoC holder also noted that natural convective cooling of the SNF assemblies during storage is accomplished with air inlet and outlet ducts that are cast into the body of the VCC assembly.

The CoC holder stated that the VCC components identified by the CoC holder to be within the scope of the renewal review are identified in Table 6 of the CoC renewal application and included in this SER in Table 2.1-3.

The CoC holder summarized the AMR results for the VCC in Table 10 of the renewal application. The staff’s evaluation of the AMR results is provided in this section.

3.3.3.1 Materials and Environments

The CoC holder stated that the VCC assembly described in Section 1.2.1.2 of the VSC-24 storage system FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009) is constructed using steel reinforced concrete that consists of Type II Portland cement and is reinforced with A615 Grade 60 steel bars. The concrete has a density of 144 pounds per cubic foot (pcf), a minimum compressive strength of 4,000 pounds per square inch (psi) and air entrainment of 3% to 6% by volume. The CoC holder stated that the VCC assembly is designed in accordance with the recommendations of ACI 349 (ACI, 1985 [1]) and constructed in accordance with ACI 318 (ACI,1989 [3]).

The CoC holder indicated that the internal cavity of the VCC assembly is lined by the inner shell and bottom plate, which are fabricated from A36 carbon steel. According to the CoC holder, A36 steel plates are also used to form the inlet and outlet duct structures, shield ring plates, and the cask lid. The CoC holder indicated that all exposed carbon steel surfaces are coated with Dimetcote 6, or an equivalent coating to protect against corrosion during storage. The CoC holder stated that the bolts that secure the inlet and outlet duct screens are made from galvanized or zinc-plated steel. Although the use of fiberglass material for the air outlet screen is permitted by Note 4 on FSAR Drawing No. VCC-24-004, the CoC holder chose not to demonstrate the safety of this material for continued use during the period of extended operation. Instead, the CoC holder proposed that the initial CoC and Amendments 1 through 6 of the VSC-24 storage system CoC be conditioned to preclude use of fiberglass material for the air outlet screen during the period of extended operation. The CoC holder stated that the VCC assembly also includes ceramic tiles at the bottom of the VCC cavity. These ceramic tiles support the MSB assembly and are intended to prevent metal-to-metal contact with the VCC bottom plate in order to prevent crevice corrosion or any bonding between the two surfaces. The CoC holder explained that, although the design drawings include the option to use galvanized steel grate instead of the ceramic tiles to elevate the MSB slightly and prevent direct contact with the VCC interior bottom shell, none of the currently loaded VSC-24 systems use this grate. Therefore, the CoC holder chose not to demonstrate the safety of the use of the galvanized steel grate during the renewal period, and instead proposed a CoC condition to preclude the use of this grate in any VSC-24 systems that are loaded under the renewed CoC. The CoC holder stated that the VCC components are exposed to sheltered, embedded and exposed environments. The CoC holder identified that the inner surfaces of the liner shell, liner bottom, cask lid, air inlet assembly, air outlet weldment, and all surfaces of the shield ring plates, and MSB support tiles are exposed to a sheltered environment. This environment includes ambient air, but not sun, rain or wind exposure. The CoC holder stated that the ambient air may contain moisture and some salinity, but clarified that none of the loaded VSC-24 casks are located in marine environments. The temperature of the ambient air inside the VCC cavity may range from that of the outside air for zero decay heat to nearly 149°C [300°F] (based on the peak temperature of the MSB shell) for the design-basis canister heat load of 24 kW and extreme hot off-normal ambient conditions. The CoC holder indicated that the components exposed to the sheltered environment experience somewhat lower gamma and neutron radiation levels than those seen in the MSB interior environment.

The CoC holder indicated that the metal components of the VCC assembly that are either cast inside or against concrete, such as the outer surfaces of the liner shell, bottom surface of the liner bottom, concrete-side surfaces of the air inlet and outlet duct structures, and reinforcing steel (rebar) embedded in the concrete are exposed to an embedded environment. As shown in Figure 4.4-5 of the VSC-24 storage system FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]), the temperature of the steel/concrete interfaces in the VCC could range from near ambient temperature to as high as 93°C [200°F].

The CoC holder indicated that all exterior surfaces of the VCC assembly are considered to be in an exposed environment that includes all weather-related effects, including insolation, wind, rain (or snow/ice), and ambient air at the plant site. The CoC holder clarified that the steel plate that forms the bottom surface of the VCC assembly is also considered to be in an exposed environment since it is in direct contact with the surface of the ISFSI pad where it is sheltered from sun and wind but it is exposed to water. The CoC holder indicated that the ambient air temperature for normal and extreme weather conditions ranges from −40°C to 38°C [−40°F to 100°F]. The CoC holder indicated that the moisture and salinity levels to which the exterior surfaces of the VCC assembly are exposed might vary widely for various plant sites, although none of the loaded VSC-24 casks are located in marine environments. The CoC holder stated that radiation levels on the exterior surfaces of the VCC are sufficiently low to satisfy the applicable regulatory dose limits and TS dose rates limits.

The staff reviewed the description of the VCC subcomponents and the materials of construction included in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the description of the VCC subcomponents and the materials of construction given in the renewal application are accurate and complete.

The staff reviewed the accuracy of the service environments for the VCC subcomponents based on the description and design drawings for the VCC included in Chapter 1 and Appendix E, as applicable, of the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the descriptions of the service environments for the VCC subcomponents are accurate and complete.

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

The CoC holder stated in Section 3.2.1.1 of the CoC renewal application that the potential degradation mechanisms for the VCC subcomponents constructed from carbon steel include loss of material from general corrosion, galvanic corrosion, and crevice corrosion, loss of fracture toughness, and crack growth. The CoC holder indicated in CoC renewal application Section 3.2.1.2 that aging effects and potential degradation mechanisms for the reinforced concrete were identified based on a review of available literature. These aging effects for reinforced concrete include cracking, pitting, and spalling of the cover concrete, loss of strength, loss of material, and thermal fatigue.

The CoC holder has indicated that the VSC-24 storage system is less vulnerable to galvanic corrosion than other storage systems since it does not use many dissimilar metals. The MSB shell exterior is all SA-516 Grade 70 carbon steel coated with a radiation-resistant, high-temperature, non-organic coating, such as Dimetcote 6 or Carbozinc 11. In addition, the VCC interior is constructed from A36 carbon steel coated with Dimetcote 6 or Carbozinc 11. Because there are no dissimilar metal combinations where the VCC liner would be preferentially anodic, galvanic corrosion of the VCC liner is not a potential degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment of galvanic corrosion of the VCC liner. The CoC holder concluded that because there are no dissimilar metal combinations where the VCC liner would be preferentially anodic, galvanic corrosion of the VCC liner is not a potential degradation mechanism during the period of extended operation. The staff reviewed the materials of construction for the VCC liner using information provided in the descriptions and design drawings contained in Chapter 1 and Appendix E, as applicable, of the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the VCC liner and the shielding ring plates are constructed from A36 carbon steel and the MSB shell is constructed from SA-516 Grade 70 steel. The staff also reviewed the coatings on the MSB shell and the VCC liner and shield ring plates. Coatings on the VSC-24 system are zinc-based coatings that would be preferentially anodic to the carbon steel MSB shell and the VCC liner. As a result, galvanic corrosion of the VCC liner would not result from the use of a zinc based coating (Hack, 1987 [52]). The staff confirmed that A36 carbon steel and SA-516 Grade 70 steel are compositionally similar and can be expected to have similar electrochemical behavior (ASTM, 2012 [21]; ASME, 2010a [14]). The staff determined that no aging management is necessary for galvanic corrosion of the MSB shell, VCC liner, and the shield rings because these components and subcomponents are constructed from compositionally similar steels. In addition, the MSB shell, VCC liner and shield rings are coated with a zinc based coating that is preferentially anodic to steel and is designed to protect the underlying steel from corrosion. For these reasons, the staff finds the CoC holder's assessment that no aging management activity is required for galvanic corrosion of the VCC liner to be acceptable.

The CoC holder indicated that locations where the potential for crevice corrosion could occur in the VSC-24 storage system includes the outer surface of the MSB bottom plate, which could potentially contact the VCC liner bottom, and the top end of the MSB shell, which could contact the VCC shield ring plates. These locations are within the sheltered environment of the VCC cavity, which is exposed to moisture in the air, but should not be exposed directly to water. The CoC holder stated that the MSB bottom plate is separated from the VCC bottom plate by ¼-inch thick ceramic tiles specifically to preclude crevice corrosion from occurring between the two surfaces and therefore crevice corrosion of the VCC liner plate does not require management during the period of extended operation.

The staff also reviewed the CoC holder's assessment that ceramic tiles located between the MSB and the VCC bottom will prevent crevice corrosion of the VCC liner, MSB shell, and MSB bottom lid. Positioning ceramic tiles between the MSB and the VCC bottom plate prevents the formation of a metal-to-metal crevice, which can promote crevice corrosion (Dexter et al., 1987 [32]). In addition, the MSB shell, MSB bottom lid, and the VCC inner shell are coated with a zinc primer that is designed to be preferentially anodic to the carbon steel MSB shell and VCC liner. The VCC is also designed to prevent the accumulation of water between the MSB shell and bottom lid and the VCC interior by allowing any water that might enter thought the vents to drain through the lower ventilation ducts. The staff determined that no aging management activity is necessary for the crevice corrosion of the VCC liner because the design of the VSC-24 systems does not include a metal-to-metal crevice; the design prevents the accumulation of water at the bottom of the VCC liner; and all carbon steel surfaces including the VCC liner are coated with a protective zinc based primer. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for crevice corrosion of the VCC liner to be acceptable.

The CoC holder considered fatigue crack growth due to cyclic loading of the carbon steel used in the VCC steel liner. The CoC holder indicated that the only significant cyclic loading of the VCC steel liner is thermal loading, which produces compressive stress in the steel liner due to differential thermal expansion with the concrete shell. The CoC holder concluded that fatigue failure cannot occur under these conditions and thus fatigue of the steel liner was not a credible degradation mechanism for the steel liner during the period of extended operation.

The staff reviewed the CoC holder's assessment of fatigue crack growth of the VCC carbon steel liner. The CoC holder indicated that the only significant thermally induced fatigue loading of the carbon steel liner would result in compressive stresses because of the differences in thermal expansion coefficients between steel and concrete. The staff reviewed the CoC holder's assessment and confirmed that the carbon steel materials have a slightly higher thermal expansion coefficient compared to concrete (Nicholls and Weerth, 1972 [59]; ACI, 2007 [7]) which will result in compressive loading of the steel shell in the VCC. The staff determined that no aging management activity is necessary for fatigue crack growth of the VCC carbon steel liner. The staff's determination is based on the design of the VSC-24 system. The design of the system results in a compressive stress on the carbon steel, and fatigue cracking of steel will not occur under compressive loads. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for fatigue crack growth of the VCC carbon steel liner to be acceptable.

The CoC holder has indicated that the carbon steel components of the VSC-24 system are, unlike stainless steels, not susceptible to stress corrosion cracking. Therefore, the CoC holder has determined that stress corrosion cracking of the carbon steel components of the VCC is not a credible degradation mechanism during the period of extended operation.

The staff reviewed the CoC holder's assessment of stress corrosion cracking of carbon steels. The staff found that carbon steels are susceptible to stress corrosion cracking in a variety of environments including chlorides, hydrogen sulfide, nitrates, hydroxides, ammonia, sulfuric acid and carbonates (Ciaraldi, 1992 [28]). Of the environments that may promote stress corrosion cracking, only the aqueous chlorides are relevant for the VSC-24 system. In practice, the yield strength of the material has a marked effect on stress corrosion cracking susceptibility. Prevention and control of stress corrosion cracking of carbon and low alloy steel in an aqueous chloride environment has been accomplished by selecting materials with yield strengths below 689 MPa (100 ksi). The staff confirmed that the A36 carbon steel used in the VCC has a minimum yield strength of 250 MPa (36 ksi) and a specified tensile strength of 400 to 500 MPa (58-80 ksi) (ASTM, 2012 [21]). Because the yield and specified tensile strength of A36 in the VCC is well below 689 MPa (100 ksi), the material is not considered susceptible to chloride stress corrosion cracking. Other chemical species that can promote cracking of carbon and low allow steels are not considered credible for the operating environment of the VSC-24 dry cask storage system. The staff determined that no aging management activity is necessary for stress corrosion cracking of the VCC carbon steel components because the carbon steels of the liner have yield strengths sufficiently low to prevent SCC and because the operating environments for the VCC carbon steel subcomponents do not contain the aggressive species necessary to promote stress corrosion cracking. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for stress corrosion cracking of the VCC carbon steel components to be acceptable.

The CoC holder considered cracking, spalling, and/or strength loss of the concrete as a result of chemical attack from long-term exposure of concrete to acidic materials or sulfates that are often present in ground water. The CoC holder noted that the VSC-24 storage system is less vulnerable to chemical attack since it is stored above ground on the ISFSI pad and is not in direct contact with ground water. In addition, the CoC holder stated that the VCCs are generally not exposed to aggressive chemical environments during storage. The CoC holder noted that the VCC concrete is designed in accordance with ACI 349 (ACI, 1985 [1]) and constructed using materials conforming to ACI standards, which have low permeability and high resistance to chemical attack. Based on this information, the CoC holder concluded that chemical attack is not considered a credible degradation mechanism for the VCC concrete for the period of extended operation.

The staff reviewed the CoC holder's assessment of cracking, spalling and loss of strength resulting from chemical attack by exposure of the concrete to acidic species or sulfates present in groundwater. The staff reviewed the CoC holder's assessment and confirmed that chemical attack other than from aggregate reactions is limited to applications where concrete is in contact with soil or water containing aggressive species (ACI, 1989 [3]; 2007 [7]). The staff determined that no aging management activity is necessary for cracking, spalling and loss of strength resulting from chemical attack by exposure of the concrete to acidic species or sulfates present in groundwater because the VSC-24 concrete SSCs and subcomponents are not in contact with aggressive soil or groundwater. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for chemical attack of the VCC concrete shell to be acceptable.

The CoC holder considered loss of concrete strength resulting from elevated temperature exposure. The CoC holder stated that the structural properties of concrete can degrade due to long-term exposure to elevated temperatures (i.e., greater than 66°C [150°F] over a general area or greater than 93°C [200°F] in a localized area). The CoC holder noted that the maximum long-term temperatures of the VCC concrete during the initial storage period are less than these values, per Table 4.1-1 of the VSC-24 storage system FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]). Since concrete temperatures will continue to decrease due to thermal decay during the period of extended operation, the CoC holder concluded that concrete degradation due to elevated temperatures is not a credible degradation mechanism for the VCC concrete for the period of extended operation.

The staff reviewed the CoC holder's assessment of loss of concrete strength resulting from exposure to elevated temperature. The CoC holder has indicated that the maximum concrete temperature with a design basis heat load of 24 kW was less than 107°C [225°F]; however, the maximum heat load for any VSC-24 system in use was 14.7 kW, and the CoC holder has proposed a condition to limit the maximum heat load for any future VSC-24 system to 15 kW. Concrete temperatures for any VSC-24 systems loaded with a maximum heat load of 15 kW would be less than 93°C [200°F]. The staff reviewed the CoC holder's assessment and confirmed that the concrete temperatures for the VSC-24 system are consistent with the guidance in ACI-349-13 (ACI, 2013 [8]) and the temperatures will decrease with time. The staff determined that no aging management activity is necessary for aging of the concrete resulting from thermal exposure because the temperature of the concrete was initially less than 93°C [200°F] and the concrete temperatures will decrease as the decay heat decreases during storage. Thus, exposure of the concrete to elevated temperatures that result in a loss of strength will not occur during the renewal period. Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for managing loss of concrete strength due to thermal aging of the concrete to be acceptable.

3.3.3.3 Proposed Aging Management Activities

The CoC holder indicated that carbon steels exposed to high neutron fluence (particularly fast neutrons) could experience a reduction of fracture toughness (i.e., an increase in the nil-ductility temperature). The CoC holder provided a TLAA in Section 3.3.3.4 of the CoC renewal application to evaluate the effects of radiation exposure on steel components of the VCC (Table 3.3-3). Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder indicated that thermal fatigue of concrete might occur when concrete is exposed to repeated thermal cycles. The CoC holder provided a TLAA in Section 3.3.3.8 of the CoC renewal application to evaluate thermal fatigue of the VCC concrete. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder indicated that cumulative gamma and neutron radiation might alter the structural and shielding properties of concrete. The CoC holder provided a TLAA in Section 3.3.3.3 of the CoC renewal application to evaluate the effects of gamma and neutron radiation on the VCC concrete. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4.

The CoC holder has indicated that VCC subcomponents constructed from carbon steel and exposed to the sheltered environment inside the VCC ventilation ducts and annulus that includes the air inlet assemblies, air outlet assemblies and the annular space between the VCC liner and the MSB shell may experience loss of material due to corrosion during the period of extended operation. The CoC holder included an AMP for the evaluation of the carbon steel VCC subcomponents in the sheltered environment of the VCC ventilation ducts and annulus in CoC renewal application Section 3.4.2.2. Staff review of the AMP provided by the CoC holder is included in SER Section 3.5.

The CoC holder has indicated that the galvanized or zinc-plated screens and attachment hardware that cover the VCC air inlet and outlet openings, and the VCC lid bolts, nuts and lockwashers, which may be zinc-plated, may experience loss of material from corrosion. The CoC holder stated that corrosion of these components requires management during the period of extended operation. The CoC holder included an AMP that addresses the evaluation of attachment hardware that includes the VCC air inlet and outlet openings in CoC renewal application Section 3.4.2.1. The CoC holder included an AMP that addresses the evaluation of VCC lid bolts in CoC renewal application Section 3.4.2.3. Staff reviews of the AMPs provided by the CoC holder are included in SER Section 3.5.

The CoC holder stated that crevice corrosion could possibly occur at the top end of the MSB shell near the VCC shield ring plates. The CoC holder indicated that crevice corrosion of VSC top end steel components requires management during the period of extended operation. These components include all surfaces of the VCC cask lid and VCC lid bolts; readily accessible top and inner radial surfaces of the VCC liner flange top surface (chamfer and weld) of the VCC shielding ring plates (liner assembly); top and inner radial surface of the VCC shielding ring plates (shield ring); top surfaces of the MSB structural lid, MSB valve covers, MSB closure weld, and top edge of the MSB shell. The CoC holder has included an AMP in CoC renewal application Section 3.4.2.3 to manage crevice corrosion of the VSC top end steel components during the period of extended operation. Staff review of the AMP provided by the CoC holder is included in SER Section 3.5.

The CoC holder stated that aging effects of concrete can occur from many degradation mechanisms including freeze-thaw cycles, aggregate reactions, and corrosion of reinforcing steel that will result in cracking, spalling, and pitting of the VCC concrete during the period of extended operation. The CoC holder has included an AMP for the evaluation of the VCC concrete that addresses degradation from freeze thaw cycles and the other aforementioned degradation mechanisms in CoC renewal application Section 3.4.2.1. Staff review of the AMP provided by the CoC holder is included in SER Section 3.5.

3.3.4 MSB Transfer Cask (MTC) Assembly

The CoC holder stated that the MSB transfer cask (MTC) assembly is the transfer cask that is used for MSB loading and unloading operations. The CoC holder stated that the MTC is designed and fabricated as a special lifting device in accordance with NUREG-0612 (NRC, 1980 [60]) and ANSI N14.6 (American National Standards Institute, 1993 [10]).

MTC components identified by the CoC holder to be within the scope of the renewal review are identified in Table 7 of the CoC renewal application and included in this SER in Table 2.1-3.

The CoC holder summarized the AMR results for the MTC assembly in renewal application Table 11. The staff's evaluation of the AMR results is provided in this section.

3.3.4.1 Material and Environments

The CoC holder described the MTC as a right circular cylindrical structure with integral lifting trunnions and hydraulically operated shield doors on the bottom end and a retainer ring at the top to prevent the MSB assembly from being inadvertently lifted out of the cavity of the MTC assembly. A detailed description of the MTC assembly is provided in Section 1.2.1.3 of the VSC-24 storage system FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The MTC assembly has both a standard and light configuration that includes three heights to accommodate the three sizes of the MSB; however, all configurations include a 3/4-inch thick ASTM A588 (ASTM, 2015 [22]) Grade A or B carbon steel inner shell, 1-inch thick ASTM A588 Grade A or B carbon steel outer shell, a 1-inch thick A516 Grade 70 carbon steel bottom ring, and a 2-inch thick A516 Grade 70 carbon steel top ring. The annular region between the inner and outer shells is filled with lead gamma shielding material and RX-277 neutron shielding material. The MTC assembly is equipped with two diametrically opposed 10.75-inch solid A516 Grade 70 steel lifting trunnions. The CoC holder indicated that most exposed carbon steel surfaces on the MTC assembly are coated with Dimetcote 6, or equivalent, to protect the spent fuel pool chemistry, facilitate decontamination, and protect against corrosion; however, certain components, such as bolts, lifting trunnions, sliding surfaces on shield doors and rails and shim plates are not coated.

The MTC design in the initial CoC and earlier amendments, seen in the drawings in the earlier revisions of the FSAR, included certain items such as a steel shell that separated the lead gamma shielding from the RX-277 neutron shielding and trunnions with lead and RX-277 shielding material. According to the CoC holder, no existing MTCs use these items, and therefore, the CoC holder chose not to demonstrate the safety of these items for this system during the period of extended operation. Instead, the CoC holder proposed a CoC condition to preclude construction of SSCs under the CoC amendments for which these items were part of the MTC design. The intent of the condition is that these items will not be used in existing or any new MTC assemblies that may be constructed and put into service. Thus, these other items are not included in the design description given here nor are they considered further in the aging management review. The staff, after reviewing this information and the proposed condition, modified the CoC condition to ensure the intent is clear.

The CoC holder has indicated that except for brief exposures to the spent fuel pool during MSB loading operations, the MTC assembly components are exposed to either a sheltered environment or an embedded environment. The CoC holder indicated that all exterior surfaces of the MTC assembly are also exposed to a sheltered environment; however, the sheltered environment seen by the MTC assembly is far less challenging than that to which the MSB assembly and VCC assembly components are exposed because the MTC assembly is generally stored inside a building or outside, provided it is adequately protected from the environment. The CoC holder stated that the stored MTC assemblies are also not exposed to the elevated temperatures and radiation levels to which the MSB assembly and VCC assembly are exposed during storage. The CoC holder also stated that the MTCs are exposed to elevated temperatures and radiation effects for brief periods during cask system loading and unloading operations. Finally, the CoC holder indicated that the surfaces of a stored MTC assembly are much more accessible for inspection and repair than the MSB exterior and VCC interior surfaces.

The CoC holder noted that some components of the MTC assembly are exposed to an embedded environment. These include the carbon steel heat transfer fins embedded in the MTC, and the RX-277 neutron shield, and the lead shield in the MTC assembly shells, and the steel surfaces that face the sealed cavities containing those shielding materials. The CoC holder reported that the MTC materials (and associated material boundaries) are exposed to elevated temperatures (up to 270°F [132°F]) for brief periods during the system loading process.

The staff reviewed the description of the MTC subcomponents and the materials of construction included in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the description of the MTC subcomponents and the materials of construction in the renewal application are accurate and complete.

The staff reviewed the accuracy of the service environments for the MTC subcomponents based on the description and design drawings for the MTC included in Chapter 1 and Appendix E, as applicable, of the VSC-24 FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]). The staff also reviewed the MSB loading and transfer procedures that require the MTC, which are described in Chapter 8 of the FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff verified that the descriptions of the service environments for the MTC subcomponents are accurate and complete.

3.3.4.2 Aging Effects/Mechanisms for the MSB Transfer Cask (MTC) Assembly During the Period of Extended Storage

The CoC holder stated the MTC assembly carbon steel components that are exposed to a sheltered environment were evaluated for multiple aging effects. These include cracking from fatigue loading, loss of fracture toughness from radiation exposure, and loss of material due to corrosion including general corrosion, galvanic corrosion, and crevice corrosion.

The CoC holder considered crack growth in carbon steel subcomponents of the MTC as a result of fatigue caused by cyclic loading. The CoC holder noted that the MTC assembly is designed as a special lifting device with minimum factors of safety of 6 against yield and 10 against ultimate (tensile strength) in accordance with the guidance in NUREG-0612 (NRC, 1980 [60]) and ANSI 14.6 (ANSI, 1993 [10]). Since actual stresses experienced in operation are low relative to the maximum allowable stresses and the MTC assembly is not subjected to a significant number of load cycles, the CoC holder concluded that fatigue is not a credible failure mode of the MTC assembly.

The staff reviewed the CoC holder's assessment of fatigue crack growth of carbon steel subcomponents in the MTC. The staff reviewed the MTC design as well as the design fatigue curves for carbon and low alloy steels (ASME, 2013 [22]). The staff determined that no aging management activity is necessary for fatigue of the MTC because the maximum stresses are low and the MTC is subjected to a limited number of loading cycles that is insufficient to require a fatigue evaluation in accordance with the ASME code (ASME, 2013 [22]). Therefore, the staff finds the CoC holder's assessment that no aging management activity is required for fatigue of the MTC liner to be acceptable.

The MTC also has a neutron shield component that is made of RX-277, like in the MSB lid. This material is also subject to the effects of neutron and gamma radiation. While the CoC holder did not explicitly evaluate the radiation effects on the MTC's RX-277 material, the staff performed an evaluation of these effects. Based on its evaluation, the staff finds that for MTCs that are only used to transfer MSBs that have already been loaded, the analysis for the MSB lid's neutron shielding is bounding for two reasons. First, the radiation source will have decayed for at least 20 years. Second, the transfers of these MSBs will be on an as needed basis, which means that, unlike the neutron shield in the MSB lid, the MTC is not, and will not be, continuously exposed to radiation. In addition, for transfers of newly loaded MSBs, the staff finds the CoC holder's analysis remains bounding for the following reasons. Loading and transfer to a VCC of an MSB is completed within a couple of days. Even accounting for the possibility of loading multiple casks per year, the exposure time for the MTC components is still approximately several days in a year. Thus, the MTC's radiation exposure would only be for a small fraction of a year. In addition, the 4-inch thick lead gamma shield significantly attenuates the gamma radiation to which the RX-277 in the MTC is exposed. Therefore, the staff determined that no aging management activity is necessary for radiation effects on the MTC's RX-277 material because: 1) the analysis provided for RX-277 material in the MSB lid more than adequately bounds the exposure of the RX-277 material in the MTC, and 2) the neutron fluence will be insufficient to result in degradation of the shielding material.

3.3.4.3 Proposed Aging Management Activities

The CoC holder has indicated that carbon steels exposed to high neutron fluence (particularly fast neutrons) can experience a reduction of fracture toughness (i.e., an increase in the nil-ductility temperature). The CoC holder has provided a TLAA in Section 3.3.3.4 of the CoC renewal application to evaluate the effects of radiation exposure on steel components. Staff review of the TLAA provided by the CoC holder is included in SER Section 3.4. The CoC holder stated that corrosion of the MTC components exposed to a sheltered environment requires management during the period of extended operation. The CoC holder has included an AMP for the evaluation of the MTC for coating degradation and corrosion in CoC renewal application Section 3.4.2.5. Staff review of the AMP provided by the CoC holder is included in SER Section 3.5.

3.3.5 Evaluation Findings

The staff reviewed the AMR for the VSC-24 CoC renewal to verify that the application adequately identified the materials, environments, and aging effects of the in-scope SSCs. Based on its review of the renewal application and responses to the staff's observations, request for supplemental information (RSIs), and requests for additional information (RAIs), the staff finds:

F3.1 The CoC holder's AMR process to be comprehensive in identifying the materials of construction and associated operating environmental conditions for those SSCs within the scope of renewal and has provided a summary of the information in the application.

F3.2 The CoC holder's review process to be comprehensive in identifying all pertinent aging mechanisms and effects applicable to the in-scope SSCs and that the CoC holder provided a summary of the information in the renewal application with changes to be incorporated into the FSAR.

3.4 Time-Limited Aging Analyses Evaluation

TLAAs are calculations or analyses used to demonstrate that in-scope SSCs will maintain their intended design function throughout an explicitly stated period of extended operation (e.g., 40 years). These calculations or analyses may be used to assess fatigue life (number of cycles to predicted failure), or time-limited life (operating timeframe until expected loss of intended design function). TLAAs should account for environment effects.

Pursuant to 10 CFR 72.3, “Definitions,” TLAAs must meet all six of the following criteria:

1. Involve SSCs important to safety (ITS) within the scope of the spent fuel storage certificate renewal, as delineated in Subpart L of 10 CFR Part 72, “Approval of Spent Fuel Storage Casks,” respectively;
2. Consider the effects of aging;
3. Involve time-limited assumptions defined by the current operating term, for example 40 years;
4. Were determined to be relevant by the CoC holder in making a safety determination;
5. Involve conclusions or provide the basis of conclusions related to the capability of SSCs to perform their intended safety functions;
6. Are contained or incorporated by reference in the design bases.

The CoC holder identified the following TLAAs meeting all six criteria per 10 CFR 72.3:

1. MSB Helium Leakage Evaluation
2. MSB Fatigue Evaluation
3. MSB Corrosion Evaluation
4. Radiation Effects Analysis
5. Fuel Cladding Creep Evaluation
6. Palisades MSB-04 Weld Crack Growth Evaluation (cask-specific TLAA)
7. Evaluation of Loss of MSB Lid RX-277 Shielding Function After 20 Years of Storage
8. VCC Concrete Thermal Fatigue Analysis

Based on its review of the design bases documents, the staff confirmed that the CoC holder identified all calculations and analyses meeting all six criteria in 10 CFR 72.3 and therefore concludes that the CoC holder adequately identified all TLAAs.

3.4.1 MSB Helium Leakage Evaluation

Section 3.3.3.1 of the CoC renewal application summarized the results of the CoC holder’s TLAA to evaluate potential MSB helium leakage and a resulting projected amount of helium within the MSB cavity during a 60-year storage period. The CoC holder previously evaluated the MSB assembly to determine the amount of the helium gas that could potentially leak from the cavity during a 50-year service period. The evaluation, which was based on ANSI N14.5, "For Radioactive Materials – Leakage Tests on Packages for Shipments", postulated different sized leak paths through the MSB confinement boundary that produce a flow rate of 1.0x 10^{-4} standard cubic centimeter (std. cc) per second (i.e., the acceptance standard for the MSB helium leak test) under the limiting helium leak test conditions. The CoC holder then determined the maximum leak rate for normal storage conditions, which were at operating temperatures and pressures different from leakage rate test conditions. Based on this leakage rate, the CoC holder calculated that 2.7% of the helium could potentially leak from the MSB during 60 years of storage. The CoC holder assessed that the effect on the MSB thermal performance from the calculated helium leakage rate would be small compared to the decay heat of the SNF assemblies.

The staff reviewed the CoC holder's assessment (ML13050A325) of the helium leak rate from the MSB during the period of extended operation. The staff determined that the size calculation for the postulated hole was based on ANSI N14.5 and, therefore, finds that the analysis performed by the CoC holder adequately considers the maximum helium leak rates for normal storage conditions The staff determined that a 2.7% loss of helium from the MSB would not be significant for thermal performance because the amount of helium lost is small and any decrease in thermal conductivity would be outweighed by the large decrease in the decay heat from the stored SNF assemblies during the extended storage period. Therefore, the staff finds the TLAA provided by the CoC holder is sufficient for managing aging effects from MSB helium leakage during the period of extended operation.

3.4.2 MSB Fatigue Evaluation

Section 3.3.3.2 of the renewal application summarizes the results of the CoC holder's TLAA to evaluate the MSB fatigue effects. The CoC holder previously conducted an evaluation of fatigue effects discussed in Section 3.4.4.1.5 of the VSC-24 storage system FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]) that demonstrated that the MSB assembly is not susceptible to fatigue failure during the 50-year storage period. In the original evaluation, the CoC holder indicated that over 50 years of service, a total of 504 cycles are expected for the four (4) criteria of Condition A of NC-3219.2 of the ASME Code (ASME, 1998 [11]), which does not exceed 1,000 cycles. In support of the CoC renewal application, the MSB fatigue analysis has been projected to the end of the 60-year service period. The CoC holder reported that the total number of expected cycles increases to 605 cycles, which remains below 1,000 cycles. The CoC holder stated that the additional expected cycles result from service pressure fluctuations that are expected to exceed 20% of the design pressure, which are conservatively assumed to occur 10 times per year. Thus, the additional 10 years of service time result in an additional 100 cycles. In addition, the CoC holder assumed the addition of one full range pressure cycle for the MSB unloading backfill operation. The CoC holder stated that the results of the fatigue analysis demonstrate that the MSB will continue to satisfy the fatigue criteria for the extended period of operation.

The staff reviewed the CoC holder's fatigue evaluation of the MSB for the period of extended operation. The staff determined that the analysis performed by the CoC holder adequately considers the number of cycles including (1) the expected number of full range pressure cycles, (2) the expected number of service pressure cycles in which the range of pressure variation exceeds 20% of the design pressure, (3) the effective number of changes in metal temperature between any two adjacent points on the MSB, and (4) the number of load cycles caused by materials with different thermal expansion coefficients. The staff reviewed the specifications for ASME SA-516 Grade 70 and confirmed that this material has a minimum specified tensile strength of 70 ksi and a maximum tensile strength of 90 ksi (ASME, 2010a [14]). The staff also reviewed information provided by the CoC holder in Sargent and Lundy Calculation No. 2007-20168, Revision 00, “Palisades Weld Flaw Analysis for Loaded Spent Fuel Cask MSB No. 4” pg. 12, which indicates that the tensile strength of SA-516 Grade 70 Traveler RE022 heat #61066-32 has a tensile strength of 78.47 ksi. (EnergySolutions Spent Fuel Division Inc., 2014d [42]). The staff also reviewed the weld filler wire specifications in SFA 5.20 (ASME, 2010b [15]) information provided by the CoC holder in Sargent and Lundy Calculation No. 2007-20168, Revision 00, “Palisades Weld Flaw Analysis for Loaded Spent Fuel Cask MSB No. 4” and confirmed that the weld filler wire has a minimum specified tensile strength of 70 ksi and a maximum tensile strength of 95 ksi. The staff noted that E7XT-1 identified in Sargent and Lundy Calculation No. 2007-20168, Revision 00, “Palisades Weld Flaw Analysis for Loaded Spent Fuel Cask MSB No. 4” has specified tensile strength of 70 to 95 ksi and that the supplied certified material test report (CMTR) for the weld metal had a reported tensile strength of 93 ksi. The staff determined that fatigue of the MSB is not a degradation mechanism that requires an aging management program because the specified minimum tensile strength of the MSB shell and weld filler metals do not exceed 80.0 ksi (552 MPa) and the total of the expected number of fatigue loading cycles does not exceed 1000 per ASME NC-3219.9 (ASME, 1998 [11]). Therefore, the staff finds the CoC holder’s TLAA is adequate to analyze the aging effects resulting from fatigue and demonstrates that the aging effect will not result in a loss of the MSB functions during the period of extended operation.

