ENERGYSOLUTIONS
Spent Fuel Division

October 12, 2012
SFD/NRC 12-004
Docket No. 72-1007

ATTN: Document Control Desk
Director, Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: **VSC-24 Ventilated Storage Cask Certificate of Compliance Renewal Application**

Reference: U.S. Nuclear Regulatory Commission, Certificate of Compliance for Spent Fuel Storage Casks, Model No.: Ventilated Storage Cask (VSC-24), Certificate No. 1007, Docket No. 72-1007.

Pursuant to 10 CFR 72.240(b), Energy*Solutions* Spent Fuel Division (Energy*Solutions* SFD) hereby submits the enclosed application for renewal of Certificate of Compliance (CoC) Number 1007 (Reference 1) for the VSC-24 Ventilated Storage Cask. The current expiration date on the CoC is May 7, 2013. Energy*Solutions* SFD is requesting CoC renewal for a term of 40 years in accordance with 10 CFR 72.240(a), which will extend the CoC expiration date to May 7, 2053. As required by 10 CFR 72.240(c)(2), the CoC renewal application includes Time-Limited Aging Analyses (TLAA) that demonstrate that structures, systems, and components important to safety will continued to perform their intended functions for the requested period of extended operation. Furthermore, a description of the Aging Management Program (AMP) is included in the CoC renewal application, as required by 10 CFR 72.240(c)(3).

Should you or any member of your staff have questions, please contact the undersigned at (408) 558-3509.

Sincerely,

Steven E. Sisley
Licensing/Regulatory Compliance Manager
Energy*Solutions* Spent Fuel Division, Inc.

Enclosure: Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. LAR 1007-007, Revision 0.

Cc w/ enclosure

Bernard White, U.S. NRC, NMSS, SFST
Pamela Longmire, PhD, U.S. NRC, NMSS, SFST

2105 South Bascom Ave., Suite 230 • Campbell, California 95008
408.558.3500 • Fax 408.558.3518 • www.energysolutions.com

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Enclosure

Certificate of Compliance Renewal Application for the VSC-24 Ventilated Storage Cask System (Docket No. 72-1007), Document No. VSC-04.1100, Revision 0

(six paper copies)

Certificate of Compliance Renewal Application

For the

VSC-24 Ventilated Storage Cask System

(Docket No. 72-1007)

Prepared by:

Energy*Solutions* Spent Fuel Division, Inc.

Campbell, CA

Document No. LAR 1007-007

Revision 0

October 12, 2012

Certificate of Compliance Renewal Application
For the
VSC-24 Ventilated Storage Cask System

(Docket No. 72-1007)

Prepared by:

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Campbell, CA

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LIST OF ACRONYMS AND ABBREVIATIONS

ACI	American Concrete Institute
AIT	Augmented Inspection Team
AMA	Aging Management Activity
AMP	Aging Management Program
AMR	Aging Management Review
ANO	Arkansas Nuclear One
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society of Testing and Materials
BPRA	Burnable Poison Rod Assembly
B&W	Babcock and Wilcox
CAL	Corrective Action Letter
CC	Criticality Control (intended function)
CE	Combustion Engineering
CH	Certificate Holder
CoC	Certificate of Compliance
CFR	Code of Federal Regulations
CLB	Current Licensing Basis
DFI	Demand For Information
DHC	Delayed Hydride Cracking
ES	Energy*Solutions*
FSAR	Final Safety Analysis Report
GL	General Licensee
HAZ	Heat-Affected Zone
HT	Heat Transfer (intended function)
ISFSI	Independent Spent Fuel Storage Installation
ITS	Important-to-Safety
LAR	License Amendment Request
kW	Kilowatt
MPa	Megapascal
MSB	Multi-assembly Sealed Basket
MTC	MSB Transfer Cask
MTU	Metric Ton Uranium

LIST OF ACRONYMS AND ABBREVIATIONS

MWd	Megawatt Day
NDE	Nondestructive Examination
NITS	Not-Important-To-Safety
NRC	U.S. Nuclear Regulatory Commission
PWR	Pressurized Water Reactor
PR	Pressure Boundary, i.e., confinement (intended function)
PT	Liquid Penetrant Test
RS	Radiation Shielding (intended function)
RT	Radiographic Test
SFA	Spent Fuel Assembly
SNF	Spent Nuclear Fuel
SS	Structural Support (intended function)
SSC	Structure, System, and Component
TLAA	Time-Limited Aging Analysis
UT	Ultrasonic Test
VCC	Ventilated Concrete Cask
VSC	Ventilated Storage Cask

1. General Information

The VSC-24 Ventilated Storage Cask System (hereafter referred to as the VSC-24 Storage System) is approved under 10 CFR 72, Subpart K (Docket No. 72-1007) for 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. The VSC-24 Certificate of Compliance (CoC) was initially issued on May 7, 1993 with an expiration date of May 7, 2013. Energy*Solutions* (ES), as the Certificate Holder (CH) of the VSC-24 Storage System CoC No. 1007 [1.1], is applying for renewal of CoC No. 1007 for a term of 40 years in accordance with 10 CFR 72.240(a). The requested 40-year CoC renewal term will extend the CoC expiration date to May 7, 2053. The VSC-24 Storage System CoC renewal application includes information required by 10 CFR 72.240(c), including:

(1) The design basis information as documented in the most recent updated Final Safety Analysis Report (FSAR) [1.2] as required by 10 CFR 72.248,

(2) Time-Limited Aging Analyses (TLAAs) that demonstrate that Structures, Systems, and Components (SSC) Important-to-Safety (ITS) will continue to perform their intended function for the requested period of extended operation, and

(3) A description of the Aging Management Program (AMP) for management of issues associated with aging that could adversely affect structures, systems, and components important to safety.

In accordance with 10 CFR 72.240(d), the VSC-24 CoC renewal application demonstrates that the storage of SNF has not adversely affected SSC ITS in a significant manner.

1.1 Background

1.1.1 VSC-24 CoC Amendment History

The initial VSC-24 Storage System CoC was issued on May 7, 1993. Subsequently, six (6) amendments were issued to the VSC-24 Storage System CoC. A summary of the VSC-24 Storage System CoC amendment history is provided in the following paragraphs, including a general description of the changes and reasons for each amendment. An overall timeline of the VSC-24 Storage System CoC amendments history is shown in Figure 1.

Amendment No. 1 – Burnable Poison Rod Assemblies (BPRA):

In December 1998, License Amendment Request (LAR) 98-01 was submitted to U.S. Nuclear Regulatory Commission (NRC) requesting that the VSC-24 Technical Specifications be revised to allow storage of Babcock & Wilcox (B&W) fuel with BPRAs. These changes were part of a previously docketed 1993 LAR that was withdrawn by the CH with a commitment to address the proposed changes, and other outstanding issues, in a future LAR. The request, as supplemented, was approved by NRC in Amendment 1 and was effective on May 30, 2000.

Amendment No. 2 – Demand For Information (DFI) Amendment:

In November 1998, a LAR (DFI Amendment) was submitted in response to a request by NRC to conform to the existing NRC Safety Evaluation Report (SER) for the previously docketed revisions of the FSAR. In addition, the LAR incorporated changes identified by NRC for closure of Confirmatory Action Letter (CAL) 97-7-01, design upgrades and calculation revisions, expanded explanation of the closure weld process and Ultrasonic Test (UT) examination, clarified ASME Code requirements for Non-Destructive Examination (NDE) of temporary attachments and impact testing of welds, base metal, and Heat Affects Zone (HAZ), address hydrogen generation of Carbo-Zinc coating in boric acid solution (NRC Bulletin 96-04), and correct errors in the thermal analysis of the VCC. The request, as supplemented, was approved by NRC in Amendment 2 and was effective on September 5, 2000.

Amendment No. 3 – CE 16x16 Fuel Amendment:

In March 2000, LAR 00-01 was submitted to NRC requesting specific changes to the VSC-24 Technical Specifications for CE 16x16 fuel assemblies. The LAR requested that the fuel specification for CE 16x16 fuel be based on a boron concentration (vs. initial enrichment) curve rather than minimum burnup. The LAR also requested reformatting of the TS to move the TS bases to a separate section. The request, as supplemented, was approved by NRC in Amendment 3 and was effective on May 21, 2001.

Amendment No. 4 – Fuel Specification Amendment:

In March 2001, LAR 01-01 (e.g., Fuel Specification Amendment) was submitted to NRC requesting that the VSC-24 Technical Specifications be changed to permit storage of fuel assemblies with inserted control components and stainless steel dummy rods to address the future needs of the GLs and to provide the technical basis for some fuel assemblies previously loaded at Palisades. Some of these changes were part of a previously docketed 1993 LAR that was withdrawn by the CH with a commitment to address the proposed changes, and other outstanding issues, in a future LAR. In addition, the maximum assembly average burnup level was reduced from 51,800 MWd/MTU to 45,000 MWd/MTU in LAR 01-01.[1] The request, as supplemented, was approved by NRC in Amendment 4 and was effective on February 3, 2003.

Amendment No. 5 – CH Name Change:

In November 2004, a LAR was submitted to NRC requesting that the CH on the VSC-24 CoC be changed to BNFL Fuel Solutions Corporation (BFS). In April 2005, the request was revised to change the CH on the VSC-24 CoC to BNG Fuel Solutions Corporation (BFS). The request, as supplemented, was approved in Amendment 5 and was effective on September 13, 2005.

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[1] No fuel assemblies with burnups exceeding 45,000 MWd/MTU have been loaded in any VSC-24 casks.

Amendment No. 6 – Elimination of Temperature Monitoring:

In June 2005, a LAR was submitted to NRC requesting to eliminate the daily temperature measurement surveillance TS requirement and incorporate editorial changes associated with the CH name change. The request was approved in Amendment 6, which was effective on June 5, 2006.

No additional amendments to the VSC-24 CoC have been requested.

1.1.2 VSC-24 Storage Cask Loading Overview

To date, a total of fifty eight (58) VSC-24 casks are loaded and stored at three different ISFSIs; eighteen (18) casks at the Palisades nuclear power plant in Michigan, sixteen (16) casks at the Point Beach nuclear power plant in Wisconsin, and twenty four (24) casks at the Arkansas Nuclear One (ANO) nuclear power plant in Arkansas. An overall timeline of the VSC-24 cask loading dates is provided in Table 1 and Figure 2. All VSC-24 casks at these three ISFSIs were loaded and placed into storage between May 1993 and June 2003. As shown in Table 1, the majority of the VSC-24 casks at all three sites were loaded under Revision 0 of the CoC, and only a few of later casks at Point Beach and ANO were loaded under Amendments 1 through 4. All of the SNF assemblies that are stored in the 58 loaded VSC-24 casks have relatively low heat loads and burnup. The maximum initial heat load for all 58 loaded VSC-24 is 14.7 kW (Palisades Cask Number VSC-15, loaded in June 1999), which is much lower than the maximum design basis heat load of 24 kW. The highest assembly average burnup of all SNF assemblies stored in the 58 loaded VSC-24 casks is 41.4 GWd/MTU, compared to the maximum allowable SNF assembly average burnup of 45 GWd/MTU.

In accordance with the guidance of NUREG-1927 [1.3], a discussion of the experience gained during the early VSC-24 storage cask loading operations is provided in Sections 3.4.3.2 through 3.4.3.4. The discussion focuses on significant events that occurred, and the corrective actions taken to assure continued safe operation and prevent recurrence of the conditions. The events discussed include several instances of MSB closure weld leaks that were identified and corrected during the MSB loading operations at all three sites, identification of flaws in the MSB longitudinal seam weld of an MSB (Palisades MSB-04) that had already been loaded and placed in storage, and a hydrogen ignition event at Point Beach. A general timeline of these events is provided in Figure 2, which shows that these events occurred relatively early in the cask loading timeline. The corrective actions taken in response to these events were effective in preventing recurrence, as discussed in Sections 3.4.3.2 through 3.4.3.4. Furthermore, the evaluation of these VSC-24 casks for the extended storage period shows that they will continue to perform their intended functions.

1.2 Application Format and Content

The VSC-24 CoC renewal application format and content are based on the requirements of 10 CFR 72.240(c) and the guidance provided in NUREG-1927 [1.3]. Table 2 provides a summary of the section numbers and headings of the VSC-24 Storage System CoC renewal application and cross-references to the applicable sections of NUREG-1927 [1.3] and 10 CFR Part 72 Regulations.

All changes to the VSC-24 Storage System that have previously been made without prior NRC approval in accordance with 10 CFR 72.48 have been incorporated in the latest FSAR [1.2]. Other than the extension of the design life[2] of the VSC-24 casks from 50 to 60 years to support the 40-year CoC renewal period, the VSC-24 Storage System CoC renewal application does not include any changes to the current design basis.

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[2] Design life is the storage period for which the VSC-24 storage system is evaluated.

1.3 References

[1.1] U.S. Nuclear Regulatory Commission, Certificate of Compliance for Spent Fuel Storage Casks, Model No.: Ventilated Storage Cask (VSC-24), Certificate No. 1007, Docket No. 72-1007; Initial Issue (Effective May 7, 1993); Amendment No. 1 (Effective May 30, 2000); Amendment No. 2 (Effective September 5, 2000); Amendment No. 3 (Effective May 21, 2001); Amendment No. 4 (Effective February 3, 2003); Amendment No. 5 (Effective September 13, 2005); Amendment No. 6 (Effective June 27, 2006).

[1.2] EnergySolutions Spent Fuel Division, Inc., "Final Safety Analysis Report for the VSC-24 Ventilated Storage Cask System," Docket No. 72-1007, Revision 8, April 2009.

[1.3] U.S. Nuclear Regulatory Commission, NUREG-1927, "Standard Review Plan for Renewal of Independent Spent Fuel Storage Installation Licenses and Dry Cask Storage System Certificates of Compliance," March 2011.

Table 1 - VSC-24 Cask Loading History

Palisades			Point Beach			ANO		
Cask No.	**Loading Date**	**CoC Amend.**	**Cask No.**	**Loading Date**	**CoC Amend.**	**Cask No.**	**Loading Date**	**CoC Amend.**
1	05/07/93	0	1	12/11/95	0	1	12/17/96	0
2	05/15/93	0	2	11/05/98	0	2	10/30/98	0
3	06/21/94	0	3	05/21/96	0	3	1/28/97	0
4	07/12/94	0	4	09/01/98	0	4	4/13/99	0
5	12/13/94	0	5	10/05/98	0	5	4/2/97	0
6	09/14/94	0	6	04/12/99	0	6	4/13/97	0
7	09/27/94	0	7	08/09/99	0	7	10/21/98	0
8	10/11/94	0	8	09/13/99	0	8	4/27/99	0
9	01/31/95	0	9	04/10/00	0	9	5/18/99	0
10	02/28/95	0	10	05/15/00	0	10	4/18/00	0
11	03/28/95	0	11	08/14/00	1	11	10/1/98	0
12	04/11/95	0	12	09/11/00	2	12	9/23/98	0
13	04/25/95	0	13	11/28/01	3	13	6/16/99	0
15	06/08/99	0	14	01/02/02	3	14	7/14/99	0
16	07/06/99	0	15	12/09/02	3	15	6/6/00	0
17	07/20/99	0	16	01/10/03	3	16	7/25/00	1
18	08/03/99	0				17	6/6/01	3
19	08/17/99	0				18	1/23/01	2
						19	6/26/01	3
						20	7/25/01	3
						21	8/14/01	3
						22	8/30/02	3
						23	9/11/02	3
						24	6/11/03	4

Table 2 - Regulatory Compliance Cross-Reference Matrix (2 Pages)

CoC Renewal Application Section Number and Heading	NUREG-1927 Section Number and Heading	10CFR72 Requirement
1. General Information	1. General Information Review	---
1.1 Background	---	---
1.1.1 VSC-24 CoC Amendment History	---	---
1.1.2 VSC-24 Storage Cask Loading Overview	---	---
1.2 Application Format and Content	1.4.4 Application Content	§72.240(b), (c)
2. Scoping Evaluation	2. Scoping Evaluation	---
2.1 Scoping Evaluation Process	2.4.1 Scoping Process	§72.236
2.2 Scoping Evaluation Discussion and Results	---	---
2.2.1 Description of SSC	---	---
2.2.2 SSC Within the Scope of CoC Renewal	2.4.2 Structures, Systems, and Components Within the Scope of License Renewal	§§72.122, 72.236
2.2.3 SSC Not Within the Scope of CoC Renewal	2.4.3 Structures, Systems, and Components Not Within the Scope of License Renewal	§72.122
3. Aging Management Review	3. Aging Management Review	---
3.1 Identification of Materials and Environments	3.4.1 Identification of Materials and Environments	---
3.1.1 Materials		
3.1.2 Environments		
3.2 Aging Effects Requiring Management	3.4.2 Identification of Aging Effects	§72.236
3.2.1 Possible Aging Effects		
3.2.2 Observed Aging Effects		

Table 2 - Regulatory Compliance Cross-Reference Matrix (2 Pages)