3.4.3 MSB Corrosion Evaluation

Section 3.3.3.3 of the CoC renewal application summarizes the results of the CoC holder’s TLAA to evaluate MSB corrosion. The CoC holder previously conducted a MSB corrosion evaluation that demonstrated that the MSB assembly is not susceptible to degradation by corrosion during the 50-year storage period. The CoC holder’s evaluation assumed a corrosion rate for the MSB shell and bottom plate in a coastal marine environment, as discussed in Section 1.2.1.1 of the VSC-24 storage system FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]). The CoC holder noted that although all external surfaces of the MSB assembly are covered with a radiation-resistant, high-temperature, non-organic coating, the coating is not relied upon for general corrosion protection of the MSB shell assembly and the MSB bottom lid external surfaces during storage. Based on a uniform corrosion rate of 0.003-inch/year for uncoated carbon steel in a marine environment, the CoC holder estimated the maximum corrosion loss on the external surfaces of the MSB shell and bottom plate to be 0.15-inch over a 50-year period. In the CoC renewal application, the CoC holder projected the MSB corrosion analysis to the end of the 60-year service period and determined that the additional thickness reduction of the MSB shell and bottom plate for the period of extended operation is 0.03 inches, for a total corrosion loss of 0.18 inches.

In addition to the effects of corrosion, the CoC holder considered manufacturing tolerances in the assessment of the effects of corrosion. The CoC holder assumed that the nominal thickness of the MSB wall might be under size from the nominal thickness of 1 inch by up to 0.03 inches. Hence, the calculation provided by the CoC holder considers the minimum initial wall thickness to be 0.97 inches before corrosion and the thickness of the MSB shell and base are reduced by 0.18 inches because of corrosion over a 60-year period. The corrosion rate assumed by the CoC holder was based on rates measured for un-coated steel in a marine environment. The CoC holder indicted this was conservative since the MSB is coated, and the sheltered environment inside the VCC will keep the MSB dry and not directly exposed to the effects of the corroding atmosphere.

The CoC holder provided an analysis of the maximum shell and base plate membrane (P_m) and membrane plus bending ($P_L + P_b$) stresses for the most onerous design margins, which have been recalculated with the reduced wall thicknesses (EnergySolutions Spent Fuel Division Inc., 2014b [45]). Based on the analysis provided by the CoC holder, limiting load combinations for the MSB shell membrane and the membrane plus bending stresses were vertical drop plus pressure. For the MSB base plate, the CoC holder's analysis shows that the limiting load combination for the membrane stress is horizontal drop plus pressure whereas the limiting load combination for the membrane plus bending stresses is dead weight plus off-normal pressure plus off-normal handling. Based on the CoC holder's analysis, all values of stress for all analyzed loading combinations with the reduced MSB shell and MSB base plate are acceptable, demonstrating that adequate margin has been provided for corrosion in the MSB over 60 years. The CoC holder concluded that the TLAA demonstrates that the maximum stresses in the corroded MSB shell and bottom plate continue to satisfy the corresponding allowable stress design criteria and therefore, the corroded MSB shell and bottom will continue to satisfy their intended safety functions for the extended period of operation.

The staff reviewed the CoC holder's assessment of the MSB corrosion rate during the period of extended operation. The assumed corrosion rate used by the licensee in the analysis was based on thickness loss of steel pilings at locations where the pilings were continuously above the splash zone from waves (Fontana, 1986 [51]). Corrosion rates of uncoated or otherwise unprotected (i.e. no cathodic protection or environmental protection) carbon steels are strongly dependent on the severity of the environment. For marine environments, the corrosion rate of carbon steels is dependent on several parameters, most notably, the distance from the shore. The staff found that corrosion rates for carbon steels in marine environments vary from 0.00053 in/yr (0.013 mm/yr) to 0.021 in/yr (0.53 mm/yr). Carbon steels at Kure Beach, NC, at a distance of 250 m (800 ft) from the shore were reported to have experienced corrosion at rates of 0.0051 in/yr (0.146 mm/yr) and corrosion rates measured at Bayonne, NJ, classified as an industrial marine environment, were 0.00305 in/yr (0.077 mm/yr) (Heidersbach et al., 1987 [54]). Based on the available data and considering the actual environments for the VSC-24 systems currently in service, the staff determined that the assumed corrosion rate of 0.003 in/yr (0.076 mm/yr) is a reasonable assumption and the CoC holder's calculation for the loss of material thickness of 0.18 inches using the assumed corrosion rate is sufficient to account for the loss of material as a result of corrosion.

The staff reviewed the CoC holder's stress analysis for loading combinations with the reduced MSB shell and MSB base plate (EnergySolutions Spent Fuel Division Inc., 2014c [36]). The staff determined that the CoC holder's analysis appropriately considered the reduced section thickness for the MSB Shell and the MSB bottom plate as a result of manufacturing tolerance and loss of material by corrosion. The staff determined that the CoC holder's stress analysis appropriately considered the reduced thickness of the MSB shell and bottom plate. The staff also determined that the stress analysis appropriately considered the limiting load combinations for the membrane stress as a result of a hypothetical horizontal drop plus pressure, the membrane plus bending stresses as a result of the combination of dead weight, off-normal pressure, and off-normal handling.

The staff also considered the effects of corrosion and the rate of uniform corrosion described by the CoC holder in terms of the storage system's shielding capability. It was not clear to the staff that the shielding analysis in the different revisions of the FSAR accounted for a corrosion allowance. Therefore, the CoC holder provided an analysis which demonstrated that any potential increases in dose rates as a result of uniform corrosion at the described rate is more than compensated for by the reduction in dose rates due to decay of the radiation source. Thus, dose rates for a MSB with the described uniform corrosion will be lower than the dose rates analyzed in the FSAR for the design basis contents or the dose rates measured at the time of loading of a new MSB. The analysis was confirmed by the staff's independent evaluation. Therefore, the staff finds that VCCs that met the dose rate limits (in the TS) previously will continue to meet those limits and the dose rates from the design basis calculations will bound the dose rates for VCCs that account for the described uniform corrosion of the MSB.

Based on the review of the information provided by the CoC holder, as well as the information examined by the staff and referenced in this review, the staff determined that the CoC holder has conservatively estimated the extent of corrosion in the TLAA for the MSB shell for the environments at ISFSIs that currently use the VSC-24 system. The staff determined that the loss of material from the MSB shell and bottom plate as a result of general corrosion would not result in significant degradation of the mechanical performance of the MSB because the remaining material of the MSB shell and MSB bottom plate is sufficient to assure that confinement would be maintained even if the MSB were subjected to limiting load combinations, including MSB dead weight plus off-normal pressure plus off-normal handling and a hypothetical horizontal drop plus pressure. The staff determined that the loss of material from the MSB shell and bottom plate as a result of general corrosion would not result in significant degradation of the storage system's shielding capability because any potential dose rate increases as a result of uniform corrosion will be more than compensated for by the reduction in the dose rates due to decay of the radiation source. For these reasons, the staff finds that the CoC holder's TLAA is adequate to analyze the aging effects resulting from MSB corrosion and demonstrates that the aging effect will not result in a loss of the MSB functions during the period of extended operation.

3.4.4 Radiation Effects Analysis

Section 3.3.3.4 of the CoC renewal application summarizes the results of the TLAA to evaluate the cumulative effect of neutron and gamma radiation on the structural and shielding properties of the VSC-24 storage system materials for a period of extended operation of 60 years. Using the information provided in EPRI TR-102462, "Shipment of Spent Fuel in Storage Canisters" (EPRI, 1993 [47]), the CoC holder estimated the total neutron fluence impacting the inner carbon steel components of the VSC-24 storage system (i.e., the MSB assembly and VCC steel liner) over 60 years will be $1.3\text{x}\ 10^{14}$ n/cm^2 and the gamma radiation dose will be $1 \text{ x } 10^{10}$ rads. The CoC holder indicated that damaging effects of neutron radiation on steel are seen at a fast neutron (i.e., > 1.0 MeV) fluence level above $1 \text{ x } 10^{17}$ n/cm^2 (EPRI, 1993 [47]) or approximately three orders of magnitude greater than the total neutron fluence for the steel components of the VSC-24 storage system. The CoC holder also indicated that gamma radiation has no measureable impact on the mechanical properties of steel (EPRI, 1993 [47]). Based on the estimated total neutron exposure, the CoC holder concluded that radiation exposure will not adversely affect the material properties or the intended safety functions of the carbon steel components of the VSC-24 system for the extended period of operation.

The CoC holder estimated the total cumulative neutron fluence and gamma dose for the VCC concrete over the 60-year period of extended operation considering the gamma attenuation provided by the 2.75-inch combined thickness of the carbon steel MSB shell and VCC liner shell. The CoC holder noted that because carbon steel does not significantly attenuate neutrons, the cumulative neutron fluence for the VCC concrete shell over the 60-year period of extended operation is approximately equal to that of the inner steel components, or 1.3 x 10^{14} n/cm^2. However, the CoC holder stated that because the gamma radiation for a typical SNF fission product gamma energy spectrum is attenuated by a factor of ten (10) by 2.75-inches of steel (Courtney, 1976 [29]), the concrete is exposed to approximately 1 x 10^9 rads of gamma radiation over the 60-year period of extended operation. The CoC holder noted that neutron radiation has little effect on shielding or thermal properties of concrete, but it can impact its structural properties at levels as low as 1 x 10^{17} n/cm^2 whereas gamma radiation doses of 1 x 10^{10} rads or higher may adversely affect the structural properties of concrete (Fillmore, 2004 [50]). The CoC holder's evaluation indicates that the total estimated neutron radiation fluence for the VCC concrete is approximately 1,000 times lower than the levels at which adverse effects are expected and the total estimated gamma radiation dose in the VCC concrete is one (1) order of magnitude lower than the levels at which adverse effects are expected. The CoC holder concluded that neither gamma nor neutron radiation will affect the structural properties or the intended safety functions of the concrete components of the VSC-24 system for the extended period of operation.

The CoC holder estimated the total cumulative neutron fluence and gamma dose for the RX-277 neutron shielding material in the MSB shield lid over the 60-year period of extended operation considering the dose attenuation provided by the 5.0-inch combined thickness of carbon steel in the MSB shield lid support plate and bottom plate. The CoC holder noted that because carbon steel does not significantly attenuate neutrons, the cumulative neutron fluence impacting the RX-277 neutron shielding material over the 60-year period of extended operation is approximately equal to that of the inner steel components, or 1.3 x 10^{14} n/cm^2. The CoC holder stated that the gamma radiation for a typical SNF fission product gamma energy spectrum is attenuated by a factor of one hundred and fifty (150) by 5-inches of steel (Courtney, 1976 [29]) and therefore, the RX-277 neutron shield material is exposed to approximately 7 x 10^7 rads of gamma radiation over the 60-year period of extended operation. The CoC holder referenced the RX-277 neutron shielding material product data (Reactor Experiments Inc., 1991 [74]), which shows that it can withstand neutron and gamma radiation levels of 5 x 10^{19} n/cm^2 and 1 x 10^{10} rads, respectively. The allowable neutron radiation level is over five (5) orders of magnitude higher that the cumulative neutron fluence estimated over the 60-year period of extended operation. Furthermore, the allowable gamma radiation level is about one hundred and fifty (150) times higher than the cumulative gamma radiation dose estimated over the 60-year period of extended operation. Thus, the CoC holder stated that neutron and gamma radiation are not expected to adversely affect the properties of RX-277 in the MSB lid during the period of extended operation.

The CoC holder stated that the shielding effectiveness of RX-277 is not adversely affected by neutron radiation during the period of extended operation. Neutron absorption in RX-277 results in transmutation of boron-10 (^{10}B) into boron-11 (^{11}B). The volume of RX-277 in the MSB shield lid (approximately 1 x 10^5 cm^3) contains approximately 2.8 x 10^{25} atoms of ^{10}B based on a boron atom density of 1.43 x 10^{21} atoms/cc (Reactor Experiments Inc., 1991 [74]), which equates to a 2.8 x 10^{20} atoms/cc ^{10}B atom density. The CoC holder noted that even if every neutron entering the RX-277 shield resulted in one ^{10}B to ^{11}B transmutation, the number of transmuted ^{10}B atoms would only be on the order of 1 x 10^{14}, which is over eleven (11) orders of magnitude lower than the number of ^{10}B atoms within the shield.

The CoC holder stated that transmutation of hydrogen into deuterium, from neutron absorption, is also not an issue during the period of extended operation for similar reasons. Boron is placed in the shielding material specifically to reduce secondary gamma production, by absorbing thermal neutrons before they are absorbed in hydrogen. Thus, the number of deuterium atoms produced would be far lower than the number of ^{11}B atoms produced, which is in turn only a fraction of the overall neutron fluence of 1.3 x 10^{14} n/cm^2. Furthermore, the number of hydrogen atoms in the RX-277 material is larger than the number of boron atoms, based on the atomic weight and the weight fractions shown for hydrogen and boron in RX-277 (Reactor Experiments Inc., 1991 [74]). The analysis by the CoC holder shows that the fraction of hydrogen atoms lost will be much lower than the fraction of ^{10}B atoms lost, which is negligible.

The staff reviewed the CoC holder's assessment of the effects of radiation on the carbon steel, concrete and the RX-277 shielding material during the period of extended operation. The staff also performed its own confirmatory assessment of the estimated exposures of the VSC components using the design basis contents specified in the FSAR. The results of this assessment are consistent with the estimated neutron fluence and gamma doses used by the CoC holder for the different components of the VSC-24 SSCs.

The staff reviewed the CoC holder's TLAA of the effects of both neutron and gamma radiation on the carbon steel components of the VSC-24 system. For the carbon steel components of the MSB, MTC and VCC, the staff confirmed that a neutron fluence greater than 1 × 10^{17} n/cm^2 is necessary to induce radiation embrittlement of steels (US Code of Federal Regulations, 2011 [78]). The staff also confirmed that the estimated level of gamma radiation is insufficient to induce radiation damage to carbon steels. The CoC holder's analysis is based on applying the assessment for the MSB's steel components to the VCC and MTC steel components. The staff finds this approach to be acceptable because it conservatively neglects any, though not significant for neutrons, radiation attenuation provided by the MSB components. It is further conservative for the MTC because the assessment is based on continuous exposure to neutron and gamma radiation whereas the MTC is only exposed to radiation for the limited duration of any loading and unloading operations, which are conducted periodically on an as needed basis. Thus, the staff determined that neutron and gamma radiation will not result in significant embrittlement, and hence significant degradation, of the carbon steel components of the VSC-24 system because the expected neutron fluence is almost 3 orders of magnitude less than the minimum neutron fluence required for embrittlement to occur. Therefore, the staff finds the CoC holder's TLAA is adequate to analyze the aging effects resulting from irradiation of the VSC-24 system's carbon steel components and demonstrates that the aging effect will not result in a loss of the VSC-24 system's SSCs functions during the period of extended operation.

The staff reviewed the CoC holder's TLAA provided in CoC renewal application Section 3.3.3.4 to assess the effects of radiation on the VCC concrete structure. The staff notes that ACI 349.3R (ACI, 2002 [5]) states that the critical, cumulative neutron fluence and gamma dose levels from historical testing results are 1 × 10^{25} neutrons/m^2 [1 × 10^{21} neutrons/cm^2] and 10^{10} rad, respectively, and a neutron fluence limit of 1 × 10^{17} neutrons/m^2 [1 × 10^{13} neutrons/cm^2] is recommended for preventing any lifetime radiation-related degradation. Thus, the expected gamma radiation dose of 10^9 rads is below the critical gamma dose level in ACI 349.3R. The staff notes that the estimated neutron fluence of 1.3 × 10^{14} n/cm^2 over a period of 60 years for the VCC concrete is above the recommended neutron fluence limit given in ACI 349.3R (ACI, 2002 [5]); however, 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 (ACI, 2002 [5]). Thus, 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. Therefore, the staff finds the CoC holder's TLAA is adequate to analyze the aging effects resulting from irradiation of the VCC concrete and demonstrates that the aging effect will not result in a loss of the VCC functions during the period of extended operation.

The staff reviewed the CoC holder's evaluation of radiation effects on the RX-277 neutron shielding material in CoC renewal application Section 3.3.3.4. These effects include potential degradation of the material and consumption of the boron in the material by neutron absorption. The analysis in CoC renewal application Section 3.3.3.4 indicates a negligible amount of ^{10}B would be consumed over a 60-year period. The CoC holder also provided technical data (Reactor Experiments Inc., 1991 [74]) for the material that describe the material's properties and performance under different conditions, including exposure to neutron and gamma radiation. The CoC holder's analysis in Section 3.3.3.4 of the CoC renewal application indicates that the neutron fluence and gamma dose to which the RX-277 in the MSB lid is exposed during a 60-year storage period is significantly less than the levels for radiation resistance listed in the referenced technical data for the material.

The staff reviewed the analysis in the application and the material's technical data. The staff also performed its own confirmatory assessment of the approximate radiation levels to which the VSC components, including the MSB lid's RX-277 material, would be exposed for 60 years of storage. The assessment used the design specifications and design-basis contents for the VSC-24, as described in the FSAR. The results of this assessment are consistent with the neutron fluence and gamma dose used in the CoC holder's analysis. Using the estimated neutron fluence, the staff confirmed the CoC holder's conclusion that the shield will experience only a negligible loss of ^{10}B as well as hydrogen from the neutron shield material.

The CoC holder initially proposed that aging management of the RX-277 in the MSB lid be part of the AMP for the VSC top end steel components. The material would have been monitored through neutron dose rate measurements on the VCC lid with an acceptance criterion of no increasing trend in dose rates. However, it was not clear to the staff that this acceptance criterion was adequate to identify degradation of the RX-277 that could possible impact safety functions or to verify the shielding effectiveness, as the meanings of these terms are applied. Thus, the CoC holder removed this activity from the proposed AMP and provided an analysis in Section 3.3.3.7 of the renewal application and a supporting calculation package (EnergySolutions Spent Fuel Division Inc., 2014e [43]) that indicates the RX-277 in the MSB lid is not needed after 20 years to perform a shielding function. The analysis is based on demonstrating continued compliance with TS 1.2.4 dose rate limits despite loss of the RX-277 material. The analysis compared the dose rates for design-basis spent fuel contents at the time of initial loading (with the RX-277 present) with the dose rates for the design-basis contents after 20 years of radioactive decay in dry storage (with the RX-277 modeled as void). The results indicate a significant reduction in dose rates despite loss of the RX-277 material due to the significant decay of the design-basis radiation source terms over 20 years.

The staff reviewed the CoC holder's analysis and performed a confirmatory assessment of the loss of the RX-277 material in the MSB lid. The staff's assessment involved a simple shielding model based on the MSB lid configuration and looked only at relative changes in dose rates. The staff analyzed the change in dose rates for two sets of spent fuel contents, the design-basis contents and spent fuel with higher burnup, lower enrichment, and longer minimum decay time (still within the allowed contents limits for the VSC-24). The choice of the second set of spent fuel contents was based on considerations that the decay of the radiation source will be less significant for these spent fuel contents versus the design-basis spent fuel, which in turn might mean that dose rates could increase over the dose rates at the initial loading and possibly approach the TS 1.2.4 limit. The results of the staff's assessment for both sets of spent fuel contents showed a decrease in dose rates for both sets of spent fuel contents, confirming the CoC holder's conclusions. Therefore, the staff finds reasonable assurance that casks that meet the TS 1.2.4 VCC lid dose rate limit at the time of loading will continue to meet that limit during the period of extended operation even without the RX-277 material in the MSB lid. Thus, the staff also finds that management of the aging of this material in an AMP is not needed.

3.4.5 Fuel Cladding Creep Evaluation

Section 3.3.3.5 of the CoC renewal application summarizes the results of the CoC holder's TLAA to evaluate the maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system, which is based on the cladding creep methodology described in PNL-6364 (Cunningham et al., 1987 [30]). The CoC holder indicated that the applied criterion limits the total strain in the fuel cladding due to creep to 1% over a 40-year storage period and noted that the creep methodology accounts for the decrease in cladding temperature and hoop stress that are expected to occur during the storage period. The CoC holder's analysis indicates that after the initial 40-year storage period, the peak cladding temperature for design basis fuel will be reduced to approximately 150°C [302°F] and the corresponding cladding hoop stress will be approximately 67 mega pascals (MPa). Based on PNL-6364 (Cunningham et al., 1987 [30]), the CoC holder estimated the cladding strain rate under these conditions to be approximately 10^{-17} s^{-1}. With the conservative assumption that the cladding strain rate remains constant for the period of extended operation, the CoC holder estimated that the additional accumulated strain for the additional 20-year period is 6.3x 10^{-9} in/in; an insignificant fraction of the allowable total strain (1%). Therefore, the CoC holder concluded that the maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system remain applicable for the 60-year period of operation.

The staff reviewed the CoC holder's assessment of the effects of temperature on cladding creep. The CoC holder stated in Section 3.2.1.3 that the peak cladding temperature during drying is estimated to be 424°C [796°F] assuming a design basis heat load of 24 KW. In addition, the CoC holder indicated that the actual maximum peak cladding temperature for any loaded VSC-24 system in use would be less than 400°C [752°F] because the maximum heat load for any VSC-24 system that has been loaded was less than 15 kW. The CoC holder has also proposed a certificate condition to limit the maximum heat load to 15kW for any future VSC-24 system put into service. The staff reviewed the CoC holder's assessment of maximum cladding temperature using the information published in Li et al., (Li et al., 2007 [56]) showing peak cladding temperatures as a function of decay heat load. The staff also reviewed the information on cladding stress in PNL-6364 (Cunningham et al., 1987 [30]) Figure D.2 and confirmed the CoC holder's assessment of cladding stress as a function of temperature. The staff reviewed ISG-11 Revision 3 and the bases for the assessment on cladding creep rupture and noted that the conclusions on zircaloy cladding creep in ISG-11 Revision 3 were based on a review of numerous reports and assessment of cladding creep data. As explained in ISG-11 Revision 3, the staff has reasonable assurance that creep under normal conditions of storage will not cause gross rupture of the cladding and that the geometric configuration of the spent fuel will be preserved, provided that the maximum cladding temperature does not exceed 400°C [752°F]. In this instance, as indicated by the CoC holder, the peak cladding temperature for all currently loaded VSC-24 systems is estimated to be below 400°C [752°F] and thus, this is consistent with the current NRC guidance in ISG-11 Revision 3 (NRC, 2003 [62]). In addition the CoC holder's proposed condition to limit the thermal power to 15 kW for any VSC-24 systems loaded in the future will assure that the peak cladding temperatures will be within the guidance provided in ISG 11 Revision 3 (NRC, 2003 [62]). Because the temperatures do not exceed 400°C [752°F], the staff has determined that this is sufficient to provide reasonable assurance that creep will not result in gross rupture of the cladding, and that the geometric configuration of the spent fuel will be preserved. The staff determined that aging of the fuel cladding from creep will not result in significant degradation of the fuel because the temperatures during loading and storage are significantly below those required to have significant cladding creep. Therefore, the staff finds the CoC holder's TLAA is adequate to analyze the aging effects on the PWR spent fuel assemblies stored in the VSC-24 system resulting from cladding creep and demonstrates that the aging effect will not result in a loss of safety functions during the period of extended operation.

3.4.6 Palisades MSB-04 Weld Crack Growth Evaluation (cask-specific TLAA)

Section 3.4.3.3 of the CoC renewal application describes identification of indications in the longitudinal seam weld of Palisades MSB-04 after the MSB was loaded and placed into service. Section 3.3.3.6 of the CoC renewal application summarizes the results of the CoC holder's TLAA to evaluate crack growth in MSB-04 stored at Palisades. In the consideration of crack growth for MSB-04 at Palisades, the CoC holder extended the fatigue crack growth analysis of Palisades MSB-04 to the end of the 60-year service period. The CoC holder's analysis includes an assessment of loading conditions that could potentially result in growth of the existing weld defects by fatigue and, using the loading inputs, a fatigue crack growth analysis. The CoC holder provided a calculation to determine the maximum membrane and bending stress intensities in the MSB-04 shell for the range of normal, off-normal, and accident conditions considered in the crack growth analysis. The CoC holder's analysis assumed that the amount of corrosion predicted on the MSB shell over a 60-year service period in a marine environment resulted in a loss of thickness of 0.18 inches, and stresses were scaled by the appropriate factors to account for the corrosion allowance of the MSB shell. The CoC holder identified membrane and bending stresses in the MSB shell due to cyclic loads from pressure testing, vacuum drying, off-normal extreme pressure fluctuations, daily pressure fluctuations, off-normal extreme ambient temperature fluctuations, daily ambient temperature fluctuations, seismic and handling loads, and residual stress in the weld. The CoC holder provided minimum and maximum membrane and bending stresses and the total number of cycles for each loading condition, which was used as inputs to the fatigue crack growth calculation of the MSB-04 shell.

The CoC holder recalculated the expected fatigue crack growth to extend the evaluation period from 50 years to 60 years using the new stresses and number of cycles for the period of extended operation (EnergySolutions Spent Fuel Division Inc., 2014f [40]). Although the CoC holder considered the loss of material from corrosion, the fatigue analysis was conducted using the original a/t ratio of 0.5. The CoC holder calculated the expected crack growth for each load case using the da/dN ratios of each load case taking the maximum ratio between the membrane and bending stress ratios and the total number of loading cycles.

In order to bound the potential crack growth in the corroded shell, the CoC holder modeled the 1-inch long by 1/2-inch deep flaw on the inside surface of the MSB shell rather than as a subsurface flaw. The CoC holder determined that a 1-inch long by ½-inch deep flaw in Palisades MSB-04 grows to 0.5000203 inches deep by 1.0000193 inches long over the 60-year extended service period, considering a corrosion allowance of 0.18-inches and the full range of normal, off-normal, and accident load conditions. The TLAA provided by the CoC holder assesses flaw stability of MSB-04 at Palisades using as inputs (1) the initial defect, (2) additional estimated crack growth from fatigue, and (3) the loss of material from uniform corrosion. The CoC holder provided a calculation that concluded the flaw stability factors of safety remain greater than those required by the ASME Code for normal and faulted conditions.

The staff reviewed the CoC holder's assessment of the Palisades MSB-04 Weld Crack Growth Evaluation. The staff determined that the calculation provided by the CoC holder in its TLAA for fatigue crack growth analysis assumes an initial defect that is a 1-inch long by ½-inch deep surface flaw, which bounds the actual weld flaws identified in the longitudinal seam weld of Palisades MSB-04. The staff determined the methodology used by the CoC holder, which uses conservative assumptions for the initial flaw size and orientation, is appropriate for the assessment of fatigue crack growth of initial weld defects in Palisades MSB-04 under the full range of normal, off-normal, and accident load conditions over 60 years. The staff determined that the fatigue crack growth from the flaws identified in MSB-04 will not result in loss of confinement integrity for MSB-04 for the extended period of operation because the amount of crack advance is very small even with conservative assumptions for both the initial flaw size and applied stresses during the period of extended operation.

The staff reviewed the flaw stability analyses in the existing Sargent and Lundy calculation from 2007 (EnergySolutions Spent Fuel Division Inc., 2014b [40]) which were performed using the rules of IWB-3610 and IWB-3620 of Section XI of the ASME B&PV Code (ASME, 1992 [13]). As stated by the CoC holder, the postulated flaw is stable, and thus acceptable, if the applied stress intensity factor for the final flaw size meets the prescribed acceptance criteria. In fracture mode transition, three metrics of toughness are commonly used to characterize the fracture toughness of ferritic steels including ASME SA516 Grade 70 steel: K_{lc}, K_{ld}, and K_{la}. These are defined as follows:

K_{lc} is the resistance to cleavage crack initiation arising from loadings that are applied slowly (i.e., quasi-statically).
K_{ld} is the resistance to cleavage crack initiation arising from loadings that are applied rapidly.
K_{la} is the ability of the steel to arrest (stop) a running cleavage crack once it has been initiated.

The staff reviewed the acceptance criteria in the ASME B&PV code for normal (including upset and test) conditions:

$$K_l < \frac{K_{ld}}{\sqrt{10}}$$

where, K_l is the maximum applied stress intensity factor for the final flaw size.

For emergency and faulted conditions the ASME B&PV code acceptance, a criterion is:

$$K_l < \frac{K_{lc}}{\sqrt{2}}$$

The CoC holder stated the fracture toughness of the weld material was taken from the existing S&L calculation (EnergySolutions Spent fuel Division Inc., 2014b [40]). The CoC holder indicated the values of both the fracture toughness based on crack arrest (K_{ld}) and the fracture toughness based on crack initiation (K_{lc}) were therein obtained from certified material test reports of the weld metal used for the seam weld of the MSB-04 shell at 0°F (less than the minimum MSB shell service temperature of 5°F, conservatively) and material Charpy V-notch impact energy (CVN) correlations. The correlations used by the CoC holder in the original Sargent and Lundy Calculation were developed by Barsom and Rolfe (Barsom et al., 1970 [24]) and are:

$$K_{Ic} = (2E \cdot CVN^{1.5})^{0.5}$$

$$K_{Id} = (5E \cdot CVN)^{0.5}$$

where: E is the elastic modulus of the material and CVN is the measured Charpy V-notch values.

For the MSB-04, the CoC holder calculated the following fracture toughness values:

$$K_{Id} = 89.247\ ksi\ in$$

$$K_{Ic} = 153.011\ ksi\ in$$

The staff reviewed the CoC holder's assessment as well as other relevant information regarding the estimation of fracture toughness of steels (Roberts and Newton, 1981 [75]; Kirk, et al., 2014 [55]; Erickson, Kirk et al., 2007 [46]). The staff notes that estimates of K_{Ic} and K_{Id} using the Barsom and Rolfe correlations as well as other developed correlations, along with the challenges and difficulties associated with these methods, were evaluated in WRC-265 in 1981 (Roberts and Newton, 1981 [75]). One fundamental challenge is that fracture toughness tests (K_{Ic}, K_{Id}, K_{Ia}) often do not experience fracture mode transition over the same temperature range as do the CVN data; this can lead to the use of ductile fracture Charpy data to predict cleavage fracture toughness which is not a technically sound practice. It is also notable that WRC-265 did not recommend the use of the Barsom and Rolfe correlations.

The staff notes that it is now widely recognized that the K_{Ic} and K_{Ia} toughness of all ferritic steels follow a common mean temperature dependence and follow a common scatter about these mean trends. The factor that distinguishes between different steels is the index temperature that is used to position the K_{Ic} and K_{Ia} toughness curves on the temperature axis. These models have been summarized in a recent paper (Kirk, et al., 2014 [55]) and have been adopted by the NRC in its PTS re-evaluation effort (Erickson, Kirk et al., 2007 [46]).

The staff applied this method to estimate the K_{Ic} from the CVN data reported by the CoC holder and then compared the estimated K_{Ic} values to the K_I values reported in the CoC holder's Calculation No. 1200250.301, Revision 1, "Flaw Tolerance Evaluation of Spent Fuel Cask MSB#4 for Palisades Power Plant" Table 6 (EnergySolutions Spent Fuel Division Inc., 2014d [36]). The results of this comparison are summarized in Table 3.4-1.

Table 3.4-1. Comparison of Flaw Tolerance Evaluation Results

Condition	Predicted fracture toughness	Fracture toughness used in evaluation	applied K (K_I) per Table 6 (ML14301A254)	Flaw tolerance demonstrated? K_{Id} or $K_{Ic} > K_I$
CoC holder Analysis				
Normal	K_{Id} = 89 ksi√in	89/√10 = 28 ksi√in	23.588 ksi√in	Yes
Off Normal	K_{Id} = 89 ksi√in	89/√10 = 28 ksi√in	26.177 ksi√in	Yes
Accident/Faulted	K_{Ic} = 153 ksi√in	153/√2 = 108	62.764 ksi√in	Yes
NRC Staff Analysis				
Normal	K_{Ic} = 70 ksi√in	K_{Ic} = 70 ksi√in	23.588 ksi√in	Yes
Off Normal	K_{Ic} = 70 ksi√in	K_{Ic} = 70 ksi√in	26.177 ksi√in	Yes
Accident/Faulted	K_{Ic} = 95 ksi√in	K_{Ic} = 95 ksi√in	62.764 ksi√in	Yes

Although the calculated values in the staff's analysis are generally lower than those calculated by the CoC holder, in all cases flaw tolerance is demonstrated because the fracture toughness used in the evaluation (either K_{Ic} or K_{Id}) remains greater than the applied stress intensity (K_I) as required by the ASME Code for normal, off-normal, and accident/faulted conditions. For this reason, the staff finds that the flaw stability criteria are satisfied for MSB-04 at the Palisades ISFSI.

Additionally, the staff determined that fatigue crack growth of MSB-04 at the Palisades ISFSI as a result of temperature fluctuations would not result in significant crack growth because the temperature fluctuations are small, resulting in conservative estimations of crack growth that are much less than 0.025 mm [0.001 inches]. The staff also determined that the increase in flaw length from the initial weld indication, combined with the loss of material from corrosion, did not significantly alter the flaw stability factors of safety below those required by the ASME code for normal and faulted conditions. The staff reached this determination because the resistance to cleavage crack initiation, obtained from measured values of Charpy V-notch toughness, was greater than the maximum applied stress intensity. For these reasons, the staff finds the CoC holder's TLAA is adequate to analyze the aging effects resulting from fatigue crack growth and flaw stability for the MSB-04 and demonstrates that the aging effect will not result in a loss of safety functions for the MSB-04 during the period of extended operation.

3.4.7 Evaluation of Loss of MSB Lid RX-277 Shielding Function after 20 Years of Storage

The CoC holder noted that the RX-277 neutron shielding material in the MSB shield lid (i.e., the shield lid neutron shield) provides radiation shielding at the top end of the MSB assembly. During the initial storage period, the CoC holder stated that the MSB shield lid is relied upon to maintain the total (neutron + gamma) average dose rate on the top surface of the VCC within the 200 mrem/hr limit required by TS 1.2.4. The CoC holder evaluated the potential degradation of the shield lid neutron shield from radiation exposure as described in CoC renewal application Section 3.3.3.4 and noted that no other significant potential sources of degradation of the shield lid neutron shield have been identified, given that it lies within a sealed chamber and is exposed to temperatures that are well below the material's service temperature. Nevertheless, as discussed in Section 3.4.4 of this SER, the CoC holder initially proposed that aging management of the RX-277 in the MSB lid be part of the AMP for the VSC top end steel components. Due to the stated concerns (see SER Section 3.4.4) regarding the proposed monitoring and acceptance criteria for that activity, the CoC holder provided a TLAA in CoC renewal application Section 3.3.3.7 to demonstrate that measures to ensure shielding performance of the RX-277 material during the extended operation period are not necessary. The TLAA evaluates the impact of a complete loss of the RX-277 material in the MSB shield lid after 20 years of storage.

The evaluation provided by the CoC holder shows that, for any assembly payload allowed by the initial certificate, the VCC top surface average neutron dose rate is lower after the initial 20-year storage period, even if no credit is taken for the neutron shielding provided by the RX-277 material in the MSB shield lid. The CoC holder indicated that the analysis shows that the reduction (decay) in neutron source strength over the initial 20-year storage period more than offsets the complete removal of the RX-277 material. The analysis shows that the significant reduction in gamma source terms that will also occur over the initial 20-year storage period will also offset the complete loss of the RX-277 material. As a result, the CoC holder indicated that the overall average total (neutron + gamma) dose rate on the top surface of the VCC will be significantly lower than the initial dose rate at the time the cask is loaded, and well under the 200 mrem/hr limit, even if the RX-277 material is completely neglected. Based on the evaluation, the CoC holder concluded that the shielding properties of the MSB lid RX-277 neutron shielding material are not needed over the period of extended operation. Consequently, the CoC holder reported that the material has no design function over the period of extended operation, and potential degradation of the material does not require management and measures to monitor the shielding performance (e.g., dose rate measurements) of the material.

The staff reviewed the CoC holder's evaluation of the MSB lid RX-277 neutron shielding degradation. This review included a calculation package that the CoC holder submitted in support of the evaluation. The staff also performed confirmatory calculations as part of its review. The staff finds that the CoC holder's proposed evaluation is an appropriate way to address considerations of the MSB's RX-277 shield material in place of proposing an AMP. Based on the staff's independent calculations confirming the CoC holder's conclusions, described below, the staff determined that the CoC holder's method is adequate to demonstrate the impacts on the VCC top surface dose rate due to decay of the stored spent fuel over the initial storage period and neglect of the MSB lid's RX-277 neutron shield for this renewal application. The staff has concerns regarding some of the specifics of the evaluation method, such as the use of ORIGEN2 data because the ORIGEN2 code and data are outdated and are no longer maintained by the code developer. Thus, there is the potential for errors in the code and data to go undetected and remain uncorrected, which can lead to inaccurate results in analyses relying on this code and data. Thus, the staff's analyses used SAS2H, which is a more recent source term code that includes corrections to any such code and data errors. The staff calculated source terms, using SAS2H, for both the design basis spent fuel specifications and another set of specifications (as discussed in Section 3.4.4 of this SER) for both the time of loading and 20 years after loading. These source terms were used in MCNP5 calculations that used very simple geometries that represent the MSB lid with and without RX-277. The results of the staff's calculations also indicate that top VCC surface dose rates without the RX-277 after 20 years will be less than the dose rates at the time of loading. Thus, the staff finds that degradation of the RX-277 neutron shielding material in the MSB lid during the period of extended operation will not result in an average dose rate on the top surface of the VCC that exceeds the 200 mrem/hr limit in TS 1.2.4. Therefore, the staff finds that the potential degradation of the RX-277 shielding material does not require management and measures to monitor the material's shielding performance during the period of extended operation.

3.4.8 VCC Concrete Thermal Fatigue Analysis

The CoC holder stated that the VCC reinforced concrete is subjected to repeated cycles of thermal stress due to seasonal and diurnal variations in ambient conditions. The CoC holder evaluated the potential degradation of the VCC concrete and reinforcing steel caused by fatigue from thermal variations in CoC renewal application Section 3.3.3.8. The CoC holder considered both extreme fluctuations in ambient air temperature and diurnal fluctuations in ambient air temperature for a 60-year period. The CoC holder cited the results of the thermal stress analysis of the VCC assembly for the steady-state normal long-term storage condition that are presented in Table 3.4-7 of the VSC-24 FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]), which show that the maximum compressive stress in the concrete is 0.4 ksi [2.6 MPa] and the maximum tensile stress in the rebar is 28.8 ksi [199 MPa]. The CoC holder determined that an extreme cold condition will result in a maximum concrete compressive stress of approximately 0.3 ksi [2.1 MPa] and a maximum tensile stress in the rebar of approximately 22.1 ksi [152 MPa]. Therefore, the maximum range of concrete compressive stress and rebar tensile stress due to seasonal variations in ambient temperature are approximately 0.1 ksi [0.7 MPa] for the concrete and 6.7 ksi [46.2 MPa] for the rebar. The CoC holder stated that the ratio of the maximum range of concrete compressive strength (Smax) to its design strength (f’c) is only 0.025 (i.e., 0.1 ksi/4 ksi). Using Figure 3 of ACI 215R-74 (ACI, 1997 [2]) and 22,500 cycles (total of diurnal variations and extreme temperature fluctuations over 60 years), the CoC holder stated that the low concrete compressive stress ratio will not result in fatigue failure of the VCC concrete because it is much lower than the stress-fatigue life (S-N) curves. Likewise, the CoC holder stated that, based on Figure 6 of ACI 215R-74, fatigue failure of the reinforcing steel in the VCC concrete will not result from 22,500 cycles at a stress range of 6.7 ksi [46.2 MPa] in the rebar because it is much lower than the S-N curves.

The staff reviewed the CoC holder’s assessment of loss of concrete strength potentially resulting from thermal fatigue in the VCC reinforced concrete for repeated cycles of seasonal and diurnal temperature fluctuations in ambient air temperature including the thermal stress analysis of the VCC assembly for the steady-state normal long-term storage condition, results of which are presented in Table 3.4-7 of the VSC-24 FSAR (EnergySolutions Spent Fuel Division Inc., 2009 [36]), and the information provided in ACI 215R-74. The staff confirmed that the stress ratio for the VCC concrete is much lower than the stress-fatigue life (S-N) curves in ACI 215R-74. The staff also confirmed that fatigue failure of the reinforcing steel in the VCC concrete will not result from 22,500 cycles at a stress range of 6.7 ksi [46.2 MPa] based on the S-N curves of Figure 6 of ACI 215R-74. The staff determined that fatigue of the VCC concrete and rebar caused by temperature fluctuations will not result in fatigue failure of either the concrete or the rebar. The staff reached this determination because the magnitude of the concrete and rebar cyclic stresses is low and the number of temperature fluctuations over a 60 year period is insufficient to result in fatigue failure of either the concrete or the rebar based on the evaluation criteria in ACI 215R-74. Therefore, the staff finds the CoC holder’s TLAA is adequate to analyze the aging effects resulting from thermal fatigue for the VCC Concrete and reinforcing steel rebar and demonstrates that the aging effect will not result in a loss of safety functions for the VCC during the period of extended operation.

3.4.9 Evaluation Findings

The staff reviewed the TLAAs provided in the renewal application and supplemental documentation (ML14301A253). The staff performed its review following the guidance provided in NUREG–1927 (NRC, 2011 [65]) and the ISGs, as identified in Table 1.4-1, and evaluated the TLAAs in terms of the regulatory requirements of 10 CFR 72.240. The staff verified that the TLAA assumptions, calculations, and analyses were adequate and bound the environment and aging mechanisms or aging effects for the pertinent SSCs. Based on its review, the staff finds:

F3.3 The CoC holder identified all aging mechanisms and effects that are pertinent to the SSCs within the scope of renewal review and identified those aging mechanisms and effects for which TLAAs are an appropriate means to address them during the period of extended operation. The methods and values of the input parameters for the CoC holder's TLAAs are adequate. Therefore, the CoC holder's TLAAs provide reasonable assurance that the SSCs will maintain their intended function(s) for the period of extended operation, require no further aging management activities, and meet the requirements for renewal.

3.5 Aging Management Program

Pursuant to 10 CFR 72.240(c)(3) requirements, the CoC holder must provide a description of AMPs for management of issues associated with aging that could adversely affect SSCs ITS. The CoC holder proposed five AMPs:

1. Examination of the VCC Assembly Exterior
2. Examination of the VCC Assembly Ventilation Ducts and Annulus
3. Examination of VSC Top End Steel Components
4. Examination of the MTC Assembly
5. Lead Cask Inspection

As specified in the new CoC conditions in Section 4 of this SER, the AMPs summarized in the CoC renewal application will be incorporated into the FSAR within 90 days of the effective date of the CoC renewal, similar to the requirement for an original FSAR in 10 CFR 72.248(a), after issuance of an initial CoC. Other FSAR changes needed for the renewal of the CoC will also be incorporated within this same timeframe. This condition will ensure that the FSAR accurately reflects the changes needed to enable continued use of the VSC-24 system and that the necessary AMPs and evaluations will be available to general licensees using the VSC-24 system in a timely manner.

Operating experience is an important component for ensuring that in-scope SSCs will maintain their intended function throughout the period of extended operation. However, operating experience on age-related degradation of dry storage systems in some areas is presently limited. Standard rules for in-service inspections, as codified in the ASME Boiler and Pressure Vessel (B&PV) Code (Code), are also not yet established for dry storage systems. Instead, the staff has agreed with the CoC holder's use of specific criteria in the Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components." NRC's 10 CFR Part 72 regulations do not currently provide for a process to allow for relief requests of ASME B&PV Section XI inspections in the same manner as 10 CFR 50.55a, "Codes and Standards". In the future, new operating experience on age-related degradation of dry storage systems may provide a basis for the development of future Code inspections.

The staff also acknowledges that the CoC holder or licensees may seek to make changes to the AMPs through the process in 10 CFR 72.48. The staff did consider adding a condition to the CoC to limit the types of changes that could be made without prior NRC approval. However, the staff determined that such a condition was not necessary to make the requisite safety findings. This determination is based on the staff's consideration that adequate data and operating experience would be needed to support any change under 10 CFR 72.48, particularly changes that relaxed the provisions or requirements of the AMP (e.g., removed aging effects/mechanisms from the scope, changed acceptance criteria to allow for acceptance of greater degradation). Thus, such changes could not be made under 10 CFR 72.48 until further data and operating experience is obtained to adequately support the change under 10 CFR 72.48 for aspects of the AMPs where the data and operating experience is currently limited.

3.5.1 Examination of VCC Assembly Exterior

The CoC holder included the Examination of VCC Assembly Exterior AMP in CoC renewal application Section 3.4.2.1. The AMP describes the activities credited for maintaining the VCC exterior concrete and all readily accessible steel-to-concrete interfaces during the period of extended operation. The CoC holder indicated the purpose of this AMP is to maintain the surface condition of the VCC assembly exterior, including concrete, in order to prevent degradation of the concrete and maintain the VCC assembly's intended functions. The program manages aging effects through inspection of the exterior surfaces for indications of aging mechanisms that may cause loss of strength of the concrete, such as cracking due to aggregate reactions or corrosion of embedded steel and increased porosity due to CaOH leaching. Steel-to-concrete interfaces are examined and monitored for gaps or voids that could potentially lead to unacceptable degradation of the embedded steel components of the VCC assembly. The program also monitors the condition of the inlet and outlet screen and hardware for degradation and damage.

This section contains the staff review of the adequacy of the Examination of VCC Assembly Exterior AMP to address the identified aging mechanisms and effects for the VCC exterior surfaces. The staff reviewed the AMP against the criteria provided in Section 3.6.1 of NUREG–1927. The staff's evaluation of each of the program elements is as follows:

1. Scope of Program

The CoC holder specified the Scope of Program as the inspection of the readily accessible exterior concrete surfaces, all readily accessible exterior steel-to-concrete interfaces of the VCC bottom plate assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets), all four VCC air outlet weldments, and all readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware. The CoC holder clarified that portions of the VCC exterior concrete surface and steel-to-concrete interfaces that are covered by the air inlet and outlet screens or other system components (e.g., monitoring equipment) are not included in the scope of the inspection.

The staff reviewed the CoC holder's Scope of Program and the design and materials of construction identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff determined that the SSCs and subcomponents necessary to maintain the VCC assembly's intended functions and that require aging management actions are included in the Scope of Program. The staff finds the Scope of Program provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

2. Preventative Actions

The CoC holder specified the Preventative Actions were to maintain the surface condition of concrete and exterior steel-to-concrete interfaces in order to prevent degradation of the concrete interior (e.g., reinforcing steel) and maintain the condition of the air inlet and outlet screen covers to prevent unacceptable breaches that could potentially lead to unacceptable blockage of the VCC ventilation ducts.

The staff reviewed the Preventative Actions, Parameters Monitored or Inspected, Detection of Aging Effects, Acceptance Criteria, and Corrective Actions. The staff notes that the aging effects managed in this AMP will be visible on the VCC exterior surfaces as indicated in ACI 201.1R (ACI, 2008 [6]). The staff determined that the Preventative Actions are adequate because the surface condition of concrete, steel-to-concrete interfaces, and the condition of the air inlet and outlet screen covers are covered by maintenance actions designed to prevent loss of the VCC assembly's intended functions as a result of aging related degradation. The staff finds the Preventative Actions provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

3. Parameters Monitored or Inspected

The CoC holder specified that the Parameters Monitored or Inspected are damage to/degradation of the concrete exterior surface including: (1) cracking and loss of material (spalling or scaling) due to freeze-thaw, aggregate reactions, or corrosion of embedded steel, (2) excretion of rust at crack openings due to rebar corrosion, (3) increased porosity and/or discoloration (i.e. efflorescence) due to CaOH leaching, or (4) gaps or voids at the exposed steel-to-concrete interfaces of the VCC bottom plate assembly around the bottom end of the VCC and the openings of all four air inlets and all four VCC air outlet weldments, and (5) corrosion and/or damage of the readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware.

The staff reviewed the Parameters Monitored or Inspected for damage to/degradation of VCC exterior surfaces and relevant information on the degradation of concrete structures identified in ACI 349.3R (ACI, 2002 [5]) and ACI 201.1R. The staff determined that the Parameters Monitored or Inspected included in the AMP are adequate because the parameters listed are direct indications of the initiation and/or progression of aging related degradation of the VCC exterior concrete, steel-to-concrete interfaces, VCC air inlets and outlets, and ventilation screens and the associated attachment hardware that could adversely affect the VCC assembly's intended functions.

The staff did consider whether the AMP should also include monitoring of VCC dose rates by means of periodic dose rate measurements. The reason for this consideration is that monitoring of dose rates for casks had been included in the license renewal for at least two specific license ISFSIs. The staff evaluated the differences between the cask designs used by those specific licensees and the VSC-24 cask design and the acceptance criteria for this AMP for the VSC-24 system (see the Acceptance Criteria AMP element discussion below). Based on that evaluation, the staff has reasonable assurance that inspection or monitoring of the parameters identified in the AMP (by the CoC holder), together with appropriate acceptance criteria and corrective actions that are evaluated below, will identify and prevent the progression of aging mechanisms and effects from causing a loss of the shielding function of the VCC. This assurance is based on an independent staff evaluation of the impacts of the parameters at the acceptance criteria values on VCC dose rates, accounting for radioactive decay of the spent fuel over the initial 20-year storage period, and the factors that influence doses to occupational personnel and to members of the public. Based on this evaluation, the staff finds that dose rate monitoring is not needed for this AMP for the VSC-24 system. Thus, the staff finds the Parameters Monitored or Inspected element of this AMP provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

4. Detection of Aging Effects

The CoC holder stated that the Examination of VCC Assembly Exterior AMP would detect aging effects on the exterior surfaces before the affected SSCs lose the ability to perform their intended functions. The CoC holder specified that the method or technique utilized would be visual examination of the VCC concrete exterior surfaces and steel-to-concrete interfaces performed per the guidelines of ACI 201.1 R-08 (ACI, 2008 [6]), or an equivalent industry consensus standard. The CoC holder stated that direct VT-3 visual examination will be used to inspect the air inlet and outlet screens and associated screen attachment hardware. The CoC holder specified that the visual examination shall be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). The CoC holder stated that inspector qualifications in accordance with ASME Code, Section XI, Subsection IWL (ASME, 2004 [13]) or ACI 349.3R (ACI, 2002 [5]) are both acceptable. The CoC holder stated that qualifications for personnel performing VT-3 inspection of the air inlet and outlet screens and screen attachment hardware in accordance with IWE-2330 (ASME, 2004 [13]) are acceptable.

The CoC holder specified that the inspection activity will be conducted with an annual frequency and the sample size includes all readily accessible external surfaces of all in-service VCC assemblies. The CoC holder stated that data collection includes video/photographs of examination, crack/defect maps with sizes and depths of cracks and voids, location and description of other surface defects such as porosity, discoloration, or rust stains on the concrete surface, and records of corrective actions. The CoC holder stated that the timing of inspections would include completion of the initial inspection within 1-year following the 20th anniversary of the first cask loaded at the site or 2-years after the effective date of the CoC renewal, whichever is later.

The staff reviewed the Detection of Aging Effects, the guidance for visual inspection of concrete in ACI 201.1R-08 and the recommended evaluation procedure contained in ACI 349.3R-02 (ACI, 2002 [5]). The staff determined that the visual inspection methods and evaluation procedures described in the Examination of VCC Assembly Exterior AMP are appropriate for detecting damage/degradation of the concrete exterior surface and aging of the exposed steel-to-concrete interfaces because the inspection methods are consistent with recommended guidance for visual inspection and evaluation procedures for concrete (ACI, 2002 [5]; 2008 [6]). The staff reviewed the qualifications for personnel performing inspections and determined that personnel qualifications identified in ASME Code, Section XI, Subsection IWL-2320 and IWE-2330 (ASME, 2004 [13]) or ACI 349.3R (ACI, 2002 [5]) are appropriate for examination of concrete subcomponents of the VCC and consistent with the cited consensus codes and standards.

The staff reviewed the CoC holder's assessment of general corrosion of galvanized or zinc plated steel screens, attachment hardware, and bolts in the VCC. The staff also reviewed the ASM Materials Handbook to obtain independent information on the galvanized coatings (Stavros and Gambrell 1987 [76]). The staff determined examination of these components using VT-3 examination using qualified personnel (ASME, 2004 [13]) is sufficient to detect significant general and localized corrosion of galvanized and primer coated carbon steel subcomponents based on the information included in Table A-110 of Section V of the ASME Boiler and Pressure Vessel Code (ASME 2010c [16]). In addition, the staff determined that qualification identified in ASME Code, Section XI, Subsection IWE-2330 (ASME, 2004 [13]) is appropriate for personnel performing VT-3 inspections of the vent screens and associated hardware.

The staff reviewed the sample size, frequency and timing proposed by the CoC holder and determined that the sample size, timing and frequency of the inspections are sufficient to ensure the intended function of these VCC subcomponents. The staff finds that the Detection of Aging Effects provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

5. Monitoring and Trending

The CoC holder stated that Monitoring and Trending will utilize data collected from each AMP examination, including crack/defect maps that identify the locations and sizes of observed aging effects to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects. In addition, the CoC holder stated that a baseline shall be developed from the initial inspection performed during the period of extended operation. Available information from previous inspections performed during the initial storage period may also be used to inform the baseline. The CoC holder stated that the results from each AMP examination shall be compared with those from all previous inspections in the period of extended operation to identify trends of increasing degradation of the structure, including: (1) cracking or loss of material on the exterior surfaces of the concrete, (2) rust visible at concrete cracks in the VCC exterior, (3) porosity and/or discoloration on the exterior surfaces of the concrete, (4) gaps or voids at the exposed steel-to-concrete interfaces and (5) corrosion and/or damage of air inlet and outlet screens and associated screen attachment hardware.

The staff reviewed the Monitoring and Trending AMP element, the guidance for visual inspection of concrete in ACI 201.1R-08 (ACI, 2008 [6]), and the recommended evaluation procedure contained in ACI 349.3R-02 (ACI, 2002 [5]). The staff determined that the parameters identified in the Monitoring and Trending element are appropriate because the AMP requires a baseline be developed from the initial inspection and that trending will be performed on the Parameters Monitored or Inspected (identified in AMP element 3) that the staff determined are direct indications of the initiation and/or progression of aging related degradation of the VCC exterior concrete, steel-to-concrete interfaces, VCC air inlets and outlets, and ventilation screens and the associated attachment hardware that could adversely affect the VCC assembly's intended functions. The staff determined that the parameters identified in the Monitoring and Trending AMP element are necessary to determine aging trends that may necessitate additional corrective actions and/or revisions to the AMP. The staff also determined that the parameters identified in the Monitoring and Trending AMP element are necessary to document and evaluate operating experience for the VSC-24 system. Thus, the staff finds that the Monitoring and Trending conducted as part of the Examination of VCC Assembly Exterior AMP provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

6. Acceptance Criteria

The CoC holder specified that concrete popouts and voids less than 1/2 inch in diameter (or equivalent surface area) are acceptable, scaling less than 3/16 inch deep is acceptable, spalling less than 3/8 inch deep and less than 4 inches wide is acceptable and passive cracks less than 1 mm (0.04 inch) wide are acceptable. In addition, the CoC holder stated that passive cracks that exceed 1 mm (0.04 inch) in width, but show no indications of other degradation mechanisms are also acceptable but must be monitored and trended for accelerated crack growth in subsequent examinations. In addition, gaps or voids at the exterior steel-to-concrete interfaces less than ½ inch wide or 1/4 inch deep are acceptable. The CoC holder specified that passive cracks that exceed 1 mm (0.04 inch) in width and show indications of other degradation mechanisms are not acceptable, and evidence of degradation mechanisms suspected to result in loss of concrete strength (e.g., aggregate reactions, leaching, or corrosion staining) is not acceptable. Damage to the screens or attachment hardware that results in an opening no greater than ½ inch in width is acceptable. No attachment hardware can be missing or dislodged. Corrosion of the screens is acceptable if it does not cause breakage of the screen mesh ligaments or result in loose or dislodged screens. Corrosion of the screen attachment hardware is acceptable if it does not cause the attachment hardware or the screen to loosen or dislodge.

The staff reviewed the CoC holder's Acceptance Criteria AMP element, the guidance for visual inspection of concrete in ACI 201.1R-08 (ACI, 2008 [6]) and the recommended evaluation procedures, acceptance criteria, and corrective actions contained in ACI 349.3R-02 (ACI, 2002 [5]). The staff determined that the acceptance criteria are appropriate to maintain the intended functions of the VCC Assembly because the acceptance criteria are quantified and consistent with the ACI 349.3R acceptance criteria. The staff notes that ACI 349.3R-02 does not specifically address the type of steel-to-concrete interfaces that are present in the VCC. However, the staff determined that the acceptance criteria identified by the CoC holder for the VCC steel-to-concrete interfaces are consistent with the acceptance criteria for other concrete aging effects. The staff determined that the acceptance criteria for the screens and hardware are sufficient to manage aging effects from corrosion and damage to these subcomponents because the acceptance criteria ensure the screens and associated hardware are present and operable. In addition, as indicated in the Parameters Monitored or Inspected element review, the staff evaluated the parameters to be monitored or inspected and the acceptance criteria in terms of shielding impacts. That evaluation included calculations of dose rate impacts due to different criteria regarding concrete acceptability, such as in ACI 349.3R, which bound the criteria of this AMP. Accounting for the radioactive decay of the spent fuel in the cask over the initial 20-year storage period, the calculations indicate that the decay of the spent fuel will more than offset the reduced shielding capacity of the cask that would be characteristic of the extent of degradation allowed by the acceptance criteria. Thus, the staff finds that the Acceptance Criteria defined in the Examination of VCC Assembly Exterior AMP provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

7. Corrective Actions

The CoC holder provided specific information with respect to the repair of defects, rebar corrosion, leaching and porosity, and aggregate reactions, and noted that defects of the concrete exterior exceeding the acceptance criteria shall be documented and evaluated in accordance with the General Licensee's (GL) corrective action program. A summary of the corrective actions for each of these aging effects is summarized in the following paragraphs.

Repair of Defects: The CoC holder indicated that defects on the concrete exterior surface exceeding acceptance criteria shall be documented and evaluated in accordance with the GL's corrective action program. The CoC holder specified that any defects on the concrete exterior surface or at the steel-to-concrete interfaces of the VCC Bottom Plate Assembly including the bottom end of the VCC and the openings of all four air inlets and VCC Air Outlet Weldments that exceed the acceptance criteria shall be repaired by appropriate means in accordance with the GL's procedures.

Rebar Corrosion: The CoC holder specified that concrete showing evidence of rebar corrosion, such as corrosion staining, splitting cracks, or accelerated crack growth, shall be tested using acoustic impact or other suitable NDE techniques, to detect rebar corrosion or concrete delamination, and evaluated for continued storage. The CoC holder specified that a cask with aging effects due to rebar corrosion that is not acceptable for continued storage shall be repaired or replaced.

Leaching and Porosity: The CoC holder stated that concrete showing evidence of leaching (staining in the form or efflorescence) and/or increased porosity shall be documented and evaluated in accordance with the GL's corrective action program. In addition, the CoC holder stated that efflorescence shall be investigated to confirm the presence of calcium hydroxide or other salts leaching from the concrete. The CoC holder specified that areas with confirmed concrete leaching and increased porosity shall be evaluated to determine the concrete compressive strength and that concrete with a compressive strength that is lower than the design basis compressive strength shall be repaired or replaced in accordance with the GL's procedures.

Aggregate Reactions: The CoC holder stated that corrective actions for concrete surfaces that show evidence of degradation from aggregate reactions, as determined by the qualified inspector, shall include a preliminary investigation to confirm or refute the presence of ASR gel in the concrete. If ASR is confirmed by the preliminary investigation, the CoC holder specified that Crack Index (CI) measurements shall be taken on the affected cask(s) in accordance with FHWA-HIF-09-004 (U.S DOT, 2010 [79]) to determine the extent of ASR-induced degradation in the concrete. Further, the CoC holder specified that any cask with a CI that is greater than 0.5 mm/m (0.018 in/yard) and/or with crack widths that exceed 0.15 mm (0.006 in) requires detailed in-situ and/or laboratory investigations to determine the current condition of the concrete and its potential for future degradation. The CoC holder stated that, at a minimum, CI measurements shall continue to be taken at least twice a year for a minimum of 3 years to monitor the progression of ASR-induced degradation. After 3 years, the CI measurement frequency may be reduced to once every 5 years if the CI shows no significant increasing trend. The CoC holder indicated that detailed laboratory testing using concrete core samples to assess affected casks, may include petrographic examination, mechanical testing, expansion testing, and alkali content testing, as required. The CoC holder stated that a VCC assembly that is determined to have concrete that has a significant potential for further expansion due to ASR and/or does not meet the strength specifications identified in the FSAR shall be evaluated for continued storage, and repaired or replaced, if necessary.

Ventilation hardware: The CoC holder stated that air inlet or outlet screens and any associated attachment hardware that does not satisfy the acceptance criteria for damage or corrosion shall be repaired or replaced.

The CoC holder indicated that Extent of Condition Evaluation actions are not applicable to this AMP because the extent of condition is known since examinations are required to be performed annually on all in-service casks.

The staff reviewed the CoC holder's Corrective Actions AMP element, the guidance for visual inspection of concrete in ACI 201.1R-08 (ACI, 2008 [6]) and the recommended evaluation procedures, acceptance criteria, and corrective actions contained in ACI 349.3R-02 (ACI, 2002 [5]). The staff determined that the corrective actions are adequate because they include specific corrective actions for the repair of defects, rebar corrosion, leaching and porosity, spalling aggregate reactions, corrosion and damage of ventilation screens and hardware, and defects at steel-to-concrete interfaces that are necessary to maintain the safety functions of the

VCC assembly. In addition, the staff determined that the corrective actions identified for the concrete subcomponents and the steel-to-concrete interfaces are consistent with the guidance in ACI 349.3R-02. The staff determined that the corrective actions for the ventilation screens and associated hardware are clearly defined and sufficient to maintain the intended function of these subcomponents because the acceptance criteria and corrective actions require repair and/or replacement of missing or degraded components. Thus, the staff finds that the corrective actions conducted as part of the Examination of VCC Assembly Exterior AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly will be adequately managed.

8. Confirmation Process

The staff reviewed the Confirmation Process AMP element, which states that the confirmation process will be conducted in accordance with the GL's Corrective Action Program, and will ensure that appropriate corrective actions are completed and are effective. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that the Confirmation Process is adequate for managing the aging mechanisms and effects identified in the AMR of the VCC Assembly.

9. Administrative Controls

The staff reviewed the Administrative Controls AMP element, which indicates that the Administrative Controls that provide a formal review and approval of appropriate corrective actions will be conducted in accordance with the GL's Corrective Action Program. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as directed in this AMP element, provides reasonable assurance that the Administrative Controls are adequate for managing the aging mechanisms and effects identified in the AMR of the VCC Assembly.

10. Operating Experience

The CoC holder stated that hairline cracks and small pits in the VCC external concrete surface that meet the acceptance criteria have been observed during the initial storage period. The CoC holder also reported that defects exceeding acceptance criteria have also been identified and repaired. Some concrete discoloration (e.g., efflorescence or mineral deposits), particularly around cracks, has also been observed on the exterior concrete of some VCCs but there has been no increasing trend in the number of reported pits seen at any of the sites for the subsequent years, nor have there been any indications of failure of grout-repairs. The CoC holder also indicated that a small void was identified at the steel-to-concrete interface of the VCC bottom plate during the lead cask inspection at Palisades, which was believed to have resulted from concrete pouring during construction, rather than from aging effects (though the GL will repair this void).

The CoC holder stated that during the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. Section 3.6 of the renewal application, which will be incorporated into the updated FSAR as Section 9.3.5, “Periodic Tollgate Assessments,” includes a description of the general elements of these assessments, including contents of assessment reports. These assessments have an important role in ensuring the adequacy of the AMPs. Therefore, the staff has added a CoC condition (see Section 4 of this SER) that requires the GLs perform assessments and maintain records of these assessments consistent with the general description given in Section 9.3.5 of the FSAR, as updated for the CoC renewal. Per this condition, each GL’s tollgate assessments and reports shall satisfy the items which are indicated to be required (including those where the FSAR indicates they “shall be” implemented) in Section 9.3.5 of the FSAR. These required items include the completion time of the initial assessment and the frequency of subsequent assessments, the kinds of operating experience that are considered, and assessment report contents. The results of the assessments should be used as described in Section 9.3.5 of the FSAR to identify any new applicable aging effects or mechanisms and to ensure the aging management activities are adequate to manage these effects or mechanisms.

The staff determined that the AMP would be effective in managing the aging effects of the SSCs and subcomponents during the period of extended operation because the operating experience to date has not indicated the existence of current issues that cannot be appropriately monitored and addressed during the period of extended operation. Therefore, staff finds that the operating experience stated and referenced in the CoC renewal application provides reasonable assurance that the AMP will be adequate for managing the aging mechanisms and effects identified in the AMR.

The staff reviewed the evaluation of operating experience required by this AMP during the period of extended operation. The staff determined that the evaluation of operating experience is adequate because the AMP directs the GL to perform periodic “tollgate” assessments of aggregated operating experience relevant to the aging effects and mechanisms addressed in the AMP. This ensures that each GL will use relevant and up-to-date information in conducting the actions required by this AMP. Thus, the staff finds that the Operating Experience stated and referenced in the CoC renewal application provides reasonable assurance that this AMP will be adequate for managing the aging mechanisms and effects identified in the AMR of the VCC Assembly.

3.5.2 Examination of VCC Assembly Ventilation Ducts and Annulus

The CoC holder included the Examination of VCC Assembly Ventilation Ducts and Annulus AMP in CoC renewal application Section 3.4.2.2. The AMP details the activities credited for maintaining the VCC ventilation ducts and annulus during the period of extended operation. The CoC holder indicated the purpose of the Examination of VCC Assembly Ventilation Ducts and Annulus AMP is to (1) confirm that no blockage has accumulated inside the VCC assembly ventilated flow path that could interfere with the natural convective air flow and prevent the VCC assembly from performing its intended heat transfer function, and (2) confirm, through remote VT-3 visual inspection, that the metal surfaces that line the VCC air inlets, air outlets, and cask annulus, which are normally inaccessible, are not experiencing any unanticipated degradation that could prevent them from performing their intended functions.

This section contains the staff review of the adequacy of the Examination of VCC Assembly Ventilation Ducts and Annulus AMP to address the identified aging mechanisms and effects for the MSB shell, subcomponents of the VCC annulus and the VCC ventilation ducts. The staff reviewed the AMP against the criteria provided in Section 3.6.1 of NUREG–1927. The staff’s evaluation of each of the program elements is as follows:

1. Scope of Program

The CoC holder specified that the Scope of Program is examination of the ventilation flow path of all VCC air inlets and outlets and the VCC annulus for blockage and examination of all readily accessible inside surfaces of all VCC air inlets and outlets, and all readily accessible annulus-facing surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shield ring plates (liner assembly and shield ring), and MSB shell for unacceptable corrosion.

The staff reviewed the Scope of Program and the design and materials of construction identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff determined that the SSCs and subcomponents necessary to maintain the intended functions of the VSC-24 system annulus and ventilation ducts and that require aging management actions are included in the Scope of Program. The staff finds the Scope of Program provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

2. Preventative Actions

The CoC holder stated that Preventative Actions include identifying and removing any unacceptable blockage in the VCC air inlets and outlets and the VCC annulus to prevent system temperatures from exceeding the applicable temperature limits. In addition, the CoC holder stated that the preventative actions also include identifying and repairing any unacceptable corrosion on the coated carbon steel surfaces that line the VCC air inlets and outlets, and the VCC annulus.

The staff reviewed the AMP's Preventative Actions, Parameters Monitored and Inspected, Detection of Aging Effects, Acceptance Criteria, and Corrective Actions. The staff determined that the Preventative Actions are adequate because specific actions are required, including identifying and removing any unacceptable blockage in the VCC air inlets and outlets and the VCC annulus to maintain the intended function of passive cooling and repair of any unacceptable coating degradation or corrosion on the coated carbon steel components to prevent continued degradation of the identified SSCs and subcomponents. The staff determined that these preventative actions are adequate to prevent degradation that could potentially affect the ability of the VCC Assembly and the MSB Assembly to perform their intended safety functions. The staff finds the Preventative Actions provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC Assembly and the MSB assembly will be adequately managed.

3. Parameters Monitored or Inspected

The CoC holder specified the Parameters Monitored or Inspected include blockage of the internal ventilation flow path and corrosion of the coated carbon steel surfaces that line the ventilation flow path including the air inlets and outlets, VCC cask liner bottom, VCC cask liner shell, VCC shield ring plates (liner assembly and shield ring), and MSB shell.

The staff reviewed the Parameters Monitored or Inspected relevant to the SSCs and subcomponents identified in the VCC Assembly Ventilation Ducts and Annulus AMP. The staff determined that the Parameters Monitored or Inspected are adequate because the CoC holder has identified actions to be taken by the GL, which are necessary to maintain the intended function of allowing heat transfer by passive cooling. These actions include monitoring for progressive growth of defects, detecting and removing blockage of the internal ventilation flow path, and inspection of the coated carbon steel surfaces that line the ventilation flow path for corrosion. The staff determined that the Parameters Monitored or Inspected are adequate because the CoC holder has identified the pertinent SSCs and subcomponents and the relevant aging effects that could adversely affect the performance of these SSCs and subcomponents of the VCC assembly and the MSB assembly. The staff finds the Parameters Monitored or Inspected provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

4. Detection of Aging Effects

Detection of Aging Effects includes identification of unanticipated blockage and degradation of the coated carbon steel surfaces on the MSB shell and VCC interior. The CoC holder specified remote visual examination (VT-3) to identify blockage and identify localized corrosion (i.e., galvanic, crevice, or pitting corrosion). The CoC holder stated that VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65) and the qualifications for personnel performing VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with IWE-2330 (ASME, 2004 [13]) are acceptable.

The CoC holder specified the inspection frequency to be 5 years and the sample size as the first cask placed in-service at each site. The CoC holder specified that data collection will include documentation of examinations, including identified blockage and the condition of the coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus and records of corrective actions. The CoC holder indicated that the timing of inspections is completion of the initial inspection within 5 years after the 20th anniversary of the first cask being loaded at the site.

The staff reviewed the Detection of Aging Effects, the environment for the SSCs and subcomponents, relevant information on the corrosion of carbon steel, and the description of VT-3 Examination in ASME B&PV Code Section XI, IWA-2213 (ASME, 2004 [13]). The staff acknowledge that the general corrosion rate of carbon steel in atmospheric exposures is dependent on a number of factors, including humidity, time of wetness, atmospheric contaminants and oxidizing species (Pohlman, 1987 [72]; Bryson et al., 1987 [26]; Tullmin and Roberge, 2000 [77]). The staff reviewed the description of VT-3 examination in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]) and notes that VT-3 examinations are conducted to determine the general mechanical and structural condition of components and their supports by verifying parameters such as clearances, settings, and physical displacements; and to detect discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion. The staff determined that the examination of these components using VT-3 examination performed by qualified personnel is adequate because the purpose of the inspection and the inspection method are consistent with the ASME B&PV code (ASME, 2004 [13]).