CoC Renewal Application Section Number and Heading	NUREG-1927 Section Number and Heading	10CFR72 Requirement
3.3 Time-Limited Aging Analyses	3.5 Time-Limited Aging Analysis Evaluation	§72.240(c)(2)
3.3.1 TLAA Identification Criteria		
3.3.2 TLAA Identification Process and Results		
3.3.3 Evaluation and Disposition of Identified TLAAs		
3.4 Aging Management Program	3.6 Aging Management Program	§72.240(c)(3)
3.4.1 Aging Effects Subject to Aging Management	3.6.1.1 Aging Effects Subject to Aging Management	
3.4.2 Aging Management Program Description	3.6.1.2 Prevention Mitigation, Condition Monitoring, and Performance Monitoring Programs	
3.4.3 Corrective Actions	3.6.1.3 Corrective Actions	
3.4.4 Lead Cask Inspection	3.6.1.4 Component Specific Guidance	
3.5 Retrievability	3.7 Retrievability	§§72.122(l), 72.236(m)
Appendix A - VSC-24 Storage System FSAR Changes	1.4.4 Application Content	§72.240(c)
Appendix B - VSC-24 Storage System Technical Specification Changes	1.4.4 Application Content	§72.240(c)

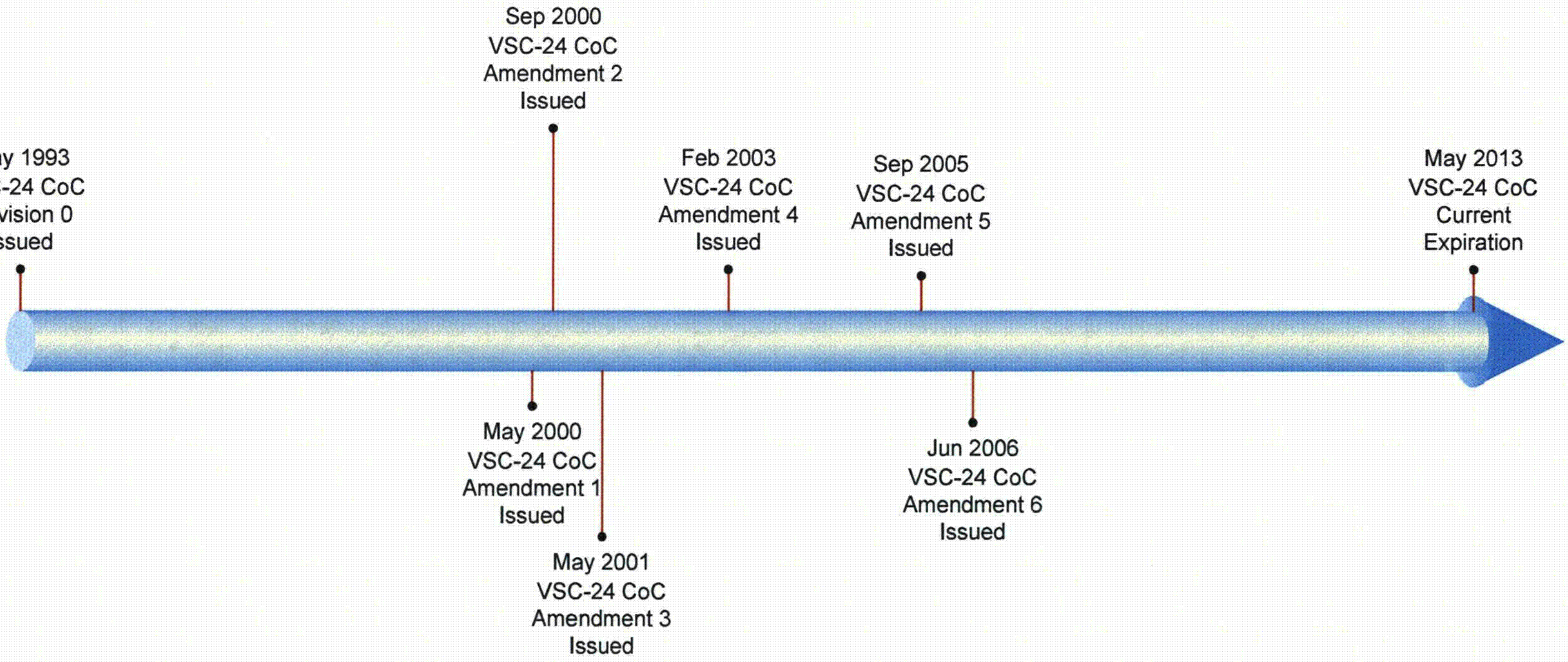

Figure 1 - VSC-24 Storage System CoC Amendment Timeline

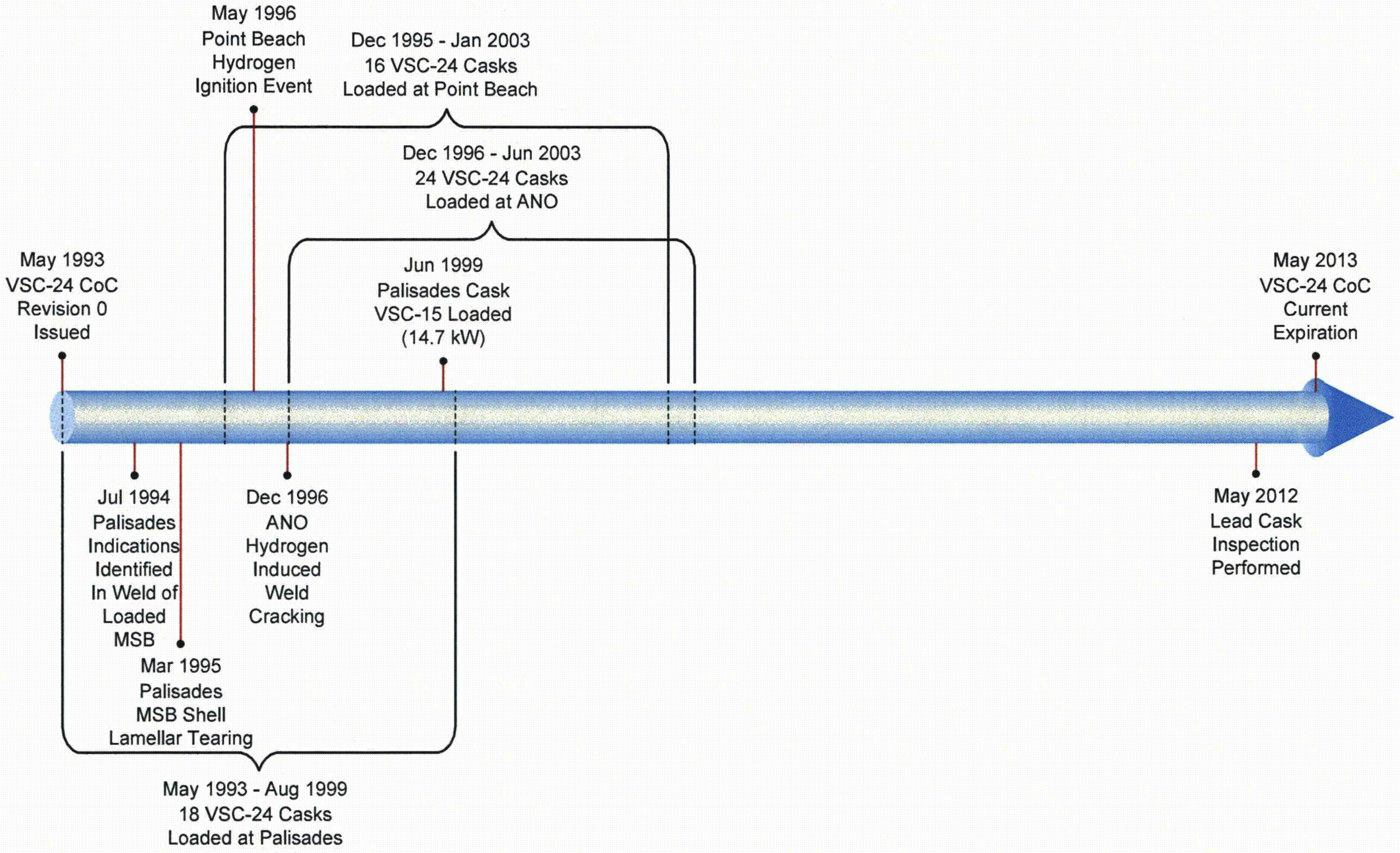

Figure 2 - VSC-24 Storage Cask Loading Timeline

2. Scoping Evaluation

The scoping evaluation identifies those SSC of the VSC-24 Storage System that are within the scope of the CoC renewal, and require further evaluation for potential aging effects. The process and methodology used for the scoping evaluation is described in Section 2.1. The scoping evaluation results are summarized in Section 2.2.

2.1 Scoping Evaluation Process

The scoping evaluation of the VSC-24 Storage System is performed based on the two-step process described in NUREG-1927 [2.1]. The first step in the process is a screening evaluation to determine which SSC are within the scope of the renewal. SSC are considered to be within the scope of the renewal if they satisfy either of the following criteria:

(1) The SSC is classified as Important-To-Safety (ITS), or

(2) The SSC is classified as Not-Important-To-Safety (NITS), but, according to the design basis, its failure could prevent fulfillment of a function that is ITS.

The second step involves further review of the SSC that are determined to be within the scope of the renewal to identify and describe the subcomponents that support the intended function(s) of the SSC. The intended functions of the SSC subcomponents include criticality control, heat transfer, radiation shielding, confinement, and structural support.

In accordance with NUREG-1927 [2.1], the VSC-24 Storage System CoC renewal is based on the continuation of the existing Current Licensing Basis (CLB) throughout the period of extended operation and maintenance of the intended safety functions of the SSC ITS. Accordingly, the sources of information reviewed in the scoping evaluation that describe the CLB and the intended safety functions of the SSC ITS are the VSC-24 Storage System FSAR, CoC, Technical Specifications (TS), and Safety Evaluation Report (SER.)

Section 2.2 discusses the VSC-24 Storage System CoC renewal scoping evaluation and results. Table 3 summarizes the results of the scoping evaluation, listing the SSC that are identified within the scope of renewal and the criteria upon which they are determined to be within the scope of renewal. Furthermore, the subcomponents of the in-scope SSC and their intended safety functions are identified in Table 4 through Table 7.

2.2 Scoping Evaluation Discussion and Results

As discussed in Section 1.2.1 of the VSC-24 Storage System FSAR [2.2], the VSC-24 Storage System includes the following components and equipment:

- Ventilated Concrete Cask (VCC)
- Multi-assembly Sealed Basket (MSB)

- MSB Transfer Cask (MTC)
- Fuel Transfer and Auxiliary Equipment (e.g., hydraulic roller skid, heavy haul transfer trailer, vacuum drying and helium back-fill system with a helium sniffer for leak detection, welding equipment)
- ISFSI Storage Pad
- ISFSI Security Equipment

2.2.1 Description of SSC

The VSC-24 Storage System is a canister-based dry cask spent fuel storage system that is comprised of two principal components; the MSB assembly (i.e., a canister) and the VCC assembly. In addition, the system includes an MTC assembly (i.e., a transfer cask) that is used for canister loading/unloading operations in the spent fuel building at the reactor site. Other site-specific system components include the MTC lifting yoke, on-site transfer equipment, MSB closure equipment, and the ISFSI storage pad. Additional descriptions of these components are provided in Chapter 1 of the VSC-24 Storage System FSAR [2.2] and in the following sections.

2.2.1.1 Spent Fuel Assemblies

The VSC-24 Storage System is designed to accommodate up to twenty-four (24) intact[3], 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 VSC-24 Storage System components are provided in three different configurations (i.e., standard, long, and short) to accommodate the range of PWR SNF assembly lengths. In all cases, the maximum heat load is limited to 1 kW per SNF assembly (i.e., 24 kW per cask). Furthermore, the maximum assembly average burnup level is limited to 45,000 MWd/MTU and the maximum initial enrichment is limited to 4.2 wt% ^{235}U. Table 2.1-1 of the VSC-24 Storage System FSAR [2.2] provides the design parameters for the PWR SNF assemblies that are permitted to be stored in the VSC-24 Storage System.

2.2.1.2 MSB Assembly

The MSB assembly is described in Section 1.2.1.1 of the VSC-24 Storage System FSAR [2.2]. The MSB assembly, which is fabricated primarily from carbon steel, is comprised of a shell assembly and a storage sleeve assembly. All exposed internal and external surfaces of the MSB shell and basket assembly are coated with a radiation-resistant, high-temperature, non-organic coating, such as Dimetcote 6 or Carbo-Zinc 11, to protect the spent fuel pool chemistry during fuel loading operations and facilitate decontamination of the MSB assembly exterior surfaces. However, the coating is not relied upon for general corrosion protection of the MSB shell

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[3] Fuel with no known or suspected gross cladding failures.

assembly external surfaces during storage. Instead, a corrosion allowance is considered in the design of the MSB shell and bottom plate.

The MSB shell assembly is designed to provide confinement of radioactive materials and to maintain the SNF payload in an inert atmosphere during on-site storage and handling operations. The MSB shell assembly is comprised of a bottom plate, cylindrical shell, shield lid assembly, shield lid support ring, and structural lid. The shield lid assembly consists of a support plate and shield plug assembly. The shield plug assembly consists of an RX-277 neutron shield core that is fully encased in carbon steel. The shield plate, which is supported axially by the shield lid support ring, is positioned at the top end of the MSB shell assembly and forms the top end of the MSB shell assembly cavity. The shield plug assembly is positioned at the top end of the MSB shell between the support plate and the structural lid. The shield lid and structural lid of the MSB shell assembly provide significant radiation shielding at the top end of the MSB assembly. To a much lesser extent, the other packaging components of the MSB assembly provide radiation shielding between the radioactive contents and the side and bottom surfaces.

The MSB storage sleeve assembly consists of a welded array of 24 storage sleeves, surrounded by three bands formed by support plates and support walls, as shown on general arrangement drawings in Section 1.5 of the VSC-24 Storage System FSAR [2.2]. Each storage sleeve assembly has an 8.8-inch square opening. The MSB storage sleeve lengths for the long, standard, and short MSB assemblies are 159.0 inches, 163.6 inches, and 147.5 inches, respectively. The MSB assembly does not include any integral criticality control features, such as neutron poisons, flux traps, or moderators. As discussed in the VSC-24 Storage System FSAR [2.2], the MSB relies on soluble boron in the spent fuel pool water for criticality control during fuel loading operations. Furthermore, criticality control is assured during on-site storage because there are no credible means by which moderator can enter and fill the MSB cavity. Thus, unlike most spent fuel basket assemblies, the primary function of the MSB storage sleeve assembly is limited to structural support rather than criticality control.

The MSB assembly is designed in accordance with the allowable stress design criteria for Class 2 components from the ASME Code, Subsection NC [2.4]. The MSB lifting devices are designed in accordance with the requirements of NUREG-0612 [2.5] and ANSI N14.6 [2.6]. Brittle fracture failure of the MSB carbon steel materials is evaluated in accordance with the requirements of NUREG/CR-1815 [2.7]. In addition, administrative controls are used to control the minimum temperatures for MSB transfer operations to preclude possible brittle fracture failure of the MSB.

2.2.1.3 Ventilated Concrete Cask Assembly

The VCC assembly is described in Section 1.2.1.2 of the VSC-24 Storage System FSAR [2.2]. The VCC assembly is a right circular cylindrical structure that is fabricated primarily from carbon steel and steel-reinforced normal-weight concrete. The VCC assembly is designed in accordance with the requirements of ACI 349 [2.8] and constructed in accordance with ACI 318 [2.9]. Carbon steel is used to form the inside cavity and air inlet and outlet ducts of the VCC assembly. Carbon steel is also used for the cask lid (i.e., weather cover) and the shield rings. All exposed steel surfaces are coated with Dimetcote 6, or equivalent, to protect against corrosion during storage. The VCC assembly concrete is constructed from 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) and a minimum compressive strength of 4,000 pounds per square inch (psi).

The VCC assembly has a 132.0-inch outside diameter, a 70.5-inch cavity diameter, and three different overall heights to accommodate the different MSB assembly configurations. The long, standard, and short VCC assembly overall heights are 225.1 inches, 213.0 inches, and 196.7 inches, respectively. The internal cavity of the VCC assembly is lined by a 1.75-inch thick carbon steel shell and a 2-inch thick carbon steel bottom plate. A carbon steel shield ring assembly is provided at the top end of the VCC assembly to reduce radiation streaming from the VCC annulus. The top end of the VCC assembly is covered with a ¾-inch thick lid that is secured to the VCC assembly by bolts.

The intended functions of the VCC assembly include structural support, radiation shielding, and heat transfer. The VCC assembly protects the MSB assembly from damage due to external events, such as tornado generated winds and missiles. The radiation shielding provided by the VCC assembly reduces occupational exposure and assures that the regulatory site-boundary dose limits are met. Air inlet and outlet ducts are cast into the body of the VCC assembly to provide natural convective cooling of the SNF assemblies during storage.

2.2.1.4 MSB Transfer Cask Assembly

A detailed description of the MTC assembly is provided in Section 1.2.1.3 of the VSC-24 Storage System FSAR [2.2]. The MTC assembly is the transfer cask that is used for MSB loading and unloading operations. The MTC assembly is designed and fabricated as a special lifting device in accordance with the requirements of NUREG-0612 [2.5] and ANSI N14.6 [2.6]. It is a right circular cylindrical structure with integral lifting trunnions and hydraulically-operated shield doors on the bottom end. The top end of the MTC assembly is open, but includes a retainer ring to prevent the MSB assembly from being inadvertently lifted out of the cavity of the MTC assembly.

The MTC assembly has both a standard and light configuration. The standard configuration has a 63.5-inch cavity diameter and an 83.5-inch outer diameter, whereas the light configuration has a 63.0-inch cavity diameter and a 82.0-inch outer diameter. Both configurations are provided with three different cavity heights to accommodate the different length MSB assemblies. The long, standard, and short MTC assembly cavity heights are 192.8 inches, 180.8 inches, and 164.7 inches, respectively. All configurations include a ¾-inch thick carbon steel inner shell, 1-inch thick carbon steel outer shell, a 1-inch thick carbon steel bottom ring, and a 2-inch thick 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. All exposed carbon steel surfaces are coated with Dimetcote 6, or equivalent, to protect the spent fuel pool chemistry, facilitate decontamination, and protect against corrosion.

2.2.1.5 Fuel Transfer and Auxiliary Equipment

The fuel transfer and auxiliary equipment necessary for ISFSI operations (e.g., lifting yoke, hydraulic roller skid, air-pallets, heavy haul trailer, engineered cask transporter, vacuum drying system, welding equipment, weld inspection equipment, drain pump equipment, and helium leak detection equipment) are not included as part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3], and as such, are not described in detail in the VSC-24 Storage System FSAR [2.2]. General descriptions of the roller skid and transfer trailer are provided in Sections 1.2.1.4 and 1.2.1.5 of the VSC-24 Storage System FSAR [2.2], respectively. Some of the fuel transfer and auxiliary equipment is also depicted in the operational schematic shown in Figure 1.1-2 of the VSC-24 Storage System FSAR [2.2].

2.2.1.6 ISFSI Storage Pad

The VSC-24 ISFSI storage pad is not part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3], and as such, is not described in detail in the VSC-24 Storage System FSAR [2.2]. A typical ISFSI storage pad layout is shown in Figure 1.4-1 of the VSC-24 Storage System FSAR [2.2]. The ISFSI storage pad is a steel-reinforced concrete slab that supports free-standing VSC-24 casks. As discussed in Section 1.4 of the VSC-24 Storage System FSAR [2.2], the ISFSI storage pad is capable of supporting the loads from the VSC-24 casks. However, the VCC and MSB assemblies are designed to withstand potential failure of the ISFSI storage pad that would not prevent them from fulfilling their intended safety functions.

2.2.1.7 ISFSI Security Equipment

The ISFSI security equipment (e.g., ISFSI security fences and gates, lighting, communications, and monitoring equipment) are not part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3], and as such, are not described in detail in the VSC-24 Storage System FSAR [2.2]. A typical ISFSI pad layout, which identifies some of the ISFSI security equipment, is shown in Figure 1.4-1 of the VSC-24 Storage System FSAR [2.2]. Existing plant programs and procedures ensure that the ISFSI security equipment requirements are met. Furthermore, potential failure of the ISFSI security equipment would not prevent the VSC-24 casks from performing their intended functions.

2.2.2 SSC Within the Scope of CoC Renewal

The SSC determined to be within the scope of renewal are the MSB, VCC, and MTC assemblies. These basic components are the only SSC ITS approved by the CoC [2.3] under 10 CFR Part 72, Subpart L. The MSB, VCC, and MTC assemblies all satisfy Criteria 1 of the scoping evaluation process. The subcomponents of the in-scope SSC and their intended safety functions are identified in Table 4 through Table 6.

The SNF assemblies, which are sealed and supported inside the MSB assembly, are also determined to be within the scope of renewal. However, as noted in NUREG-1927 [2.1], the fuel pellet is not within the scope of renewal. The intended safety functions of the SNF assembly subcomponents are identified in Table 7.

2.2.3 SSC Not Within the Scope of CoC Renewal

The SSC that are not in the scope of renewal include fuel transfer and auxiliary equipment, ISFSI storage pad, ISFSI security equipment, and VCC instrumentation. All of these components are classified as NITS and do not meet scoping Criteria 2.

Fuel Transfer and Auxiliary Equipment

The fuel transfer and auxiliary equipment necessary for ISFSI operations (e.g., lifting yoke, hydraulic roller skid, air-pallets, heavy haul trailer, engineered cask transporter, vacuum drying system, welding equipment, weld inspection equipment, drain pump equipment, and helium leak detection equipment) are not included as part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3] under 10 CFR Part 72, Subpart L. As discussed in Section 1.1 of the VSC-24 Storage System FSAR [2.2], 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 safety functions. Therefore, the fuel transfer equipment does not meet scoping Criteria 2 and are not in the scope of renewal. The fuel transfer and auxiliary equipment are addressed on a site-specific basis in site reviews.

ISFSI Storage Pad

The VSC-24 ISFSI storage pad is not part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3] under 10 CFR Part 72, Subpart L. The ISFSI storage pad provides free-standing support of the VSC-24 casks. The VCC assembly and MSB assembly are designed to withstand potential failure of the ISFSI pad that would not prevent them from fulfilling their intended safety functions. Therefore, the ISFSI storage pad does not meet scoping Criteria 2 and is not in the scope of renewal.

ISFSI Security Equipment

The ISFSI security equipment (e.g., ISFSI security fences and gates, lighting, communications, and monitoring equipment) are NITS components that are not part of the VSC-24 Storage System approved by the VSC-24 Storage System CoC [2.3] in accordance with 10 CFR Part 72, Subpart L. Failure of the ISFSI security equipment would not prevent fulfillment of a function that is important to safety.

2.3 References

[2.1] U.S. Nuclear Regulatory Commission, NUREG-1927, "Standard Review Plan for Renewal of Independent Spent Fuel Storage Installation Licenses and Dry Cask Storage System Certificates of Compliance," March 2011.

[2.2] EnergySolutions Spent Fuel Division, Inc., "Final Safety Analysis Report for the VSC-24 Ventilated Storage Cask System," Docket No. 72-1007, Revision 8, April 2009.

[2.3] U.S. Nuclear Regulatory Commission, *Certificate of Compliance for Spent Fuel Storage Casks, Model No.: Ventilated Storage Cask (VSC-24)*, Certificate No. 1007, Docket No. 72-1007; Initial Issue (Effective May 7, 1993); Amendment No. 1 (Effective May 30, 2000); Amendment No. 2 (Effective September 5, 2000); Amendment No. 3 (Effective May 21, 2001); Amendment No. 4 (Effective February 3, 2003); Amendment No. 5 (Effective September 13, 2005); Amendment No. 6 (Effective June 27, 2006).

[2.4] American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, *Rules for Construction of Nuclear Power Plant Components*, Subsection NC, *Class 2 Components*, 1986 through 1998 Editions, with 2000 Addenda.

[2.5] NUREG-0612, *Control of Heavy Loads at Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, 1980.

[2.6] ANSI N14.6, *Special Lifting Devices for Shipping Containers Weighing 10,000 lbs (4500 kg) or More*, American National Standards Institute, 1993.

[2.7] NUREG/CR-1815, *Recommendations for Protecting Against Failure by Brittle Fracture in Ferritic Steel Shipping Containers Up to Four Inches Thick*, 1981.

[2.8] ACI 349-90, *Code Requirements for Nuclear Related Concrete Structures and Commentary,* American Concrete Institute.

[2.9] ACI 318-89, *Building Code Requirements for Reinforced Concrete,* American Concrete Institute.

Table 3 - Summary of Scoping Evaluation Results

SSC Description	Scoping Results		In-Scope SSC?
	Criteria 1[1]	Criteria 2[2]	
MSB Assembly	Yes	N/A	Yes
VCC Assembly	Yes	N/A	Yes
MTC Assembly	Yes	N/A	Yes
SNF Assembly[3]	Yes	N/A	Yes
Fuel Transfer and Auxiliary Equipment[4][5]	No	No	No
ISFSI Storage Pad	No	No	No
ISFSI Security Equipment[6]	No	No	No

Notes:

(1) SSC is Important-To-Safety (ITS).

(2) SSC is Not-Important-To-Safety (NITS), but its failure could prevent an ITS function from being fulfilled.

(3) Fuel pellets are not within the scope of the renewal.

(4) Fuel transfer equipment includes the lifting yoke, hydraulic roller skid, air-pallets, heavy haul trailer, and engineered cask transporter.

(5) Auxiliary equipment includes MSB closure equipment used to drain, backfill, and seal the MSB assembly (e.g., the vacuum drying system, welding equipment, weld inspection equipment, drain pump equipment, and helium leak detection equipment.)

(6) ISFSI security equipment includes the ISFSI security fences and gates, lighting, communications, and monitoring equipment.

Table 4 - Intended Functions of MSB Assembly Subcomponents

Subcomponent	Part or I.D. No.	Reference Drawing[1]	Intended Functions[2]
Shell	MSB-001	MSB-24-002	HT, RS, PR, SS
Bottom Plate	MSB-002	MSB-24-002	HT, RS, PR, SS
Shield Lid Support Ring	MSB-003	MSB-24-002	SS
Lifting Lug	MSB-004	MSB-24-002	SS
Structural Lid	MSB-005	MSB-24-002	HT, RS, PR, SS
Closure Weld Backing Ring	MSB-010	MSB-24-001	---
Shim	MSB-006	MSB-24-001	RS
Shield Lid Top Plate	MSB-011	MSB-24-003	RS, PR, SS
Shield Lid Bottom Plate	MSB-012	MSB-24-003	RS, PR, SS
Shield Lid Side Ring	MSB-013	MSB-24-003	PR, SS
Shield Lid Neutron Shield	MSB-014	MSB-24-003	RS
Shield Lid Pipe & Flex Tubing	MSB-007 & -016	MSB-24-003	---
Swagelok Quick Connect	MSB-008	MSB-24-003	---
Structural Lid Valve Covers	MSB-009	MSB-24-002	PR, RS
Shield Lid Support Plate	MSB-017	MSB-24-003	RS, SS
Storage Sleeve	MSB-018	MSB-24-004	CC, HT, RS, SS
Basket Edge Structure	MSB-019 thru -021	MSB-24-004	SS
Coating	Dwg. Note 1	MSB-24-001	---(3)

Notes:

(1) Included in Section 1.5 of the VSC-24 Storage System FSAR [2.2].

(2) Intended functions are abbreviated as follows: Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

(3) The MSB carbon steel surfaces are coated with a zinc primer, but the primer is conservatively neglected in the licensing analyses.

Table 5 - Intended Functions of VCC Assembly Subcomponents

Subcomponent	Part or I.D. No.	Reference Drawing(1)	Intended Functions(2)
Concrete Shell	VCC-014	VCC-24-001	HT, RS, SS
Rebar	VCC-051 thru -071	VCC-24-006	SS
Cask Liner Shell	VCC-003	VCC-24-002	HT, RS, SS
Cask Liner Bottom	VCC-012	VCC-24-002	HT, RS, SS
Liner Flange	VCC-004	VCC-24-002	SS
Cask Lid	VCC-001	VCC-24-002	RS, SS
Lid Bolts, Nuts, Lockwashers	VCC-002	VCC-24-002	SS
Locking Wire w/ Lead Seal	VCC-006	VCC-24-002	---
Lid Gasket	VCC-015	VCC-24-002	---
Shielding Ring Plates	VCC-039 thru -042	VCC-24-008	RS
Tile (MSB support)	VCC-016	VCC-24-002	---
Air Inlet Assembly	VCC-030 thru -038	VCC-24-003	HT
Air Outlet Weldment	VCC-022 thru -028	VCC-24-004	HT
Air Inlet Screen/Hardware	VCC-005, -007 & -008	VCC-24-001	HT
Air Outlet Screen/Hardware	VCC-019 & -029	VCC-24-004	HT
Bottom Plate Assembly	VCC-050 & -011	VCC-24-005	HT
MTC Alignment Plates	VCC-043 & -044	VCC-24-008	---
Coating	Dwg. Note 1	VCC-24-002	---
VSC Lifting Lugs (Optional)	VSC-24 Storage System FSAR [2.2], App. B	Figures B.3-1 and B.3-2	SS

Notes:

(1) Included in Section 1.5 of the VSC-24 Storage System FSAR [2.2].

(2) Intended functions are abbreviated as follows: Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

Table 6 - Intended Functions of MTC Assembly Subcomponents

Subcomponent	Part or I.D. No.	Reference Drawings(1)	Intended Functions(2)
Outer Shell	MTC-001	MTC-24-002	SS, RS, HT
Inner Shell	MTC-003	MTC-24-002	SS, RS, HT
Top Ring	MTC-004	MTC-24-002	SS
Bottom Ring	MTC-011	MTC-24-002	SS
Neutron Absorber Shield	MTC-014	MTC-24-002	RS, HT
Lead Shield	MTC-002	MTC-24-002	RS, HT
Drain Pipe	MTC-021	MTC-24-002	---
Angle, Heat Transfer	MTC-045	MTC-24-002	RS, HT
Trunnion	MTC-018	MTC-24-008	SS
Trunnion Cylinder/End Covers	MTC-016, -013, & -017	MTC-24-008	---
MTC Lid	MTC-005	MTC-24-006	SS
Lid Bolts	MTC-006	MTC-24-001	SS
Shim/Flange	MTC-009 & -010	MTC-24-006	RS
Rail Shield	MTC-008	MTC-24-007	SS, RS
Rail Lower Plate	MTC-024	MTC-24-007	SS
Rail Alignment Plate/Door Bolt	MTC-028 & -025	MTC-24-007	---
Shield Door	MTC-007	MTC-24-009	SS, RS, HT
Door Top Cover	MTC-023	MTC-24-009	---
Door Hydraulics/Brackets/ Attachment Hardware	MTC-026, -027, -030, -039, & -012	MTC-24-009 & -003	---
Coating	Dwg. Note 1	MSB-24-001 & -002	---

Notes:

(1) Included in Section 1.5 of the VSC-24 Storage System FSAR [2.2].

(2) Intended functions are abbreviated as follows: Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

Table 7 - Intended Functions of SNF Assembly Subcomponents

Subcomponent	Intended Functions(1)
Fuel Pellets	---
Fuel Cladding	CC, RS, PR, SS
Spacer Grid Assemblies	CC, SS
Upper End Fitting	SS
Lower End Fitting	SS
Guide Tubes	SS
Holddown Spring & Upper End Plugs	---
Control Components	---(2)

Notes:

(1) Intended functions are abbreviated as follows: Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

(2) 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.

3. Aging Management Review

The Aging Management Review (AMR) of the VSC-24 Ventilated Storage Cask System provides an assessment of aging effects that could adversely affect the ability of in-scope SSC to perform their intended functions during the renewal period. The methodology used for the AMR of the VSC-24 Ventilated Storage Cask System is based on the guidance provided in NUREG-1927 [3.1]. The AMR process includes five (5) steps:

(1) Identification of the materials and environments for all subcomponents of the in-scope SSC.

(2) Identification of the aging effects that require management during the extended storage period.

(3) Identification and evaluation of TLAAs for the extended storage period.

(4) Identification of AMPs for managing aging effects during the extended storage period.

(5) Evaluation of fuel retrievability during the extended storage period.

Identification of materials and environments for all in-scope SSC is discussed in Section 3.1. Aging effects that require management during the extended storage period are discussed in Section 3.2. In-scope SSC that are determined to be subject to an aging effect that could adversely affect their ability to perform their safety function(s) during the extended storage period are required to either be evaluated with Time-Limited Aging Analysis (TLAA) or to be managed through an existing, modified, or new Aging Management Program (AMP). The TLAA evaluations and AMP used to manage aging effects on the in-scope SSC are discussed in Section 3.3 and Section 3.4 respectively. Finally, fuel retrievability during the extended storage period is evaluated in Section 3.5. The results of the AMR are summarized in Table 8 through Table 11.

3.1 Identification of Materials and Environments

The first step in the AMR process is to identify the materials of construction for each subcomponent of the in-scope SSC and the environments to which those materials are exposed during normal storage conditions. The materials of construction for the in-scope SSC of the VSC-24 storage system are identified based on a review of the design basis documents; primarily the design drawings contained in Section 1.5 of the VSC-24 Storage System FSAR [3.2]. The environments to which the materials are normally exposed are identified based on a review of the VSC-24 Storage System FSAR [3.2] and plant records. The materials of construction and environments for each of the subcomponents of the in-scope SSC are discussed in Sections 3.1.1 and 3.1.2, respectively, and summarized in Table 8 through Table 11. The combinations of materials and environments are used to identify the potential aging effects that require management during the extended storage period, as discussed in Section 3.2.

3.1.1 Materials

3.1.1.1 MSB Assembly

The MSB assembly is constructed entirely from carbon steel (primarily SA-516, Grade 70), 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 carbon steel shell, bottom plate, top lids, and storage sleeve assembly (i.e., internal basket) are all coated with a radiation-resistant, high-temperature, non-organic hard surface, such as Dimetcote 6 or Carbo-Zinc 11. 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 assembly is not relied on for corrosion protection or any other safety-related function during storage operations. A conservative corrosion allowance is applied on the radial and bottom outer surfaces of the MSB shell assembly.

3.1.1.2 VCC Assembly

The VCC assembly is constructed primarily from steel-reinforced concrete and carbon steel. The side walls and bottom end of the VCC assembly are constructed from normal weight steel-reinforced concrete made from Type II Portland cement and reinforced with A615 Grade 60 steel bars. The internal cavity of the VCC assembly is lined by the inner shell and bottom plate, which are fabricated from A36 carbon steel. Carbon steel (A36) plates are also used to form the inlet and outlet duct structures, shield ring (which lies above the main ventilation duct), and the cask lid. All exposed carbon steel surfaces are coated with Dimetcote 6, or an equivalent coating. The VCC assembly also includes ceramic tiles at the bottom of the VCC cavity, which 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. Finally, the bolts that secure the inlet and outlet duct screens are made from galvanized or zinc-plated steel.