The staff reviewed the sample size, frequency, and timing proposed by the CoC holder in the Examination of VCC Assembly Ventilation Ducts and Annulus AMP and determined that the sample size, timing and frequency of the inspections are adequate to ensure the intended functions of these VCC subcomponents. The staff determined that examination of the first cask at each site is an adequate sampling size because this cask will have the greatest time in service. The staff determined that examination of one cask at each site was sufficient because (1) the VSC-24 systems in use at each site are similar, (2) if degradation that exceeds the acceptance criteria is identified, the corrective actions of this AMP require additional systems to be inspected. The staff finds that the Detection of Aging Effects provides reasonable assurance that the aging mechanisms and effects for the ventilation flow path including the air inlets and outlets, VCC liner shell, VCC shield ring plates (liner assembly and shield ring), and MSB shell identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

5. Monitoring and Trending

The monitoring and trending element of the VCC Assembly Ventilation Ducts and Annulus AMP requires the establishment of a baseline inspection as the initial inspection during the period of extended operation. The results of the baseline inspection would then be compared against results from subsequent inspections in areas including blockage, coating degradation, and corrosion of the internal ventilation flow path, to identify potential accelerated degradation of the structure during the period of extended operation.

The staff reviewed the data collection specifications in the Parameters Monitored or Inspected, Detection of Aging Effects, Monitoring and Trending, and Corrective Actions AMP elements. The staff determined that the parameters identified in the Monitoring and Trending element are adequate because the Monitoring and Trending AMP element requires that a baseline be developed from the initial inspection during the period of extended operation and, along with monitoring and trending of the parameters identified in the third element of the AMP, including coating condition, corrosion, and blockage, that records of corrective actions will be kept. The staff determined that the parameters identified in the Monitoring and Trending AMP element are necessary to determine aging trends that may necessitate additional corrective actions and/or revisions to the AMP. The staff also determined that the parameters identified in the Monitoring and Trending AMP element are necessary to document and evaluate operating experience for the VSC-24 system. The staff finds that the Monitoring and Trending conducted as part of the Examination of VCC Assembly Ventilation Ducts and Annulus AMP provides reasonable assurance that the aging mechanisms and effects for the ventilation flow path, including the air inlets and outlets, VCC liner shell, VCC cask liner bottom, VCC shield ring plates (liner assembly and shield ring), and MSB shell identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

6. Acceptance Criteria

The CoC holder specified the acceptance criteria for blockage to be that no more than 10 percent of the segment cross-section area of any airflow paths may be blocked. The CoC holder stated that coating degradation and any type of corrosion on the duct-facing coated steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage of any airflow path.

The CoC holder stated that general corrosion on the annulus-facing coated steel surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring),and MSB shell that does not result in significant blockage of the annulus is acceptable.

The CoC holder stated that any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), and MSB shell is unacceptable and evidence of crevice corrosion at the gap between the inner (shield ring) and outer (liner assembly) VCC shielding ring plates is also unacceptable.

The staff reviewed the Detection of Aging Effects and Acceptance Criteria AMP elements. The staff determined that the acceptance criteria for blockage and corrosion on the duct-facing coated steel surfaces of the VCC air inlets and air outlets are adequate because the AMP element has specific criteria on aging effects and allowable limits on the amount of blockage to maintain the intended functions of the SSCs and subcomponents included in the VCC ventilation ducts and annulus. The staff determined that uniform corrosion of subcomponents constructed of carbon steel, including the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), and MSB shell, is not a concern for this AMP because uniform corrosion will not result in loss of material that impedes the intended safety function of these subcomponents. The staff finds the acceptance criteria that localized corrosion is unacceptable for these subcomponents to be adequate because localized corrosion, if allowed to propagate, could compromise the intended functions of these subcomponents. The staff finds that the Acceptance Criteria defined in the Examination of VCC Assembly Ventilation Ducts and Annulus AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

7. Corrective Actions

The CoC holder specified that blockage that exceeds the acceptance criteria shall be evaluated in accordance with the GL's corrective action program, and any blockage that can be removed by reasonable means shall be removed. In addition, the CoC holder specified the extent of condition evaluation shall include examination of at least two additional VCC assemblies at the site for blockage and that the GL shall select the additional VCC assemblies based upon those factors that are most relevant to the type of blockage observed (e.g., location or orientation of the VCC assembly on the ISFSI pad or time in service). If unacceptable blockage is identified in any of the additional VCC examinations, the CoC holder specified that the condition shall be evaluated in accordance with the GL's corrective action program, the blockage shall be removed by reasonable means, and all VCC assemblies at the site shall be examined for blockage.

The CoC holder specified that a VCC or MSB assembly with unacceptable corrosion (i.e., localized corrosion) requires additional evaluation to determine corrosion depth. Areas of corrosion that exceed the allowable limit of 0.003 inches multiplied by the number of years in service must be repaired and recoated. A VCC or MSB with localized corrosion that does not exceed the allowable limit of 0.003 inches multiplied by the number of years in service may be cleaned and recoated without repair; however, additional VT-3 examination must be performed to verify that the corrective actions and coating repair have mitigated the localized corrosion. The CoC holder specified that a VCC and/or MSB assembly that is not acceptable for continued storage shall be repaired or replaced.

The CoC holder specified that if localized corrosion is identified on the MSB shell, VCC cask liner bottom, VCC cask liner shell, or VCC shielding ring plates (liner assembly or shield ring), then the extent of condition evaluation shall include additional visual examination of the normally inaccessible surfaces of the MSB bottom plate and VCC cask liner bottom of that cask for unacceptable corrosion. In addition, the CoC holder specified that the extent of condition evaluation shall include remote visual examination of at least two additional casks for corrosion, including the normally inaccessible surfaces of the MSB bottom plate and VCC cask liner bottom if unacceptable corrosion is identified on these surfaces of the first cask. The CoC holder stated that the two additional casks should be selected based on maximum susceptibility to the type of localized corrosion identified. If unacceptable corrosion is identified in either of the additional cask inspections, the CoC holder specified that remote visual examination for corrosion shall be performed on all casks at the site.

The CoC holder stated that areas of localized corrosion that do not exceed the depth criteria of 0.003 inches times the number of years in service may be repaired or may be cleaned to bare metal and the area recoated to prevent further corrosion. For areas that are not repaired but cleaned and recoated, the CoC holder stated that re-examination of the mitigated areas must be conducted within 3 years of the mitigation action. The CoC holder stated that if no corrosion is found in the 3-year re-examination, the mitigated area need not be inspected until the next scheduled AMP inspection.

The staff reviewed the Acceptance Criteria and Corrective Actions AMP elements. The staff determined that the corrective actions required if acceptance criteria are not met are adequate because the corrective actions required of the GL, including removal of blockages from ventilation pathways, evaluation of localized corrosion, mitigation and/or repair of areas affected by localized corrosion, and an assessment of the extent of condition are specific actions that are required when the acceptance criteria are not met and serve to maintain the intended functions of the SSCs and subcomponents within the scope of the Examination of VCC Assembly Ventilation Ducts and Annulus AMP. Thus, the staff finds that the corrective actions conducted as part of the Examination of VCC Assembly Ventilation Ducts and Annulus AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

8. Confirmation Process

The staff reviewed the Confirmation Process AMP element, which states that the confirmation process will be conducted in accordance with the GL's Corrective Action Program, and will ensure that appropriate corrective actions are completed and are effective. The staff considers that implementing corrective actions in accordance with a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that the Confirmation Process is adequate for managing the aging mechanisms and effects identified in the AMR of the VCC's ventilation ducts and annulus.

9. Administrative Controls

The staff reviewed the Administrative Controls AMP element, which indicates that the Administrative Controls that provide a formal review and approval of appropriate corrective actions will be conducted in accordance with the GL's Corrective Action Program. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that Administrative Controls are adequate for managing the aging mechanisms and effects identified in the AMR of the VCC's ventilation ducts and annulus.

10. Operating Experience

The CoC holder reported that no significant blockage has accumulated within the ventilation flow path of the inspected casks and that the majority of the inspected steel surfaces had little coating degradation or signs of corrosion.

The CoC holder indicated that during the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. Section 3.6 of the renewal application, which will be incorporated into the updated FSAR as Section 9.3.5, "Periodic Tollgate Assessments," includes a description of the general elements of these assessments, including contents of assessment reports. These assessments have an important role in ensuring the adequacy of the AMPs. Therefore, the staff has added a CoC condition (see Section 4 of this SER) that requires the GLs perform assessments and maintain records of these assessments consistent with the general description given in Section 9.3.5 of the FSAR, as updated for the CoC renewal. Per this condition, each GL's tollgate assessments and reports shall satisfy the items which are indicated to be required (including those where the FSAR indicates they "shall be" implemented) in Section 9.3.5 of the FSAR. These required items include the completion time of the initial assessment and the frequency of subsequent assessments, the kinds of operating experience that are considered, and assessment report contents. The results of the assessments should be used as described in Section 9.3.5 of the FSAR to identify any new applicable aging effects or mechanisms and to ensure the aging management activities are adequate to manage these effects or mechanisms.

The staff determined that the AMP would be effective in managing the aging effects of the SSCs and subcomponents during the period of extended operation because the operating experience to date has not indicated the existence of current issues that cannot be appropriately monitored and addressed during the period of extended operation. Therefore, staff finds that the operating experience stated and referenced in the CoC renewal application provides reasonable assurance that the AMP will be adequate for managing the aging mechanisms and effects identified in the AMR.

The staff reviewed the evaluation of operating experience required by this AMP during the period of extended operation. The staff determined that the evaluation of operating experience is adequate because the AMP directs each GL to perform periodic "tollgate" assessments of aggregated operating experience relevant to the aging effects and mechanisms addressed in the AMP. This ensures that each GL will use relevant and up-to-date information in conducting the actions required by this AMP. Thus, the staff finds that the Operating Experience stated and referenced in the CoC renewal application provides reasonable assurance that this AMP will be adequate for managing the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly.

3.5.3 Examination of VSC Top End Steel Components

The CoC holder included the Examination of VSC Top End Steel Components AMP in CoC renewal application Section 3.4.2.3. The AMP describes the activities for maintaining the normally inaccessible SSCs and subcomponents at the top of the VCC assembly and the MSB assembly during the period of extended operation. The CoC holder indicated the purpose of the Examination of VSC Top End Steel Components AMP is to confirm through VT-3 visual inspection, that these subcomponents (listed in the following paragraph) are not experiencing any unanticipated degradation that could prevent them from performing their intended functions.

This section contains the staff review of the adequacy of the Examination of VSC Top End Steel Components AMP to address the identified aging mechanisms and effects for the VCC cask lid, the top and inner radial surfaces of the VCC liner flange, the top surface of the VCC shielding ring plates (liner assembly), the top and inner radial surfaces of the VCC shielding ring plates (shield ring), the top surface of the MSB structural lid, MSB valve/port covers, the MSB closure weld, the top edge of the MSB shell, and all exposed surfaces of the VCC lid bolts. The staff reviewed the AMP against the criteria provided in Section 3.6.1 of NUREG–1927. The staff's evaluation of each of the program elements is as follows:

1. Scope

The CoC holder specified that the scope of the program includes the inspection of the following component surfaces for coating degradation and corrosion:

- All surfaces of the VCC cask lid and VCC lid bolts;
- Readily accessible top and inner radial surfaces of the VCC liner flange;
- Top surface (chamfer and weld) of the VCC shielding ring plates (liner assembly);
- Top and inner radial surface of the VCC shielding ring plates (shield ring);
- Top surfaces of the MSB structural lid, MSB valve/port covers, MSB closure weld, and top edge of the MSB shell.

In addition, the CoC holder indicated that the VCC lid gasket and locking wire, if used, would be replaced at the completion of the inspection.

The staff reviewed the Scope of Program and the design and materials of construction identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff determined that the SSCs and subcomponents necessary to maintain the VCC assembly and MSB assembly intended functions and that require aging management actions are included in the Scope of Program. The staff finds the Scope of Program provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

2. Preventative Actions

The CoC holder stated that Preventative Actions include identification and repair of any coating degradation or corrosion on the VCC top interior components and prevent continued degradation that could potentially affect the ability of the SCCs to perform their intended functions during the period of extended operation.

The staff reviewed the Preventative Actions, Parameters Monitored or Inspected, Detection of Aging Effects, Acceptance Criteria, and Corrective Actions. The staff determined that Preventative Actions are adequate because the actions require identification and repair of any coating degradation or corrosion and will prevent loss of the VCC and MSB assembly's intended functions caused by aging-related degradation. Thus, the staff finds the Preventative Actions provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

3. Parameters Monitored or Inspected

The CoC holder stated that the Parameters Monitored or Inspected include coating degradation and corrosion of the VCC cask lid, liner flange, shielding ring plates (liner assembly and shield ring), and lid bolts, and the MSB structural lid, valve/port covers, closure weld, and the MSB shell.

The staff reviewed the Parameters Monitored or Inspected. The staff determined that the Parameters Monitored or Inspected are adequate because all SSCs and subcomponents included in this AMP will be monitored or inspected for coating degradation or corrosion that could adversely affect the performance. Thus, the staff finds the Parameters Monitored or Inspected provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

4. Detection of Aging Effects

The CoC holder defined the Detection of Aging Effects as the identification of unanticipated degradation on the VCC top interior surfaces and identification of unanticipated degradation on the top surfaces of the MSB assembly. The CoC holder specified the inspection method as either direct or remote VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). The CoC holder identified that the qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with IWE-2330 ASME, 2004 Section XI (ASME, 2004 [13]) are acceptable. The CoC holder specified that the frequency of the inspections is once every 10 years and the sample size is one cask at each site. The CoC holder also specified that the cask selected shall not be the same as the cask selected for the Lead Cask Inspection (SER section 3.5.5) The CoC holder specified data collection as documentation of the examination, including the condition of the VCC top interior surfaces and the top MSB assembly surfaces and records of corrective actions. The CoC holder stated that the initial inspection is to be completed within 1-year after the 20th anniversary of the first cask being loaded at the site or within 2-years of the effective date of the CoC renewal, whichever is later.

The staff reviewed the Detection of Aging Effects and the description of VT-3 examination in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]). The staff determined that the direct or remote VT-3 visual examination is adequate because this inspection method is capable of detecting coating degradation and corrosion of the VCC cask lid, liner flange, shield ring plates (liner assembly and shield ring), and lid bolts, and the MSB structural lid, valve/port covers, closure weld, and shell. The staff determined that the personnel qualifications of ASME

B&PV code Section XI IWE-2330 (ASME, 2004 [13]) are appropriate for personnel performing VT-3 inspections.

The staff determined that the sample size, timing, and frequency in the Examination of VSC Top End Steel Components AMP are adequate to ensure the intended function of these subcomponents. The staff determined that the examination of one cask at each site every 10 years was sufficient because the cask design and protective coatings should prevent degradation to the structural steel components even if the coating has local degradation. The staff determined that if degradation from corrosion were to occur, the corrosion rate would be slow and significant degradation would not be expected to occur during a 10-year inspection interval. The staff determined that examination of one cask at each site was sufficient for several reasons: (1) the VSC-24 systems in use at each site are similar, (2) if degradation that exceeds the acceptance criteria is identified, the corrective actions of this AMP require additional systems to be inspected, and (3) the system inspected must be different from the Lead Cask Inspection (SER section 3.5.5) that also requires examination of the VSC Top End Steel Components. Thus, the staff finds that the Detection of Aging Effects provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

5. Monitoring and Trending

The CoC holder stated that data collected from each AMP inspection, including coating degradation and corrosion on all VSC top end steel components, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects. The CoC holder also stated that a baseline shall be developed from the initial inspection during the period of extended operation. In addition, the CoC holder specified that coating degradation and corrosion results shall be compared with the results from previous inspections to identify accelerated degradation of the structure during the period of extended storage.

The staff reviewed the data collection specifications identified in the Detection of Aging Effects AMP element and the Monitoring and Trending AMP element and noted that the AMP calls for documentation of the examination, including the condition of the VSC top end steel components, and records of the corrective actions. The staff determined that the parameters identified in the monitoring and trending element are appropriate because the AMP requires a baseline be developed from the initial inspection along with monitoring and trending of the parameters identified in the third element of the AMP, which include direct indications of the initiation and/or progression of aging related degradation, including coating degradation and corrosion of the VSC-24 top end steel components, that could adversely affect the intended functions of the VCC and MSB assemblies. The staff determined that the parameters identified in the Monitoring and Trending AMP element are necessary to determine aging trends that may necessitate additional corrective actions and/or revisions to the AMP. The staff also determined that the parameters identified in the Monitoring and Trending AMP element are necessary to document and evaluate operating experience for the VSC-24 system. Thus, the staff finds that the Monitoring and Trending conducted as part of the Examination of VSC Top End Steel Components AMP provides reasonable assurance that the aging mechanisms and effects for these subcomponents identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

6. Acceptance Criteria

The CoC holder specified that the acceptance criteria include no coating degradation on the examined surfaces that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces. This includes coating that is blistered, bubbled, or peeling. The CoC holder specified that corrosion on the underlying steel shall not exceed 1/16 inch in depth. For lid bolts, the CoC holder specified that corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.

The staff reviewed the Acceptance Criteria AMP element and the description of VT-3 Examination provided in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]). The staff determined that coating degradation on the VCC cask lid, liner flange, shield ring plates (liner assembly and shield ring), lid bolts, the MSB structural lid, valve/port covers, closure weld, and shell (top edge) could allow uniform corrosion of these subcomponents. The staff determined that inspection of the VSC top end steel components using direct or remote VT-3 inspection is adequate to determine whether the subcomponents included in the scope of the inspection meet the prescribed acceptance criteria using VT-3 examination described in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]). The staff has determined that the acceptance criteria for coating degradation are necessary to ensure that loss of material that negatively affects the intended safety function of these subcomponents due to corrosion is mitigated. The staff determined that the acceptance criteria are adequate because the inspection methods used are appropriate for assessing whether the acceptance criteria are met and the CoC holder has quantified the allowable loss of material from corrosion to ensure that the subcomponents included in the AMP continue to perform their intended safety functions. Thus, the staff finds that the Acceptance Criteria defined in the Examination of VSC Top End Steel Components AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

7. Corrective Actions

The CoC holder specified that all examination results that do not satisfy the applicable acceptance criteria shall be evaluated in accordance with the GL's Corrective Action Program, including extent of condition. Degraded coating that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, which shall be visually examined for corrosion. Corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded. The CoC holder specified that a VCC or MSB assembly with corrosion that exceeds the allowable depth acceptance criteria shall be repaired or replaced in accordance with the GL's procedures. The CoC holder specified that coating that is degraded or that has been removed to examine the underlying steel surface shall be repaired in accordance with the GL's procedures. The CoC holder specified that any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced. The CoC holder specified that the extent of condition evaluation shall include visual examination of at least two additional casks for coating degradation and/or corrosion and the GL shall select the additional casks to be inspected based upon the factors that contribute most significantly to the observed degradation on the first cask (e.g., time in service, heat load, or fabrication differences). If coating degradation and/or corrosion is identified in either of the additional cask inspections that do not satisfy the acceptance criteria, the CoC holder specified that the condition of the cask shall be entered into the GL's corrective action program and the extent of condition evaluation shall be expanded to include visual examination of all casks at the site for coating degradation and/or corrosion.

The staff determined that the corrective actions are adequate because the AMP provided by the CoC holder identified specific corrective actions for coating degradation and corrosion of the VCC cask lid, liner flange, shield ring plates (liner assembly and shield ring), lid bolts, and the MSB structural lid, valve/port covers, closure weld and MSB shell to maintain the intended functions of the SSCs and subcomponents within the scope of the AMP. Further, the staff has determined that the extent of condition evaluation proposed by the CoC holder is sufficient to assess coating degradation and corrosion of the VSC top end steel components for the VSC-24 systems in use at a GL's site because the extent of condition assessment requires the examination of at least two additional systems at the GL's site. The staff finds that the initial expansion of the examination to two additional casks is acceptable because, together with the initially examined cask, they represent a significant fraction of the casks currently in service at the ISFSIs that use the VSC-24 system and so should be adequately representative of the remaining, uninspected casks at the GL's site. Thus, the staff finds that the corrective actions conducted as part of the Examination of VSC Top End Steel Components AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

8. Confirmation Process

The staff reviewed the Confirmation Process AMP element, which states that the confirmation process will be conducted in accordance with the GL's Corrective Action Program, and will ensure that appropriate corrective actions are completed and are effective. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B as is directed in this AMP element, provides reasonable assurance that the Confirmation Process is adequate for managing the aging mechanisms and effects identified in the AMR of the VSC top end steel components.

9. Administrative Controls

The staff reviewed the Administrative Controls AMP element, which indicates that the Administrative Controls that provide a formal review and approval of appropriate corrective actions will be conducted in accordance with the GL's Corrective Action Program. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that Administrative Controls are adequate for managing the aging mechanisms and effects identified in the AMR of the VSC top end steel components.

10. Operating Experience

The CoC holder reported that results of the initial lead cask inspection performed on Palisades Cask No. VSC-15 show that there has been no unanticipated degradation of the VCC top interior during the initial storage period. The CoC holder noted that the top end of the MSB assembly (structural lid and closure weld) had no evidence of significant corrosion, although small areas of coating were scraped off when temporary shielding used during the inspection was removed. In these areas, the CoC holder reported the steel surfaces under the damaged coating showed no signs of significant corrosion and the areas of damaged coating were subsequently cleaned and recoated.

The CoC holder indicated that during the period of extended operation, each GL shall perform periodic “tollgate” assessments of aggregated operating experience and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. Section 3.6 of the renewal application, which will be incorporated into the updated FSAR as Section 9.3.5, “Periodic Tollgate Assessments,” includes a description of the general elements of these assessments, including contents of assessment reports. These assessments have an important role in ensuring the adequacy of the AMPs. Therefore, the staff has added a CoC condition (see Section 4 of this SER) that requires the GLs perform assessments and maintain records of these assessments consistent with the general description given in Section 9.3.5 of the FSAR, as updated for the CoC renewal. Per this condition, each GL’s tollgate assessments and reports shall satisfy the items which are indicated to be required (including those where the FSAR indicates they “shall be” implemented) in Section 9.3.5 of the FSAR. These required items include the completion time of the initial assessment and the frequency of subsequent assessments, the kinds of operating experience that are considered, and assessment report contents. The results of the assessments should be used as described in Section 9.3.5 of the FSAR to identify any new applicable aging effects or mechanisms and to ensure the aging management activities are adequate to manage these effects or mechanisms.

The staff determined that the AMP would be effective in managing the aging effects of the SSCs and subcomponents during the period of extended operation because the operating experience to date has not indicated the existence of current issues that cannot be appropriately monitored and addressed during the period of extended operation. Therefore, staff finds that the operating experience stated and referenced in the CoC renewal application provides reasonable assurance that the AMP will be adequate for managing the aging mechanisms and effects identified in the AMR.

The staff reviewed the evaluation of operating experience required by this AMP during the period of extended operation. The staff determined that the evaluation of operating experience is adequate because the AMP directs each GL to perform periodic “tollgate” assessments of aggregated operating experience relevant to the aging effects and mechanisms addressed in the AMP. This ensures that each GL will use relevant and up-to-date information in conducting the actions required by this AMP. Thus, the staff finds that the operating experience stated and referenced in the CoC renewal application provides reasonable assurance that this AMP will be adequate for managing the aging mechanisms and effects identified in the AMR of the VCC Assembly and the MSB Assembly.

3.5.4 Examination of MTC Assembly

The CoC holder included the Examination of MTC Assembly AMP in CoC renewal application Section 3.4.2.4. The AMP describes the activities credited for maintaining the MTC during the period of extended operation. The CoC holder indicated the purpose of the AMP is to identify and repair aging issues such as coating degradation and corrosion of the coated and uncoated carbon steel surfaces that could prevent the MTC assembly from performing its intended functions.

This section contains the staff review of the adequacy of the Examination of MTC Assembly AMP to address the identified aging mechanisms and effects for all readily accessible interior and exterior surfaces of the MTC assembly. The staff reviewed the AMP against the criteria provided in Section 3.6.1 of NUREG–1927. The staff's evaluation of each of the program elements is as follows:

1. Scope of Program

The CoC holder stated the Scope of Program is visual examination of the following component surfaces of the MTC assembly for coating degradation and corrosion:

- Exposed external surfaces of the outer shell, inner shell, top ring, and bottom ring;
- Inner and outer surfaces (i.e., those normally covered by the trunnion cylinder/end cover) of both trunnions;
- All surfaces of the MTC lid, lid bolts, and shim/flange;
- All readily accessible surfaces of the rail shields, rail lower plates, and shield doors (with shield doors in fully opened and fully closed positions).

The staff reviewed the Scope of Program and the design and materials of construction identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff determined that the SSCs and subcomponents necessary to perform and maintain the intended functions of the MTC Assembly and that require aging management actions are included in the Scope of Program. Thus, the staff finds the Scope of Program provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC assembly will be adequately managed.

2. Preventative Actions

The CoC holder stated that the Preventative Actions include the identification and repair of unacceptable coating degradation and corrosion on the exposed surfaces of the MTC assembly. These actions prevent continued degradation that could potentially affect the ability of the SSCs to perform their intended functions during the period of extended operation, protect pool chemistry during fuel loading/unloading operations, and facilitate decontamination of the exposed MTC surfaces.

The staff reviewed the Preventative Actions, Parameters Monitored or Inspected, Detection of Aging Effects, Acceptance Criteria, and Corrective Actions. The staff determined the preventative actions are adequate because the AMP has specific actions for the identification and repair of unacceptable coating degradation and corrosion on the exposed surfaces of the MTC assembly to prevent degradation that could potentially affect the ability of the MTC to perform its intended functions during the period of extended operation, protect pool chemistry during fuel loading/unloading operations, and facilitate decontamination of the exposed MTC surfaces. Thus, the staff finds the preventative actions provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC assembly will be adequately managed.

3. Parameters Monitored or Inspected

The CoC holder specified the Parameters Monitored or Inspected include degradation of the coating and corrosion of the underlying carbon steel on all readily accessible surfaces.

The staff reviewed the Parameters Monitored or Inspected along with the design and construction of the MTC assembly. The staff determined that the Parameters Monitored or Inspected are adequate because the CoC holder has identified the pertinent SSCs and subcomponents and the relevant aging effects that could adversely affect the performance of these SSCs and subcomponents of the MTC assembly. The staff finds the Parameters Monitored or Inspected provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC assembly will be adequately managed.

4. Detection of Aging Effects

The CoC holder defined the Detection of Aging Effects as the identification of unanticipated degradation of coatings and corrosion of the MTC assembly subcomponents. The CoC holder stated that the examination of the MTC assembly was to be performed using direct VT-3 visual examination of readily accessible surfaces. In addition, the CoC holder indicated that VT-3 visual examination will be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). The CoC holder indicated that qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the MTC assembly in accordance with IWE-2330 (ASME, 2004 [13]) are acceptable. The CoC holder specified visual examination of each MTC assembly to detect aging effects is to be conducted once every 10-years (± 1 year) when the MTC is not in use and within 1-year prior to use. The CoC holder indicates that data collection will include written descriptions and/or sketches of the location(s) and extent of observed degradation (i.e., coating degradation and corrosion) and records of corrective actions taken. Video and/or photographs of the inspection provide additional visual evidence to support monitoring and trending activities and operating experience. The CoC holder has indicated that completion of the initial inspection shall be within 1-year following the 20th anniversary of the first cask being loaded at the site or within 2-years of the effective date of the CoC renewal, whichever is later.

The staff reviewed the Detection of Aging Effects, the environment for the SSCs and subcomponents, relevant information on the corrosion of carbon steel, and the description of VT-3 examination in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]). The staff acknowledges that the general corrosion rate of carbon steel in atmospheric exposures is dependent on a number of factors including humidity, time of wetness, atmospheric contaminants and oxidizing species (Pohlman, 1987 [72]; Bryson et al., 1987 [26]; Tullmin and Roberge, 2000 [77]). The staff reviewed the description of VT-3 examination in ASME B&PV code Section XI IWA-2213 (ASME, 2004 [13]) and notes that VT-3 examinations are conducted to determine the general mechanical and structural condition of components and their supports by verifying parameters such as clearances, settings, and physical displacements; and to detect discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion. The staff determined that the VT-3 inspection performed by qualified personnel as specified in the Examination of MTC Assembly AMP for detecting coating degradation and corrosion on the readily accessible interior and exterior surfaces of the MTC assembly is adequate because the purpose of the inspection and the inspection method are consistent with the guidance in the ASME B&PV code (ASME, 2004

[13]). The staff verified that conduct of examinations by personnel that are qualified in accordance with ASME B&PV code section XI IWE-2330 is appropriate (ASME, 2004 [13]). The staff reviewed the sample size, frequency, and timing in the Examination of MTC Assembly AMP. Since each MTC is inspected, all MTCs in service at GL ISFSIs will be evaluated per the AMP's specifications. Therefore, the staff finds the sample size to be acceptable. Since the MTC is used periodically on an as needed basis for loading and unloading operations only, the staff finds acceptable an inspection frequency that allows for less frequent inspections when the MTC is not in use while still ensuring the adequate function of the MTC when needed for loading or unloading operations. The AMP's inspection frequency meets that criterion; so, the staff finds it to be adequate to ensure the intended function of the MTC SSCs and subcomponents. Thus, the staff finds that the Detection of Aging Effects provides reasonable assurance that the aging mechanisms and effects identified in the AMR for the MTC assembly will be adequately managed.

5. Monitoring and Trending

The CoC holder stated that data collected from each AMP inspection, including coating degradation and corrosion on all readily accessible interior and exterior surfaces of the MTC assembly, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects. The CoC holder stated that a baseline shall be developed from the initial inspection performed during the period of extended operation. The CoC holder stated that locations of degraded coating and corrosion shall be recorded and monitored during subsequent examinations to identify potential accelerated degradation of the structure.

The staff reviewed the data collection specifications identified in the Detection of Aging Effects AMP element and the Monitoring and Trending AMP element. The staff determined that the parameters identified in the Monitoring and Trending element are adequate because the AMP requires a baseline be developed from the initial inspection and documentation be kept of the location and the extent of observed degradation and corrosion that could adversely affect the intended functions of the MTC assembly. The staff determined that the parameters identified in the Monitoring and Trending AMP element are necessary to determine aging trends that may necessitate additional corrective actions and/or revisions to the AMP. The staff also determined that the parameters identified in the Monitoring and Trending AMP element are necessary to document and evaluate operating experience for the VSC-24 system. Thus, the staff finds that the Monitoring and Trending conducted as part of this AMP provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC Assembly will be adequately managed.

6. Acceptance Criteria

The CoC holder specified that individual local areas of coating loss may not expose more than 2 in^2 of underlying steel and the total combined coating loss may not expose more than a total of 40 in^2 of underlying steel. The CoC holder specified that corrosion must not exceed 10% of a component's nominal thickness (or depth) or reduce a bolt's nominal cross-sectional area by more than 5%.

The staff reviewed the Acceptance Criteria and the description of VT-3 Examination in ASME B&PV Code Section XI IWA-2213 (ASME, 2004 [13]). The staff determined that inspection using direct VT-3 examination is adequate to determine whether the subcomponents included in the scope of the inspection meet the prescribed acceptance criteria based on the VT-3 examination identified in ASME B&PV Code Section XI IWA-2213 (ASME, 2004 [13]). The staff has determined that the acceptance criteria for coating degradation are necessary to ensure that loss of material that negatively affects the intended safety function of these subcomponents due to corrosion is mitigated. The staff determined that the acceptance criteria are adequate because they are quantified criteria that are measurable and the CoC holder determined, and the staff has confirmed, that material losses not exceeding the criteria do not negatively affect the MTC assembly's ability to perform its intended safety functions. Thus, the staff finds that the Acceptance Criteria defined in the Examination of MTC Assembly AMP provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC will be adequately managed.

7. Corrective Actions

The CoC holder specified that areas of degraded coating that exceed the acceptance criteria shall be documented and evaluated in accordance with the GL's corrective action program, and repaired by re-coating in accordance with the GL's procedures. If corrosion has resulted in loss of material that exceeds the acceptance criteria, the CoC holder specified the affected components shall be repaired or replaced.

The staff determined that these corrective actions are adequate because the AMP requires coating repairs on the MTC assembly and either repair or replacement of MTC components affected by corrosion. Therefore, the staff finds that the corrective actions provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the MTC assembly will be adequately managed.

8. Confirmation Process

The staff reviewed the Confirmation Process AMP element, which states that the confirmation process will be conducted in accordance with the GL's Corrective Action Program, and will ensure that appropriate corrective actions are completed and are effective. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that the Confirmation Process is adequate for managing the aging mechanisms and effects identified in the AMR of the MTC assembly.

9. Administrative Controls

The staff reviewed the Administrative Controls AMP element, which indicates that the Administrative Controls that provide a formal review and approval of appropriate corrective actions will be conducted in accordance with the GL's Corrective Action Program. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that Administrative Controls are adequate for managing the aging mechanisms and effects identified in the AMR of the MTC assembly.

10. Operating Experience

The CoC holder stated that during the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated operating experience and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. Section 3.6 of the renewal application, which will be incorporated into the updated FSAR as Section 9.3.5, "Periodic Tollgate Assessments," includes a description of the general elements of these assessments, including contents of assessment reports. These assessments have an important role in ensuring the adequacy of the AMPs. Therefore, the staff has added a CoC condition (see Section 4 of this SER) that requires the GLs perform assessments and maintain records of these assessments consistent with the general description given in Section 9.3.5 of the FSAR, as updated for the CoC renewal. Per this condition, each GL's tollgate assessments and reports shall satisfy the items which are indicated to be required (including those where the FSAR indicates they "shall be" implemented) in Section 9.3.5 of the FSAR. These required items include the completion time of the initial assessment and the frequency of subsequent assessments, the kinds of operating experience that are considered, and assessment report contents. The results of the assessments should be used as described in Section 9.3.5 of the FSAR to identify any new applicable aging effects or mechanisms and to ensure the aging management activities are adequate to manage these effects or mechanisms.

The staff reviewed the evaluation of operating experience required by this AMP during the period of extended operation. The staff determined that the evaluation of operating experience is adequate because the AMP directs each GL to perform periodic "tollgate" assessments of aggregated operating experience relevant to the aging effects and mechanisms addressed in the AMP. This ensures that each GL will use relevant and up-to-date information in conducting the actions required by this AMP. Thus, the staff finds that the operating experience stated and referenced in the CoC renewal application provides reasonable assurance that this AMP will be adequate for managing the aging mechanisms and effects identified in the AMR of the MTC assembly.

3.5.5 Lead Cask Inspection

The CoC holder included a description of the Lead Cask Inspection Program in CoC renewal application Section 3.4.4. The program describes the activities credited for maintaining the normally inaccessible subcomponents of the VSC-24 system, including the MSB and the VCC annulus, during the period of extended operation. The CoC holder indicated the purpose of the Lead Cask Inspection Program is to demonstrate that the VCC and MSB assemblies have not undergone unanticipated degradation while in storage, in accordance with guidance provided in Appendix E of NUREG-1927 (NRC, 2011 [65]).

This section describes the staff review of the adequacy of the Lead Cask Inspection Program to address the identified aging mechanisms and effects for the VCC and MSB components that are not normally accessible for inspection, including the VCC annulus, VCC liner and bottom plate, and the MSB structural lid and closure weld. The Lead Cask Inspection Program is detailed and organized in the same manner as the other AMPs. Therefore, the staff reviewed the Lead Cask Inspection Program against the AMP criteria provided in Section 3.6.1 of NUREG–1927. The staff's evaluation of each of the Lead Cask Inspection Program elements is as follows:

1. Scope of Program

The CoC holder stated that the Scope of Program consists of both direct and remote visual inspection. Direct visual examination is specified for the following readily accessible surfaces of the lead cask:

- All surfaces of the VCC cask lid and VCC lid bolts;
- Readily accessible top and inner radial surfaces of the VCC liner flange;
- Top surface (chamfer and weld) of the VCC shielding ring plates (liner assembly);
- Top and inner radial surface of the VCC shielding ring plates (shield ring);
- Top surfaces of the MSB structural lid, MSB valve/port covers, MSB closure weld, and top edge of the MSB shell;

Remote visual examination is specified for the following readily accessible surfaces of the lead cask:

- Duct-facing surfaces of all the VCC air inlets and outlets;
- Annulus-facing surfaces of the VCC cask liner shell and MSB shell;
- Annulus-facing surfaces (i.e., bottom surfaces) of the VCC shielding ring plates (liner assembly) and VCC shielding ring plates (shielding ring).