3.1.1.3 MTC Assembly

The MTC assembly materials of construction consist primarily of carbon steels (A588 Grade A or B, A516 Grade 70 and A36), common lead, and castable neutron shielding material (RX-277). The carbon steel inner radial liner, outer radial shell, and top and bottom plates (or flanges) create an annular cavity in which the lead gamma shield and RX-277 neutron shield are sealed. Carbon steel heat transfer fins are embedded within the RX-277 neutron shield. The MTC assembly also features a top ring (which prevents the MSB from being lifted out of the MTC), lifting trunnions, and a bottom door and rail structure, all of which are also constructed of carbon steel. All carbon steel components of the MTC are covered with Dimetcote 6, or equivalent, to protect the spent fuel pool chemistry during the fuel loading operations, facilitate decontamination, and provide corrosion protection. The only metal MTC components that may not be carbon steel are the A325 bolts used to fasten on the MTC lid.

3.1.1.4 Spent Nuclear Fuel Assembly

The SNF assembly subcomponents consist of zircaloy fuel rod cladding, zircaloy or stainless steel spacer grids and guide tubes, and stainless steel and/or inconel top and bottom end nozzle structures. The fuel pellets consist of UO_2 along with a wide array of other actinide and fission product isotopes. 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 SNF assemblies may also contain zircaloy or stainless steel dummy rods in place of fuel rods in one or more array locations.

3.1.2 Environments

With the exception of the SSC subcomponents that are exposed to the inert gas atmosphere within the MSB cavity, the environment to which the each subcomponent of the in-scope SSC is exposed depends on the characteristics of the plant site environment and their location within the system. VSC-24 casks are currently stored at three nuclear plant sites; the Point Beach site in Wisconsin (on the western shore of Lake Michigan), the Palisades plant in southwest Michigan (on the eastern shore of Lake Michigan) and the Arkansas Nuclear One site, which lies on a smaller lake (Lake Dardanelle, a dam-created lake on the Arkansas River) in northwest Arkansas. All three sites lie on moderate to large bodies of fresh water in the central region of the United States, relatively far from the oceans or Gulf of Mexico, so none of them constitute a marine environment. All three sites have moderate levels of rainfall and humidity. Average monthly temperatures range from approximately 20°F to 70°F at Point Beach and Palisades and from approximately 30°F to 93°F at ANO. There are four basic types of environments identified, as discussed in the following paragraphs: Inert Gas, Sheltered, Embedded, and Exposed.

Inert Gas (MSB Cavity)

The SNF assemblies, MSB storage sleeve assembly (basket), and the inside (cavity facing) surfaces of the MSB shell assembly are all exposed to the inert gas (helium) environment inside the MSB cavity. The temperature of this gas can range from the ambient air temperature for zero decay heat to as high as 700°F for the maximum canister heat load of 24 kW. The gas pressure inside the MSB cavity is close to one atmosphere. The presence of oxygen or moisture within the MSB cavity is limited to very low levels by the vacuum drying process to avoid deleterious chemical changes in the fuel cladding. In addition to elevated temperatures and trace amounts of oxygen and/or moisture, the MSB interior components are exposed to significant gamma and neutron radiation.

Sheltered Environment

The outer surfaces of the MSB assembly and the interior components of the VCC assembly (inner surfaces of the liner shell, liner bottom, cask lid (weather cover), 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 ambient air may contain moisture and some salinity; although 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 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. Generally, the elevated temperature of the sheltered environment air will keep moisture levels below those seen on the outer surfaces of the cask system. Components exposed to the sheltered environment experience somewhat lower gamma and neutron radiation levels than those seen in the MSB interior environment.

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. The MTC assembly is generally stored inside a building where air temperature and moisture levels are less variable and more controlled than those of the sheltered air environment of the VCC assembly. However, the MTC assembly may also be stored outside, provided it is adequately protected from the environment. 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 (although the MTCs are exposed to these effects for brief time periods, during the cask system loading and unloading operations). Also, the surfaces of a stored MTC assembly are much more accessible for inspection and repair than the MSB exterior and VCC interior surfaces.

Embedded Environment

The embedded environment applies for materials that are embedded or sealed inside another material. These include 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. The RX-277 neutron shield material inside the MSB shield lid and MTC assembly shells, the carbon steel heat transfer fins embedded in the MTC 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 are also exposed to an embedded environment.

The primary issue for embedded environments is any potential chemical reaction between the two materials that meet at a given surface. Any such reactions will be potentially governed by temperature, as well as the combination of materials (and the associated chemistry). Thus, for the VCC, the primary issue is any potential reactions between carbon steel and concrete. As shown in Figure 4.4-5 of the VSC-24 Storage System FSAR [3.2], the temperature of the steel/concrete interfaces in the VCC could range from near ambient temperature to as high as 200°F. Temperatures of the MSB lid RX-277 range up to 150°F for normal storage conditions. For stored MTCs, temperatures of all materials will be kept within a low, narrow range (close to "room temperature"). The MTC materials (and associated material boundaries) are exposed to elevated temperatures (up to 270°F) for brief periods during the system loading process. The radiation levels seen in the embedded environments are lower than those seen by the sheltered air environments.

Exposed Environment

During storage, all exterior surfaces of the VCC assembly are exposed to all weather-related effects, including insolation, wind, rain (or snow/ice), and ambient air at the plant site. The steel plate that forms the bottom surface of the VCC assembly is also exposed, in most respects. Since it is in direct contact with the surface of the ISFSI pad, it is sheltered from sun and wind, but it is exposed to water. The ambient air temperature for normal and extreme weather conditions ranges from -40°F to 100°F. The moisture and salinity levels to which the exterior surfaces of the VCC assembly are exposed may vary widely for various plant sites, although none of the loaded VSC-24 casks are located in marine environments. The radiation levels on the exterior surfaces of the VCC are sufficiently low to satisfy the applicable regulatory dose rate limits.

3.2 Aging Effects Requiring Management

Aging effects, and the mechanisms that cause them, are evaluated for the combinations of materials and environments identified for the subcomponent of the in-scope SSC based upon a comprehensive review of known literature, industry operating experience, and maintenance and inspection records. Possible (or theoretical) aging effects for the materials of construction used in the VSC-24 storage system are determined primarily from research of literature on degradation mechanisms, such as ASTM C1562 [3.4] and NUREG/CR-6831 [3.5]. Aging effects that have actually occurred during the initial storage period for the VSC-24 storage system are determined based on a review of the available licensee records and operating experience. Aging effects that could adversely affect the ability of the in-scope SSC to perform their safety function(s) require additional Aging Management Activity (AMA) to address potential degradation that may occur during the extended storage period. These additional AMAs consist of either Time-Limited Aging Analysis (TLAA) or Aging Management Programs (AMPs), as discussed in Sections 3.3 and 3.4, respectively. The possible and observed aging effects and associated aging mechanisms identified for the in-scope SSC for the extended storage period are discussed in the following subsections and summarized in Table 8 through Table 11.

3.2.1 Possible Aging Effects

The possible (theoretical) aging effects in carbon steel, reinforced concrete, SNF assemblies, and other materials are addressed in the following sections.

3.2.1.1 Carbon Steel

The VSC-24 storage system steel components are either exposed to the inert gas atmosphere of the MSB assembly cavity, the sheltered air environment inside the VCC assembly annulus, the embedded environment (i.e., in direct contact with another material, such as concrete), or the exposed (exterior) environment. The possible aging effects for the carbon steel surfaces of the in-scope SSC subcomponents include loss of material due to corrosion, loss of fracture toughness due to radiation exposure, and crack growth due to fatigue. Each of these aging effects and the associated degradation mechanism are discussed in the following paragraphs.

Loss of Material:

Carbon steel components that are in an exposed or sheltered environment may experience loss of material due to corrosion during the extended storage period. Although less likely, carbon steel components that are embedded in concrete may also corrode during the extended storage period, as discussed in Section 3.2.1.2. Finally, carbon steel components that are exposed to the inert gas environment inside the MSB cavity are not susceptible to corrosion during the extended storage period since it is a non-oxidizing environment.

All of the exposed carbon steel surfaces of the in-scope SSC subcomponents are covered with a non-organic epoxy or zinc-based coating that is resistant to high-temperature and radiation, although in most cases the coating is not relied upon to prevent corrosion during storage. A conservative corrosion allowance is assumed for the carbon steel surfaces on the outside of the MSB shell and bottom plate, as discussed in Section 3.3.3.3. However, a corrosion allowance has not been included in the CLB for any other carbon steel components in the VSC-24 storage system. There are several types of corrosion degradation mechanisms that are possible, including general corrosion, galvanic corrosion, and crevice corrosion.

Carbon steel surfaces that are exposed to moist air or water are subject to general corrosion. The rate of general corrosion is governed by several factors, such as the moisture content and salinity level of the air, the temperature of the metal surface, and the specific type of metal involved. Most of the carbon steel components of the VSC-24 storage system are exposed to the sheltered environment inside the VCC annulus, which is relatively warm and dry. Although significant general corrosion in this environment is not expected to occur, it is an aging effect that requires management during the extended storage period for those components for which a corrosion allowance has not been included in the CLB.

Galvanic corrosion can occur when two dissimilar metals are in direct contact with one another, particularly in a moist or wet environment. Active metal components such as zinc or zinc-plated components may corrode fairly rapidly when in contact with less active metals such as ferrous steels. The VSC-24 storage system is less vulnerable to galvanic corrosion since it does not use many dissimilar metals. One exception to this is the galvanized or zinc-plated screens and attachment hardware that cover the VCC air inlet and outlet opening. Corrosion of these components requires management during the extended storage period.

Crevice corrosion can occur when two metal surfaces are in close contact, separated by a narrow gap. In the presence of water or moisture, enhanced corrosion may occur within the gap, resulting in significant loss of material, as well as possible "bonding" of the metal surfaces/components. Two locations where the potential for crevice corrosion to occur in the VSC-24 storage system is considered 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 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. Therefore, crevice corrosion of the MSB bottom plate does not require management during the extended storage period. However, crevice corrosion could possibly occur between at top end of the MSB shell near the VCC shield ring. Therefore, loss of material due to crevice corrosion at the top end of the MSB assembly is an aging effect that requires management during the extended storage period.

Loss of Fracture Toughness:

Steel material exposed to high neutron fluence (particularly fast neutrons) can experience a reduction of fracture toughness (i.e., an increase in the nil-ductility temperature). However, the neutron radiation levels seen by the metal components of dry fuel storage systems are generally orders of magnitude lower than that required to produce any significant effect, so neutron radiation is unlikely to be a significant aging effect for the steel components of the VSC-24 storage system. Gamma radiation does not have any significant impact on the properties of steel. The effects of radiation exposure on steel components are evaluated as discussed in Section 3.3.3.4.

Crack Growth:

Crack growth in carbon steel is a degradation mechanism that is considered for the extended storage period. The primary causes of crack growth in carbon steel are fatigue due to cyclic loading and delayed hydride cracking. Unlike stainless steels, carbon steel is not susceptible to stress corrosion cracking.

Fatigue failure can occur if cyclic stresses are high enough and there are a sufficient number of stress cycles. Fatigue failure of the MSB assembly is addressed by TLAA, as discussed in Section 3.3.3.2. Fatigue failure in the steel components of the VCC and MTC assemblies is not a credible degradation mechanism. The MTC assembly is designed as a special lifting device with minimum factors of safety of 6 against yield and 10 against ultimate. Since the maximum stresses in the MTC assembly are required to be very low and the MTC assembly is not subjected to a significant number of load cycles, fatigue is not a credible failure mode of the MTC assembly. 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. Fatigue failure cannot occur under these conditions.

Another potential source of weld cracking is delayed, hydrogen induced underbead weld cracking (or DHC) that occurs due to disassociation of water vapor in the weld arc, and subsequent absorption of the hydrogen in the weld metal. This cracking may lead to lamellar tearing, particularly in an over-constrained weld joint, such as that of the MSB closure weld. 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. The potential for DHC was evaluated by analysis, which showed that the time for delayed hydride cracking to occur was on the order of minutes, not hours or days. 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. Corrective actions were taken that prevented this condition from occurring during subsequent MSB loading operations.

3.2.1.2 Reinforced Concrete

The potential aging effects and degradation mechanisms for reinforced concrete are discussed in this section. The VCC assembly is the only in-scope SSC of the VSC-24 storage system that includes reinforced concrete. The VCC reinforced concrete is normal weight concrete that is constructed using Type II Portland cement, which has higher sulfate resistance and lower heat of hydration than general-purpose cement. The required compressive strength of the concrete is 4,000 psi. Air entrainment is required to be 3% to 6% by volume. The concrete is reinforced with ASTM A615, Grade 60 steel bars. The VCC reinforced concrete is designed in accordance with ACI-349 [3.8] and constructed in accordance with ACI-318 [3.9].

Aging effects and potential degradation mechanisms for the reinforced concrete are identified based on a review of available literature. Generally, the aging effects in concrete include cracking, pitting, and spalling of the cover concrete, loss of strength, and loss of material (e.g., corrosion of reinforcing steel). Each of the potential degradation mechanisms and the associated aging effects on concrete are discussed below.

Cracking, Pitting, and Spalling:

Cracking, pitting, and/or spalling of exposed cover concrete can result from several different degradation mechanisms, including freeze-thaw cycles, chemical attack, aggregate reactions, and corrosion of embedded steel (i.e., rebar). Although the concrete aging effect (i.e., cracking) is common, the degradation mechanisms that produce the aging effect are significantly different. Each of these degradation mechanisms are discussed in the following paragraphs. Of the possible degradation mechanism that can cause cracking, pitting, or spalling in the exposed cover concrete, freeze-thaw cycles, aggregate reactions, and corrosion of reinforcing steel require management during the extended storage period.

Freeze-thaw cycles can cause cracking in exposed cover concrete over time, particularly in areas where concrete is in direct contact with standing or flowing water. The severity of freeze-thaw aging effects can vary significantly with the characteristics of the concrete mixture, such as permeability and porosity. Site characteristics, such as the number of annual freeze-thaw cycles and the amount of winter precipitation, can also significantly affect the severity of freeze-thaw aging effects. Cracking of the VCC cover concrete during the initial storage period has been attributed to freeze-thaw cycles, as discussed in Section 3.2.2. These aging effects have been effectively managed during the initial storage period through annual examination of the VCC exterior concrete and grout repair of cracks in the concrete to prevent corrosion of the reinforcing steel.

Long-term exposure of concrete to acidic materials or sulfates (i.e., chemical attack), often present in ground water may result in expansive stresses, leading to cracking, spalling, or strength loss. 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. The VCC concrete is designed in accordance with ACI 349 [3.8] and constructed using materials conforming to ACI standards, which have low permeability and high resistance to chemical attack. Furthermore, the VCCs are generally not exposed to aggressive chemical environments during storage. Therefore, chemical attack is not considered a credible degradation mechanism for the VCC concrete.

Chemical reactions between concrete cement and aggregate are known to cause aging effects in concrete, including cracking and loss of strength, as discussed in NRC Information Notice 2011-20 [3.14]. There are three types of aggregate reactions that can occur; alkali-aggregate reaction, cement-aggregate reaction, and alkali-carbonate reaction. Alkali-aggregate reaction (also known as alkali-silica reaction, or ASR) can occur when aggregate containing silica is exposed to alkaline solutions. It can cause severe expansion and cracking of concrete structures. The degree of vulnerability of the concrete to this effect is primarily a function of the aggregate that is used. Cement-aggregate reaction occurs between alkalis in the cement and silicates in the aggregates. It mainly occurs in environments that promote concrete shrinkage and alkali concentrations in the surface due to drying. Alkali-carbonate reaction (between carbonate aggregates and alkalis) may produce expansion and cracking of the concrete. It often results in map cracking on the concrete surface. It has been known to occur for certain limestone aggregates.

Although the cement and aggregate combinations used in the VCC concrete mix design were tested for potential alkali reactivity in accordance with ASTM C289, the potential for aggregate reactions during the extended storage period exists. The aging effects of the aggregate reaction degradation mechanisms are generally map or pattern cracking on the concrete surface (more or less uniform spacing of cracks over the entire concrete surface) and possible presence of alkali-silica gel on the concrete surface, as discussed in ACI 221 [3.10]. Aggregate reactions also have the potential to adversely affect the structural (strength) properties of the concrete. Therefore, aggregate reactions will require management during the extended storage period.

Corrosion of rebar can cause significant aging effects in the concrete, such as concrete cracking or spalling. Corrosion causes rebar to swell, since the corrosion products occupy greater volume than the steel, and the swelling produces tensile stress in the concrete that can eventually cause the cover concrete to crack or spall. Generally, when concrete is designed and constructed in accordance with the current ACI standards and adequate concrete cover of embedded steel is provided, corrosion of embedded steel is not a significant degradation mechanism. However, concrete degradation by other mechanisms can expose the embedded steel to a corroding environment. Therefore, corrosion of rebar is an aging effect that requires management during the extended storage period. Management of rebar corrosion during the extended storage period is addressed by the AMP discussed in Section 3.4.

Loss of Strength:

Loss of concrete strength can result from many different degradation mechanisms, including leaching, elevated temperature, radiation exposure, chemical attack, and aggregate reactions. Radiation exposure of concrete during the extended storage period is shown by TLAA to not adversely affect the concrete strength, as discussed in Section 3.3.3.4. Of the remaining possible degradation mechanism that can cause loss of concrete strength, only leaching and aggregate reactions require management during the extended storage period. Each of the remaining possible degradation mechanisms that can result in loss of concrete strength are discussed in the following paragraphs.

Leaching of Calcium Hydroxide (CaOH) due to water penetration through cracks can result in loss of concrete material (specifically, the conversion of binder/cement into gels that have no structural strength). The significance of the effect is governed by water temperature and salt content. Over the long-term, CaOH leaching can increase the porosity and permeability of concrete, rendering it more vulnerable to other degradation mechanisms. CaOH leaching of the VCC concrete can result from water flowing through cracks on the VCC exterior. Management of the aging effects caused by CaOH leaching during the extended storage period is addressed by the AMP discussed in Section 3.4.

The structural properties of concrete can degrade due to long-term exposure to elevated temperatures (i.e., greater than 150°F over a general area or greater than 200°F in a localized area.) 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 [3.2]. During the extended storage period, the concrete temperatures will continue to decrease due to thermal decay. Therefore, concrete degradation due to elevated temperatures is not a concern for the extended storage period.

Loss of Material:

As discussed above, corrosion of rebar can cause concrete cracking or spalling due to swelling. In addition, corrosion of rebar can reduce the cross-sectional area of the steel bars, which results in a reduction of the section capacities of the reinforced concrete. Therefore, corrosion of rebar requires management during the extended storage period. Management of rebar corrosion during the extended storage period is addressed by the AMP discussed in Section 3.4.

3.2.1.3 Spent Nuclear Fuel Assemblies

The potential degradation mechanisms identified for the SNF assemblies include oxidation, corrosion, cladding creep, cladding annealing and hydride redistribution and reorientation within the cladding. These aging effects and the associated degradation mechanisms are discussed in this section. The aging effects that are considered credible for the SNF assemblies stored in the VSC-24 casks are summarized in Table 11.

Oxidation:

Oxidation of the zircaloy fuel cladding and the irradiated UO_2 fuel pellets can occur if the fuel is exposed to air. The potential degradation mechanism and aging effects associated with oxidation of fuel and fuel cladding are described in ASTM C1562 [3.4]. Oxidation of the fuel pellets can cause swelling and has the potential to split the fuel cladding. Excessive oxidation of the fuel cladding, combined with internal stress, can cause the fuel cladding to breach. Both effects could affect the ability to retrieve fuel.

For low burnup fuel assemblies (i.e., assemblies with an average burnup level less than 45 GWd/MTU), such as those stored in the VSC-24 casks, research [3.5] suggests that 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 MSB confinement boundary is designed, constructed, and tested to assure that it will maintain confinement and the inert atmosphere in the MSB cavity during the storage period. Oxidation of the fuel and cladding, even if exposed to air during the extended storage period, is not considered a credible degradation mechanism since the peak temperatures of the fuel are much lower than the temperatures required to produce significant oxidation (i.e., generally above 300°C).

Corrosion:

Corrosion of the fuel assembly components can potentially occur if they are exposed to moisture during the storage period. Possible corrosion degradation mechanisms that could occur in the presence of moisture include pitting, stress corrosion cracking (SCC), and galvanic corrosion [3.4]. All of these forms of corrosion require a corroding atmosphere (i.e., moisture) to occur. Potential sources of moisture in the MSB cavity are residual water in the MSB cavity and fuel assemblies following MSB loading operations and off-gassing of the RX-277 neutron shielding material in the MSB shield lid. However, residual water within the MSB cavity is limited to very low levels (i.e., less than 1/62,500th of an atmosphere) through the vacuum drying process, which requires the MSB cavity pressure to be pumped down to 3 torr or less, held at that pressure for at least 30 minutes, back-filled with helium, and then the process repeated a second time. Furthermore, the RX-277 material is pre-heated during the fabrication process to temperatures that exceed the normal operating temperatures to remove excess unbound water. Therefore, no significant amount of moisture is expected to be released from the RX-277 during storage. Thus, the potential amount of residual water remaining in the cavity after MSB loading and from off-gassing of the RX-277 neutron shield material during storage is very small and will not result in any significant amount of corrosion. Furthermore, water ingress into the MSB cavity during storage is not considered to be credible for the double welded closure configuration of the MSB assembly.

Cladding Creep:

The rate of creep in fuel cladding is a function of the cladding temperature and hoop stress. Cladding creep exceeding 1.0% strain could cause gross rupture of the fuel cladding. However, as discussed in ISG-11 [3.7], creep will not cause gross rupture of the fuel if the cladding temperatures do not exceed 400°C during loading or storage. Cladding creep is not likely to be a significant effect over the extended storage period, since the rate of creep is a strong function of temperature, and the cladding temperatures that occur after 20 years of dry storage are relatively low and continue to reduce with time, as shown by the TLAA discussed in Section 3.3.3.5.

Cladding Annealing:

Extended exposure to elevated temperature may result in annealing of the fuel rod cladding, which in turn may affect its structural properties. However, examination of low burnup (35.7 GWd/MTU) fuel rods, such as those in the VSC-24 storage system, after 15 years of dry storage showed that little if any cladding annealing occurred over the storage period [3.5]. If no annealing occurred in the first 15 years of storage, none is expected to occur in later years, due to the significantly lower cladding temperatures that will exist. Therefore, it is concluded that cladding annealing is not a significant degradation mechanism that needs to be addressed for extended storage (past 20 years).

Hydride Redistribution and Reorientation:

Excessively high cladding temperatures and hoop stresses that can occur during the cask loading process (e.g., vacuum drying) may result in hydrogen within cladding forming a solid solution that precipitates into hydrides when the cladding subsequently cools [3.5]. High concentrations of these hydrides, particularly those oriented in the radial direction, can adversely affect the structural properties of the cladding. 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. As discussed below, 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.

Per ISG-11 [3.7], significant hydride re-orientation is not expected to occur in low burnup fuel assemblies (i.e., fuel assemblies having assembly average burnups not exceeding 45 GWd/MTU), such as those stored in the VSC-24 casks. This is confirmed by 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 [3.5]. Furthermore, ISG-11 [3.7] states that the structural integrity of SNF assemblies is assured for low burnup fuel if the peak cladding temperature during cask loading process remains under 400°C. ISG-11 further states that the 570°C 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 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 796°F (424°C), which is slightly higher that the 400°C temperature limit recommended by ISG-11 (it is noted that the maximum 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.) After 20 years of storage, maximum cladding temperatures will be significantly lower. Thus, for the low burnup fuel stored in the VSC-24 casks, hydride redistribution and reorientation are not a credible aging effect during the extended storage period.

3.2.1.4 Other Materials

The aging effects considered for the RX-277 neutron shielding material in the MSB and MTC assemblies, the lead shielding material in the MTC assembly, and the polymeric gasket material in the VCC assembly include loss of shielding effectiveness and loss of strength due to elevated temperature and/or radiation effects. The maximum temperatures of these materials during the initial storage period are all shown to be within their recommended temperature limits for the design-basis canister heat load of 24 kW. During the extended storage period, the temperatures of these materials will continue to decline due to decay of the heat load. Thus, no significant temperature-related aging effects of these materials are expected to occur during the extended storage period. Loss of shielding effectively in the RX-277 neutron shielding material is possible due to reduction in ^{10}B concentration that occurs as a result of accumulated neutron flux exposure. However, this aging effect is not expected to be significant due to the relatively low neutron radiation exposure over 60 years of storage, as discussed in Section 3.3.3.4.

3.2.2 Observed Aging Effects

This section discusses the aging effects of the VSC-24 storage system that have been observed based on operating experience. Surveillance records from the periodic examinations of the VCC cask exterior and interior are discussed in Sections 3.2.2.1 and 3.2.2.2, respectively. Performance monitoring trends are discussed in Section 3.2.2.3. Lastly, the results of the lead cask inspection performed near the end of the initial storage period are discussed in Section 3.2.2.4. Additional discussion of the corrective actions and design modifications of the VSC-24 storage system is provided in Section 3.4.3.

3.2.2.1 VCC Exterior Surface Examination

Periodic visual examinations are performed on the exterior of each VCC assembly in accordance with the requirements of Technical Specifications 1.3.1 and 1.3.2. The wire mesh screens that cover the inlet and outlet ducts of all VCC assemblies are inspected daily in accordance with Technical Specification 1.3.1 for signs of blockage or degradation. In addition, the exterior concrete surfaces of all VCCs are inspected annually in accordance with Technical Specification 1.3.2 for damage, such as cracking, chipping, or spalling. This section discusses the aging effects that have been observed during the periodic inspections of the VCC assemblies all three sites, as documented in the site inspection reports, condition reports, and work orders.

Vent Screen Degradation and Blockage:

Site records show that partial blockage of the air inlet duct screens from snowfall and debris (e.g., leaves) is periodically found. In addition, small amounts of debris have been found inside the VCC air inlet ducts (usually just behind the inlet screens) while performing daily visual inspections of the wire mesh screens. In addition, damaged screens have been identified during the periodic inspections. Typically, the screen damage consisted of bent screens or missing/damaged screen attachment hardware. When identified, debris was removed and damaged screens were repaired or replaced in accordance with existing maintenance procedures.

Concrete Degradation:

Site records associated with the annual inspection of the VCC exterior surface show that several aging effects have been observed in the concrete during the initial storage period. Generally, the aging effects consist of small surface defects, such as hairline cracks and pits (e.g., bug holes[4] or popouts) and local discoloration of the concrete from mineral deposits.

Some hairline cracks and pits in the VCC concrete surface are expected, and generally appear soon after a cask is placed in service. Cracks and surface pits exceeding the size permitted by TS 1.3.2 (i.e., any defect wider than ½-inch and deeper than ¼-inch) have been identified and repaired by re-grouting in accordance with existing maintenance procedures. Reports of defects requiring repair were uncommon during the first 10 years of ISFSI operation, and none of these involved exposure of reinforcing steel. Although some cracks have been observed to be increasing in size and length in recent years, there has been no clear increasing trend in the number of reported cracks or pits seen at any of the sites for the subsequent years, nor have there been any indications of failure of grout-repairs.

Efflorescence and mineral deposits in the location of cracks have been observed on the VCC exterior. Chemical analysis of similar deposits on other areas of a VCC shows that the deposits are primarily calcium carbonate. Efflorescence, which is caused by migration of minerals (e.g., calcium hydroxide) from the concrete to the surface when water passes through cracks, if left

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[4] Bug holes are small regular or irregular cavities, resulting from entrapment of air bubbles in the surface of formed concrete during placement and consolidation.

unmanaged over long periods of time, can result in a reduction of concrete strength properties. However, re-grouting of cracks in accordance with the existing maintenance programs prevents the flow of water through cracks and leaching of calcium hydroxide from the concrete.

Other Degradation:

Small amounts of debris have been observed in the inlet ducts of some casks. The debris is believed to be small pieces of coating from the surfaces of the MSB assembly and/or VCC assembly liner. This is consistent with the observations of the 5-year cask inspections (discussed in Section 3.2.2.2). As noted in the 5-year inspections, the MSB shell and VCC liner are in good condition, with no significant coating degradation or corrosion. Thus, there is no apparent unanticipated degradation of the coating on the MSB exterior and VCC liner surfaces.

At Point Beach, a small amount of coating failure and corrosion has been observed on the optional VSC lifting lugs located at the top end of the VCC. The rust was removed and rust inhibiting coating was applied.

3.2.2.2 VCC Interior Surface Inspection

In accordance with TS 1.3.3, the ventilation ducts and annulus of the first cask placed into service at each site are visually examined every 5 years. The primary purpose of these inspections is to check for blockage of the ventilation ducts. However, these periodic examinations also provide a visual indication of the condition of MSB shell and VCC liner, inlet ducts, and outlet ducts, which are normally inaccessible. To date, three 5-year cask inspections have been performed at each of the three plant sites where the VSC-24 storage system is deployed (i.e., 5, 10 and 15 years after the first casks were placed into service). The year of initial cask placement was 1993, 1994 and 1996 for the Palisades, Point Beach and Arkansas Nuclear One sites, respectively. In general, none of the 5-year inspections showed any significant deterioration of the inspected surfaces. Minor degradation was generally seen in the first 5-year inspection, with no significant worsening of those conditions observed in the subsequent inspections. The observations of the 5-year inspections are discussed in this section.

Blockage of Ventilation Paths:

The results of the 5-year inspections show that very little blockage has accumulated in the ventilation ducts and cask annulus. The most common form of blockage observed in the casks is small amounts of debris that have accumulated at the bottom of the main ventilation duct on the VCC bottom plate surface between the four crescent-shaped air entry holes. Chemical analysis showed that this debris was comprised of zinc, which was most likely from small pieces of zinc coating that were dislodged during the VCC handling operations or from paint over-spray during final MSB structural lid coating following loading into the VCC. In a few cases, the inspections showed spiders living inside the cask annulus. A small mud dobber's nest, approximately 1.5-inches tall by 2.5-inches wide, was discovered within an air outlet duct of one VCC. Finally, small local mineral deposits (i.e., stalactites) were seen around the entry to the outlet ducts on one VCC. Chemical analysis of these deposits shows that they are made up of calcium carbonate (from exposed concrete at the joint between the liner shell and outlet duct) and zinc (from the coating used on the VCC liner) and have non-reactive properties. These deposits are believed to be due to condensation of moisture from the air flow in the VCC annulus as it exits the VCC annulus. The calcium leached from the concrete is not expected to prevent the VCC from performing its intended functions because the calcium deposits are very small and they have non-reactive properties. All of the obstructions discovered inside the VCC ventilation ducts and annulus were small and judged to have no significant impact on the airflow. All such obstructions were removed whenever possible.

Condition of MSB Shell:

In general, the 5-year inspections show that the majority of the MSB shell surface is in excellent condition, with very little coating degradation or signs of corrosion. All 5-year inspections found some discoloration on the MSB shell near the top end. The coating discoloration is believed to have resulted from high temperatures in the heat affected zone of the MSB closure welds. Also, some localized light oxidation has been observed on the MSB shell coating. The coating on the outside of the MSB shell and bottom plate is not relied upon for corrosion protection during the storage period. The MSB design basis includes a corrosion allowance of 0.003-inch per year, or 0.06 inches for the initial 20-year storage period. The results of the 5-year inspections show that only local coating failure and corrosion has occurred on the MSB shell, and the amount of corrosion is significantly less than the design basis. Some white residue was identified on the MSB shell, which is believed to residuals from the solution used for the MSB decontamination.

Condition of VCC Liner and Ventilation Duct Surfaces:

The inspections show that the coating is in good shape and there is no corrosion over the majority of the VCC liner surface and VCC inlet and outlet duct surfaces. There are a few small areas where coating failure and surface corrosion was observed. Some rust staining was observed in some of the cask inlet ducts, although there was no other visual evidence of corrosion occurring on these surfaces. There is no evidence of any degradation of the VCC liner surface and VCC inlet and outlet duct surfaces that would prevent the VCC from perform its intended design functions.

3.2.2.3 Performance Monitoring

Two system performance parameters that have been monitored during the initial storage period by the VSC-24 cask system operators are the temperature of the air leaving the cask outlet vents (relative to the external ambient temperature) and dose rates around the casks and ISFSI. These system parameters are trended to identify degradation that could possibly impact safety functions. Historical data from the outlet temperature readings and dose rate surveys at the existing ISFSIs are discussed below.

Outlet Temperature Readings:

Prior to Amendment 6 of the VSC-24 CoC, which was issued in June 2006, TS 1.2.3 included a requirement to monitor the air temperature at the outlet vents of the loaded VSC-24 casks to verify that the rise in air temperature above ambient did not exceed 110°F. An air temperature rise greater than 110°F could indicate blockage of the ventilation ducts and may result in system temperatures that are approaching the thermal acceptance criteria.

The historical outlet temperature monitoring records from the three VSC-24 ISFSI sites have been reviewed to identify any potential trends that may indicate aging effects in the casks. The daily measurements of the temperature increase (i.e., the difference between the air outlet temperature and ambient air temperature) in each VSC-24 cask during the initial storage period show that the average temperature rise has not changed significantly over time. The data does show cyclic behavior, with larger ΔT values generally occurring in the summer months. In all cases, the data show that the ΔT values are generally less than half the limit (i.e., less than 55°F) and consistent with the actual cask heat loads.

The air outlet temperature data, for all three sites, indicates that the component temperatures in the cask system have remained below the design-basis and/or allowable values by a wide margin during the initial storage period. The data also provides evidence that no significant blockage of the airflow path in any VSC-24 cask has occurred over the initial storage period.

Dose Rate Surveys:

Dose rates are periodically measured at various locations around the casks and ISFSI at each site to verify that the doses are within the regulatory limits. The dose rate measurement records have been reviewed for trends that may indicate aging effects in the casks. The results show no adverse trends in the dose rate measurements that would indicate aging effects in the cask shielding materials.

At the Palisades plant, regular dose rate readings were taken at the inlet ducts of the 18 casks in the ISFSI. The data clearly shows a decreasing trend of air inlet dose rate with time, which is expected given the decay of SNF. In all cases, the measured inlet duct dose rates are far below the dose rate limit. Measurements of the dose rate on the cask side were not taken on a regular basis. The side dose measurements that were taken show that no cask side dose rate measurements exceed the value measured at the time of initial cask loaded, or the dose rate limit of TS 1.2.4.

The Palisades dose rate records also state that the dose rate all around the perimeter of the ISFSI has remained low (< 0.5 mrem/hr) throughout the initial storage period. Swipes were also taken of the cask exterior surfaces, and there were no instances of contamination levels over the 1000 dpm/100 cm^2 beta-gamma criterion. Palisades' records also include environmental surveys taken in the vicinity of the ISFSI, which show no indication of closure weld leakage.

The Palisades data described above shows decreasing dose rate trends for the cask inlet vents, and show no evidence of any increasing dose rates on or around the casks or ISFSI. The data also show no evidence of contamination or leakage of isotopes out of the casks.