Remote visual examination is specified for the following normally inaccessible surfaces of the lead cask:

- Bottom surface of the VCC bottom plate assembly (requires VCC assembly to be lifted);
- Bottom surface of the MSB bottom plate and top surface of the VCC cask liner bottom (requires MSB assembly to be lifted).

In addition, the CoC holder indicated that the VCC lid gasket and locking wire, if used, would be replaced at the completion of the inspection.

The staff reviewed the Scope of Program and the design and materials of construction identified in the VSC-24 FSAR (Pacific Sierra Nuclear Associates and Sierra Nuclear Corporation, 1991; 2000; 2001; Pacific Sierra Nuclear Associates, Sierra Nuclear Corporation and BNFL Fuel Solutions Corporation, 2001; 2002; BNFL Fuel Solutions Corporation, 2003; EnergySolutions Spent Fuel Division Inc., 2006; 2007; 2009). The staff determined that the SSCs and subcomponents necessary to perform and maintain the intended functions of the VCC Assembly and the MSB Assembly and that require aging management actions are included in the Scope of Program. The staff determined that direct and remote visual inspection is adequate to detect coating degradation and corrosion of the VCC and MSB assembly SSCs and subcomponents included in the Scope of Program. The staff finds the Scope of Program provides reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

2. Preventative Actions

The CoC holder specified that the Preventative Actions include:

- Identify and remove any unacceptable blockage in the VCC ventilation ducts and annulus to prevent system temperatures from exceeding the applicable temperature limits.
- Identify and repair, as applicable, any unacceptable coating degradation or corrosion on the coated carbon steel components to prevent continued degradation that could potentially affect the ability of the SCCs to perform their intended functions during the period of extended operation.

The staff reviewed the Preventative Actions, Parameters Monitored or Inspected, Detection of Aging Effects, Acceptance Criteria, and Corrective Actions. The staff determined that the preventative actions are adequate because specific actions are required, including identifying and removing any unacceptable blockage in the VCC air inlets and outlets and the VCC annulus to maintain the intended function of passive cooling and repair of any unacceptable coating degradation or corrosion on the coated carbon steel components to prevent continued degradation of the identified SSCs and subcomponents. Therefore, the staff determined the preventative actions are adequate to prevent degradation that could potentially affect the ability of the VCC Assembly and the MSB Assembly to perform their intended safety functions.

3. Parameters Monitored or Inspected

The CoC holder specified the Parameters Monitored or Inspected are:

- Degradation of the VCC bottom surface;
- Blockage of the VCC internal ventilation flow path;
- Degradation of the coated carbon steel surfaces that line the VCC ventilation flow path (i.e., VCC air inlet assemblies and VCC air outlet weldments, VCC cask liner shell, and MSB shell);
- Degradation of the coated carbon steel surfaces on the MSB bottom plate and VCC cask liner bottom;
- Degradation of the VCC cask lid, VCC liner flange, VCC lid bolts, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), MSB structural lid, MSB lid valve/port covers, and MSB closure weld.

The staff reviewed the Scope of Program and the Parameters Monitored or Inspected. The staff determined that the Parameters Monitored or Inspected are adequate because (1) the CoC holder has identified that the actions taken by the GL will include detecting and managing blockage of the internal ventilation flow path that could adversely affect the internal ventilation flow path and diminish the passive cooling of the stored SNF and (2) the CoC holder has identified the aging effects relevant for the SSCs and subcomponents managed by this AMP and that must be adequately managed in order to maintain the intended functions of the VCC assembly and the MSB assembly. The staff finds the Parameters Monitored or Inspected provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

4. Detection of Aging Effects

The CoC holder specified direct VT-3 visual examination of the VSC top end steel components and remote VT-3 visual examination of the VCC ventilation flow path, MSB bottom plate, VCC cask liner bottom, and VCC bottom surface for the identification of unacceptable blockage in the ventilation flow path and unacceptable coating degradation and/or corrosion on all metal surfaces.

The CoC holder stated VT-3 visual examination is to be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). The CoC holder indicated qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with IWE-2330 are acceptable.

The CoC holder has specified that data collection would include documentation of the examination, including written descriptions and/or sketches of the location(s) and extent of observed degradation (i.e., blockage, coating degradation, and corrosion) and records of corrective actions taken. The CoC holder indicated that video/photographs of the examination provide additional visual evidence to support monitoring and trending activities and operating experience.

The CoC holder stated that the initial inspection is to be completed within 1-year after the 20th anniversary of the first cask being loaded at the site or within 2-years of the effective date of the CoC renewal, whichever is later. The CoC holder specified the Lead Cask Inspection Program must be performed once every 20 years with a sample size of one or more casks at the GL's site unless the GL provides justification (in its 10 CFR 72.212 report) that its casks are bounded by lead cask inspection(s) performed for VSC-24 systems at another site(s). The CoC holder has stated that repeat lead cask inspections are to be performed on the same cask(s). The cask selected for the lead cask inspection program may not be the same cask used for the Examination of the VSC Top End Steel Components AMP.

The staff reviewed the Detection of Aging Effects, the environment for the SSCs and subcomponents, relevant information on the corrosion of carbon steel, and the description of VT-3 examination in ASME B&PV Code Section XI IWA-2213 (ASME, 2004 [13]) and notes that VT-3 examinations are conducted to determine the general mechanical and structural condition of components and their supports by verifying parameters such as clearances, settings, and physical displacements; and to detect discontinuities and imperfections, such as loss of integrity at bolted or welded connections, loose or missing parts, debris, corrosion, wear, or erosion. The staff reviewed the Detection of Aging Effects and determined that the direct or remote VT-3 visual examination of readily accessible surfaces using qualified personnel is adequate for detecting coating degradation and corrosion of the VCC and MSB Assembly SSCs and subcomponents included in the Lead Cask Inspection Program because the purpose of the inspection and the inspection method are consistent with the guidance in the ASME B&PV Code (ASME, 2004 [13]). The staff verified that conduct of examinations by personnel that are qualified in accordance with ASME B&PV Code Section XI IWE-2330 is appropriate (ASME, 2004 [13]). The staff reviewed the sample size, frequency, and timing proposed by the CoC holder in the Lead Cask Inspection Program and determined that they are adequate for managing the aging mechanisms and effects identified in the AMR of the VSC-24 system and ensuring the intended function of the identified SSCs and subcomponents. Thus, the staff finds that the Detection of Aging Effects provides reasonable assurance that the aging mechanisms and effects identified in the AMR for the VCC assembly and MSB assembly will be adequately managed.

5. Monitoring and Trending

The CoC holder stated that a baseline shall be developed from the initial inspection during the period of extended operation. In addition, the CoC holder specified that coating degradation and corrosion results shall be compared with those from previous inspections to identify accelerated degradation of the structure during the period of extended storage.

The staff reviewed the data collection specifications identified in the Detection of Aging Effects, Monitoring and Trending, Acceptance Criteria, and Corrective Actions. The staff determined that the parameters identified in the Monitoring and Trending element are appropriate because the Lead Cask Inspection Program identifies specific actions, including that a baseline be developed from the initial inspection during the period of extended operation. The staff's determination is also based upon documentation to be kept of the examination, including the written descriptions on the location and the extent of observed degradation of the VCC assembly and MSB assembly and records of the corrective actions as identified in the AMP. The staff determined that the parameters identified in the Monitoring and Trending element are necessary to determine aging trends that may necessitate additional corrective actions and/or revisions to the Lead Cask Inspection Program. The staff also determined that the parameters identified in the Monitoring and Trending element are necessary to document and evaluate operating experience for the VSC-24 system. The staff finds that the Monitoring and Trending conducted as part of the Lead Cask Inspection Program provides reasonable assurance that the aging mechanisms and effects for these subcomponents identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

6. Acceptance Criteria

The CoC holder stated that there shall be no significant blockage (i.e., >10% of segment cross-section area) of any airflow paths.

In addition, the CoC holder specified that coating degradation and corrosion on the bottom end of the VCC assembly (i.e., the bottom surface of the VCC bottom plate assembly) is expected and acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross-section area) of the air inlets.

The CoC holder stated that coating degradation and any type of corrosion on the inlet or outlet duct-facing steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross-section area) of any air flow path.

The CoC holder stated that general (e.g., atmospheric) corrosion on the annulus-facing coated steel surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), and MSB shell that does not result in significant blockage (i.e., >10% of segment cross-section area) of the annulus is acceptable.

The CoC holder stated that any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), and MSB shell, and on the bottom surface of the MSB bottom plate or top surface of the VCC cask liner bottom is unacceptable. Indication of crevice corrosion in the gap between the inner (i.e., shield ring) and outer (i.e., liner assembly) VCC shielding ring plates is also unacceptable.

The CoC holder stated that coating degradation on the VSC top end steel components (i.e., VCC cask lid, VCC liner flange, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), MSB structural lid, MSB lid valve/port covers, MSB closure weld, and MSB shell (top edge)) that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces (e.g., coating that is blistered, bubbled, or peeling) is unacceptable. Corrosion on the underlying steel surfaces of these components shall not exceed 1/16 inch in depth. Corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.

The staff reviewed the Acceptance Criteria and the description of VT-3 Examination in ASME B&PV Code Section XI IWA-2213 (ASME, 2004 [13]). The staff determined that the acceptance criteria are sufficient to maintain the intended functions of the VCC Assembly and the MSB Assembly because the Lead Cask Inspection Program contains specific criteria on the acceptable area of coating degradation and metal loss from corrosion to prevent a loss of intended function of the VCC Assembly and the MSB assembly during the period of extended operation. The staff reviewed the system design and intended functions of the SSCs and subcomponents and determined that coating degradation and uniform corrosion of subcomponents constructed of carbon steel, including the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), and MSB shell, are not unexpected and will not result in loss of material that negatively impacts the intended safety function of these subcomponents. The staff determined that galvanic corrosion of the MSB and the VCC liner, cask liner shell and shield rings is not credible because of the compositional similarity of the carbon steels used in the construction of these subcomponents. Although the staff determined that localized corrosion is unlikely, pitting corrosion, where significant coating degradation exposes the underlying carbon steel or crevice corrosion of the shield ring assemblies, is possible. The staff determined that inspection of the VSC top end steel components using direct or remote VT-3 inspection is appropriate to determine whether the subcomponents included in the scope of the inspection meet the prescribed acceptance criteria based on the information included in Table A-110 in Section V of the ASME Boiler and Pressure Vessel Code (ASME 2010c [16]). The staff determined that the frequency of inspection is sufficient to detect localized corrosion, should it occur, prior to corrosion degradation that would affect the safety function of these subcomponents. Thus, the staff finds that the Acceptance Criteria defined in the Lead Cask Inspection Program provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

7. Corrective Actions

The CoC holder specified that blockage that exceeds the acceptance criteria shall be evaluated in accordance with the GL's corrective action program, including cause and extent of condition.

The CoC holder stated that blockage that exceeds the acceptance criteria and any blockage that can be removed by reasonable means shall be removed. Coating degradation or corrosion resulting in blockage of any airflow path that exceeds the acceptance criteria, and any blockage that that can be removed by reasonable means, shall be removed.

The CoC holder specified that all VSC top end steel components examination results that do not satisfy the applicable acceptance criteria shall be evaluated in accordance with the GL's Corrective Action Program, including extent of condition. Degraded coating that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, which shall be visually examined for corrosion. Corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded. The CoC holder specified that a VCC assembly or MSB assembly with corrosion that exceeds the allowable depth acceptance criteria shall be repaired or replaced in accordance with the GL's procedures. The CoC holder specified that coating that is degraded or that has been removed to examine the underlying steel surface shall be repaired in accordance with the GL's procedures. The CoC holder specified that any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced. A VCC and/or MSB assembly that is not acceptable for continued storage shall be repaired or replaced. A MSB assembly that is determined to be unacceptable for continued storage shall be removed from service and the used fuel retrieved from the MSB assembly.

The CoC holder specified that all localized corrosion on the annulus-facing steel surfaces of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly and shield ring), evidence of localized corrosion in the gap between the VCC shielding ring plates, and localized corrosion on the MSB Shell or MSB Bottom Plate requires additional examination to determine the corrosion depth. Coating in the area of localized corrosion shall be removed by appropriate means to expose the underlying steel surface(s), corrosion products on the underlying steel surface(s) shall be removed by appropriate means to reveal “clean” metal, and the depth of the excavated location(s) shall be measured using a suitable measuring device (e.g., a depth probe) and recorded. The CoC holder stated that locations of localized corrosion on the annulus-facing steel surface of the VCC assembly or MSB assembly that exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service shall be repaired and recoated in accordance with the GL’s procedures. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly or MSB assembly that do not exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service may be repaired and recoated in accordance with the GL’s procedures, or they may be recoated in accordance with the GL’s procedures to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations increased to confirm the effectiveness of the mitigating actions. The CoC holder stated that for a VCC assembly or MSB assembly with localized corrosion that is not repaired, but mitigated by recoating the affected surface(s) to prevent further corrosion, additional confirmatory VT-3 visual examinations of the affected location(s) for localized corrosion shall be performed at an increased frequency.

The CoC holder stated that if no mitigating action is taken, the VCC assembly or the MSB Assembly shall be removed from service. When a VCC is removed form service, the MSB assembly shall be transferred to an acceptable VCC assembly for continued storage. When a MSB is removed from service, the used fuel shall be retrieved from the MSB assembly.

The CoC holder specified the extent of condition evaluation shall include examination of at least two additional VCC assemblies at the site for the unacceptable degradation identified in the lead cask inspection. The GL shall select the additional VCC assemblies based upon those factors that are most relevant for the type of unacceptable degradation observed (e.g., location or orientation of the VCC assembly on the ISFSI pad or time in service). The CoC holder specified that if unacceptable degradation is identified in any of the additional VCC examinations, then the condition shall be evaluated in accordance with the GL's corrective action program, the cask shall be repaired or replaced as necessary and all remaining VCC assemblies at the site shall be examined for the identified degradation.

The staff reviewed the CoC holder's Acceptance Criteria and Corrective Actions for the Lead Cask Inspection Program. The staff determined that the corrective actions are acceptable because the CoC holder identified provisions for addressing coating degradation and corrosion to maintain the intended functions of the SSCs and subcomponents included in the scope of the Lead Cask Inspection Program. Further, the staff has determined that the extent of condition evaluation required in the Lead Cask Inspection Program proposed by the CoC holder is sufficient to assess and, if necessary, mitigate blockage of the VCC ventilation system and localized corrosion of the VCC cask liner bottom, VCC cask liner shell, VCC shielding ring plates (liner assembly), VCC shielding ring plates (shield ring), MSB shell, and bottom surface of the MSB bottom plate for the VSC-24 systems in use at a GL's site. Thus, the staff finds that the corrective actions conducted as part of the Lead Cask Inspection Program provide reasonable assurance that the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly will be adequately managed.

8. Confirmation Process

The staff reviewed the Confirmation Process AMP element, which states that the confirmation process will be conducted in accordance with the GL's Corrective Action Program, and will ensure that appropriate corrective actions are completed and are effective. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that the Confirmation Process is adequate for managing the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly.

9. Administrative Controls

The staff reviewed the Administrative Controls for the Lead Cask Inspection Program that specifies that the Administrative Controls that provide a formal review and approval of appropriate corrective actions will be conducted in accordance with the GL's Corrective Action Program. The staff considers that implementing corrective actions per a GL's Corrective Action Program that meets the quality assurance requirements in 10 CFR Part 50, Appendix B, as is directed in this AMP element, provides reasonable assurance that Administrative Controls are adequate for managing the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly.

The CoC holder has stated that the documentation of the lead cask selection, the basis for relying on lead cask inspections performed at other sites as bounding, and the lead cask inspection results are to be documented in the GL's 10 CFR 72.212 report. The staff determined that the GL's 10 CFR 72.212 report is appropriate for the documentation of the lead cask selection, the basis for relying on lead cask inspections performed at other sites as bounding, and the lead cask inspection results. This process is consistent with the process used by GLs that begin dry storage operations with certified casks; the GL's evaluations of compatibility of its site with the cask design bases is captured in the GL's 10 CFR 72.212 report. As in that process, the information related to the GL's implementation of the Lead Cask Inspection Program that is documented in the report will be subject to inspection by the NRC.

10. Operating Experience

The CoC holder reported that the results of the initial lead cask inspection performed on Palisades Cask No. VSC-15 show that there has been no unanticipated degradation of the inspected components during the initial storage period. The CoC holder stated that the bottom surface of the VCC did not show any evidence of significant corrosion or degradation and the readily accessible surfaces of the MSB shell and VCC liner, inlets, and outlets had no evidence of significant corrosion and all airflow paths were free of blockage. The CoC holder also stated that the top end of the MSB assembly (structural lid and closure weld) showed no evidence of significant coating degradation and no corrosion.

The CoC holder stated that during the period of extended operation, each GL shall perform periodic “tollgate” assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. Section 3.6 of the renewal application, which will be incorporated into the updated FSAR as Section 9.3.5, “Periodic Tollgate Assessments,” includes a description of the general elements of these assessments, including contents of assessment reports. These assessments have an important role in ensuring the adequacy of the AMPs. Therefore, the staff has added a CoC condition (see Section 4 of this SER) that requires the GLs perform assessments and maintain records of these assessments consistent with the general description given in Section 9.3.5 of the FSAR, as updated for the CoC renewal. Per this condition, each GL’s tollgate assessments and reports shall satisfy the items which are indicated to be required (including those where the FSAR indicates they “shall be” implemented) in Section 9.3.5 of the FSAR. These required items include the completion time of the initial assessment and the frequency of subsequent assessments, the kinds of operating experience that are considered, and assessment report contents. The results of the assessments should be used as described in Section 9.3.5 of the FSAR to identify any new applicable aging effects or mechanisms and to ensure the aging management activities are adequate to manage these effects or mechanisms.

The staff reviewed the evaluation of operating experience required by the Lead Cask Inspection Program during the period of extended operation. The staff determined that the evaluation of operating experience is adequate because the program directs each GL to perform periodic “tollgate” assessments of aggregated operating experience relevant to the aging effects and mechanisms addressed in the Lead Cask Inspection Program. This ensures that each GL will use relevant and up-to-date information in conducting the actions required by the program. The staff finds that the Operating Experience stated and referenced in the CoC renewal application provides reasonable assurance that this Lead Cask Inspection Program will be adequate for managing the aging mechanisms and effects identified in the AMR of the VCC assembly and the MSB assembly.

3.5.6 Evaluation Findings

The staff reviewed the AMPs provided in the renewal application and supplemental documentation (EnergySolutions Spent Fuel Division Inc., 2014f [40]). The staff performed its review following the guidance provided in NUREG–1927 (NRC, 2011 [65]) and the ISGs identified in Table 1.4-1. Based on its review, the staff finds:

F3.4 The CoC holder has identified maintenance and surveillance 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, “Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste.”

4 CERTIFICATE OF COMPLIANCE CONDITIONS & TECHNICAL SPECIFICATION CHANGES TO ADDRESS RENEWAL

This section provides a consolidated list of the changes to the CoC conditions and technical specifications resulting from the review of the renewal application, many of which have been described throughout the previous sections of this SER. This section also describes the different amendments to which the changes, which include new CoC conditions, apply since some changes do not apply to all of the CoC amendments. The basis of the changes is provided here for those changes that are not described elsewhere in this SER.

1. **Added the following condition to the Initial CoC and Amendments 1 through 3:**

> “*AUTHORIZATION UNDER RENEWED COC*
>
> *No new VSC-24 storage system structures, systems and components (SSCs) may be constructed or put into service under this amendment to the CoC after the effective date of the renewal of the CoC. However, for VSC-24 systems that have been put into service and are in operation under this amendment as of the effective date of the renewal of the CoC, cask operations, including performance of maintenance and repairs of SSCs, may continue in accordance with the conditions of this CoC.”*

2. **Added the following condition to Initial CoC and Amendments 1 through 6:**

> *“72.212 EVALUATIONS FOR RENEWED COC USE*
>
> *Any general licensee that initiates spent fuel dry storage operations with the VSC-24 storage system after the effective date of the renewal of the CoC and any general licensee operating VSC-24 storage systems as of the effective date of the renewal of the CoC, including those that put additional VSC-24 SSCs into service after that date, shall:*
>
> a. *as part of the evaluations required by 10 CFR 72.212(b)(5), include evaluations related to the terms, conditions, and specifications of this CoC amendment as modified (i.e., changed or added) as a result of the renewal of the CoC;*
> b. *as part of the document review required by 10 CFR 72.212(b)(6), include a review of the FSAR changes resulting from the renewal of the CoC and the NRC Safety Evaluation Report related to the renewal of the CoC; and*
> c. *ensure that the evaluations required by 10 CFR 72.212(b)(7) and (8) capture the evaluations and review described in (a.) and (b.) of this CoC condition.”*

With the renewal of the CoC, and the storage of spent fuel in VSC-24 casks beyond the period certified in the initial CoC, the staff finds it is important to ensure that appropriate considerations for extended storage are evaluated in the general licensee’s 72.212 report. These considerations arise from the analyses and assumptions in the renewal application regarding operations during extended storage. This includes potential use by general licensees that may use new VSC-24 casks after the CoC has been renewed whether at a new or at an existing general license ISFSI. The renewal of the CoC is based on assumptions and analyses regarding the storage system and the sites where it is used that licensees considering the use of the VSC-24 storage system should evaluate for use at their respective sites. This condition also makes it clear that general licensees that currently use the VSC-24 system will need to update their 10 CFR 72.212 reports even if they do not put additional casks into service after the renewal's effective date in order to meet the requirements in 10 CFR 72.212(b)(11). For the initial CoC and Amendments 1 through 3, the language of the condition prior to items (a.) through (c.) will read as "Any general licensee operating VSC-24 storage systems as of the effective date of the renewal of the CoC, shall". This difference in the language is due to the condition that prohibits construction of and placing into service new VSC-24 SSCs under the initial CoC and Amendments 1 through 3.

3. Added the following condition to the Initial CoC and Amendments 1 through 6:

> *"FSAR UPDATE FOR RENEWED COC*
>
> *The CoC holder shall submit an updated FSAR to the Commission, in accordance with 10 CFR 72.4, within 90 days after the renewal of the CoC has been approved by the Commission. The updated FSAR shall reflect the changes and CoC holder commitments resulting from the review and approval of the renewal of the CoC. The CoC holder shall continue to update the FSAR pursuant to the requirements of 10 CFR 72.248."*

The CoC holder has indicated that changes will be made to the FSAR to address the renewal of the CoC. This condition ensures that the FSAR changes are made in a timely fashion to enable general licensees using the storage system for extended operations to develop and implement necessary procedures.

4. Added the following condition to the Initial CoC and Amendments 1 through 6:

> "*OPERATING PROCEDURES FOR SYSTEMS IN SERVICE LONGER THAN 20 YEARS*
>
> *The general licensee (i.e., the user) that operates VSC-24 storage system SSCs for more than 20 years shall establish, implement, and maintain written procedures for each aging management program (AMP), including the lead cask inspection program, described in Section 9.3.3, "Aging Management Program" of the FSAR. The procedures shall be consistent with the AMP descriptions in the FSAR and shall include provisions for changing AMP elements as necessary and within the limitations specified in other CoC conditions and technical specifications to address new information on aging effects that is derived from the results of AMP inspections and/or industry operating experience. Each procedure shall contain a reference to the specific aspect of the AMP element*

> *implemented by that procedure, and that reference shall be maintained even if the procedure is modified."*
>
> *The general licensee shall establish and implement these written procedures within 300 days of the effective date of the renewal of the CoC or 300 days of the 20th anniversary of the loading of the first cask at its site, whichever is later. The general licensee shall maintain these written procedures for as long as the general licensee continues to operate VSC-24 storage system SSCs that have been in service for longer than 20 years."*

This condition is similar in nature to the currently existing conditions in the CoC and TS regarding operating procedures for using casks under this CoC and extends the requirement for operating procedures to address activities required for extended storage operations. The timeframe in the condition is to ensure operating procedures are developed in a timely manner and is consistent with conditions placed in specific licenses that have been renewed.

5. Added the following condition to the Initial CoC and Amendments 1 through 6:

> *"AMENDMENTS FOR RENEWED COC*
>
> *All future amendments to this CoC shall also include evaluations of the impacts of the changes in the amendment on aging management activities for the VSC-24 storage system, modifying the TLAAs and AMPs, including the lead cask inspection program, accordingly."*

The CoC may continue to be amended after it has been renewed. This condition ensures that amendments to the CoC also address aging management impacts that may arise from the changes to the system in proposed amendments. The term 'aging management activities' includes the scoping evaluation, the aging management review, the TLAAs, and the AMPs. As is indicated by the language of the new conditions in 2 and 8 of this section of the SER, the lead cask inspection program is included in the references to AMPs. Thus, this condition also applies to the lead cask inspection program.

6. Added the following condition to Initial CoC and Amendments 1 through 6:

> *"PERIODIC TOLLGATE ASSESSMENTS*
>
> *The general licensee shall perform and maintain records of periodic tollgate assessments as part of the 'Operating Experience' element of each AMP, including the lead cask inspection program, that are consistent with the general description of the assessment elements and report contents in Section 9.3.5, "Periodic Tollgate Assessments" of the FSAR."*

7. **Added the following condition to Initial CoC and Amendments 1 through 6:**

> *"ADDITIONAL DESIGN CONDITIONS FOR RENEWED COC*
>
> *As of the effective date of the renewal of the CoC, the following conditions apply to the VSC-24 design feature alternatives:*
>
> a. *The galvanized steel grate described in Note 6 of FSAR Drawing No. VCC-24-002 may not be used on any new or currently in service VSC-24 VCCs.*
> b. *The fiberglass screen material for the air outlet screens listed in Note 4 of FSAR Drawing No. VCC-24-004 may not be used on any new or currently in service VSC-24 VCCs after the VCC has reached an in-service life of 20 years."*

For the initial CoC and Amendments 1 through 3, the language for a. and b. does not include the words 'new or' since, as described in item 1 at the beginning of this section, a condition is being added to preclude fabrication of new SSCs under the initial CoC and Amendments 1 through 3.

8. **For Amendments 4 through 6, all CoC and technical specification language that discusses 10 CFR Part 50 licensees was modified to include both 10 CFR Part 50 and Part 52 licensees.**

   This change is made for consistency with the language that is currently in the rule (i.e., 10 CFR 72.210). The following is <u>an example</u> of the change from CoC Amendment 4. Changes to the text are in bold, which only involves adding new text.

> *"Casks authorized by this certificate are hereby approved for use by holders of 10 CFR Part 50* ***and 10 CFR Part 52*** *licenses for nuclear power reactor sites under the general license issued pursuant to 10 CFR 72.210, subject to the conditions specified by 10 CFR 72.212 and the attached Conditions for Cask Use and Technical Specifications."*

9. **For the Initial CoC and Amendment 1, the following conditions are being removed since a condition has been added that precludes new fabrication under the Initial CoC and Amendment 1 (see Item 1 at the beginning of this section)**:

> *"Cask fabrication activities shall be conducted in accordance with a quality assurance program as described in Section 13.0 of the SAR.*
>
> *Notification of cask fabrication schedules shall be made in accordance with the requirements of 10 CFR 72.232(c)."*

TECHNICAL SPECIFICATIONS

1. For Amendments 4 through 6, a note was added to Table 1, "Characteristics of Spent Fuel To Be Stored in the VSC-24 System," of Attachment A to the CoC, "Conditions for System Use and Technical Specifications," as follows (text changes are shown in bold):

Amendment 4 and Amendment 5	*Decay Power Per Assembly* ***(see Note 3)***	*Less than or equal to 1 kW*
	Note 3: For casks loaded after the effective date of the renewal of the CoC (and its amendments), the maximum decay power per assembly is limited to 0.625 kW to preclude possible zinc-zircaloy interactions.	
Amendment 6	*Decay Power Per Assembly*	*Less than or equal to 1 kW* ***[3]***
	(3) For casks loaded after the effective date of the renewal of the CoC (and its amendments), the maximum decay power per assembly is limited to 0.625 kW to preclude possible zinc-zircaloy interactions.	

The change only applies to Amendments 4 through 6 because of the new condition (see item 1 at the beginning of this section) that precludes fabrication and placement into service of new SSCs under the initial CoC and Amendments 1 through 3.

2. The technical basis sections were removed from the technical specifications of the initial CoC and Amendments 1 and 2. This change is to make the technical specifications content more consistent with current guidance regarding the content of the technical specifications.

5 CONCLUSION

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 72.240(d), the Commission may issue a renewed Certificate of Compliance (CoC) if it finds that actions have been identified and have been or will be taken, such that there is reasonable assurance that the intended functions of the dry storage system will be maintained throughout the period of extended operation.

The staff of the U.S. Nuclear Regulatory Commission (NRC) (the staff) reviewed the renewal application for the Ventilated Storage Cask System (VSC-24), in accordance with NRC regulations in 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 staff followed the guidance provided in NUREG–1927 (NRC, 2011 [65]) and the interim staff guidance (ISG) identified in Table 1.4-1. Based on its review of the renewal application and the additional CoC conditions, the staff has reasonable assurance that the dry storage system meets the requirements of 10 CFR 72.240, “Conditions for spent fuel storage cask renewal.”

APPENDIX A
AGING MANAGEMENT PROGRAMS

Aging Management Program

The in-scope SSC that are subject to aging effects that require AMA are identified in Section 3.2. Section 3.3 discusses the TLAA used to evaluate aging effects and associated aging mechanism(s) and demonstrate that they do not adversely affect the ability of the SSC to perform their intended functions during the extended storage period. Those aging effects that are not adequately addressed by TLAA require an AMP. The AMP elements used to manage aging effects in the in-scope SSC are discussed in this section.

3.4.1 Aging Effects Subject to Aging Management

Aging effects that could result in loss of in-scope SSC intended functions are required to be managed during the extended storage period. The aging effects that require management are discussed in Section 3.2 and summarized in Table 9 through Table 12. Many aging effects are dispositioned for the extended storage period using TLAA, as discussed in Section 3.3. An AMP is used to manage those aging effects that are not dispositioned by TLAA, as summarized in Table 13. The AMP is described in Section 3.4.2. In addition, the lead cask inspection is discussed in Section 3.4.4.

3.4.2 Aging Management Program Description

The AMP that manages each of the identified aging effects for all in-scope SSC is described in this section. The AMP consists of the existing surveillance requirements in the VSC-24 Technical Specifications, with additional examinations to address aging that could potentially occur during the extended storage period. In addition to the AMP described in the following sections, the lead cask inspection described in Section 3.4.4 provides additional assurance that the VCC and MSB assemblies do not experience any unanticipated degradation.

Each GL shall establish, implement, and maintain programs and operating procedures for each of the AMPs described in Sections 3.4.2.1 through 3.4.2.4 and the lead cask inspection described in Section 3.4.4. The GL programs shall include provisions for changing the AMP elements, as necessary, to address new information on aging effects based on inspection findings and/or industry operating experience identified by the periodic tollgate assessments performed during the renewal period in accordance with the requirements of Section 3.6.

3.4.2.1 Examination of the VCC Assembly Exterior

The exterior surfaces of all VCC assemblies are required to be visually inspected for degradation on a yearly frequency, with the initial inspection completed within 1 year after the 20th anniversary of the first cask loaded at that site or within 2-years after the CoC renewal date, whichever is later. The scope of this AMP includes all readily accessible exterior concrete surfaces, all readily accessible steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and all four (4) VCC Air Outlet Weldments, and all readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware. Portions of the VCC exterior concrete surface and steel-to-concrete interfaces that are covered by the air inlet and outlet screens or other system components (e.g., monitoring equipment) are not included in the scope of the inspection.

The purpose of the examination is to maintain the exterior surface of the VCC assembly, including the air inlet and outlet screens and attachment hardware, in order to prevent degradation of the reinforced concrete and blockage of the VCC ventilation ducts and annulus, and maintain the VCC assembly's intended functions. The exterior concrete surfaces are examined and monitored in accordance with this AMP for cracking, loss of material, excretion of rust, increased porosity and/or CaOH leaching that may lead to loss of concrete material and/or loss of concrete strength. The steel-to-concrete interfaces are examined and monitored for gaps or voids that could potentially lead to unacceptable degradation of the embedded steel components of the VCC assembly. The air inlet and outlet screens and attachment hardware are examined for degradation and/or damage that could potentially lead to an unacceptable breach of the screen covers. The aging effects that this AMP is credited with managing are identified in Table 13. All elements of this AMP are summarized in Table 14 and several of the key AMP elements are discussed in the remainder of this section.

Aging effects for the VCC assembly concrete shell that are managed by the examination of the VCC assembly exterior concrete include cracking/loss of material and loss of strength. Cracking and loss of material on the concrete surface can result from several different aging mechanisms, including freeze-thaw cycles, aggregate reactions (e.g., ASR-induced expansion,) and corrosion of embedded steel (e.g., rebar), as discussed in Section 3.2.1.2. The exterior concrete surfaces of the VCC assembly are visually inspected for damage, such as concrete cracking, scaling, spalling, rust stains, increased porosity, and/or discoloration that are indicative of rebar corrosion and CaOH leaching. In addition, the concrete-to-steel interfaces at the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four inlets) and VCC Air Outlet Weldments are visually inspected for gaps and voids that may provide a pathway for water to enter the VCC concrete. The aging effect for the VCC air inlet and outlet screens and their attachment hardware that is managed by this AMP is loss of material due to corrosion.

Visual examinations of the VCC concrete exterior surfaces and the steel-to-concrete interfaces shall be performed per the guidelines of ACI 201.1 R-08 (ACI, 2008 [A-2]), or an equivalent industry consensus standard. Direct VT-3 visual examination of the air inlet and outlet screens and associated screen attachment hardware shall be performed by qualified personnel. Visual examinations shall be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65).

Qualifications for personnel performing inspection of concrete surfaces and steel-to-concrete interfaces in accordance with ASME Code, Section XI, Subsection IWL (ASME, 2004a [A-3]) or ACI 349.3R (ACI, 2002 [A-1]) are both acceptable. Qualifications for personnel performing VT-3 inspection of the air inlet and outlet screens and screen attachment hardware in accordance with IWE-2330 (ASME, 2004b [A-4]) are acceptable.

<u>Detection of Aging Effects - Data Collection:</u>

Data shall be collected and documented in accordance with the guidelines of ACI 201.1 R-08 (ACI, 2008 [A-2]), or an equivalent industry consensus standard. A checklist or visual inspection form shall be used to record the inspection data. Written descriptions of observed aging effects, accompanied by crack/defect maps that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

Monitoring and Trending:

The data collected from each AMP examination, including crack/defect maps that identify the locations and sizes of observed aging effects, shall be monitored and trended during the extended storage period to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Available information from previous inspections performed during the initial storage period, such as VCC exterior surface inspections performed in accordance with the requirements of TS 1.3.2, may also be used to inform the baseline. However, data from previous inspections performed during the initial storage period may not have been performed using the same method or technique required by this AMP, and therefore, should not be used as the basis of the baseline.

Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VCC exterior surfaces shall be monitored for trends of: (1) Increasing cracking or loss of material (e.g., pitting, pop-outs, spalling or scaling) on the exterior surfaces of the concrete, (2) Increasing excretion of rust at crack opening on the VCC exterior, (3) Increasing porosity and/or discoloration on the exterior surfaces of the concrete, (4) Increasing gaps or voids at the exposed steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and all four VCC Air Outlet Weldments, (5) Increasing corrosion and/or damage of the readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware. The GL shall evaluate trends of increasing degradation of the structure against the acceptance criteria to ensure that the rates of degradation will not result in exceeding the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Acceptance Criteria:

The following acceptance criteria for defects on the exposed concrete surfaces are based on the first-tier criteria of ACI 349.3R-02 (ACI, 2002 [A-1]). Popouts and voids in the concrete that are less than ½ inch in diameter (or equivalent surface area) and gaps and voids at the exterior steel-to concrete interfaces that are less than ½-inch wide or ¼-inch deep are acceptable. Scaling on the concrete surface less than 3/16 inch deep is acceptable. Spalling of the concrete that is less than 3/8 inch deep and 4 inch wide (in any dimension) is acceptable. Passive cracks (i.e., those absent of recent growth) on the concrete exterior that do not exceed 1 mm (0.04 inch) wide are acceptable. In addition, passive cracks that exceed 1 mm (0.04 inch) wide and show no indications of other degradation mechanism are also acceptable, but must be monitored and trended for accelerated crack growth in subsequent examinations. However, passive cracks that exceed 1 mm (0.04 inch) wide and show indications of other degradation mechanism are not acceptable and require corrective action.

Damage to the air inlet or outlet screens or attachment hardware that results in an opening no greater than ½ inch in width (i.e., twice the screen mesh size) is acceptable. No screen attachment hardware can be missing or dislodged. Corrosion of the air inlet or outlet screens is acceptable if it does not cause breakage of the screen mesh ligaments or result in loose or dislodged screens. Corrosion of the screen attachment hardware is acceptable if it does not cause the attachment hardware or the screen to loosen or dislodge. Air inlet or outlet screens and any associated attachment hardware that does not satisfy the acceptance criteria for damage or corrosion shall be repaired or replaced.

Corrective Actions:

Defects in the exterior concrete that do not satisfy the acceptance criteria must be evaluated to determine their cause, and monitored (e.g., crack/defect mapping) and trending during the extended storage period to identify possible concrete aging effects, such as ASR-induced expansion and corrosion of embedded steel. Any defects on concrete exterior surface (e.g., popouts, voids, scaling and spalling) or at the steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and VCC Air Outlet Weldments that exceed the acceptance criteria shall be repaired by appropriate means (e.g., filled with grout or covered with a suitable protective barrier system) in accordance with the GL's procedures. Repair of defects in the concrete surface prevents exposure of the rebar to oxygen and moisture, which is required for rebar corrosion. Progressive growth of defects in the concrete surface may indicate degradation due to ASR-induced expansion, leaching or CaOH, or corrosion of reinforcing steel, which require further corrective actions.

Concrete that shows evidence of rebar corrosion, such as splitting cracks (i.e., longitudinal cracks that propagate parallel to the rebar) or excretion of rust (i.e., discoloration or staining at or below cracks on the concrete surface), shall be tested using non-destructive examination (NDE) techniques, such as impact or other suitable methods, to detect rebar corrosion and/or delamination of concrete (which can result from rebar corrosion), and evaluated for continued storage. A cask with aging effects due to rebar corrosion that is not acceptable for continued storage shall be repaired or replaced.

Loss of concrete strength may result from aggregate reactions or leaching of CaOH, as discussed in Section 3.2.1.2. These aging mechanisms are typically indicated by map cracking (i.e., more or less uniform spacing of cracks over the entire concrete surface), surface deposits (efflorescence or gel staining), or increased porosity on the concrete surface. Concrete showing evidence of leaching (staining in the form or efflorescence) and/or increased porosity shall be documented and evaluated in accordance with the GL's corrective action program. Efflorescence shall be investigated to confirm the presence of calcium hydroxide or other salts leaching from the concrete. Areas with confirmed concrete leaching and increased porosity shall be evaluated to determine the concrete compressive strength. Concrete with a compressive strength that is lower than the design basis compressive strength shall be repaired or replaced in accordance with the GL's procedures.

Concrete surfaces that show visual evidence of degradation from aggregate reactions, as determined by the qualified inspector, shall be further investigation to confirm or refute the presence of ASR gel in the concrete. The preliminary investigation shall consist of field tests of the affected cask(s) to detect the presence of ASR silica gel on the concrete surface using. Uranyl acetate fluorescence, as described in Federal Highway Administration Report No. FHWA-HIF-09-004 [3.39], or other suitable methods identified by the GL. Alternatively, samples of surface deposits can be sent for X-ray analysis to help determine if silica gel is present.

If silica gel is not present in the concrete, then there is a low potential for ASR-induced degradation and no further immediate corrective actions are required. However, if the presence of silica gel is confirmed, then Crack Index (CI) measurements shall be taken on the affected cask(s) in accordance with FHWA-HIF-09-004 (US DOT, 2010 [A-5]) to determine the extent of ASR-induced degradation in the concrete. Any cask with a CI that is greater than 0.5 mmi/m (0.018 in/yard) and/or with crack widths that exceed 0.15 mm (0.006 in) requires detailed in-situ and/or laboratory investigations to determine the current condition of the concrete and its potential for future degradation.

At a minimum, detailed in-situ investigations shall include periodic CI measurements, taken at least twice a year for a minimum of 3 years, to monitor the progression of ASR induced degradation. After 3 years, the CI measurement frequency may be reduced to once every 5 years if the CI shows no significant increasing trend. As discussed in FHWA-HIF-09-004 (US DOT, 2010 [A-5]), CI measurements should be taken under similar environmental conditions each time since crack widths are affected by temperature and humidity.

Although destructive examination of the concrete should be avoided if possible, detailed laboratory testing, including petrographic examination, mechanical testing, expansion testing, and alkali content testing, may be performed using concrete core samples from the cask, if required to assess the condition of the concrete and the potential for further ASR-induced degradation. The collective results from the detailed in-situ and laboratory testing are used to identify mitigation measures and evaluate the cask. Potential mitigation measures for ASR-affected concrete, as discussed in Section 6.0 of FHWA-HIF-09-004 (US DOT, 2010 [A-5]), include application of a siloxane or silane sealer to the concrete surface to reduce its moisture content below 80%, the level below which ASR-induced expansion is significantly reduced or suppressed. A VCC assembly that is determined to have concrete that has a significant potential for further expansion due to ASR and/or does not meet the strength requirements specified in the FSAR shall be evaluated for continued storage, and repaired or replaced, if necessary.

Air inlet or outlet screens and any associated attachment hardware that does not satisfy the acceptance criteria for damage or corrosion shall be repaired or replaced.

Extent of Condition:

No actions are required to evaluate extent of condition for unacceptable degradation because the extent of condition is known since examinations are required to be performed annually on all in-service casks.

Operating Experience:

As discussed in Section 3.2.2.1, operating experience during the initial storage period shows that typical degradation of the concrete exterior surface consists of small surface defects, such as hairline cracks and pits (e.g., "bug holes" or "popouts") and local discoloration of the concrete from mineral deposits. Defects exceeding the size permitted by TS 1.3.2 have been identified and repaired by re-grouting in accordance with existing maintenance procedures. There has been no clear increasing trend in the number surface defects seen at any of the sites for the subsequent years, nor have there been any indications of failure of grout-repairs. Bent air inlet or outlet screens and missing/damaged screen attachment hardware, which were corrected in accordance with existing maintenance procedures, have also been observed during the initial storage period. Therefore, the AMP will adequately manage the aging effects identified for the exterior concrete surfaces, steel-to-concrete interfaces, and air inlet and outlet screens and attachment hardware of the VCC assembly during the extended storage period.

During the period of extended operation, each GL shall perform periodic "tollgate" assessments of OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. The periodic tollgate assessments performed by each GL shall satisfy the requirements described in Section 3.6.

3.4.2.2 Examination of the VCC Assembly Ventilation Ducts and Annulus

The ventilation ducts and annulus of the first VSC-24 cask loaded at each site is visually examined on a 5-year frequency, with initial inspection completed within 5 years after the 20th anniversary of the first cask loaded at the site. A VT-3 visual examination of each VCC air inlet, outlet, and the VCC annulus is performed using remote visual equipment (e.g., bore-scope and video recorder). The main purpose of this examination is to confirm that no blockage has accumulated inside the VCC assembly ventilated flow path that could interfere with the natural convective airflow and prevent the VCC assembly from performing its intended heat transfer function. The other purpose of this examination is to confirm, through remote VT-3 visual inspection, that the metal surfaces that line the annulus, which are normally inaccessible, are not experiencing any localized corrosion (i.e., galvanic, crevice, or pitting corrosion).

The scope of the VT-3 visual examination for corrosion includes all readily accessible inside surfaces of all VCC air inlets and outlets, and all readily accessible annulus-facing surfaces of the VCC Cask Liner Bottom (i.e., surfaces not obstructed by the MSB assembly), VCC Cask Liner Shell, VCC Shield Ring Plates (Liner Assembly and Shield Ring), and MSB Shell. Surfaces that require inspection are those that may be inspected using reasonable means given the specified method or technique, considering the inspection equipment used. A surface that cannot be viewed with sufficient resolution or lighting for a qualified inspector to evaluate is not considered readily accessible. Monitoring the condition of the interior of the first VSC-24 cask placed in service at each site for unanticipated blockage and material degradation provides confirmation that the design is performing as intended. As shown in Table 13, this AMP is credited with managing loss of material due to corrosion of the VCC air inlet and outlet ducts, liner shell, and liner bottom. All elements of this AMP are summarized in Table 15 and several of the key AMP elements are discussed in the remainder of this section.

Remote visual examination (VT-3) is used to identify blockage and localized (i.e., galvanic, crevice, or pitting) corrosion. VT-3 visual examination shall be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 (ASME, 2004b [A-4]) are acceptable.

<u>Detection of Aging Effects - Data Collection:</u>

Data from the examination, including any blockage of the VCC air inlets and outlets and VCC annulus, and degradation of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., height, width, area) of the observed aging effect, and photographs for additional visual evidence, shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

<u>Monitoring and Trending:</u>

The data collected from each AMP inspection, including blockage of the VCC air inlets and outlets and VCC annulus and degradation of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Available information from previous inspections performed during the initial storage period, such as interior VCC surface inspections performed in accordance with the requirements of TS 1.3.3, may also be used to inform the baseline. However, data from previous inspections performed during the initial storage period may not have been performed using the same method or technique required by this AMP, and therefore, should not be used as the basis of the baseline.

Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The ventilation flow path of all VCC air inlets and outlets and the VCC annulus shall be monitored for increasing trends of blockage, coating degradation, and corrosion. The GL shall evaluate trends of increasing degradation of the structure against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Acceptance Criteria:

The VCC air inlets, air outlets, and the annular space that is formed between the MSB Shell and the VCC Cask Liner Shell provide the ventilation flow path required for convective cooling. Blockage of any individual segment flow path of the ventilation ducts and annulus from any source (e.g., animals or insects, insect nests, debris, corrosion products) that does not exceed 10% of the segment's cross-sectional flow area is acceptable.

The steel plates that line the VCC air inlet and outlet ducts serve as cast-in-place formwork, which form the VCC geometry that provides the ventilation flow path, thus providing a heat transfer function. Although the exposed surfaces of these steel components are coated, degradation of the coating and general (e.g., atmospheric) corrosion may occur during the extended storage period. Coating degradation and any type of corrosion (i.e., general and localized corrosion) on the duct-facing coated steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross section area) of any air flow path. General corrosion (e.g., atmospheric corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell that does not result in significant blockage (i.e., >10% of segment cross-section area) of the annulus is also acceptable. However, any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell is unacceptable.

Corrective Actions:

A VCC assembly with blockage of the air inlets, air outlets, or annulus that exceeds the acceptance criteria shall be evaluated in accordance with the GL's corrective action program, to determine cause and extent of condition (discussed below), and any blockage that can be removed by reasonable means shall be removed.

If localized corrosion is found on any of the annulus-facing steel surfaces of the VCC and MSB assemblies, or if evidence of localized corrosion in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring) is identified, the inspected cask shall be evaluated for continued storage in accordance with the GL's corrective action program, to determine cause and extent of condition, and the following corrective actions shall be taken.

Localized corrosion on the annulus-facing steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), and VCC Shielding Ring Plates (Shield Ring), and evidence of localized corrosion in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), requires additional examination to determine the corrosion depth. To determine the depth of localized corrosion on the annulus-facing steel surface of the VCC assembly, or in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), the MSB assembly may be temporarily transferred from the VCC assembly into the MTC assembly to allow direct access to VCC cavity surfaces. Coating in the area of localized corrosion shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface(s), corrosion products on the underlying steel surface(s) shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of the excavated location(s) shall be measured using a suitable measuring device (e.g., a depth probe) and recorded. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service[1] shall be repaired[2] (e.g., base metal weld repair) and recoated in accordance with the GL's procedures. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that do not exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service may be repaired, but do not require repair if they are recoated to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the VCC assembly shall be removed from service and the MSB assembly shall be transferred to an acceptable VCC assembly for continued storage.

Localized corrosion on the MSB Shell or MSB Bottom Plate requires additional examination to determine the corrosion depth. The depth of localized corrosion on the MSB Shell or MSB Bottom Plate shall be determined using suitable NDE methods, such as eddy current or ultrasonic measurements, that have been qualified for use by the GL. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service[1] may be repaired[2] (e.g., base metal weld repair) and recoated (if possible), or the MSB assembly shall be removed from service, in which case the used fuel must be retrieved from the MSB assembly. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that do not exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service may be repaired (if possible), but do not require repair if the affected surface(s) are recoated to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action

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[1] The depth of localized corrosion that is permitted without repair is based on the maximum general corrosion rate of 0.003 inch/year for uncoated carbon steel in a marine environment that is used for the MSB Corrosion Evaluation TLAA**.** This criterion assures that continued general corrosion of the steel surfaces over the remainder of the renewal period, conservatively taking no credit for corrosion protection provided by the coating, will not exceed the maximum corrosion allowance of 0.18 inches based on a constant general corrosion rate of 0.003 inch/year over 60 years.

[2] Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2 inches from the perimeter of area to be welded. Following weld repair, steel surfaces shall be re-coated in accordance with coating manufacturer's instructions. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement.

is taken, the MSB assembly shall be removed from service, in which case the used fuel must be retrieved from the MSB assembly.

For a VCC assembly or MSB assembly with localized corrosion that is not repaired, but mitigated by recoating the affected surface(s) to prevent further corrosion, additional confirmatory VT-3 visual examinations of the affected location(s) for localized corrosion must be performed at an increased frequency (i.e., more often) in accordance with the applicable elements of this AMP to confirm the effectiveness of the mitigating actions. The initial confirmatory examination of the affected location(s) shall be performed no later than 3 years after the completion of the mitigating action. If the initial examination confirms that no further localized corrosion has occurred in the previously affected area(s), then the affected location(s) need not be inspected again until the next scheduled AMP examination. However, if a confirmatory examination identifies further localized corrosion of the previously affected location(s), then the corrective actions described above shall be repeated and the confirmatory examination frequency shall be restarted at 3 years.

Extent of Condition:

If blockage exceeding the acceptance criteria is identified, the extent of condition evaluation shall include remote visual examination of the air inlets, air outlets, and annulus of at least two additional VSC-24 storage systems (i.e., casks) at the site for blockage. The GL shall select the additional casks based upon those factors that are most relevant to the type of blockage observed (e.g., location or orientation of the casks on the ISFSI pad or time in service). If unacceptable blockage is identified in any of the additional casks examined, then all casks at the site shall be examined for blockage. Any blockage identified in the casks examined for extent of condition that can be removed by reasonable means shall be removed.

If localized corrosion is identified on the annulus-facing surfaces of the MSB Shell, VCC Cask Liner Bottom, or VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), or VCC Shielding Ring Plates (Shield Ring) then the extent of condition evaluation shall include additional remote visual examination of the normally inaccessible surfaces of the MSB Bottom Plate and VCC Cask Liner Bottom of that cask for unacceptable corrosion. The extent of condition evaluation shall also include visual examination of two additional casks for the unacceptable corrosion, including the normally inaccessible surfaces of the MSB bottom plate and VCC cask liner bottom if unacceptable corrosion is identified on these surfaces of the first cask. If either of those two casks also have unacceptable corrosion, all of the other casks at the site shall be inspected for corrosion. The two additional casks selected for additional inspections shall be those considered to have maximum susceptibility to corrosion of the ventilation path metal surfaces, based on factors such as time in service, heat load, fabrication variations, etc. If localized corrosion is identified on the any of the casks examined for the extent of condition evaluation, then the associated corrective actions for localized corrosion discussed above shall be taken on the affected cask(s).

Operating Experience:

Operating experience during the initial storage period shows that no significant blockage has accumulated within the ventilation flow path of the inspected casks and that the majority of the steel surfaces inspected are in excellent condition, with little coating degradation or signs of corrosion. Therefore, this AMP will adequately manage the aging effects identified for the VCC assembly interior during the extended storage period.

During the period of extended operation, each GL shall perform periodic "tollgate" assessments of OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. The periodic tollgate assessments performed by each GL shall satisfy the requirements described in Section 3.6.

3.4.2.3 Examination of VSC Top End Steel Components

The top end of one VSC-24 cask loaded at each site is visually examined on a 10-year frequency (+ 1-year) during the extended storage period to manage loss of material (corrosion) on the coated steel surfaces. The first examination is to be performed on one cask at each site, with the initial inspection completed within 1 year after the 2 0th anniversary of the first cask loaded at that site or within 2-years after the CoC renewal date, whichever is later. The examination shall be performed on the first cask loaded at each site. Alternatively, the GL may select a different cask for inspection based on maximum cask heat load or cask accessibility. However, the same cask shall be used for the subsequent examinations such that trending can be performed. In addition, the cask selected for examination shall not be the same cask that is selected for the Lead Cask Inspection AMP.

The scope of the examination includes VT-3 visual inspection of all readily accessible VSC system top end surfaces, including all surfaces of the VCC cask lid (which is removed as part of the inspection), the top and inner radial surfaces of the VCC liner flange, the top surface of the VCC Shielding Ring Plates (Liner Assembly) (i.e., the outer portion of the shielding ring that is welded to the VCC liner shell), the top and inner radial surfaces of the VCC Shielding Ring Plates (Shield Ring) (i.e., the inner shielding ring assembly that is removable), the top surface of the MSB structural lid, MSB valve covers, and MSB closure weld, the top end (i.e., upward facing surface) of the MSB shell, and all surfaces of the VCC lid bolts.

The purpose of this examination is to confirm, through VT-3 visual inspection, that the surfaces listed above, many of which are normally inaccessible, are not experiencing any unanticipated degradation that could prevent them from performing their intended functions. Monitoring the condition of the VSC top end steel components of one cask at each site for unanticipated material degradation provides confirmation that the design is performing as intended. The aging effects that this AMP is credited with managing are identified in Table 13. The AMP elements of this examination are summarized in Table 16 and discussed in this section.

VT-3 visual inspection of the VSC top end steel components may be performed directly, or using long-handled tools and/or remote visual equipment (e.g., borescope/camera), if necessary. In order to perform the visual examination of the VSC top end steel components, the VCC cask lid must be removed. If the view of the MSB closure weld and/or the top end of the MSB shell is blocked by the VCC Shielding Ring Plates (Shield Ring), it may be lifted slightly (no more than 2") to expose these surfaces for visual examination. Dose rates around the MSB closure weld shall be monitored and temporary shielding may be used to minimize occupational exposure. Following the completion of the surveillance activities, lower the VCC Shielding Ring Plates (Shield Ring) into position (if lifted), replace the VCC cask lid gasket, secure the VCC cask lid, and replace the locking wire.

Detection of Aging Effects - Data Collection:

Data from the examination, including coating degradation and corrosion of the VSC top end steel components, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

Monitoring and Trending:

The data collected from each AMP inspection, including coating degradation and corrosion on all VSC top end steel components, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Any available information from previous inspections performed during the initial storage period may also be used to inform the baseline. However, data from previous inspections performed during the initial storage period may not have been performed using the same method or technique required by this AMP, and therefore, should not be used as the basis of the baseline.

Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VSC top end steel components shall be monitored for increasing trends of coating degradation and corrosion, which shall be evaluated against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Acceptance Criteria:

Coating degradation on the VSC top end steel components that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces (e.g., coating that is blistered, bubbled, or peeling) in not acceptable. Corrosion on the underlying steel surfaces of the VSC top end steel components shall not exceed 1/16 inch in depth. Corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.

Corrective Actions:

All examination results that do not satisfy the applicable acceptance criteria shall be evaluated in accordance with the GL's Corrective Action Program to determine the cause of the degradation and the extent of condition (discussed below), and the following corrective actions shall be taken.

Degraded coating that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, which shall be visually examined for corrosion. Corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded.

Steel components with corrosion that exceeds the allowable depth acceptance criteria shall be repaired (i.e., weld repair) or replaced in accordance with the GL's procedures. Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2 inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement. Coating that is degraded or has been removed to permit examination and/or repair of the underlying steel shall be repaired in accordance with the GL's procedures. Any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced.

Extent of Condition:

The extent of condition evaluation shall include visual examination of at least two additional VSC-24 storage systems (i.e., casks) for coating degradation and/or corrosion. The GL shall select the additional casks to be inspected based upon the factors that contribute most significantly to the observed degradation on the first cask (e.g., time in service, heat load, or fabrication differences). If coating degradation and/or corrosion is identified in either of the additional cask inspections that do not satisfy the acceptance criteria, it shall be entered into the GL's corrective action program and the extent of condition evaluation shall be expanded to include visual examination of all casks at the site for coating degradation and/or corrosion.

Operating Experience:

Operating experience from the initial lead cask inspection performed on Palisades Cask Number VSC-15 shows that the VCC lid gasket showed no evidence of leakage during the initial storage period. The coating on the VCC lid, liner flange, shield ring plates, and the MSB structural lid and closure weld were also found to be intact and adhered to the underlying steel, except in two small areas where the coating was intact but appeared to be blistered or bubbled. In addition, one small area of coating was inadvertently scraped off the MSB structural lid during the inspection. The coating in the areas that appeared to be blistered and the area that had been scraped was removed, and visual inspection of the underlying steel surface did not identify any signs of corrosion. Upon completion of this inspection, the coating on the MSB structural lid was repaired and the VCC cask lid was installed with a new gasket.

During the period of extended operation, each GL shall perform periodic "tollgate" assessments of OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. The periodic tollgate assessments performed by each GL shall satisfy the requirements described in Section 3.6.

3.4.2.4 Examination of the MTC Assembly

The MTC assembly aging effects that require management by AMP, as identified in Table 13, are limited to loss of material due to corrosion of the exposed surfaces of the coated and uncoated carbon steel subcomponents. The scope of the AMP includes visual examination of all readily accessible interior and exterior surfaces of the MTC assembly. The MTC assembly used at each site is examined on a 10-year frequency (±- 1-year), with the initial inspection completed within 1-year after the 20th anniversary of the first cask loaded at that site or within 2-years after the CoC renewal date, whichever is later. The AMP elements of the MTC assembly examination are summarized in Table 17 and discussed in this section.

Although the MTC assembly is stored in a sheltered environment, the MTC assembly is intermittently exposed to the wet environment of the spent fuel pool during the MSB assembly loading operations. Most surfaces of the MTC assembly that are exposed to the spent fuel pool water are coated to protect the spent fuel pool chemistry, facilitate decontamination, and protect against corrosion. Coating degradation and exposure to moist atmospheric conditions (i.e., sheltered environment) may lead to corrosion of the MTC assembly carbon steel subcomponent.

Visual examination of all readily accessible interior and exterior surfaces is performed to identify degradation of the coating and corrosion of the coated and uncoated carbon steel surfaces that could prevent the MTC assembly from performing its intended functions. Exposed surfaces of the MTC assembly where the coating is degraded (e.g., blistered, cracked, chipped, or peeling) to the extent that the underlying steel is exposed shall be further examined to determine if corrosion of the underlying steel has occurred.

Detection of Aging Effects - Data Collection:

Data from the examination, including any observed coating degradation and corrosion of the exposed surfaces of the MTC assembly, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination may also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

Monitoring and Trending:

The data collected from each AMP inspection, including coating degradation and corrosion on all readily accessible interior and exterior surfaces of the MTC assembly, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Any available information from previous maintenance activities performed during the initial storage period may also be used to inform the baseline. However, data from previous maintenance activities performed during the initial storage period may not have been performed using the same method or technique required by this AMP, and therefore, should not be used as the basis of the baseline.

Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The MTC assembly components shall be monitored for increasing trends of coating degradation and corrosion, which shall be evaluated against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Acceptance Criteria:

Individual local areas of coating loss that expose no more than 2 in2 of underlying steel or a total combined area of coating loss (not including steel surfaces that are not coated by design) that exposes no more than 40 in^2 of underlying steel (e.g., roughly 0.05% of the total coated surface area) are acceptable. Corrosion must not exceed 10% of a component's nominal thickness (or depth) or reduce a bolts nominal cross-sectional area by more than 5%.

Corrective Actions:

Areas of degraded coating that exceed the acceptance criteria shall be repaired by re-coating in accordance with the GL's procedures. If corrosion has resulted loss of material that exceeds that acceptance criteria, the affected components shall be repaired (i.e., weld repair) or replaced.

Prior to making weld repairs on the coated steel surfaces of the MTC assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2 inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement.

Operating Experience:

During the period of extended operation, each GL shall perform periodic "tollgate" assessments of OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. The periodic tollgate assessments performed by each GL shall satisfy the requirements described in Section 3.6.

3.4.3 Corrective Actions

This section provides a detailed discussion of the operating history of the VSC-24 storage system, including design modifications made by the GLs and CH and significant events that occurred during the initial storage period, along with the identified causes of those events and corrective actions to prevent recurrence. Whereas all design modifications made by the GLs and CH and significant events that occurred during the initial storage period have been evaluated for the initial storage period, the operating history is reviewed herein to identify potential issues that may affect safe operation during the extended storage period. Based on the operating history, there is reasonable assurance that all VSC-24 storage systems that are currently loaded satisfy the confinement, fuel integrity, and subcriticality requirements of 10 CFR Part 72 and reasonable assurance of continued safe operation of the VSC-24 storage system during the extended storage period.

3.4.3.1 Design Changes Made in Accordance With 10 CFR 72.48

When the VSC-24 Storage System CoC was issued in 1993, only the GLs were permitted by 10 CFR Part 72.48 to make specific changes in the facility or spent fuel storage cask design described in the FSAR without prior NRC approval. On April 5, 2001, 10 CFR Part 72.48 was changed to also authorize the CH to evaluate and implement changes to the facility or spent fuel storage cask design described in the FSAR meeting the criteria of 10 CFR Part 72.48 without obtaining prior NRC approval. However, because this change to the 10 CFR Part 72.48 did not occur until after most of the VSC-24 storage system components had already been fabricated, relatively few changes to the VSC-24 storage system were made by the CH. The changes to the VSC-24 storage system made by the GLs and CH under the provisions of 10 CFR 72.48 have been reviewed in the context of operating history to identify potential aging effects for in-scope SSC. This section provides a summary of the review of design changes made in accordance with 10 CFR Part 72.48.

Most of the changes made by the GLs in accordance with 10 CFR Part 72.48 addressed unit specific issues, such as fabrication non-conformances, and some of the 10 CFR Part 72.48 changes were related to the issues discussed in the following sections. Changes made by the GLs were reported to the CH for evaluation as generic changes. Most of these changes were included in License Amendment Request (LAR) 00-02 (see Section 1.1.1), which was submitted to NRC in May 2000 to address commitments made in response to the Demand For Information (DFI) issued by NRC on October 6, 1997. NRC concluded their review of LAR 00-02 stating that the changes requested could be made by the CH in accordance with the provisions of 10 CFR Part 72.48. In response, the CH evaluated the changes in accordance with 10 CFR Part 72.48 and determined that, although some editorial changes could be made without prior NRC approval, many of the changes required a LAR. These changes were included in LAR 01-01 (see Section 1.1.1) that was submitted to NRC and approved in Amendment 4 of the VSC-24 CoC in January 2003. Also, in 2002, a change was made by the CH under 10 CFR Part 72.48 (in response to a request from NRC) to add a requirement for a minimum helium purity of 99.995%. It was concluded that this change did not require prior NRC approval.

All of the changes made under the provisions of 10 CFR Part 72.48 were incorporated into the

VSC-24 Storage System FSAR no later than Revision 5. Since 2003, the CH has made no additional changes in accordance with 10 CFR Part 72.48. None of the issues identified in the review of design changes made in accordance with 10 CFR Part 72.48 were determined to prevent the in-scope SSC from performing their intended functions during the extended storage period.

3.4.3.2 MSB Closure Weld Cracks

Between March 1995 and March 1997, cracks were identified in four (4) different MSB closure welds during NDE examinations performed during the loading process. In April 1997, NRC issued Inspection Report 72-1007/97-204 (NRC, 1997a [A-6]) to identified NRC safety concerns related to these issues; then issued Corrective Action Letter (CAL) Number 97-7-001 (NRC, 1997b [A-7]) to Sierra Nuclear Corporation (SNC) in May 1997. Subsequently, SNC submitted the response to CAL 97-7-001 (Sierra Nuclear Corporation, 1997 [A-8]), which discussed SNC's evaluation of the weld failures and identified several different root causes of the weld failures, including: (1) Lamellar tearing of the MSB shell base metal, (2) Improper fit-up of MSB structural lid and backing ring, (3) Moisture contamination during the welding process, and (4) Hydrogen-induced cracking. This section summarizes the conditions associated with weld failures, the associated root causes and corrective actions to prevent recurrence, and the evaluation of the weld cracks for extended storage.

Lamellar Tearing in MSB Shell:

In March 1995, a leak was discovered in the shield lid-to-shell weld of Palisades MSB-05 during the helium leak test. NDE revealed that the leak was caused by a defect in the MSB shell base metal. The defect was removed by grinding, which resulted in a 1/8-inch deep by 6-inch long defect cavity, and the defect cavity was repaired in accordance with approved welding procedures. Metallographic analysis by the GL of remnants of the removed defect indicated that the shell material defect could have resulted from a weld of unknown origin in the MSB shell.

However, further investigation of the fabrication records concluded that no weld repairs on the shell of MSB-05 were located in the area of interest. A review team ultimately concluded that the failure was caused by a lamellar defect in the shell material that was opened up during the welding process (i.e., lamellar tearing) and propagated along the grain boundary of a pre-existing weld of unknown origin. Several corrective actions were taken to determine the extent of condition and prevent recurrence of the condition that occurred on MSB-05.

All of the MSB shells that had already been fabricated but not loaded were subjected to an acid-etching test in the closure weld region (i.e., top 4-inches on the inside surface) to detect the presence of weld repairs. The acid-etch results showed evidence of undocumented welds on ten (10) MSB shells at ANO. Further investigation revealed that the undocumented welds were limited to one fabricator that welded temporary attachments to the MSB shell during the fabrication process. The extent of condition evaluation concluded that fourteen (14) of the ANO MSBs and five (5) of the Palisades MSBs from this fabricator were affected. Subsequently, Liquid Penetrant Test (PT) and Ultrasonic Test (UT) examinations performed on all undocumented welds detected on the ANO MSBs by the acid-etching test revealed no indications that were unacceptable. Furthermore, samples of the affected material were extracted and sent to an independent laboratory for testing. The tests revealed that the chemical composition, hardness levels, and microstructure of the affected material were all consistent with expectations for shallow weld repairs.

Evaluations were performed to assess the potential for adverse effects of the undocumented weld repairs, including hydrogen-induced cracking and propagation of undiscovered defects (crack growth). The evaluation of hydrogen-induced cracking in weld repairs concluded that the risk is low, even considering the highly constrained shield lid-to-shell weld joint. However, additional acid etching and/or UT examinations were also required and performed on the top 4-inches of all subsequent MSB shells, including those that were already fabricated but not loaded, to identify the presence of lamellar defects near the closure weld region. In addition, low-sulfur material was required for all later MSB shells. These changes were included in CoC Amendment 2 [A-9] and subsequently incorporated in FSAR Revision 2 [A-10].

A fracture mechanics analysis of the MSB shell and bottom plate was performed using Linear Elastic Fracture Mechanics (LEFM) techniques based on the requirements of ASME Section XI to evaluate the possible effects of undocumented weld repairs. The analysis is conservatively based on the Double Edge Cracked Plate (DECP) model, which assumes opposing flaws on the inside and outside surfaces of the plate and infinite crack length (i.e., aspect ratio a/l = 0). The results of the fracture mechanics analysis show that the 1/8-inch deep by 6-inch long defect identified in Palisades MSB-05 and any defects that could be present in the MSB shell and bottom plate from undocumented weld repairs, will not affect the structural adequacy of the components. Therefore, it is concluded that any potentially undiscovered flaws from undocumented weld repairs would not prevent the MSB from performing its intended functions during the initial or extended storage period.

Improper Fit-Up of MSB Structural Lid and Backing Ring:

In May 1996, cracks were identified by a PT examination of the root pass of the structural lid-to shell weld of the second cask loaded at Point Beach. The defects were removed by grinding and repaired in accordance with approved welding procedures. An investigation by the GL concluded that the indications were caused by wide fit-up gaps that were not sufficiently backed by shim plates, which caused lack of fusion to occur between the weld and base metals. The corrective actions included pre-fitting the MSB assembly lid components to ensure tighter fit-up of the backing ring to the shell and manual welding to fill any gaps exceeding 1/16-inch prior to starting the automated welding process. Similar measures to prevent the type of failure that occurred at Point Beach were already in-use by the other GLs. The corrective actions taken restored the failed weld to its intended condition and prevented recurrence of the condition in later cask loading operations at Point Beach.

Moisture Contamination of Welds:

In May 1996, cracking and weld porosity were noted on the root pass of the structural lid-to-shell weld of the second cask loaded at Point Beach. The defects were removed by grinding and repaired in accordance with approved welding procedures. The GL evaluation concluded that the weld cracking and porosity were caused by water forced up through the drain line during cask loading, which resulted in moisture contaminating the weld. The corrective actions included removal of approximately 40-gallons of water from the MSB cavity to protect against water entering the weld area and preheating the area to be welded to 200°F. Similar measures to prevent the type of failure that occurred at Point Beach were already in-use by the other GLs. These corrective actions were effective in preventing recurrence of this condition at Point Beach.

Hydrogen-Induced Weld Cracking:

In December 1996, when loading the first cask at ANO, a leak in the MSB shield lid-to-shell weld was discovered by the helium leak test. Subsequent PT examination confirmed the presence of a crack along the weld fusion line. The defect was removed by grinding, which resulted in a 1/8-inch deep by 4-inch long defect cavity, and the defect cavity was repaired in accordance with approved welding procedures. The initial evaluation by the GL concluded that the crack had been caused by lamellar tearing of the MSB shell. The crack was removed by grinding and repaired in accordance with approved welding procedures. Then, in March 1997, when loading the third cask at ANO, a similar crack along the weld fusion line of the root pass of the MSB shield lid-to-shell weld was identified by PT examination. This defect was removed by grinding, which resulted in a 1/16-inch deep by 18-inch long defect cavity, and the defect cavity was repaired in accordance with approved welding procedures. Since the resulting defect cavity was relatively shallow, it is bounded by the fracture mechanics analysis described above under "Lamellar Tearing of MSB Shell."