At Point Beach, dose rates were monitored on the West, East, North and South fences around the ISFSI. The data show no significant increasing trend of area dose rate with time, after the last of the 16 casks was placed in the ISFSI in 2003. Dose rates did increase while casks were being added, particularly on the West fence. Point Beach has continued to load and store other cask designs at their ISFSI, which also affects the area dose rates.

A limited number of area dose rate measurements were performed at ANO. Dose rate measurements were taken at several locations around the ISFSI pad edge, and within the cask array. The measurements showed maximum gamma dose rates of 2 mrem/hr and maximum neutron dose rates of 0.2 mrem/hr. These dose rates are less than the dose rates present at the time of cask loading, and no trends of increasing dose rate with time was observed.

Given the lack of any significant dose rate increases with time, or over any temporary period, it is concluded that significant degradation of the shielding performance of the casks has not occurred during the initial storage period.

3.2.2.4 Lead Cask Inspection

The initial lead cask inspection for the VSC-24 Storage System was performed on Palisades Cask Number VSC-15 from May 21, 2012 through May 24, 2012, prior to the start of the extended storage period. As discussed in Section 3.4.4, the scope of the lead cask inspection included visual examination of the VCC bottom surface, remote visual examination of the VCC annulus (i.e., VCC liner and MSB shell), inlet air ducts, and outlet air ducts, and visual examination of the VCC cask lid, MSB structural lid and closure weld. The results of the initial lead cask inspection, which are discussed in greater detail in the following paragraphs, indicate that VSC-24 storage system components have not undergone any unanticipated degradation during the initial storage period.

As discussed in Section 3.4.4, the VSC-24 lead cask is selected based upon a number of parameters that contribute to degradation, such as design configuration, environmental conditions, time in service, and total heat load of the SNF stored in the MSB. For the initial lead cask inspection, a single cask (Palisades Cask Number VSC-15) was selected from the fifty-eight loaded VSC-24 casks at the three ISFSIs. This cask, which was loaded in June 1999, was selected primarily because it has the highest initial heat load (14.7 kW) of all loaded VSC-24 casks. No significant differences were identified between the environmental conditions or design configuration used at the three (3) different sites. An overall timeline of the VSC-24 casks loaded to date is provided in Figure 2. The VSC-24 cask with the longest time in service is Palisades Cask Number VSC-01, which was loaded in May 1993. Although this cask has approximately six (6) more years in service than Palisades Cask Number VSC-15, it was not selected for the lead cask inspection since it is already inspected on the exterior every year, as discussed in Section 3.4.2.2, and on the interior at a 5-year frequency, as discussed in Section 3.4.2.3. Rather, the cask with the highest heat load was selected for the initial lead cask inspection to gain additional operating experience.

Although not required for the lead cask inspection, the exposed concrete surfaces on the sides and top of the VCC lead cask were visually examined for concrete aging effects, including scaling, cracking, or spalling, increased porosity, map or pattern cracking, and other unanticipated concrete degradation. The exterior surfaces of the concrete were concluded to be in good overall condition. The visual examination of the VCC concrete exterior showed only a small number of bug holes that exceeded the acceptance criteria and required grout repair. No other aging effects were identified on the VCC concrete exterior.

The VCC was lifted and a remote visual inspection (borescope) of the VCC bottom surface, which is lined by a ¼-inch thick coated carbon steel plate, was performed to identify coating degradation and corrosion. In addition, the normally inaccessible underlying surface of the storage pad, which is not an in-scope SSC, was also remote visually inspected. The inspection results show that no unanticipated degradation of the VCC bottom surface has occurred during the initial storage period. The coating on the VCC bottom plate and the concrete surface of the underlying storage pad were both concluded to be in good condition. After the inspection of the VCC bottom surface, a 3-foot long by 1/8-inch wide gap was noted between the VCC bottom plate and the VCC bottom concrete. The separation of the bottom plate from the concrete resulted from flexing of the plate when the VCC was lifted to inspect its bottom surface. Since the VCC bottom plate provides no other function than to form the geometry of the air inlet ventilation ducts during the concrete pour, this condition will not prevent the VCC from performing its intended functions during the extended storage period.

A remote visual examination of the readily accessible surfaces of the VCC annulus (VCC liner and MSB shell), inlet ducts, and outlet ducts was performed using a borescope to identify blockage of air flow and degradation of the coated carbon steel surfaces that line the ventilation paths. The results showed very little debris (e.g., leaves and bugs) and mineral deposits had accumulated in the ventilation flow path and that the air ducts were essentially clear. In addition, no coating degradation or corrosion was identified on the MSB shell, VCC liner, inlet ducts, or outlet ducts.

The VCC cask lid, MSB structural lid, and MSB closure weld were visually examined for evidence of coating degradation and corrosion. In order to access the MSB structural lid and closure weld, the VCC cask lid was removed and the VCC shield ring was lifted a small amount. Although some corrosion was noted on the cask lid bolts, they were determined to be acceptable. Upon removal of the VCC cask lid, the VCC lid gasket was found to be in good condition with no evidence of leakage during the initial storage period. The coating on the MSB structural lid and closure weld was also found to be in good condition, with a few small areas that had "bubbled" but were still intact. Upon removal of the temporary shielding used during the inspection, a small area (approximately ½-inch wide by 6-inches long) of coating adjacent to the closure weld inadvertently scraped off. In addition, the coating around one of the threaded plugs in the lifting hole of the MSB structural lid was bubbled. The steel surfaces underneath the coating that was bubbled and scraped off did not show any signs of corrosion. The exposed steel surfaces were cleaned and recoated. Upon completion of this inspection, a new VCC lid gasket was installed and the VCC cask lid was attached.

In conclusion, the results of the initial lead cask inspection show that no unanticipated degradation of Palisades Cask Number VSC-15 has occurred during the initial storage period. The inspected surfaces of the VCC and MSB assembly were in very good condition.

3.3 Time-Limited Aging Analyses

In-scope SSC that are subject to a potential aging effect are addressed either through Time-Limited Aging Analysis (TLAA) or by an Aging Management Program (AMP). TLAAs that can adequately predict degradation associated with identified aging effects, and can be reconfirmed for the period of extended operation, do not require additional Aging Management Activities (AMAs). This section discusses the criteria used to identify TLAAs and the evaluation and disposition of the identified TLAAs for the extended period of operation. In accordance with 10 CFR 72.240(c)(2), the TLAAs demonstrate that SSC ITS will continue to perform their intended safety function for the period of extended operation.

3.3.1 TLAA Identification Criteria

The following criteria defined in NUREG-1927 [3.1] are used to identify TLAAs for existing SSC with a time dependent operating life:

(1) Involves in-scope SSC,

(2) Considers the effects of aging,

(3) Involves time limited assumptions (e.g., 20-year) that are explicit in the analysis,

(4) Determined to be relevant in making a safety determination,

(5) Provides conclusions, or the basis for conclusions, regarding the capability of the SSC to perform its intended safety function through the operating term, and

(6) Contained or incorporated by reference in the licensing basis.

3.3.2 TLAA Identification Process and Results

Design documents for the VSC-24 Storage System were reviewed against the TLAA identification criteria discussed in Section 3.3.1. These included the CoC [3.3], NRC Safety Evaluation Reports (SERs), and Technical Specifications for the VSC-24 Storage System, VSC-24 Storage System FSAR [3.2], docketed licensing correspondence, and generic calculations and site-specific calculations and evaluations. The following TLAAs were identified for further evaluation and disposition for the extended period of operation:

(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)

Each of these TLAAs is further evaluated and dispositioned for the extended period of operation as follows: (i) Remains valid for the extended license period, (ii) Projected to the end of the extended period of operation, or (iii) Aging effects on intended safety functions will be adequately managed for the extended period of operation. The evaluations and dispositions of these TLAAs for the extended period of operation are discussed in Section 3.3.3.

3.3.3 Evaluation and Disposition of Identified TLAAs

3.3.3.1 MSB Helium Leakage Evaluation

The CLB for the MSB assembly includes an evaluation to determine the amount of the helium gas that could potentially leak from the cavity during a 50-year service period. The evaluation postulates different sized leak paths through the MSB confinement boundary that produce a flow rate of $1.0x10^{-4}$ 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 helium leakage rates for normal, off-normal, and accident storage conditions are determined for postulated leak paths using the maximum upstream pressure and temperature. The maximum helium leakage rate is then used to determine the total volume of helium gas leaked over the 50-year service period, conservatively assuming a constant leakage rate. The evaluation concludes that up to 2.4% of the helium volume in the MSB cavity may be leaked over the 50-year service period, and that this will have a smaller effect on the MSB thermal performance than the decay of the SNF heat-generation rate.

The MSB helium leakage analysis has been projected to the end of the 60-year service period. The results show that the maximum amount of helium gas leaked from the MSB cavity during the 60-year extended storage period increases to approximately 2.7%. The conclusions of the helium leakage analysis remain unchanged for the 60-year extended storage period.

3.3.3.2 MSB Fatigue Evaluation

The CLB for the MSB assembly includes an evaluation of fatigue effects for a 50-year storage period, as discussed in Section 3.4.4.1.5 of the VSC-24 Storage System FSAR [3.2]. The evaluation demonstrates that the MSB assembly is not susceptible to fatigue failure during the 50-year storage period. 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 [3.11], which does not to exceed 1,000 cycles.

The MSB fatigue analysis has been projected to the end of the 60-year service period. The total number of expected cycles increases to 605 cycles, which remains below 1,000 cycles. 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, one full-range pressure cycle is added for the MSB unloading backfill operation. The results demonstrate that the MSB will continue to satisfy the fatigue criteria for the extended period of operation (i.e., 60 years.)

3.3.3.3 MSB Corrosion Evaluation

The CLB for the MSB assembly includes an evaluation of corrosion on the MSB shell and bottom plate for a 50-year service period in a coastal marine environment, as discussed in

Section 1.2.1.1 of the VSC-24 Storage System FSAR [3.2]. 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 external surfaces during storage. The maximum corrosion loss on the external surfaces of the MSB shell and bottom plate is conservatively estimated to be 0.15-inch over a 50-year period based on a uniform corrosion rate of 0.003-inch/year for uncoated carbon steel in a marine environment. The MSB corrosion TLAA demonstrates that the corroded MSB shell and bottom plate satisfy the applicable allowable stress design criteria for the controlling load conditions.

The MSB corrosion analysis has been projected to the end of the 60-year service period. The additional thickness reduction of the MSB shell and bottom plate for the extended storage period is 0.03 inches, for a total corrosion allowance of 0.18 inches. The TLAA demonstrates that the maximum stresses in the corroded MSB shell and bottom plate continue to satisfy the corresponding allowable stress design criteria. Therefore, the corroded MSB shell and bottom will continued to satisfy their intended safety functions for the extended period of operation (i.e., 60 years.)

3.3.3.4 Radiation Effects Analysis

The cumulative effect of neutron and gamma radiation on the structural and shielding properties of the VSC-24 storage system materials is evaluated for an extended storage period of 60-years. As discussed below, the cumulative neutron and gamma radiation levels in all components of the VSC-24 storage system over 60-years of storage are much lower than the radiation levels at which the structural and shielding properties of the carbon steel, concrete, and neutron shielding materials are adversely affected.

Carbon Steel:

The total neutron and gamma radiation exposures for the inner steel components of the VSC-24 storage system (i.e., the MSB assembly and VCC steel liner) over 60-years are estimated to be approximately 1.3×10^{14} n/cm^2 and 1×10^{10} rads, respectively, based on EPRI TR-102462, *Shipment of Spent Fuel in Storage Canisters* [3.15]. The damaging effects of neutron radiation on steel are seen at a fast neutron (i.e., > 1.0 MeV) fluence level above 1×10^{17} n/cm^2 [3.15], or approximately three orders of magnitude greater than the total neutron exposure for the steel components of the VSC-24 storage system. Gamma radiation has no measureable impact on the mechanical properties of steel [3.15].

Concrete:

The total cumulative neutron and gamma radiation doses on the VCC concrete over the 60-year extended storage period are estimated considering the dose attenuation provided by the 2.75-inch combined thickness of carbon steel MSB shell and VCC liner shell. Carbon steel does not significantly attenuate neutrons. Therefore, the cumulative neutron dose to the VCC concrete shell over the 60-year extended storage period is approximately equal to that of the inner steel components, or 1.3×10^{14} n/cm^2. However, gamma dose for a typical SNF fission product gamma energy spectrum is attenuated by a factor of ten (10) by 2.75-inches of steel [3.18]. Therefore, the concrete is exposed to approximately 1x10^9 rads of gamma radiation over the 60-year extended storage period.

Neutron radiation has little effect on shielding or thermal properties of concrete, but it can impact its structural properties at levels as low as 1x10^{17} n/cm^2 [3.16]. Thus, the total estimated neutron radiation exposure of the VCC concrete is approximately 1,000 times lower than the levels at which adverse affects are expected. Gamma radiation at doses of 1x10^{10} rads or higher may adversely affect the structural properties of concrete [3.16]. Thus, the total estimated gamma radiation exposure of the VCC concrete is one (1) order of magnitude lower than the levels at which adverse affects are expected.

RX-277 Neutron Shield:

The total cumulative neutron and gamma radiation doses on the RX-277 neutron shielding material in the MSB shield lid over the 60-year extended storage period are estimated 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. Carbon steel does not significantly attenuate neutrons. Therefore, the cumulative neutron dose to the RX-277 neutron shielding material over the 60-year extended storage period is approximately equal to that of the inner steel components, or 1.3x10^{14} n/cm^2. However, gamma dose 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 [3.18]. Therefore, the RX-277 neutron shield material is exposed to approximately 7x10^7 rads of gamma radiation over the 60-year extended storage period.

The RX-277 neutron shielding material product data [3.17] shows that it can withstand neutron and gamma radiation levels of 5x10^{19} n/cm^2 and 1x10^{10} rads, respectively. The allowable neutron radiation level is over five (5) orders of magnitude higher that the cumulative neutron radiation dose estimated over the 60-year extended storage period. Furthermore, the allowable gamma radiation level is over one hundred and fifty (150) times higher that the cumulative neutron radiation dose estimated over the 60-year extended storage period. Thus, neutron and gamma radiation are not expected to adversely affect the properties of RX-277 during the extended storage period.

The shielding effectiveness of RX-277 is not adversely affected by neutron radiation during the extended storage period. Neutron absorption in RX-277 results in transmutation of ^{10}B into ^{11}B. The volume of RX-277 in the MSB shield lid (approximately 1x10^5 cm^3) contains approximately 2.8 x 10^{25} atoms of ^{10}B based on a boron atom density of 1.43x10^{21} atoms/cc [3.17], which equates to a 2.8x10^{20} atoms/cc ^{10}B atom density. 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 1x10^{14}, which is over eleven (11) orders of magnitude lower than the number of ^{10}B atoms within the shield.

Transmutation of hydrogen into deuterium, from neutron absorption, is also not an issue 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 1.3x10^{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 [3.17]. Thus, the fraction of hydrogen atoms lost will be much lower than the fraction of ^{10}B atoms lost, which is negligible, as discussed above.

3.3.3.5 Fuel Cladding Creep Evaluation

The maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system are based on the cladding creep methodology described in PNL-6364 [3.13]. The criterion applied limits the total strain in the fuel cladding due to creep to 1% over a 40-year storage period. The creep methodology accounts for the decrease in cladding temperature and hoop stress that are expected to occur during the storage period.

After the initial 40-year storage period, the peak cladding temperature for design basis fuel will reduce to approximately 150°C and the corresponding cladding hoop stress will be approximately 67 megapascals (MPa). Based on PNL-6364 [3.13], the cladding strain rate under these conditions is estimated to be approximately 10^{-17} s^{-1}. Conservatively assuming the cladding strain rate remains constant for the extended storage period, the additional accumulated strain for the additional 20-year period is $6.3x10^{-9}$ in/in; an insignificant fraction of the allowable total strain (1%). Therefore, it is concluded that the maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system remain applicable for the 60-year extended storage period.

3.3.3.6 Palisades MSB-04 Weld Crack Growth Evaluation

As discussed in Section 3.4.3.3, indications of flaws were identified in the longitudinal seam weld of Palisades MSB-04 after the MSB was loaded and placed into service. A fatigue crack-growth analysis of a bounding 1-inch long by ½-inch deep subsurface flaw was performed, which showed 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. The analysis also demonstrates that the flaw stability factors of safety are greater than those required by the ASME Code for normal and faulted conditions.

The fatigue crack growth analysis of Palisades MSB-04 has been projected to the end of the 60-year service period. The 0.18-inch corrosion thickness reduction of the outside surface of the MSB shell for the extended storage period has been included in the fatigue crack growth analysis. In order to bound the potential crack growth in the corroded shell, the 1-inch long by ½-inch deep flaw has been modeled on the inside surface of the MSB shell rather than the subsurface. The TLAA demonstrates that the bounding 1-inch long by ½-inch deep flaw in Palisades MSB-04 grows to 0.5000072 inches deep by 1.0000025 inches long over the 60-year extended service period, considering a bounding corrosion allowance of 0.18-inches and the full range of normal, off-normal, and accident load conditions. Finally, the TLAA demonstrates that the flaw stability factors of safety remain greater than those required by the ASME Code for normal and faulted conditions.

3.4 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 8 through Table 11. 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 12. 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.