A detailed evaluation by the GL also concluded that this crack was caused by mechanical tearing of the shell due to weld shrinkage stresses. However, further detailed evaluation by a team of welding experts and testing by The Welding Institute (TWI), an independent laboratory, showed that the weld failures at ANO were not caused by lamellar tearing, as originally thought, but instead by hydrogen-induced cracking. This conclusion was based upon: (1) Comparison of the welding parameters, chemical compositions, and other pertinent information with similar weld failures observed at other sites, (2) Re-examination of a weld crack replica of the third ANO MSB using light microscopy and scanning electron microscopy, (3) Chemical testing of the weld wire used for making the third ANO MSB shield lid weld by TWI, and (4) Through-thickness tensile testing by TWI of material from the same heat that was used to fabricate the third ANO MSB.

Delayed Hydride Cracking (DHC), which could theoretically occur weeks or months after the welding operation, was identified by NRC as a possible failure mechanism for welds with underbead cracking made in a moist environment [A-6]. The potential for DHC-induced failure of the MSB closure welds was evaluated by the team of welding experts. It was also concluded that there is no known mechanism for crack growth of defects in the closure welds [A-8]. Based on industry research on welds, and VSC-24 closure weld characteristics such as weld temperature, it was concluded that the delay time for the onset of hydrogen-induced cracking (deemed the only credible type of delayed cracking) is only a matter of hours; shorter than the time period between placement of the weld and weld inspections. No other longer-term mechanisms for delayed cracking or crack growth were identified.

Nevertheless, UT examinations were performed on the closure welds of all previously loaded MSB assemblies using the Time-of-Flight Diffraction (TOFD) ultrasonic examination technique to identify any weld flaw indications that may have resulted from DHC-induced cracking and assure that the MSB assemblies will continue to perform their intended functions during the initial storage period. All weld flaw indications identified by the UT examination were evaluated against conservative flaw size acceptance screening criteria developed using Linear Elastic Fracture Mechanics (LEFM) techniques based on the requirements of ASME Section XI.

Weld flaw indications that exceeded the initial screening criteria were documented in accordance with the GL's corrective action program and further evaluated using the same LEFM or Elastic- Plastic Fracture Mechanics (EPFM) methods, and plant-specific criteria, as appropriate. These plant-specific evaluations accounted for geometric constraints using a finite element model, increased material toughness based upon upper shelf temperature behavior, and a revised limiting load condition for the MSB structural lid-to-shell welds Since the plant-specific criteria was developed using upper shelf fracture toughness properties, plant-specific administrate controls were added to allow cask movement only when the ambient air temperature is 35'F or higher. The evaluations of the flaw indications show that all MSB closure weld indications identified by the UT examinations satisfy the applicable fracture mechanics acceptance criteria and the applicable primary stress limits of ASME Section III.

The corrective actions to address hydrogen-induced weld cracking and the possibility of DHC--

induced failure of the MSB closure welds that were implemented include: (1) use of larger tack welds and a more balanced- weld sequence to secure the MSB shield lids to the MSB shell before welding, which more evenly distributes the shrinkage forces that result from the welding process, (2) use of welding consumables with low hydrogen levels, (3) holding a 200'F temperature for a minimum of 1-hour after completing the weld to accelerate diffusion of hydrogen from the weld and Heat-Affected Zone (HAZ), and (4) waiting a minimum of 2-hours after completing the weld to inspect the weld to account for DHC, should it occur. In addition, a requirement to perform UT examination of welded closures of the loaded MSB assemblies was added to TS 1.2.9 to check for possible DHC-induced failure. The allowable flaw size for the UT examination was established under the limiting loading conditions based on the flaw evaluation criteria of ASME Section XI. These requirements were included in CoC Amendment 2 [A-11] and subsequently incorporated in FSAR Revision 2 [A-10]. Based on the results of the UT examination and associated evaluations, and the determination that flaws within the allowable size will not propagate under normal, off-normal, and accident storage conditions, it was concluded that the MSB closure welds were acceptable for continued storage.

3.4.3.3 Palisades MSB-04 Shell Seam Weld RT Indications

In 1992, Palisades MSB-04 was built and inspected in accordance with the requirements of the MSB assembly fabrication specification, which required Radiographic Test (RT) examination of all MSB shell seam welds. Later, in July 1994, a review of the radiographs for MSB-04 by the GL's Level III Inspector identified a 1-inch long linear crack-like indication in the longitudinal seam weld located at approximately 52-inches below the top end of the shell that was not identified by the fabricator. In August 1994, the same radiographs were reviewed again by other Level III Inspectors. They confirmed the presence of a 3¾-inch long by 3/16-inch deep linear crack-like indication in the longitudinal seam weld located at approximately 52-inches below the top end of the shell and identified two (2) additional indications 'in the longitudinal seam weld; a 5/16-inch long by 5/16-inch deep transverse crack-like indication located at approximately 57-inches below the top end of the shell, and a 3/8-inch long by 1/3-inch deep linear slag-like indication located at approximately 116-inches below the top end of the shell.

The conditions were evaluated in accordance with the GL's corrective action process and it was concluded that MSB-04 was structural sound and capable of withstanding normal operating and test loads, and that the flaws would not propagate significantly during storage. This conclusion was based on a fatigue crack-growth analysis of a bounding 1-inch long by ½2-inch deep subsurface flaw. The analysis, which was reviewed by NRC staff [A-12], shows that the fatigue crack growth over the 50-year storage period of the MSB assembly is less than 0.00001-inches, considering the full range of normal, off-normal, and accident load conditions. Furthermore, the analysis demonstrates that the flaw stability factors of safety are greater than those required by the ASME Code for normal and faulted conditions.

The GL also implemented several corrective actions to ensure the safe operation of MSB-04. Radiological surveys were performed for all four (4) VSC-24 casks loaded at Palisades and there were no unusual dose rates or contamination levels identified. The periodic surveys of the Palisades ISFSI were increased temporarily to monitor the performance of MSB-04. Helium leak tests were performed at the air outlet ducts of Palisades VSC-04 (i.e., the Palisades VSC-24 cask loaded with MSB-04), but the environmental conditions were not adequate and the results were determined to be inconclusive. In addition, in order to prevent recurrence of this condition, the fabrication process was changed to require a hold-point for an independent review of radiographs.

The fatigue crack-growth analysis of MSB-04 has been revised for the extended storage period of 60-years, as discussed in Section 3.3.3.6. The evaluation demonstrates that the growth of the flaw during the extended storage period is insignificant. Therefore, it is concluded that the cracks in the longitudinal seam weld of MSB-04 will not prevent it from performing its intended functions (primarily confinement) during the extended storage period.

3.4.3.4 Point Beach Hydrogen Ignition Event

While loading the third VSC-24 cask at Point Beach on May 28, 1996, a hydrogen ignition event occurred when welding the MSB shield lid to the MSB shell. The incident occurred when the weld arc was struck, resulting in the ignition of combustible gas that had collected in the free space at the top of the MSB cavity, which forced the MSB shield lid upward inside the shell and dislodged some of the shims that were wedged between the shield lid and shell. While no personnel were injured, no equipment was damaged, and no increase in radiological exposure to workers or the public resulted from the incident, cask-loading operations were immediately discontinued and an evaluation of the incident was initiated. Following the incident, the MSB was returned to the spent fuel pool and the SNF assemblies were removed from the MSB basket and placed in the spent fuel pool storage racks.

An NRC Augmented Inspection Team (AIT) was sent to Point Beach shortly after the incident occurred to conduct an inspection. NRC also sent a separate inspection team to the offices of SNC and, on June 3, 1996, issued CALs to the three GLs directing that measures be taken to address the potential for hydrogen ignition during MSB loading and unloading operations. On June 21, 1996, NRC issued CAL supplements to the three GLs that identified NRC concerns related to a "white foamy precipitate" that was identified when the MSB shield lid was removed from the MSB shell in the spent fuel pool. Finally, on July 5, 1996, NRC issued Bulletin 96-04 [A-13] requesting responses to questions regarding potential reactions between the spent fuel storage and transportation cask systems materials and the environments to which they are exposed.

In response, investigations were performed by SNC and the GLs to determine the causes of the incident and respond to NRC questions. Initial indications following the incident were that the coating on the MSB basket and shell internals was the likely source of the hydrogen gas generation. The coating manufacturer confirmed that the Carbo Zinc 11 coating used on the MSB basket and shell internals can react with acidic solutions, such as the borated water in the spent fuel pool, and generate hydrogen gas. Subsequent tests were performed by the GLs and NWT Corporation to determine the characteristics of the reaction between Carbo Zinc 11 and spent fuel pool water. The results of the tests confirmed that Carbo Zinc 11 reacts with spent fuel pool water and forms insoluble zinc compounds that remain on the coated surfaces, a small amount of precipitate that is released into solution and subsequently settles out on horizontal surfaces, and hydrogen gas. The hydrogen gas generation rate was determined to be sufficient to have produced ignitable concentrations in the air space inside the MSB cavity during the time required for loading operations. Hydrogen generation due to radiolysis inside the MSB was also evaluated. The results showed that radiolysis, by itself, could not have produced an ignitable concentration of hydrogen gas in the air space inside the MSB cavity during the time required for loading operations.

Investigation of the white foamy precipitate that was identified on the underside of the MSB shield lid and suspended in the spent fuel pool water upon removal of the MSB shield lid to retrieve the SNF assemblies revealed that it contained a significant organic content (approximately 40% by weight). Since there are no organic materials in cured Carbo Zinc 11 coating, and only very small concentrations of organics in the spent fuel pool water, it was concluded that the foreign material must have been introduced to the MSB assembly during either fabrication or loading operations. The GL's investigation indicated that some hydraulic fluid might have been spilled onto the shield lid during the MSB loading operations, which could have leaked into the MSB and ignited, either causing or contributing to the incident. Another aspect of the incident that was investigated is the possible reduction of boron concentration in the spent fuel pool water caused by the reaction with the Carbo Zinc 11 coating.

Soluble boron in the spent fuel pool water is required to provide criticality control during MSB loading and unloading operations. Chemical testing performed by Entergy indicated the presence of zinc borate in the precipitate. The reduction in boron concentration in the spent fuel pool water was calculated based on the amount of precipitate resulting from the tests using conservative assumptions. The results show that the decrease in the boron concentration is small in comparison to the administrative margin included in the boron concentration used for the fuel loading operation. Although it was concluded that the reaction between the Carbo Zinc 11 coating and the spent fuel pool water does not significantly reduce the amount of boron available for criticality control, the corrective actions implemented as a result of this incident include monitoring of the boron concentration inside the MSB cavity during the fuel loading operations to confirm that the design basis boron concentration requirements are satisfied.

The investigation of the incident included an assessment of the potential for hydrogen generation to occur after MSB draining and drying operations and the possible effects that the precipitates from the reaction between the coating and spent fuel pool water could have on the intended functions of the MSB assembly. Possible effects on cladding integrity and structural, thermal, and criticality performance of the MSB assembly were evaluated. In addition, the effects of radiation and elevated temperature on the precipitate were evaluated. The amount water that could remain inside the MSB cavity following the draining and drying operations was shown to produce a hydrogen concentration of only 0.0016%, compared to the 4% combustible concentration limit. Therefore, hydrogen ignition during MSB unloading operations is not credible. It was also concluded that the precipitates from the reaction would not have any significant effect on the intended functions of the system.

Because of this incident, a number of corrective actions were implemented to prevent recurrence. These included consideration of alternate MSB coatings that would not react with the spent fuel pool water, and changes to the loading and unloading procedures to address the conditions that contributed to the incident. Despite the tendency of the Carbo Zinc 11 coating to react with the borated spent fuel pool water, it was determined that its use would be continued due to its many strengths, including the ability to withstand high temperatures and high radiation.

Instead, changes were made to the loading and unloading procedures to address the potential effects of the reaction between the coating and spent fuel pool water. The changes to the loading procedures included measures to remove any foreign materials from the MSB assembly prior to loading and assure that foreign materials are not introduced into the MSB during loading, minimize the accumulation of combustible gas inside the MSB cavity, and periodically monitor the boron concentration of the water inside the MSB cavity and maintain the required boron concentration. The changes to the unloading procedure included measures to monitor the MSB cavity for combustible gases, remove combustible gases from the MSB cavity, and monitor the boron concentration of the water inside the MSB cavity and maintain the required boron concentration. The corrective actions implemented were effective in preventing recurrence of this incident in all subsequent loading operations.

3.4.3.5 MSB Storage Sleeve Tube Cracks

During fabrication of the-MSB storage sleeve tubes, stress crack indications were identified in the comer bend regions of some storage sleeve tubes by the fabricator. The condition was documented by the supplier in a nonconformance report and weld repairs of the stress-cracks were subsequently performed. Cracks identified during fabrication inspections were marked with soap stone, ground to remove the crack, and then weld repaired. During an NRC inspection of the fabricator, the NRC review team identified concerns about the fabrication and quality control inspection of the storage sleeve tubes. However, as discussed in Section 3.3 of the NRC Inspection Report No. 72-1007/97-204, the NRC inspection team verified that the fabricator had developed and implemented a detailed procedure for inspecting storage sleeve tubes for cracks, prepared nonconformance reports and weld repair travelers for defective storage sleeve tubes, and repaired storage sleeve tubes using an approved weld procedure and using qualified personnel.

The procedures used for inspecting the storage sleeve tubes for cracks and repairing detected cracks provides reasonable assurance that all stress cracks in the storage sleeve tubes have been detected and repaired. Nevertheless, a fracture mechanics analysis of a hypothetical undetected crack in a storage sleeve tubes has been performed using the methodology of Section X1 of the ASME Code to determine the potential impact on safe storage. A bounding hypothetical crack size of 0.05-inch deep by 0.3-inch long has been assumed for the analysis, based on the guidance from Appendix G of Section XI of the ASME code. The results of the fracture mechanics analysis show that the bounding hypothetical crack in the storage sleeve tube is not expected to propagate under the maximum stress conditions present during normal, off-normal, and accident conditions. Since the crack will not propagate and the sleeves are maintained in the inert environment of the MSB cavity, it is concluded that any undetected cracks in the storage sleeve tubes will not prevent the tubes from performing their intended functions during-the extended storage period.

3.4.4 Lead Cask Inspection

The lead cask inspection program further demonstrates that the VCC and MSB assemblies have not undergone unanticipated degradation while in storage in accordance with guidance provided in Appendix E of NUREG-1927 [A-11]. Each GL shall complete the initial lead cask inspection(s) at their site within 1 year after the 20 anniversary of the first cask loaded at the site or 2-years after the effective date of the CoC renewal, whichever is later, and shall repeat lead cask inspection(s) on the same cask(s) at 20-year intervals (± 1-year) during the extended storage period. The aging effects that the lead cask inspection is credited with managing are identified in Table 13. The elements of the lead cask inspection program are summarized in Table 18 and discussed in this section. The results of the initial lead cask inspection of Palisades Cask Number VSC- 15, which was performed at the end of the initial storage period to support the CoC renewal application, are discussed in Section 3.2.2.4. Other key elements of the Lead Cask Inspection AMP are discussed as follows.

Detection of Aging Effects - Sample Size (Lead Cask Selection):

The lead cask, at a given site, is selected based upon a number of parameters that contribute to degradation, such as any variations in cask design configuration (from license amendments or 72.48 changes), any variations in cask as-built configuration (due to fabrication deviations, etc.), time in service, maximum heat load of the SNF stored in the MSB, and other parameters that may contribute to degradation, such as operating history and operating conditions. However, the cask(s) selected for examination shall not be the same cask that is selected for the Examination of VSC Top End Steel Components AMP.

Each GL shall perform a lead cask inspection of one or more casks at their site, unless they provide justification that the casks at their site are bounded by lead cask inspection(s) performed for similar VSC-24 storage system(s) at other site(s). Such justifications must consider all differences in the site environment that may affect cask system aging, including ambient temperatures, humidity, salinity levels, and any significant local pollution that could enhance corrosion of any cask components. Salinity levels (which may enhance metal corrosion) must be considered in the selection of the lead cask(s), regardless of whether the site in question is a marine site. In addition to differences in site environmental parameters, the GL must consider whether the individual VSC-24 lead cask(s) inspected at the other site bounds all of the casks at the GL's site, with respect to the considerations discussed in the paragraph above.

It is possible that some parts of the overall lead cask inspection scope (discussed below) will be bounded by VSC-24 lead cask inspection(s) performed at other sites, but others will not. In that case, a GL may reduce the scope of the lead cask inspection(s) performed at their site to include only those components that are not determined to be bounded by the VSC-24 lead cask inspection(s) performed at another site.

The basis for lead cask selection, as well as any justifications for reducing or eliminating lead cask inspection scope should be documented in the 72.212 evaluation report for each site in accordance with the GL's QA program.

Inspection Scope and Methods:

The scope of the VSC-24 lead cask inspection includes remote visual examination (VT-3) of the VCC air inlets, air outlets, and cask annulus for blockage and degradation of the coated steel surface that line the ventilation flow path (i.e., similar to the AMP described in Section 3.4.2.2 and Table 15) and visual examination (VT-3) of the VSC top end steel components for coating degradation and corrosion (i.e., similar to the AMP described in Section 3.4.2.3 and Table 16).

The AMP elements for these inspections are described in Table 18. In addition, the bottom surface of the VCC assembly (i.e., the area of the VCC Bottom Plate Assembly that are normally in contact with the ISFSI pad), the bottom surface of the MSB Bottom Plate, and top surface of the VCC Cask Liner Bottom, which are all normally inaccessible, are required to be visually examined during the lead cask inspection. These additional inspections are described in Table 18 and the following paragraphs.

Remote visual examination (VT-3) is used to identify blockage in the VCC air inlets, air outlets, and cask annulus and localized (i.e., galvanic, crevice, or pitting) corrosion of the coated steel surface that line the VCC air inlets, air outlets, and cask annulus. In order to examine the VCC ventilation ducts and annulus, one or more of the VCC Air Inlet Screens or VCC Air Outlet Screens that cover the VCC air inlet and outlet ducts must be removed. Following the completion of the examination of the VCC ventilation ducts and annulus, all VCC Air Inlet Screens and VCC Air Outlet Screens must be re-attached to the VCC assembly.

VT-3 visual inspection of the VSC top end steel components may be performed directly, or using long-handled tools and/or remote visual equipment (e.g., borescope/camera), if necessary. In order to perform the visual examination of the VSC top end steel components, the VCC cask lid must be removed. If the view of the MSB closure weld and/or the top end of the MSB shell is blocked by the VCC Shielding Ring Plates (Shield Ring), it may be lifted slightly (no more than 2") to expose these surfaces for visual examination. Dose rates around the MSB closure weld shall be monitored and temporary shielding may be used to minimize occupational exposure.

Following the completion of the surveillance activities, lower the VCC Shielding Ring Plates (Shield Ring) into position (if lifted), replace the VCC cask lid gasket, secure the VCC cask lid, and replace the locking wire.

The bottom surface of the VCC assembly, which is normally inaccessible during storage, is visually examined (VT-3) for evidence of unanticipated degradation. Although the ISFSI pad is not an in-scope component SSC, it is also recommended to perform a visual inspection of the normally inaccessible ISFSI pad surface underneath the lead cask for evidence of concrete degradation, given the opportunity. The VCC is lifted off the ISFSI pad by a few inches to perform the inspections using long-handled tools and/or remote visual equipment (e.g., borescope/camera). Remote visual examination (VT-3) of the bottom surface of the MSB bottom plate and the top surface of the VCC Cask Liner Bottom, which are normally inaccessible during storage, is performed during the lead cask inspection. The MSB is lifted up by a few inches to allow inspection the two surfaces using remote visual equipment (e.g., bore-scope/camera). The bottom surface of the MSB bottom plate and the top surface of the VCC Cask Liner Bottom are examined for localized corrosion (i.e., galvanic, crevice, or pitting corrosion), which may diminish their ability to perform their design functions.

The VT-3 visual examinations of the VCC Ventilation ducts and annulus, VSC top end steel components, and VCC bottom surface shall be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 [A-4] are acceptable.

Detection of Aging Effects - Data Collection:

Data from the examination, including coating degradation and corrosion of the VSC top end steel components, blockage of the VCC air inlets and outlets and VCC annulus, coating degradation and corrosion of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, coating degradation and corrosion of the bottom surface of the MSB Bottom Plate and top surface of the VCC Cask Bottom Liner, and coating degradation and corrosion of the bottom surface of the VCC Bottom Plate, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions, when possible) for additional visual evidence, shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

Monitoring and Trending:

The data collected from each lead cask inspection shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial lead cask inspection performed during the extended storage period. Any available information from previous inspections performed during the initial storage period may also be used to inform the baseline. However, data from previous inspections performed during the initial storage period may not have been performed using the same method or technique required by this AMP, and therefore, should not be used as the basis of the baseline.

Results from each lead cask inspection shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VSC top end steel components shall be monitored for increasing trends of coating degradation and corrosion. The ventilation flow path of all VCC air inlets and outlets and the VCC annulus shall be monitored for increasing trends of blockage, coating degradation, and corrosion. The normally inaccessible bottom surface of the MSB Bottom Plate and top surface of the VCC Cask Liner Bottom shall be monitored for increasing trends in coating degradation and corrosion. The normally inaccessible bottom surface of the VCC Bottom Plate Assembly shall be monitored for increasing trends in corrosion. The GL shall evaluate trends of increasing degradation against the acceptance criteria to ensure that the rates of degradation will not result in exceeding the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Acceptance Criteria:

The bottom surface of the VCC is covered by ¼-inch thick carbon steel plate, which is secured to the VCC concrete by stud anchors and serves as cast-in-place formwork that forms the VCC air inlet ducts. The bottom plate also helps prevent loss of material (i.e., spalling of bottom concrete) in the event of a postulated bottom drop accident. Although the steel plate on the bottom surface of the VCC assembly is coated, degradation of the coating and corrosion of the steel plate is expected to occur during the initial storage period and is acceptable, provided that the steel plates lining the air inlet ducts do not displace and result in blockage of more than 10% of the air flow area. Coating degradation and general corrosion occurring on the bottom surface of the VCC Bottom Plate Assembly (excluding the air inlet ducts) will not prevent the VCC from fulfilling its intended safety functions, and need not be repaired, but is documented using appropriate means (i.e., photographs, and/or written descriptions.)

Coating degradation on the VSC top end steel components (i.e., VCC Cask Lid, VCC Liner Flange, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), MSB Structural Lid, MSB Lid Valve Covers, MSB Closure Weld, and MSB Shell (top end)) that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces (e.g., coating that is blistered, bubbled, or peeling) is not acceptable because the coating is relied upon to protect the underlying steel surfaces from corrosion. Corrosion on the underlying steel surfaces of these components shall not exceed 1/16 inch in depth. Corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.

Coating degradation and any type of corrosion on the inlet or outlet duct-facing steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross-section area) of any air flow path. General (e.g., atmospheric) corrosion on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell, and on the bottom surface of MSB Bottom Plate and top surface of VCC Cask Liner Bottom, that does not result in significant blockage (i.e., >10% of segment cross-section area) of the annulus is acceptable. However, any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell, and on the bottom surface of the MSB Bottom Plate or top surface of the VCC Cask Liner Bottom is unacceptable.

Corrective Actions:

A lead cask with blockage of the air inlets, air outlets, or annulus that exceeds the acceptance criteria shall be evaluated in accordance with the GL's corrective action program, including extent of condition (discussed below), and any blockage that can be removed by reasonable means shall be removed.

Degraded coating on the VSC top end steel components (i.e., all surfaces of the VCC Cask Lid, all readily accessible top and inner radial surfaces of VCC Liner Flange, top surface of VCC Shielding Ring Plates (Liner Assembly), top and inner radial surface of VCC Shielding Ring

Plates (Shield Ring), top surfaces of MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and top edge of the MSB Shell) that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded. In addition, if the visual examination of the VCC shield rings indicates localized corrosion (e.g., crevice corrosion) in the gap between the inner and outer VCC shielding rings, then the inner shield ring shall be lifted to allow examination of the gap surfaces and determination of corrosion depths, as described above.

Corrosion that exceeds the allowable depth acceptance criteria shall be repaired or replaced in accordance with the GL's procedures. Coating that is degraded or that has been removed to examine the underlying steel surface shall be repaired in accordance with the GL's procedures. Any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced.

Localized corrosion on the annulus-facing steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), and VCC Shielding Ring Plates (Shield Ring), and evidence of localized corrosion in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), requires additional examination to determine the corrosion depth. To determine the depth of localized corrosion on the annulus-facing steel surface of the VCC assembly, or in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), the MSB assembly must be temporarily transferred from the VCC assembly into the MTC assembly to allow direct access to VCC cavity surfaces. Coating in the area of localized corrosion shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface(s), corrosion products on the underlying steel surface(s) shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of the excavated location(s) shall be measured using a suitable measuring device (e.g., a depth probe) and recorded. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service[3] shall be repaired[4] (e.g., base metal weld repair) and recoated in accordance with the GL's procedures. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that do not exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service may be repaired, but do not require repair if they are recoated to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the VCC assembly shall be

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[3] The depth of localized corrosion that is permitted without repair is based on the maximum general corrosion rate of 0.003 inch/year for uncoated carbon steel in a marine environment that is used for the MSB Corrosion Evaluation TLAA. This criterion assures that continued general corrosion of the steel surfaces over the remainder of the renewal period, conservatively taking no credit for corrosion protection provided by the coating, will not exceed the maximum corrosion allowance of 0.18 inches based on a constant general corrosion rate of 0.003 inch/year over 60 years.

[4] Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2 inches from the perimeter of area to be welded. Following weld repair, steel surfaces shall be re-coated in accordance with coating manufacturer's instructions. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement.

removed from service and the MSB assembly shall be transferred to an acceptable VCC assembly for continued storage.

Localized corrosion on the MSB Shell or MSB Bottom Plate requires additional examination to determine the corrosion depth. The depth of localized corrosion on the MSB Shell or MSB Bottom Plate shall be determined using suitable NDE methods, such as eddy current or ultrasonic measurements, that have been qualified for use by the GL. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service[1] may be repaired[2] (e.g., base metal weld repair) and recoated (if possible), or the MSB assembly shall be removed from service, in which case the used fuel must be retrieved from the MSB assembly. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that do not exceed a depth equal to 0.003 inches times the number of years that the lead cask has been in service may be repaired (if possible), but do not require repair if the affected surface(s) are recoated to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the MSB assembly shall be removed from service, in which case the used fuel must be retrieved from the MSB assembly.

For a VCC assembly or MSB assembly with localized corrosion that is not repaired, but mitigated by recoating the affected surface(s) to prevent further corrosion, additional confirmatory VT-3 visual examinations of the affected location(s) for localized corrosion must be performed at an increased frequency (i.e., more often) in accordance with the applicable elements of this AMP to confirm the effectiveness of the mitigating actions. The initial confirmatory examination of the affected location(s) shall be performed no later than 3 years after the completion of the mitigating action. If the initial examination confirms that no further localized corrosion has occurred in the previously affected area(s), then the affected location(s) need not be inspected again until the next scheduled AMP examination. However, if a confirmatory examination identifies further localized corrosion of the previously affected location(s), then the corrective actions described above shall be repeated and the confirmatory examination frequency shall be restarted at 3 years.

Extent of Condition:

The extent of condition evaluation shall include inspection of at least two additional VSC-24 storage systems (i.e., casks) for similar degradation. The two additional casks should be selected based on maximum susceptibility to the degradation mechanism in question. For example, if unacceptable corrosion is detected, two casks of similar age (time in storage) to the lead cask may be selected. If one or more of the additional casks also show degradation in excess of the applicable acceptance criteria, then all casks at the site must be inspected, for the specific component degradation that was initially observed. Corrective actions, specified in Table 18, would be performed on all inspected casks, as necessary.

Operating Experience:

The lead cask inspection that was performed prior to the end of the initial storage period is discussed in Section 3.2.2.4. The results of that lead cask inspection show no evidence of any unanticipated aging effects that would prevent the in-scope SSC from performing their intended functions.

During the period of extended operation, each GL shall perform periodic "tollgate" assessments of OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge. The periodic tollgate assessments performed by each GL shall satisfy the requirements described in Section 3.6.

Table A-1 - Examination of VCC Assembly Exterior (5 Pages)

AMP Element	AMP Activity
Scope	Inspection of the readily accessible exterior concrete surfaces, all readily accessible exterior steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and all four (4) VCC Air Outlet Weldments, and all readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware of the VCC assembly. Portions of the VCC exterior concrete surface and steel-to-concrete interfaces that are covered by the air inlet and outlet screens or other system components (e.g., monitoring equipment) are not included in the scope of the inspection.
Preventative Actions	Maintain surface condition of concrete and exterior steel-to-concrete interfaces in order to prevent degradation of the concrete interior (e.g., reinforcing steel), and maintain the condition of the air inlet and outlet screen covers to prevent unacceptable breeches that could potentially lead to unacceptable blockage of the VCC ventilation ducts.
Parameters Monitored or Inspected	Damage/degradation of concrete exterior surface including: (1) Cracking, and loss of material (e.g., pitting, pop-outs, spalling or scaling) due to freeze-thaw, aggregate reactions, or corrosion of embedded steel, (2) Excretion of rust at crack opening due to rebar corrosion, (3) Increased porosity and/or discoloration due to CaOH leaching, or (4) Gaps or voids at the exposed steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and all four VCC Air Outlet Weldments, (5) Corrosion and/or damage of the readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware.
Detection of Aging Effects	Aging effects on the exterior concrete surfaces, the exterior steel-to-concrete interfaces of the VCC Bottom Plate Assembly and all VCC Air Outlet Weldments, and the air inlet and outlet screens and attachment hardware will be detected before the affected SSC lose the ability to perform their intended functions.
-Method or Technique:	Visual examination of the VCC concrete exterior surfaces and steel-to-concrete interfaces shall be performed per the guidelines of ACI 201.1 R-08 [A-2], or an equivalent industry consensus standard. Direct VT-3 visual examination of the air inlet and outlet screens and associated screen attachment hardware shall be performed by qualified personnel. Visual examination shall be performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing inspection of concrete surfaces and steel-to-concrete interfaces in accordance with ASME Code, Section XI, Subsection IWL [A-3] or ACI 349.3R [A-1] are both acceptable. Qualifications for personnel performing VT-3 inspection of the air inlet and outlet screens and screen attachment hardware in accordance with IWE-2330 [A-4] are acceptable.
-Frequency:	Yearly.
-Sample Size:	All in-service casks.

Table A-1 - Examination of VCC Assembly Exterior (5 Pages)

AMP Element	AMP Activity
-Data Collection:	Data shall be collected and documented in accordance with the guidelines of ACI 201.1 R-08 [A-2], or an equivalent industry consensus standard. A checklist or visual inspection form shall be used to record the inspection data. Written descriptions of observed aging effects, accompanied by crack/defect maps that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.
-Timing of inspections:	Completed the initial inspection within 1-year after the 20th anniversary of the first cask loaded at the site or 2-years after the effective date of the CoC renewal, whichever is later.
Monitoring and Trending	The data collected from each AMP examination, including crack/defect maps that identify the locations and sizes of observed aging effects, shall be monitored and trended during the extended storage period to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Available information from previous inspections performed during the initial storage period, such as VCC exterior surface inspections performed in accordance with the requirements of TS 1.3.2, may also be used to inform the baseline. Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VCC exterior surfaces shall be monitored for trends of: (1) Increasing cracking or loss of material (e.g., pitting, pop-outs, spalling or scaling) on the exterior surfaces of the concrete, (2) Increasing excretion of rust at crack opening on the VCC exterior, (3) Increasing porosity and/or discoloration on the exterior surfaces of the concrete, (4) Increasing gaps or voids at the exposed steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and all four VCC Air Outlet Weldments, (5) Increasing corrosion and/or damage of the readily accessible surfaces of all air inlet and outlet screens and associated screen attachment hardware. The GL shall evaluate trends of increasing degradation of the structure against the acceptance criteria to ensure that the rates of degradation will not result in exceeding the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.

Table A-1 - Examination of VCC Assembly Exterior (5 Pages)

AMP Element	AMP Activity
Acceptance Criteria	Concrete Surfaces: Popouts and voids less than ½ inch in diameter (or equivalent surface area) are acceptable. Scaling less than 3/16 inch deep is acceptable. Spalling that is less than 3/8 inch deep and 4 inch wide (in any dimension) is acceptable. Passive cracks less than 1 mm (0.04 inch) wide are acceptable. Passive cracks that exceed 1 mm (0.04 inch) in width, but show no indications of other degradation mechanisms are also acceptable, but must be monitored and trended for accelerated crack growth in subsequent examinations. However, passive cracks that exceed 1 mm (0.04 inch) wide and show indications of other degradation mechanisms are not acceptable. Evidence of degradation mechanisms suspected to result in loss of concrete strength (e.g., aggregate reactions, leaching, or corrosion staining) is not acceptable. Steel-to-Concrete Interfaces: Gaps or voids at the exterior steel-to-concrete interfaces less than ½ inch wide or ¼ inch deep are acceptable. Air Inlet and Outlet Screens/Hardware: Damage to the screens or attachment hardware that results in an opening no greater than ½ inch in width is acceptable. No attachment hardware can be missing or dislodged. Corrosion of the screens is acceptable if it does not cause breakage of the screen mesh ligaments or result in loose or dislodged screens. Corrosion of the screen attachment hardware is acceptable if it does not cause the attachment hardware or the screen to loosen or dislodge.
Corrective Actions	Repair of Surface Defects: Defects on the concrete exterior surface exceeding acceptance criteria shall be documented and evaluated in accordance with the GL's corrective action program. Any defects on concrete exterior surface (e.g., popouts, voids, scaling and spalling) or at the steel-to-concrete interfaces of the VCC Bottom Plate Assembly (i.e., around the bottom end of the VCC and the openings of all four air inlets) and VCC Air Outlet Weldments that exceed the acceptance criteria shall be repaired by appropriate means (e.g., filled with grout or covered with a suitable protective barrier system) in accordance with the GL's procedures. Rebar Corrosion: Concrete showing evidence of rebar corrosion, such as corrosion staining, splitting cracks, or accelerated crack growth, shall be tested using acoustic impact or other suitable NDE techniques, to detect rebar corrosion or concrete delamination (which can result from rebar corrosion), and evaluated for continued storage. A cask with aging effects due to rebar corrosion that is not acceptable for continued storage shall be repaired or replaced. Leaching and Porosity: Concrete showing evidence of leaching (staining in the form or efflorescence) and/or increased porosity shall be documented and evaluated in accordance with the GL's corrective action program. Efflorescence shall be investigated to confirm the presence of calcium hydroxide or other salts leaching from the concrete. Areas with confirmed concrete leaching and increased porosity shall be evaluated to determine the concrete compressive strength. Concrete with a compressive strength that is

Table A-1 - Examination of VCC Assembly Exterior (5 Pages)

AMP Element	AMP Activity
	lower than the design basis compressive strength shall be repaired or replaced in accordance with the GL's procedures. Aggregate Reactions: Corrective actions for concrete surfaces that show evidence of degradation from aggregate reactions, as determined by the qualified inspector, shall include a preliminary investigation to confirm or refute the presence of ASR gel in the concrete. This may consist of field tests of the affected cask(s) to detect the presence of ASR silica gel on the concrete surface using uranyl acetate fluorescence, or other suitable methods identified by the GL. Alternatively, samples of surface deposits can be sent for X-ray analysis to help determine if ASR gel is present. If ASR is confirmed by the preliminary investigation, Crack Index (CI) measurements shall be taken on the affected cask(s) in accordance with FHWA-HIF-09-004 [A-5] to determine the extent of ASR induced degradation in the concrete. Any cask with a CI that is greater than 0.5 mm/m (0.018 in/yard) and/or with crack widths that exceed 0.15 mm (0.006 in) requires detailed in-situ and/or laboratory investigations to determine the current condition of the concrete and its potential for future degradation. At a minimum, CI measurements shall continue to be taken at least twice a year for a minimum of 3 years to monitor the progression of ASR-induced degradation. After 3 years, the CI measurement frequency may be reduced to once every 5 years if the CI shows no significant increasing trend. Detailed laboratory testing, performed using concrete core samples from the cask, may include petrographic examination, mechanical testing, expansion testing, and alkali content testing, as required. The affected cask(s) shall be assessed based on the results of the detailed investigation to identify mitigation measures. A VCC assembly that is determined to have concrete that has a significant potential for further expansion due to ASR and/or does not meet the strength requirements specified in the FSAR shall be evaluated for continued storage, and repaired or replaced, if necessary. Air Inlet and Outlet Screens/Hardware Damage or Corrosion: Air inlet or outlet screens and any associated attachment hardware that does not satisfy the acceptance criteria for damage or corrosion shall be repaired or replaced. Extent of Condition Evaluation: No actions are required to evaluate extent of condition for unacceptable degradation because the extent of condition is known since examinations are required to be performed annually on all in-service casks.
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.
Administrative Controls	Formal review and approval of Corrective Actions in accordance with the GL's Corrective Action Program.