3.4.2.1 Examination of VCC Assembly Air Inlets and Outlets

The wire mesh screens that cover the inlet and outlet ducts of all VCC assemblies are visually inspected on a daily frequency in accordance with the TS 1.3.1. The purpose of this examination is to monitor the cask for conditions that cause blockage of the air ventilation paths (e.g., accumulation of snow or debris) or degradation of the wire mesh screens (and screen attachment hardware) that could prevent them from performing their intended functions (i.e., preventing material from entering and blocking the VCC air flow paths.) As shown in Table 12, this examination is credited with managing loss of material due to corrosion of the air inlet and outlet screens and attachment hardware. The AMP elements of this examination are summarized in Table 13 and discussed in this section.

Detection and removal of blockage of the screens that cover the VSC assembly air inlets and outlets on a daily frequency assures that natural convective heat transfer will be maintained within the VCC assembly annulus and maximum material temperatures will not exceed the temperature limits. Identification and repair of degradation of the wire mesh screens (and attachment hardware) in accordance with the GL's Corrective Action Program assures that the wire mesh screens will maintain their intended functions.

Operating experience during the initial storage period shows that TS 1.3.1 provides adequate management of aging effects that could potentially result in a loss of the vent screens intended functions. As discussed in Section 3.2.2.1, only small amounts of debris (e.g., leaves or mud) have been observed inside the VCC air inlet ducts. Typical degradation of the screens during the initial storage period included bent screens or missing/damaged screen attachment hardware, which were corrected in accordance with existing maintenance procedures. Therefore, the AMP will adequately manage the aging effects identified for the VCC assembly wire mesh screen covers (and attachment hardware) during the extended storage period.

3.4.2.2 Examination of the VCC Assembly Exterior Concrete

The exterior surfaces of all VCC assemblies are required to be visually inspected for concrete degradation (e.g., cracking, chipping, or spalling) on a yearly frequency in accordance with TS 1.3.2. The purpose of the examination is to maintain the surface condition of the VCC assembly concrete in order to prevent degradation of the concrete and maintain the VCC assembly's intended functions. The exterior concrete surfaces are examined and monitored for indications of aging mechanisms that may cause loss of strength, such as cracking due to aggregate reactions or corrosion of embedded steel and increased porosity due to CaOH leaching or aggressive chemical attack. The aging effects that TS 1.3.2 is credited with managing are identified in Table 12. The AMP elements of this examination are summarized in Table 14 and discussed in this section.

Aging effects for the VCC assembly concrete shell that are managed by the examination of the VCC assembly exterior concrete include cracking, scaling, spalling, and loss of strength. Cracking, scaling, and spalling of the concrete surface can result from several different aging mechanisms, including freeze-thaw cycles, 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 cracking, scaling, or spalling, in accordance with Technical Specification 1.3.2. Concrete defects that exceed ½-inch in diameter (or width) and ¼-inch deep are required to be repaired by re-grouting to prevent further degradation of the interior concrete and embedded steel reinforcing, evaluated to determine their cause, and monitored (i.e., crack mapping) and trending during the extended storage period to identify possible concrete aging effects, such as ASR-induced expansion and corrosion of embedded steel. Progressive growth of defects in the concrete surface may indicate degradation due to ASR-induced expansion or corrosion of reinforcing steel.

Loss of concrete strength may result from ASR 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), mineral deposits, or increased porosity on the concrete surface. The exposed concrete surfaces on the sides and top of the VCC assembly shall be visually examined for evidence that may indicate loss of strength. Performance monitoring (i.e., crack mapping) performed at regular intervals (i.e., annually), provides a non-destructive means to assess potential degradation of the VCC concrete strength. If performance monitoring indicates the potential presence of ASR-induced degradation or leaching of CaOH, then additional actions shall be taken to confirm the presence of the degradation mechanism, determine the cause of the aging effect, determine if the aging effect has adversely affected the concrete strength, and evaluate the VCC assembly for continued storage.

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. Cracks and surface pits 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 of reported cracks or pits seen at any of the sites for the subsequent years, nor have there been any indications of failure of grout-repairs. Therefore, the AMP will adequately manage the aging effects identified for the exterior surfaces of the VCC assembly during the extended storage period.

3.4.2.3 Examination of the VCC Assembly Ventilation Ducts and Annulus

In accordance with the requirements of TS 1.3.3, the first VSC-24 cask loaded at each site is visually examined on a 5-year frequency. The visual examination of each air inlet duct, air outlet duct, and the VCC annular region (top to bottom) 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 air flow and prevent the VCC assembly from performing its intended heat transfer function. The other purpose of this examination is to confirm, through remote visual inspection, that the metal surfaces that line the inside the VCC assembly air inlets, air outlets, and cask annulus (including the MSB shell), which are normally inaccessible, are not experiencing any unanticipated degradation that could prevent them from performing their intended functions. 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 12, TS 1.3.3 is credited with managing loss of material due to corrosion of the VCC air inlet and outlet ducts, liner shell, and liner bottom. The AMP elements of TS 1.3.3 are summarized in Table 15 and discussed in this section.

The steel plates that line the VCC air inlet and outlet ducts and the cask annulus serve as cast-in-place formwork, which form the VCC geometry that provides the ventilation flow path, thus providing a heat transfer function. In addition, the VCC liner provides radiation shielding and is credited for structural support for certain load conditions. The shield ring plates located at the top of the VCC annulus provide radiation shielding at the top of the cask. Although the exposed surfaces of these steel plates are coated, degradation of the coating and corrosion may occur during the extended storage period. If significant corrosion is observed on these steel plates, then the VCC assembly shall be evaluated for continued storage. Significant corrosion is considered to be corrosion that results in loss of material, such as excessive pitting or scaling that has an adverse affect on the shielding, structural, or thermal safety functions of the VCC assembly. Corrosion that results only in discoloration of the surface, such as rust blooms, will not result in the loss of any of the VCC assembly's intended functions.

Although the exterior surfaces of the MSB are coated, a corrosion allowance of 0.003 inches per year is conservatively assumed for the MSB shell and bottom plate, as discussed in

Section 3.3.3.3. This general corrosion rate is based on uncoated carbon steel in a marine environment. Some degradation of the coating and corrosion on the exterior surfaces of the MSB shell and bottom plate is expected to occur during storage, and is acceptable. The visual examination of the exterior surface of the MSB shell provides qualitative confirmation that there is not any unanticipated degradation of the MSB shell (e.g., excessive pitting corrosion greater than the design basis corrosion allowance) that could prevent the MSB from performing its intended safety functions.

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, TS 1.3.3 will adequately manage the aging effects identified for the VCC assembly interior during the extended storage period.

3.4.2.4 Examination of VSC Top End Steel Components

The top interior of one VSC-24 cask loaded at each site is visually examined on a 10-year interval 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 within one (1) year before or after the first cask loaded at the site has been in storage for 20-years. All subsequent examinations must also be performed within one (1) year before or after the date of the 10-year interval. 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.[5] However, the same cask shall be used for the subsequent examinations such that trending can be performed.

The scope of the examination includes measurement of the neutron dose rate on the top centerline surface of the VCC cask lid and visual inspection of all readily accessible surfaces (internal and external) of the VCC cask lid, VCC liner flange, VCC shield ring plates, VCC lid gasket, VCC lid bolts, MSB structural lid, MSB valve covers, and MSB closure weld. The purposes of this examination are: (1) to confirm through neutron dose rate measurement and trending that aging effects in the RX-277 neutron shielding material do not affect its ability to perform its shielding function during the extended storage period, and (2) to confirm, through visual inspection, that the surfaces of the VCC cask lid, VCC liner flange, VCC shield ring plates, VCC lid gasket, VCC lid bolts, MSB structural lid, MSB valve covers, and MSB closure weld, 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

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[5] Since this examination is included in the scope of the lead cask inspection discussed in Section 3.4.4, it may be included in the lead cask inspection for the 20-year intervals, but must be performed separately for the intermediate 10-year intervals. For those sites that do not perform lead cask inspections, this examination must be performed per the specified timing and intervals.

is credited with managing are identified in Table 12. The AMP elements of this examination are summarized in Table 16 and discussed in this section.

Visual inspection of the VCC liner flange, shield ring plates, MSB structural lid, and MSB closure weld may be performed using long-handled tools and/or remote visual equipment (e.g., borescope/camera). In order to perform the examination of the VSC top end steel components, the VCC cask lid must be removed. If the view of the MSB closure weld is blocked by the VCC shield ring plates, the VCC shield ring plates may be lifted slightly (no more than 2") to expose the MSB closure weld. 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, replace the VCC cask lid gasket, secure the VCC cask lid, and replace the locking wire.

The VCC cask lid provides radiation shielding and structural support safety functions. In addition, the cask lid and lid gasket serve to protect the MSB assembly from the exposed external environment. Corrosion of the VCC cask lid or liner flange could diminish their structural and shielding capacities. Also, degradation of the VCC cask lid, liner flange, or lid gasket could allow water to leak into the top of the VCC assembly, which could potentially lead to unanticipated degradation of the MSB structural lid and closure weld and the steel components inside VCC. The VCC shield ring plates provide only a shielding safety function. Coating degradation and general surface corrosion of the VCC shield ring plates is permitted as it will not significantly diminish their shielding capacity.

The safety function of the MSB shield lid neutron shield (RX-277) is radiation shielding. As discussed in Section 3.3.3.4, a TLAA shows the cumulative neutron and gamma radiation exposure over the 60-year extended storage period will not adversely affect the properties of the MSB shield lid neutron shield RX-277 material. Measurement and trending of the neutron shield dose rate at the center of the VCC cask lid provides additional confirmation that the shielding effectiveness of the RX-277 neutron shielding material in the MSB shield lid is maintained during the extended storage period. Neutron dose rates are expected to gradually decrease during the extended storage period. Increases in the measured neutron dose rate, which could indicate degradation of the RX-277 shielding effectiveness, shall be evaluated by the GL in accordance with the site's Corrective Action Program. If the GL's evaluation concludes that degradation of the RX-277 shielding effectiveness has occurred, then extent of condition must be determined and the affected casks must be evaluated for continued storage.

The safety functions of the MSB structural lid, valve covers, and closure weld include confinement, structural support, shielding, and heat transfer. Significant corrosion of the MSB structural lid, valve covers, and closure weld (i.e., corrosion resulting in loss of material, such as scaling) could diminish their ability to perform the intended safety functions. However, corrosion that results only in discoloration of the steel surfaces, such as rust blooms, is not considered to be significant since it will not result in the loss of intended functions. Safety analyses of the MSB structural lid and closure weld are based on nominal dimensions and do not include a corrosion allowance.

Indications of water leakage into the top of the VCC assembly, degradation of the coating that exposes the underlying steel, or corrosion that is identified during the visual inspection shall be documented using appropriate means (i.e., photographs, video recording, and/or written descriptions.) If necessary, areas of degraded coating on the VCC cask lid and liner flange, and MSB structural lid, valve covers, and closure weld should be removed and the underlying metal surface examined to determine if any significant loss of material has occurred. If the coating is degraded to the extent that the underlying steel is exposed, or it is determined that corrosion of the MSB structural lid, valve covers, and/or closure weld has caused significant loss of material, then the GL shall document the condition in accordance with the site's Corrective Action Program. Coating on the MSB structural lid, valve covers, and/or closure weld that is degraded or has been removed to permit examination of the underlying steel shall be repaired. If the inspected VCC and/or MSB assembly is determined to have significant corrosion, it must be evaluated for continued storage and the extent of condition must be determined.

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 in good condition. Upon removal of the temporary shielding used during the inspection, a small area of coating was inadvertently scraped off of the MSB structural lid, but the underlying steel surface did not show 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.

3.4.2.5 Examination of the MTC Assembly

The MTC assembly aging effects that require management by AMP, as identified in Table 12, are limited to loss of material due to corrosion of the exposed surfaces of the coated and uncoated carbon steel subcomponents. 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. Coating degradation and exposure to moist atmospheric conditions (i.e., sheltered environment) may lead to corrosion of the MTC assembly carbon steel subcomponent. The purposes of this examination are to ensure that the MTC assembly does not experience any loss of material during the extended storage period that could prevent it from performing its intended functions. The AMP elements of the MTC assembly examination are summarized in Table 17 and discussed in this section.

The scope includes a visual examination of all readily accessible interior and exterior surfaces of the MTC assembly and a functional test of the MTC shield doors. The MTC assembly examination shall be performed annually. However, if the MTC assembly has not been used for a period exceeding one year, annual examination is not required, but the examination must be performed prior to using the MTC assembly for MSB loading or unloading operations. The visual examination of all readily accessible interior and exterior surfaces is performed to identify degradation of the coating and corrosion of the underlying 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. The functional test of the MTC shield door assembly is performed to verify that the shield doors slide as required for the MSB vertical transfer operations.

Coating degradation and corrosion identified during the visual examination of the MTC assembly will be documented using appropriate means (i.e., photographs, and/or written descriptions) and evaluated, reviewed, approved, and corrected using the GL's Corrective Action Program. Coating degradation that exposes a significant area of the underlying carbon steel surface must be evaluated by the GL for continued use. If it is determined that corrosion on the underlying steel has resulted in loss of material (as opposed to just discoloration), then the MTC assembly shall be evaluated for continued use and the corroded surfaces shall be repaired. Unacceptable coating degradation and corrosion shall be repaired to prevent further loss of material during the extended storage period.

The functional test of the MTC shield door assembly shall demonstrate that the shield doors can be opened and closed with the MTC hydraulic assemblies. Degradation of the lubrication coating on the sliding surfaces of the shield doors may cause increased sliding resistance. If required, the sliding surfaces may be re-coated with lubrication.

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 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 10CFR72.48

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, no additional changes have been made in accordance with 10 CFR Part 72.48 by the CH. 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 [3.20] to identified NRC safety concerns related to these issues; then issued Corrective Action Letter (CAL) Number 97-7-001 [3.21] to Sierra Nuclear Corporation (SNC) in May 1997. Subsequently, SNC submitted the response to CAL 97-7-001 [3.22], 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 and 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 yet 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 UT examinations were also performed of the top 4-inches of the already-fabricated MSB shells to identify the presence of lamellar defects near the closure weld region and low-sulfur material was required for all later MSB shells, as discussed below. The results of the ASME Section XI fracture mechanics analysis that was performed for possible defects in the MSB shell show they are smaller than the threshold for crack propagation due to cyclic loading for all normal, off-normal, and accident condition stresses. 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 4-inch long crack along the weld fusion line. 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. 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 under-bead cracking made in a moist environment [3.20]. 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 [3.22]. 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.

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, UT examination of welded closures of the loaded MSB assemblies was performed 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. 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 ¾-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 ½-inch deep subsurface flaw. The analysis, which was reviewed by NRC staff [3.25], shows that the fatigue crack growth over the 50-year storage period of the MSB assembly is less that 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 3.3.3.4. 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 [3.23] 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 either during fabrication or loading operations. The GL's investigation indicated that some hydraulic fluid may 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.

As a result 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.

3.4.4 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 [3.1]. The lead cask inspection is performed at the end of the initial 20-year storage period and at 20-year intervals during the extended storage period. The results of the lead cask inspection performed at the end of the initial storage period are discussed in Section 3.2.2.4. The aging effects that the lead cask inspection is credited with managing are identified in Table 12. The elements of the lead cask inspection program are summarized in Table 18 and discussed in this section.

The VSC-24 lead cask is selected based upon a number of parameters that contribute to degradation, such as design configuration, environmental conditions, time in service, and total heat load of the SNF stored in the MSB. The lead cask inspection may be limited to a single VSC-24 cask at one site if there are not significant differences in the cask selection parameters that warrant separate inspections. The selection of the lead cask should also consider possible overlap of inspections previously performed on VSC-24 casks.

The scope of the VSC-24 lead cask inspection includes visual inspection of the VCC concrete exterior surfaces (discussed in Section 3.4.2.2) and visual inspection of the VCC interior (discussed in Section 3.4.2.3). In addition, the VCC bottom surface and the VCC top interior (including the MSB structural lid and closure weld), which all normally inaccessible, are included in the scope of the lead cask inspection. These additional inspections are described in the following paragraphs.

The bottom surface of the VCC assembly, which is normally inaccessible during storage, is visually examined 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., bore-scope/camera).

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 the air flow.

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.)

All readily accessible surfaces of the VCC cask lid, liner flange, and shield rings, and the MSB structural lid and closure weld are visually examined for evidence of coating degradation and corrosion. Also, the VCC cask lid gasket and the top end of the VCC cavity are visually examined for evidence of water intrusion. In order to perform this surveillance, the cask lid is removed. Visual inspection of the VCC liner flange, VCC shield rings, MSB structural lid, and MSB closure weld may be performed using long-handled tools and/or remote visual equipment (e.g., bore-scope/camera). If required, the VCC shielding ring is lifted slightly to expose the MSB closure weld for visual examination.

The VCC cask lid provides radiation shielding and structural support safety functions. In addition, the cask lid and lid gasket serve to protect the MSB assembly from the exposed external environment. Corrosion of the cask lid or cask flange could diminish their structural and shielding capacities. Also, degradation of the cask lid, cask flange, or lid gasket could allow water to leak into the top of the VCC, which could potentially lead to unanticipated degradation of the MSB structural lid and closure weld and the steel components inside VCC. The VCC shield rings provide only a shielding safety function. Coating degradation and general surface corrosion of the VCC shield rings is permitted as it will not significantly diminish the shielding capacity of the VCC shield rings.

The safety functions of the MSB structural lid and closure weld include confinement, structural support, shielding, and heat transfer. Corrosion of the MSB structural lid and closure weld that results in loss of material (as opposed to discoloration) could diminish their ability to perform the intended safety functions. Safety analyses of the MSB structural lid and closure weld are based on nominal dimensions and do not include a corrosion allowance.