Table A-1 - Examination of VCC Assembly Exterior (5 Pages)

AMP Element	AMP Activity
Operating Experience	Hairline cracks and small pits in the VCC external concrete surface that meet the acceptance criteria have been observed during the initial storage period. Defects exceeding acceptance criteria have also been identified and repaired. Some concrete discoloration (e.g., efflorescence or mineral deposits), particularly around cracks, has also been observed on the exterior concrete of some VCCs. There has been no increasing trend in the number of reported pits seen at any of the sites for the subsequent years, nor have there been any indications of failure of grout-repairs. A small void was identified at the steel-to-concrete interface of the VCC bottom plate during the lead cask inspection at Palisades. This void is believed to have resulted from concrete pouring during construction rather than from aging effects. Bent screens and missing/damaged screen attachment hardware, which were corrected in accordance with existing maintenance procedures, have also been observed during the initial storage period. During the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge.

Table A-2 - Examination of VCC Assembly Ventilation Ducts and Annulus (5 Pages)

AMP Element	AMP Activity
Scope	Examination of the ventilation flow path of all VCC air inlets and outlets and the VCC annulus for blockage. Examination of all readily accessible(1) inside surfaces of all VCC air inlets and outlets, and all readily accessible annulus-facing surfaces of the VCC Cask Liner Bottom (i.e., surfaces not obstructed by the MSB assembly), VCC Cask Liner Shell, VCC Shield Ring Plates (Liner Assembly and Shield Ring), and MSB Shell for unacceptable corrosion.
Preventative Actions	Identify and remove any unacceptable blockage in the VCC air inlets and outlets, and VCC annulus to prevent system temperatures from exceeding the applicable temperature limits. Identify and repair any unacceptable corrosion on the coated carbon steel surfaces that line the VCC air inlets and outlets, and the VCC annulus.
Parameters Monitored or Inspected	Blockage of the internal ventilation flow path and corrosion of the coated carbon steel surfaces that line the ventilation flow path (i.e., VCC air inlets and outlets, VCC Cask Liner Bottom (i.e., surfaces not obstructed by the MSB assembly), VCC Cask Liner Shell, VCC Shield Ring Plates (Liner Assembly and Shield Ring), and MSB Shell).
Detection of Aging Effects	Identification of unanticipated blockage and degradation of the coated carbon steel surfaces on the MSB shell and VCC interior.
-Method or Technique:	Remote visual examination (VT-3) to identify blockage and localized (i.e., galvanic, crevice, or pitting) corrosion. VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 [A-4] are acceptable.
-Frequency:	5-year.
-Sample Size:	First cask placed in-service at each site.
-Data Collection:	Data from the examination, including any blockage of the VCC air inlets and outlets and VCC annulus and degradation of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., height, width, area) of the observed aging effect, and photographs for additional visual evidence, shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.
-Timing of inspections:	Completed the initial inspection within 5-years after the 20th anniversary of the first cask loaded at the site.
Monitoring and Trending	The data collected from each AMP inspection, including blockage of the VCC air inlets and outlets and VCC annulus and degradation of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by

Table A-2 - Examination of VCC Assembly Ventilation Ducts and Annulus (5 Pages)

AMP Element	AMP Activity
	this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Available information from previous inspections performed during the initial storage period, such as interior VCC surface inspections performed in accordance with the requirements of TS 1.3.3, may also be used to inform the baseline. Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The ventilation flow path of all VCC air inlets and outlets and the VCC annulus shall be monitored for increasing trends of blockage, coating degradation, and corrosion. The GL shall evaluate trends of increasing degradation of the structure against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.
Acceptance Criteria	<u>Blockage</u>: No significant blockage (i.e., >10% of segment cross-section area) of any air flow paths. <u>Coating Degradation and Corrosion</u>: Coating degradation and any type of corrosion on the duct-facing coated steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross-section area) of any air flow path. General corrosion (e.g., atmospheric corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell that does not result in significant blockage (i.e., >10% of segment cross-section area) of the annulus is acceptable. Any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell is unacceptable.
Corrective Actions	Any examination results that exceeds the acceptance criteria shall be documented and evaluated in accordance with the GL's corrective action program, including cause and extent of condition (discussed below), and the following corrective actions shall be taken: <u>Blockage</u>: Blockage that exceeds the acceptance criteria, and any blockage that can be removed by reasonable means, shall be removed. <u>Coating Degradation and Corrosion</u>: If coating degradation or corrosion that results in blockage of any airflow path that exceeds the acceptance criteria is

Table A-2 - Examination of VCC Assembly Ventilation Ducts and Annulus (5 Pages)

AMP Element	AMP Activity
	identified, then the corrective actions for blockage described above shall be taken. Localized corrosion on the annulus-facing steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), and VCC Shielding Ring Plates (Shield Ring), and evidence of localized corrosion in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), requires additional examination to determine the corrosion depth. To determine the depth of localized corrosion on the annulus-facing steel surface of the VCC assembly, or in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), the MSB assembly may be temporarily transferred from the VCC assembly into the MTC assembly to allow direct access to VCC cavity surfaces. Coating in the area of localized corrosion shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface(s), corrosion products on the underlying steel surface(s) shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of the excavated location(s) shall be measured using a suitable measuring device (e.g., a depth probe) and recorded. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(2) shall be repaired(3) (e.g., base metal weld repair) and recoated in accordance with the GL's procedures. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that do not exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(2) may be repaired(3), but do not require repair if they are recoated in accordance with the GL's procedures to prevent further corrosion of the affected location(s) <u>and</u> the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the VCC assembly shall be removed from service and the MSB assembly shall be transferred to an acceptable VCC assembly for continued storage. Localized corrosion on the MSB Shell requires additional examination to determine the corrosion depth. The depth of localized corrosion on the MSB Shell shall be determined using suitable NDE methods, such as eddy current or ultrasonic measurements, that have been qualified for use by the GL. Location(s) of localized corrosion on the MSB Shell that exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(2) may be repaired(3) (e.g., base metal weld repair) and recoated (if possible), or the MSB assembly shall be removed from service and the used fuel must be retrieved from the MSB assembly. Location(s) of localized corrosion on the MSB Shell that do not exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(2) may be repaired(3) (if possible), but do not require repair if the affected surface(s) are

Table A-2 - Examination of VCC Assembly Ventilation Ducts and Annulus (5 Pages)

AMP Element	AMP Activity
	recoated to prevent further corrosion of the affected location(s) and the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the MSB assembly shall be removed from service and the used fuel must be retrieved from the MSB assembly. For a VCC assembly or MSB assembly with localized corrosion that is not repaired, but mitigated by recoating the affected surface(s) to prevent further corrosion, additional confirmatory VT-3 visual examinations of the affected location(s) for localized corrosion must be performed at an increased frequency (i.e., more often) in accordance with the applicable elements of this AMP to confirm the effectiveness of the mitigating actions. The initial confirmatory examination of the affected location(s) shall be performed no later than 3 years after the completion of the mitigating action. If the initial examination confirms that no further localized corrosion has occurred in the previously affected area(s), then the affected location(s) need not be inspected again until the next scheduled AMP examination. However, if a confirmatory examination identifies further localized corrosion of the previously affected location(s), then the corrective actions described above shall be repeated and the confirmatory examination frequency shall be restarted at 3 years. Extent of Condition: If blockage exceeding the acceptance criteria is identified, the extent of condition evaluation shall include remote visual examination of the air inlets, air outlets, and annulus of at least two additional VSC-24 storage systems (i.e., casks) at the site for blockage. The GL shall select the additional casks based upon those factors that are most relevant to the type of blockage observed (e.g., location or orientation of the casks on the ISFSI pad or time in service). If unacceptable blockage is identified in any of the additional casks examined, then all casks at the site shall be examined for blockage. Any blockage identified in the casks examined for extent of condition that can be removed by reasonable means shall be removed. If localized corrosion is identified on the annulus-facing surfaces of the MSB Shell, VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), or VCC Shielding Ring Plates (Shield Ring) then the extent of condition evaluation shall include additional remote visual examination of the normally inaccessible surfaces of the MSB Bottom Plate and VCC Cask Liner Bottom of that cask for unacceptable corrosion. In addition, the extent of condition evaluation shall include remote visual examination of at least two additional casks for corrosion, including the normally inaccessible surfaces of the MSB Bottom Plate and VCC Cask Liner Bottom if unacceptable corrosion is identified on these surfaces of the first cask. The two additional casks should be selected based on maximum susceptibility to the type of localized corrosion identified. If unacceptable corrosion is identified in either of the additional cask inspections, then the

Table A-2 - Examination of VCC Assembly Ventilation Ducts and Annulus (5 Pages)

AMP Element	AMP Activity
	corrective actions for corrosion discussed above shall be taken, and remote visual examination for corrosion shall be performed on all casks at the site. If localized corrosion is identified on the any of the casks examined for extent of condition, then the associated corrective actions for localized corrosion discussed above shall be taken on the affected cask(s).
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.
Administrative Controls	Formal review and approval of Corrective Actions in accordance with the GL's Corrective Action Program.
Operating Experience	No significant blockage has accumulated within the ventilation flow path of the inspected casks and the majority of the steel surfaces inspected are in excellent condition, with little coating degradation or signs of general corrosion and no indications of localized corrosion. During the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge.

Notes:

(1) Surfaces that require inspection are those that may be inspected using reasonable means given the specified method or technique, considering the inspection equipment used. A surface that cannot be viewed with sufficient resolution or lighting for a qualified inspector to evaluate is not considered readily accessible.

(2) The depth of localized corrosion that is permitted without repair is based on the maximum general corrosion rate of 0.003 inch/year for uncoated carbon steel in a marine environment that is used for the MSB Corrosion Evaluation TLAA. This criterion assures that continued general corrosion of the steel surfaces over the remainder of the renewal period, conservatively taking no credit for corrosion protection provided by the coating, will not exceed the maximum corrosion allowance of 0.18 inches based on a constant general corrosion rate of 0.003 inch/year over 60 years.

(3) Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2-inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement. Following weld repair, steel surfaces shall be re-coated in accordance with the GL's procedures.

Table A-3 - Examination of VSC Top End Steel Components (4 Pages)

AMP Element	AMP Activity
Scope	Inspection of the following component surfaces for coating degradation and corrosion: • All surfaces of the VCC Cask Lid and VCC Lid Bolts; • Readily accessible top and inner radial surfaces of the VCC Liner Flange; • Top surface (chamfer and weld) of the VCC Shielding Ring Plates (Liner Assembly); • Top and inner radial surface of the VCC Shielding Ring Plates (Shield Ring);(1) • Top surfaces of the MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and top edge of the MSB Shell; Replacement of the VCC lid gasket and locking wire.(2)
Preventative Actions	Identification and repair of any coating degradation or corrosion on the VCC top interior components prevents continued degradation that could potentially affect the ability of the SCCs to perform their intended functions during the extended storage period.
Parameters Monitored or Inspected	Coating degradation and corrosion of the steel surfaces of the VSC top end steel components (i.e., VCC Cask Lid and VCC Lid Bolts, VCC Liner Flange, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and the MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and MSB Shell) that are identified in the AMP scope.
Detection of Aging Effects	Identification of unanticipated degradation on the VCC top interior surfaces; Identification of unanticipated degradation on the top surfaces of the MSB assembly.
-Method or Technique:	Direct or remote VT-3 visual examination of readily accessible surfaces. VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 [A-4] are acceptable.
-Frequency:	10-year (± 1 year).
-Sample Size:	One cask at each site.(3)
-Data Collection:	Data from the examination, including coating degradation and corrosion of the VSC top end steel components, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.

Table A-3 - Examination of VSC Top End Steel Components (4 Pages)

AMP Element	AMP Activity
-Timing of Inspections:	Completed the initial inspection within 1-year after the 20th anniversary of the first cask loaded at the site or within 2-years after the effective date of the CoC renewal, whichever is later.
Monitoring and Trending	The data collected from each AMP inspection, including coating degradation and corrosion on all VSC top end steel components, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Any available information from previous inspections performed during the initial storage period may also be used to inform the baseline. Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VSC top end steel components shall be monitored for increasing trends of coating degradation and corrosion, which shall be evaluated against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.
Acceptance Criteria	No coating degradation on the examined surfaces that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces (e.g., coating that is blistered, bubbled, or peeling). Corrosion on the underlying steel shall not exceed 1/16 inch in depth. Corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.
Corrective Actions	All examination results that do not satisfy the applicable acceptance criteria shall be documented and evaluated in accordance with the GL's Corrective Action Program, including cause and extent of condition (discussed below), and the following corrective actions shall be taken: Degraded coating that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, which shall be visually examined for corrosion. Corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded. Steel components with corrosion that exceeds the allowable depth acceptance criteria shall be repaired(4) or replaced in accordance with the GL's procedures. Coating that is degraded or that has been removed to examine the underlying steel surface shall be repaired(4) in accordance with

Table A-3 - Examination of VSC Top End Steel Components (4 Pages)

AMP Element	AMP Activity
	the GL’s procedures. Any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced. The extent of condition evaluation shall include visual examination of at least two additional VSC-24 storage systems (i.e., casks) for coating degradation and/or corrosion. The GL shall select the additional casks to be inspected based upon the factors that contribute most significantly to the observed degradation on the first cask (e.g., time in service, heat load, or fabrication differences). If coating degradation and/or corrosion is identified in either of the additional cask inspections that do not satisfy the acceptance criteria, it shall be entered into the GL’s corrective action program and the extent of condition evaluation shall be expanded to include visual examination of all casks at the site for coating degradation and/or corrosion.
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.
Administrative Controls	Formal review and approval of Corrective Actions in accordance with the GL's Corrective Action Program.
Operating Experience	The results of the initial lead cask inspection performed on Palisades Cask No. VSC-15 show that there has been no unanticipated degradation of the VSC top end steel components during the initial storage period. The top end of the MSB assembly (structural lid and closure weld) had no evidence of significant corrosion, although small areas of coating were scraped off when temporary shielding used during the inspection was removed. The steel surfaces under the damaged coating showed no signs of significant corrosion. The areas of damaged coating were subsequently cleaned and recoated. During the period of extended operation, each GL shall perform periodic “tollgate” assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge.

Notes on following page:

Notes for Table A-3:

(1) If the VCC Shielding Ring Plate (Shield Ring) is lifted to expose the MSB closure weld and shell top edge for visual examination, then the top portion of the outer radial surface on the VCC Shielding Ring Plate (Shield Ring) that is exposed when lifted shall also be visually inspected for coating degradation and corrosion.

(2) The VCC lid gasket shall be replaced with a new gasket prior to re-installation of the VCC cask lid following the inspection, regardless of its condition.

(3) The examination shall be performed on the first cask loaded at each site. Alternatively, the GL may select a different cask for inspection based on maximum cask heat load or cask accessibility. However, the same cask shall be used for the subsequent examinations such that trending can be performed. In addition, the cask selected shall not be the cask selected for the Lead Cask Inspection AMP.

(4) Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2-inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement. Following weld repair, steel surfaces shall be re-coated in accordance with the GL's procedures.

Table A-4 - Examination of MTC Assembly (2 Pages)

AMP Element	AMP Activity
Scope	Visual examination of following component surfaces of the MTC assembly for coating degradation and corrosion: • Exposed external surfaces of the Outer Shell, Inner Shell, Top Ring, and Bottom Ring; • Inner and outer surfaces (i.e., those normally covered by the Trunnion Cylinder / End Cover) of both Trunnions; • All surfaces of the MTC Lid, Lid Bolts, and Shim/Flange; • All readily accessible surfaces of the Rail Shields, Rail Lower Plates, and Shield Doors (with shield doors in fully-opened and fully-closed positions).
Preventative Actions	Identification and repair of unacceptable coating degradation and corrosion on the exposed surfaces of the MTC assembly prevents continued degradation that could potentially affect the ability of the SCCs to perform their intended functions during the extended storage period, protects pool chemistry during fuel loading/unloading operations, and facilitates decontamination of the exposed MTC surfaces.
Parameters Monitored or Inspected	Degradation of the coating and corrosion of the underlying carbon steel on all readily accessible surfaces.
Detection of Aging Effects	Identification of unanticipated degradation of coatings, corrosion of the MTC assembly subcomponents.
-Method or Technique:	Direct VT-3 visual examination of readily accessible surfaces. VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the MTC assembly in accordance with the requirements of IWE-2330 [A-4] are acceptable.
-Frequency:	10-years (± 1 year) when not in use and within 1-year prior to use.
-Sample Size:	Each MTC assembly.
-Data Collection:	Data from the examination, including any observed coating degradation and corrosion of the exterior surfaces of the MTC assembly, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions), shall be used to further document the results of the inspection. Video coverage of the examination may also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.
-Timing of inspections:	Completed the initial inspection within 1-year after the 20th anniversary of the first cask loaded at the site or 2-years after the effective date of the CoC renewal, whichever is later.

Table A-4 - Examination of MTC Assembly (2 Pages)

AMP Element	AMP Activity
Monitoring and Trending	The data collected from each AMP inspection, including coating degradation and corrosion on all readily accessible interior and exterior surfaces of the MTC assembly, shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial inspection performed during the extended storage period. Any available information from previous maintenance activities performed during the initial storage period may also be used to inform the baseline. Results from each AMP examination shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The coated steel surfaces of the MTC assembly shall be monitored for increasing trends of coating degradation and corrosion, which shall be evaluated against the acceptance criteria to ensure that the rates of degradation will not result in aging effects that exceed the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.
Acceptance Criteria	Individual local areas of coating loss may not expose more than 2 in^2 of underlying steel and the total combined coating loss may not expose more than a total of 40 in^2 of underlying steel. Corrosion must not exceed 10% of a component's nominal thickness (or depth) or reduce a bolts nominal cross-sectional area by more than 5%.
Corrective Actions	Areas of degraded coating that exceed the acceptance criteria shall be documented and evaluated in accordance with the GL's corrective action program, and repaired by re-coating in accordance with the GL's procedures. If corrosion has resulted loss of material that exceeds that acceptance criteria, the affected components shall be repaired(1) or replaced.
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.
Administrative Controls	Formal review and approval of Corrective Actions in accordance with the GL's Corrective Action Program.
Operating Experience	During the period of extended operation, each GL shall perform periodic "tollgate" assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge.

Notes:

(1) Prior to making weld repairs on the coated steel surfaces of the MTC assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2-inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement. Following weld repair, steel surfaces shall be re-coated in accordance with the GL's procedures.

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
Scope	Direct visual examination of the following readily accessible surfaces of the lead cask: • All surfaces of VCC Cask Lid and VCC Lid Bolts; • Readily accessible top and inner radial surfaces of VCC Liner Flange; • Top surface (chamfer and weld) of VCC Shielding Ring Plates (Liner Assembly); • Top and inner radial surface of VCC Shielding Ring Plates (Shield Ring);(1) • Top surfaces of MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and top edge of the MSB Shell; Remote visual examination of the following readily accessible surfaces(1) of the lead cask: • All readily accessible(1) duct-facing surfaces of all VCC air inlets and outlets; • All readily accessible(1) annulus-facing surfaces of VCC Cask Liner Shell and MSB Shell; • All readily accessible annulus-facing surfaces (i.e., bottom surfaces) of VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shielding Ring). Remote visual examination of the normally inaccessible surfaces(1) of the lead cask: • Bottom surface of VCC Bottom Plate Assembly (requires VCC assembly to be lifted); • Bottom surface of MSB Bottom Plate and top surface of VCC Cask Liner Bottom (requires MSB assembly to be lifted). Replacement of VCC Lid Gasket and locking wire.(2)
Preventative Actions	Identify and remove any unacceptable blockage in VCC ventilation ducts and annulus to prevent system temperatures from exceeding the applicable temperature limits. Identify and repair, as applicable, of any unacceptable coating degradation or corrosion on the coated carbon steel components to prevent continued degradation that could potentially affect the ability of the SCCs to perform their intended functions during the extended storage period.
Parameters Monitored or Inspected	Degradation of the VCC bottom surface; blockage of the VCC internal ventilation flow path; degradation of the coated carbon steel surfaces that line the VCC ventilation flow path (i.e., VCC Air Inlet Assemblies and VCC Air Outlet Weldments, VCC Cask Liner Shell, and MSB Shell); degradation of the coated carbon steel surfaces on the MSB Bottom Plate and VCC Cask Liner Bottom; and degradation of the VCC Cask Lid, VCC Liner Flange, VCC Lid Bolts, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), MSB Structural Lid, MSB Lid Valve Covers, and MSB Closure Weld.

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
Detection of Aging Effects	Identification of unacceptable blockage in the ventilation flow path and unacceptable coating degradation and/or corrosion on all metal surfaces.
-Method or Technique:	Direct VT-3 visual examination of VSC top end steel components and remote VT-3 visual examination of the VCC ventilation flow path, MSB bottom plate, VCC cask liner bottom, and VCC bottom surface. VT-3 visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.65). Qualifications for personnel performing the VT-3 visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 are acceptable.
-Frequency:	20-year (± 1-year).
-Sample Size:	One or more casks at each site.(3)
-Data Collection:	Data from the examination, including coating degradation and corrosion of the VSC top end steel components, blockage of the VCC air inlets and outlets and VCC annulus, coating degradation and corrosion of coated carbon steel surfaces that line the VCC air inlets and outlets and VCC annulus, coating degradation and corrosion of the bottom surface of the MSB Bottom Plate and top surface of the VCC Cask Bottom Liner, and coating degradation and corrosion of the bottom surface of the VCC Bottom Plate, shall be collected and documented on a checklist or visual inspection form. Written descriptions of observed aging effects, accompanied by sketches that identify the location and size (e.g., width, area, and depth) of the observed aging effect, and photographs (including a scale to indicate dimensions, when possible) for additional visual evidence, shall be used to further document the results of the inspection. Video coverage of the examination should also be used to document the inspection, as it may provide additional information that is useful for evaluation of inspection results. Corrective actions resulting from each AMP inspection shall also be documented.
-Timing of inspections:	Completed the initial lead cask inspection within 1-year after the 20th anniversary of the first cask loaded at the site, or 2-years after the effective date of the CoC renewal, whichever is later.
Monitoring and Trending	The data collected from each lead cask inspection shall be monitored and trended to identify progressive growth of defects that may indicate potentially accelerated degradation due to aging effects managed by this AMP. A baseline shall be developed from the initial lead cask inspection performed during the extended storage period. Any available information from previous inspections performed during the initial storage period may also be used to inform the baseline. Results from each lead cask inspection shall be compared with those from all previous inspections in the extended storage period to identify trends of increasing degradation of the structure. The VSC top end steel components shall be monitored for increasing trends of coating degradation and corrosion. The ventilation flow path of all VCC air inlets and outlets and the VCC annulus shall be monitored for increasing trends of blockage, coating degradation, and corrosion. The normally inaccessible bottom surface of the MSB Bottom Plate

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
	and top surface of the VCC Cask Liner Bottom shall be monitored for increasing trends in coating degradation and corrosion. The normally inaccessible bottom surface of the VCC Bottom Plate Assembly shall be monitored for increasing trends in corrosion. The GL shall evaluate trends of increasing degradation against the acceptance criteria to ensure that the rates of degradation will not result in exceeding the corresponding acceptance criteria before the next scheduled inspection. Trends that indicate that acceptance criteria may be exceeded prior to the next scheduled inspection shall be documented and evaluated in accordance with the GL's corrective action program, and appropriate corrective actions (e.g., mitigating actions or increased inspection frequency) shall be taken to prevent acceptance criteria from being exceeded.
Acceptance Criteria	<ins>Blockage</ins>: No significant blockage (i.e., >10% of segment cross-section area) of any airflow paths. <ins>Coating Degradation and Corrosion</ins>: Coating degradation and corrosion on the bottom end of the VCC assembly (i.e., the bottom surface of the VCC Bottom Plate Assembly) is expected and acceptable provided that it does not results in significant blockage (i.e., >10% of segment cross-section area) of the air inlets. Coating degradation and any type of corrosion on the inlet or outlet duct-facing steel surfaces of the VCC air inlets and air outlets is acceptable provided that it does not result in significant blockage (i.e., >10% of segment cross-section area) of any air flow path. General (e.g., atmospheric) corrosion on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell, and on the bottom surface of MSB Bottom Plate and top surface of VCC Cask Liner Bottom, that does not result in significant blockage (i.e., >10% of segment cross-section area) of the annulus is acceptable. Any localized corrosion (e.g., galvanic, crevice, or pitting corrosion) on the annulus-facing coated steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), and MSB Shell, and on the bottom surface of the MSB Bottom Plate or top surface of the VCC Cask Liner Bottom is unacceptable. Coating degradation on the VSC top end steel components (i.e., VCC Cask Lid, VCC Liner Flange, VCC Shielding Ring Plates (Liner Assembly), VCC Shielding Ring Plates (Shield Ring), MSB Structural Lid, MSB Lid Valve Covers, MSB Closure Weld, and MSB Shell (top end)) that exposes the underlying steel surfaces or indicates potential corrosion of the underlying steel surfaces (e.g., coating that is blistered, bubbled, or peeling) is

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
	unacceptable. Corrosion on the underlying steel surfaces of these components shall not exceed 1/16 inch in depth. Corrosion on any VCC lid bolt must not reduce its cross section area by more than 5%.
Corrective Actions	All examination results that do not satisfy the applicable acceptance criteria shall be documented and evaluated in accordance with the GL's Corrective Action Program, including cause and extent of condition (discussed below), and the following corrective actions shall be taken: Blockage: Blockage that exceeds the acceptance criteria, and any blockage that that can be removed by reasonable means, shall be removed. Coating Degradation and Corrosion: Coating degradation or corrosion resulting in blockage of any airflow path that exceeds the acceptance criteria, and any blockage that that can be removed by reasonable means, shall be removed. Degraded coating on the VSC top end steel components (i.e., all surfaces of the VCC Cask Lid, all readily accessible top and inner radial surfaces of VCC Liner Flange, top surface of VCC Shielding Ring Plates (Liner Assembly), top and inner radial surface of VCC Shielding Ring Plates (Shield Ring), top surfaces of MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and top edge of the MSB Shell) that indicates potential corrosion of the underlying steel surfaces shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface, corrosion products identified on the underlying metal surface shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of corrosion (relative to the adjacent uncoated surface) shall be measured using a suitable measure device (e.g., a depth probe) and recorded. In addition, if the visual examination of the VCC shield rings indicates localized corrosion (e.g., crevice corrosion) in the gap between the inner and outer VCC shielding rings, then the inner shield ring shall be lifted to allow examination of the gap surfaces and determination of corrosion depths, as described above. All surfaces of the VCC Cask Lid, all readily accessible top and inner radial surfaces of VCC Liner Flange, top surface of VCC Shielding Ring Plates (Liner Assembly), top and inner radial surface of VCC Shielding Ring Plates (Shield Ring), top surfaces of MSB Structural Lid, MSB Valve Covers, MSB Closure Weld, and top edge of the MSB Shell with corrosion that exceeds the allowable depth acceptance criteria shall be repaired(4) or replaced in accordance with the GL's procedures. Coating that is degraded or that has been removed to examine and/or repair the underlying steel surface shall be repaired in accordance with the GL's procedures. Any VCC lid bolt(s) that do not satisfy the corrosion acceptance criteria shall be replaced. Localized corrosion on the annulus-facing steel surfaces of the VCC Cask Liner Bottom, VCC Cask Liner Shell, VCC Shielding Ring Plates (Liner Assembly), and VCC Shielding Ring Plates (Shield Ring), and evidence of

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
	localized corrosion in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), requires additional examination to determine the corrosion depth. To determine the depth of localized corrosion on the annulus-facing steel surface of the VCC assembly, or in the gap between the VCC Shielding Ring Plates (Liner Assembly) and VCC Shielding Ring Plates (Shield Ring), the MSB assembly must be temporarily transferred from the VCC assembly into the MTC assembly to allow direct access to VCC cavity surfaces. Coating in the area of localized corrosion shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to expose the underlying steel surface(s), corrosion products on the underlying steel surface(s) shall be removed by appropriate means (e.g., a scraper, wire brush, or grinder) to reveal "clean" metal, and the depth of the excavated location(s) shall be measured using a suitable measuring device (e.g., a depth probe) and recorded. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(5) shall be repaired(4) (e.g., base metal weld repair) and recoated in accordance with the GL's procedures. Locations of localized corrosion on the annulus-facing steel surface of the VCC assembly that do not exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(5) may be repaired(4) and recoated in accordance with the GL's procedures, but do not require repair if they are recoated in accordance with the GL's procedures to prevent further corrosion of the affected location(s) <u>and</u> the frequency of subsequent examinations is increased to confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the VCC assembly shall be removed from service and the MSB assembly shall be transferred to an acceptable VCC assembly for continued storage. Localized corrosion on the MSB Shell or MSB Bottom Plate requires additional examination to determine the corrosion depth. The depth of localized corrosion on the MSB Shell or MSB Bottom Plate shall be determined using suitable NDE methods, such as eddy current or ultrasonic measurements, that have been qualified for use by the GL. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(5) may be repaired(4) (e.g., base metal weld repair) and recoated (if possible) in accordance with the GL's procedures, or the MSB assembly shall be removed from service and the used fuel must be retrieved from the MSB assembly. Location(s) of localized corrosion on the MSB Shell or MSB Bottom Plate that do not exceed a depth equal to 0.003-inches times the number of years that the lead cask has been in service(5) may be repaired(4) (if possible) and recoated in accordance with the GL's procedures, but do not require repair if the affected surface(s) are recoated in accordance with the GL's procedures to prevent further corrosion of the affected location(s) <u>and</u> the frequency of subsequent examinations is increased to

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
	confirm the effectiveness of the mitigating actions, as discussed below. If no mitigating action is taken, the MSB assembly shall be removed from service and the used fuel must be retrieved from the MSB assembly. For a VCC assembly or MSB assembly with localized corrosion that is not repaired, but mitigated by recoating the affected surface(s) to prevent further corrosion, additional confirmatory VT-3 visual examinations of the affected location(s) for localized corrosion must be performed at an increased frequency (i.e., more often) in accordance with the applicable elements of this AMP to confirm the effectiveness of the mitigating actions. The initial confirmatory examination of the affected location(s) shall be performed no later than 3 years after the completion of the mitigating action. If the initial examination confirms that no further localized corrosion has occurred in the previously affected area(s), then the confirmatory examination interval may be increased to 7 years (i.e., no later than 10 years after the completion of the mitigating action). If the second confirmatory examination confirms that no further localized corrosion has occurred in the previously affected location(s), then the affected location(s) need not be inspected again until the next scheduled Lead Cask Inspection. However, if a confirmatory examination identifies further localized corrosion of the previously affected location(s), then the corrective actions described above shall be repeated and the confirmatory examination frequency shall be restarted at 3 years. Extent of Condition: The extent of condition evaluation shall include examination of at least two additional VSC-24 storage systems (i.e., casks) at the site for the unacceptable degradation identified in the lead cask inspection. The GL shall select the additional casks based upon those factors that are most relevant the type of unacceptable degradation observed (e.g., location or orientation of the cask on the ISFSI pad or time in service). If unacceptable degradation is identified in any of the additional cask examinations, then the condition shall be evaluated in accordance with the GL's corrective action program, the cask shall be repaired or replaced, as necessary, and all remaining casks at the site shall be examined for the identified degradation.
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.
Administrative Controls	Documentation of lead cask selection, basis for relying on lead cask inspections performed as other sites as bounding, and lead cask inspection results are documented in the GL's 10 CFR 72.212 report. Formal review and approval of Corrective Actions are performed in accordance with the GL's Corrective Action Program.
Operating Experience	The results of the initial lead cask inspection performed on Palisades Cask No. VSC-15 show that there has been no unanticipated degradation of the inspected components during the initial storage period. The bottom surface of the VCC did not show any evidence of significant corrosion or degradation. The readily accessible surfaces of the MSB shell and VCC liner, inlets, and outlets had no evidence of significant corrosion and all air flow paths were

Table A-5 - Lead Cask Inspection (7 Pages)

AMP Element	AMP Activity
	free of blockage. Finally, the top end of the MSB assembly (structural lid and closure weld) showed no evidence of significant coating degradation and no corrosion. During the period of extended operation, each GL shall perform periodic “tollgate” assessments of aggregated OE and other information related to the aging effects and mechanisms addressed by this AMP to determine if changes to the AMP are required to address the current state-of-knowledge.

Notes:

(1) Surfaces that require inspection are those that may be inspected using reasonable means given the specified method or technique, considering the inspection equipment used. A surface that cannot be viewed with sufficient resolution or lighting for a qualified inspector to evaluate is not considered readily accessible.

(2) The VCC lid gasket shall be replaced prior to re-installation of the VCC cask lid following the inspection, regardless of its condition.

(3) Each GL must perform lead cask inspection(s) at their site unless they provide justification that their casks are bounded by lead cask inspection(s) performed for similar VSC-24 storage systems at other site(s). The lead cask(s) are selected based upon those parameters that may contribute to degradation, such as time in service, heat load (temperature), design configuration, and operating conditions/history. The cask(s) selected shall not be the same cask used for the Examination of VSC Top End Steel Components AMP.

(4) Prior to making weld repairs on the coated steel surfaces of the VCC assembly or MSB assembly, the coating on the surface to be repaired shall be removed over an area extending at least 2-inches from the perimeter of area to be welded. This assures that the coating temperature during the weld repair does not exceed its maximum service temperature in order to avoid the potential for liquid metal embrittlement. Following weld repair, steel surfaces shall be re-coated in accordance with the GL’s procedures.

(5) The depth of localized corrosion that is permitted without repair is based on the maximum general corrosion rate of 0.003 inch/year for uncoated carbon steel in a marine environment that is used for the MSB Corrosion Evaluation TLAA. This criterion assures that continued general corrosion of the steel surfaces over the remainder of the renewal period, conservatively taking no credit for corrosion protection provided by the coating, will not exceed the maximum corrosion allowance of 0.18 inches based on a constant general corrosion rate of 0.003 inch/year over 60 years.

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