Coatings on the readily accessible surfaces of the VCC cask lid, VCC liner flange, and MSB structural lid and closure weld are considered degraded if the underlying metal surface is exposed. Corrosion of the VCC cask lid, VCC liner flange, and MSB structural lid and closure weld that results in loss of material (e.g., excessive pitting or scaling) is considered significant if it will adversely affect the structural or shielding safety functions of the components. Discoloration (e.g., rust staining) of the steel caused by corrosion is not considered to be significant since it will not result in the loss of intended functions.

Indications of water leakage into the top of the VCC assembly, degradation of the coating that exposes the underlying steel, or corrosion that is identified during the visual inspection shall be documented using appropriate means (i.e., photographs, video recording, and/or written descriptions.) If necessary, areas of degraded coating on the VCC cask lid and liner flange, and MSB structural lid, valve covers, and closure weld should be removed and the underlying metal surface examined to determine if any significant loss of material has occurred. If the coating is degraded to the extent that the underlying steel is exposed, or it is determined that corrosion of the MSB structural lid, valve covers, and/or closure weld has caused significant loss of material, then the GL shall document the condition in accordance with the site's Corrective Action

Program. Coating on the MSB structural lid, valve covers, and/or closure weld that is degraded or has been removed to permit examination of the underlying steel shall be repaired. If the inspected VCC and/or MSB assembly is determined to have significant corrosion, it must be evaluated for continued storage and the extent of condition must be determined.

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.

3.5 Retrievability

The VSC-24 storage system is designed to allow ready retrieval of the SNF assemblies for further processing and disposal, in accordance with 10 CFR 72.122(l). The VSC-24 storage system does not include a dual-purpose (storage and transportation) canister design to satisfy the requirements of 10 CFR 72.236(m). Therefore, as discussed in ISG-2 [3.19], ready retrieval of the SNF assemblies from the MSB assembly requires: (1) the ability to transfer the sealed MSB assembly to a spent fuel pool (or other facility), and (2) the ability to unload the SNF assemblies from the MSB assemblies for repackaging to allow removal from the reactor site, transportation, and ultimate disposition by the Department of Energy.

The results of the AMR show that there are no credible aging effects in the SNF assemblies that require management during the extended storage period. Only low burnup (≤ 45 GWd/MTU), intact, zircaloy-clad PWR SNF assemblies are stored in the VSC-24 storage system. Degradation of the cladding of low burnup fuel will not occur during the initial storage period and should not occur during extended storage if the inert atmosphere inside the MSB cavity is maintained. Corrosion of the MSB assembly structural lid and closure weld are managed by the AMP during the extended storage period to ensure that no aging effect result in the loss of their intended functions (primarily confinement and structural support.) This provides reasonable assurance that the MSB assembly will be able to be transferred to a spent fuel pool and the SNF assemblies will be capable of being removed from the MSB assembly by normal means. Furthermore, the MSB re-flooding analyses that were performed for the initial storage period to demonstrate that the fuel cladding would not be damaged by the effects of "thermal shock" remain valid and bounding for the extended storage period since the MSB heat loads only decrease with time.

3.6 References

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[3.3] U.S. Nuclear Regulatory Commission, Certificate of Compliance for Spent Fuel Storage Casks, Model No.: Ventilated Storage Cask (VSC-24), Certificate No. 1007, Docket No. 72-1007; Initial Issue (Effective May 7, 1993); Amendment No. 1 (Effective May 30, 2000); Amendment No. 2 (Effective September 5, 2000); Amendment No. 3 (Effective May 21, 2001); Amendment No. 4 (Effective February 3, 2003); Amendment No. 5 (Effective September 13, 2005); Amendment No. 6 (Effective June 27, 2006).

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[3.6] U.S. Nuclear Regulatory Commission, NUREG/CR-6745, *Dry Cask Storage Characterization Project – Phase 1: CASTOR V/21 Cask Opening and Examination*, September 2001.

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[3.8] ACI 349-90, *Code Requirements for Nuclear Safety Related Concrete Structures*, American Concrete Institute.

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[3.11] American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, Division 1, *Rules for Construction of Nuclear Power Plant Components*, Subsection NC, *Class 2 Components*, 1986 through 1998 Editions, with 2000 Addenda.

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[3.14] U.S. Nuclear Regulatory Commission, Office of Nuclear Material Safety and Safeguards, NRC Information Notice 2011-20, *Concrete Degradation by Alkali-Silica Reaction*, November 18, 2011.

[3.15] EPRI TR-102462, *Shipment of Spent Fuel in Storage Canister*, Electric Power Research Institute, June 1993.

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[3.17] RX-277 Shielding Material Product Data Sheet, Bulletin S-73N, Reactor Experiments, Inc., Sunnyvale, CA, August 1991.

[3.18] ANS/SD-76/14, *A Handbook of Radiation Shielding Data*, Shielding and Dosimetry Division, American Nuclear Society, July 1976.

[3.19] U.S. Nuclear Regulatory Commission, Interim Staff Guidance 2, Revision 1, *Fuel Retrievability*, February 2010.

[3.20] U.S. Nuclear Regulatory Commission, NRC Inspection Report No. 72-1007/97-204 and Notice of Nonconformance, April 15, 1997.

[3.21] U.S. Nuclear Regulatory Commission, Confirmatory Action Letter No. 97-7-001, May 16, 1997.

[3.22] Sierra Nuclear Corporation, *Responses to CAL 97-7-001*, July 30, 1997.

[3.23] U.S. Nuclear Regulatory Commission, Bulletin 96-04, *Chemical, Galvanic, or Other Reactions in Spent Fuel Storage and Transportation Casks*, July 5, 1996.

[3.24] Executive Summary, VSC-24 Lead Cask Inspection – Palisades, Revision 0 September 19, 2012.

[3.25] U.S. Nuclear Regulatory Commission, Memorandum from Eric Benner to Christine Lipa, Subject: Response to Region III Technical Assistance Request - Palisades Plant Multi-Assembly Sealed Basket No. 4 (MSB #4) - Weld Flaw Analysis, January 20, 2010, Docket Nos. 50-255; 72-007.

Table 8 - MSB Assembly AMR Results (2 Pages)

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Shell	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
			Crack Growth	Fatigue	TLAA
		Sheltered	Loss of Fracture Toughness	Radiation	TLAA
			Crack Growth	Fatigue	TLAA
			Loss of Material	Corrosion	TLAA
Bottom Plate	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
			Crack Growth	Fatigue	TLAA
		Sheltered	Loss of Fracture Toughness	Radiation	TLAA
			Crack Growth	Fatigue	TLAA
			Loss of Material	Corrosion	TLAA
Shield Lid Support Ring	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Lifting Lug	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Structural Lid	Coated CS	Inert Gas	Crack Growth	Fatigue	TLAA
			Loss of Fracture Toughness	Radiation	TLAA
		Sheltered	Loss of Material	Corrosion	AMP
			Crack Growth	Fatigue	TLAA
			Loss of Fracture Toughness	Radiation	TLAA
Closure Weld Backing Ring	Coated CS	Inert Gas	N/A	N/A	None
Shim	Coated CS	Inert Gas	N/A	N/A	None
Shield Lid Top Plate	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Bottom Plate	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Side Ring	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Neutron Shield	RX-277	Embedded	Loss of Shielding Effectiveness	Radiation	TLAA & AMP
Shield Lid Pipe & Flex Tubing	Alloy Steel	Inert Gas	N/A	N/A	None

Table 8 - MSB Assembly AMR Results (2 Pages)

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Swagelok Quick Connect	Steel	Inert Gas	N/A	N/A	None
Structural Lid Valve Covers	Coated CS	Inert Gas	Crack Growth	Fatigue	TLAA
			Loss of Fracture Toughness	Radiation	TLAA
		Sheltered	Loss of Material	General Corrosion	AMP
			Crack Growth	Fatigue	TLAA
			Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Support Plate	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Storage Sleeve	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Basket Edge Structure	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA

Notes:

(1) Safety functions of the MSB assembly subcomponents are provided in Table 4.

Table 9 - VCC Assembly AMR Results (2 Pages)

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Concrete Shell	Concrete	Exposed	Loss of Strength	ASR	AMP
				CaOH Leaching	
				Radiation	TLAA
			Scaling, Cracking, & Spalling	Freeze/Thaw	AMP
				ASR	AMP
				Corrosion (Rebar)	AMP
Rebar	CS	Embedded	Loss of Material	Corrosion (Rebar)	AMP
			Loss of Fracture Toughness	Radiation	TLAA
Cask Liner Shell	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Cask Liner Bottom	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Liner Flange	Coated CS[2]	Exposed	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Cask Lid	Coated CS	Exposed	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA

Table 9 - VCC Assembly AMR Results (2 Pages)

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Lid Bolts, Nuts, Lockwashers	Coated CS	Exposed	Loss of Material	Corrosion	AMP
Locking Wire w/ Lead Seal	SS/Lead	Exposed	N/A	N/A	N/A
Lid Gasket	Polymer	Exposed	N/A	N/A	N/A
Shielding Ring Plates	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Tile (MSB support)	Ceramic	Sheltered	N/A	N/A	N/A
Air Inlet Assembly	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
		Embedded	N/A	N/A	N/A
Air Outlet Weldment	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
		Embedded	N/A	N/A	N/A
Air Inlet Screen/Hardware	Galvanized Steel	Exposed	Loss of Material	Corrosion	AMP
Air Outlet Screen/Hardware	Varies	Exposed	Loss of Material	Corrosion	AMP
Bottom Plate Assembly	Coated CS[2]	Exposed	Loss of Material	Corrosion	AMP
		Embedded	N/A	N/A	N/A
MTC Alignment Plates	Coated CS[2]	Exposed	N/A	N/A	N/A
VSC Lifting Lugs (Optional)	Coated CS[2]	Exposed	Loss of Material	Corrosion	AMP
		Embedded	Loss of Fracture Toughness	Radiation	TLAA

Notes:

(1) Safety functions of the VCC assembly subcomponents are provided in Table 5.

(2) Coatings are only applied to the air-facing surfaces of these steel components. The embedded surfaces are not coated.

Table 10 - MTC Assembly AMR Results (2 Pages)

Subcomponent[1]	**Material**	**Environment**	**Aging Effect**	**Aging Mechanism**	**Aging Management Activities**
Outer Shell	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Inner Shell	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Top Ring	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Bottom Ring	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
			Loss of Fracture Toughness	Radiation	TLAA
		Embedded	Loss of Fracture Toughness	Radiation	TLAA
Neutron Absorber Shield	RX-277	Embedded	Loss of Shielding Effectiveness	Radiation	TLAA
Lead Shield	Lead	Embedded	None	None	None
Drain Pipe	CS	Embedded	N/A	N/A	N/A
Angle, Heat Transfer	Coated CS	Embedded	None	None	None
Trunnion	CS	Sheltered	Loss of Material	General Corrosion	AMP
Trunnion Cylinder / End Covers	Coated CS	Sheltered	Loss of Material	General Corrosion	AMP
MTC Lid	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Lid Bolts	CS	Sheltered	Loss of Material	Corrosion	AMP
Shim/Flange	CS	Sheltered	Loss of Material	Corrosion	AMP
Rail Shield	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Rail Lower Plate	Coated CS	Sheltered	Loss of Material	Corrosion	AMP

Table 10 - MTC Assembly AMR Results (2 Pages)

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Rail Alignment Plate/Door Bolt	Coated CS	Sheltered	N/A	N/A	N/A
Shield Door	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Door Top Cover	Coated CS	Sheltered	N/A	N/A	N/A
Door Hydraulics/Brackets/ Attach. Hardware	Coated CS	Sheltered	N/A	N/A	N/A

Notes:

(1) Safety functions of the MTC assembly subcomponents are provided in Table 6.

Table 11 - SNF Assembly AMR Results

Subcomponent[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Fuel Pellets	UO_2	Inert Gas	N/A	N/A	None Required
Fuel Cladding	Zircaloy	Inert Gas	Change in Dimension	Cladding Creep	TLAA
Spacer Grid Assemblies	Zircaloy or SS	Inert Gas	N/A	N/A	None Required
Upper End Fitting	SS / inconel	Inert Gas	N/A	N/A	None Required
Upper End Fitting	SS / inconel	Inert Gas	N/A	N/A	None Required
Guide Tubes	Zircaloy	Inert Gas	N/A	N/A	None Required
Holddown Spring & Upper End Plugs	SS / inconel	Inert Gas	N/A	N/A	None Required
Control Components	Varies[3]	Inert Gas	N/A	N/A	None Required

Notes:

[1] Safety functions of the SNF assembly subcomponents are provided in Table 7.

[2] 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.

[3] Generally stainless steel clad, containing neutron absorbing materials such as boron-carbide, borosilicate glass or silver-indium-cadmium alloy.

Table 12 - Summary of Aging Effects Managed by AMP (2 Pages)

In-Scope SSC	Subcomponent	Material	Environment	Aging Effect	Aging Mechanism	AMP Section(s)
MSB Assembly	Structural Lid	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.4
	Lid Valve Covers	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.4
	Shield Lid Neutron Shield	RX-277	Embedded	Loss of Shielding Effectiveness	Radiation	3.4.2.4
VCC Assembly	Concrete Shell	Concrete	Exposed	Loss of Strength	ASR	3.4.2.2
					CaOH Leaching	3.4.2.2
				Cracking, Spalling & Pitting	Freeze/Thaw	3.4.2.2
					ASR	3.4.2.2
					Corrosion (Rebar)	3.4.2.2
	Rebar	CS	Embedded	Loss of Material	Corrosion (Rebar)	3.4.2.2
	Cask Liner Shell	Coated CS$^{(1)}$	Sheltered	Loss of Material	Corrosion	3.4.2.3
	Cask Liner Bottom	Coated CS$^{(1)}$	Sheltered	Loss of Material	Corrosion	3.4.2.3
	Liner Flange	Coated CS$^{(1)}$	Exposed	Loss of Material	Corrosion	3.4.2.4, 3.4.4
			Sheltered	Loss of Material	Corrosion	3.4.2.4, 3.4.4
	Cask Lid	Coated CS	Exposed	Loss of Material	Corrosion	3.4.2.4, 3.4.4
			Sheltered	Loss of Material	Corrosion	3.4.2.4, 3.4.4
	Lid Bolts/Nuts/Lockwashers	Coated CS	Exposed	Loss of Material	Corrosion	3.4.2.4, 3.4.4
	Shielding Ring Plates	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.3, 3.4.2.4, 3.4.4
	Air Inlet Assembly	Coated CS$^{(1)}$	Sheltered	Loss of Material	Corrosion	3.4.2.3
	Air Outlet Weldment	Coated CS$^{(1)}$	Sheltered	Loss of Material	Corrosion	3.4.2.3
	Air Inlet Screen/Hdwr.	Galvanized Steel	Exposed	Loss of Material	Corrosion	3.4.2.1

Table 12 - Summary of Aging Effects Managed by AMP (2 Pages)

In-Scope SSC	Subcomponent	Material	Environment	Aging Effect	Aging Mechanism	AMP Section(s)
	Air Outlet Screen/Hdwr.	Varies	Exposed	Loss of Material	Corrosion	3.4.2.1
	Bottom Plate Assy.	Coated CS(1)	Exposed	Loss of Material	Corrosion	3.4.4
	VSC Lifting Lug (Optional)	Coated CS(1)	Exposed	Loss of Material	Corrosion	3.4.2.3
MTC Assembly	Outer Shell	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Inner Shell	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Top Ring	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Bottom Ring	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Trunnion	CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Trunnion Cylinder / End Covers	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	MTC Lid	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Lid Bolts	CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Shim/Flange	CS	Sheltered	Loss of Material	Corrosion	3.4.2.5
	Rail Shield	Coated CS	Sheltered	Loss of Material	Corrosion	3.4.2.5

Notes:

(1) Coatings are only applied to the air-facing surfaces of these steel components. The embedded surfaces are not coated.

Table 13 - Examination of VCC Assembly Air Inlets and Outlets (2 Pages)

AMP Element	AMP Activity
Scope	Inspection of the wire mesh screen covers on all air inlets and outlets of all in-service casks (TS 1.3.1).
Preventative Actions	Maintain inlets and outlets free from blockage for prolonged periods to prevent system temperatures from exceeding the applicable temperature limits.
Parameters Monitored or Inspected	The wire mesh screens that cover the air inlet and outlet openings are inspected for blockage (e.g., from debris or snow drifts) and degradation or damage (e.g., bent screens, missing attachment hardware, and corrosion.)
Detection of Aging Effects	Detection and removal of screen blockage ensures that system temperatures will not exceed the applicable temperature limits. Detection of degraded or damaged screen covers ensures that screen covers will not be breached.
-Method or Technique:	Visual examination by personnel qualified in accordance with the GLs procedure.
-Frequency:	Daily.
-Sample Size:	All wire mesh screen covers on all in-service casks.
-Data Collection:	Records of corrective actions.
-Timing of inspections:	Routine.
Monitoring and Trending	Trending may be performed based on deficiencies documented in accordance with GL's Corrective Action Program.
Acceptance Criteria	Wire mesh screen shall cover the VCC air inlet and outlet duct openings and be free of blockage.
Corrective Actions	If surveillance shows blockage of the wire mesh screen covers, remove the blockage. If wire mesh screens and the associated attachment hardware are degraded or damaged to the extent that they cannot perform their intended function, repair or replace degraded or damaged components in accordance with the GL's Corrective Action Program. In the event that an unacceptable screen breach is identified, conduct a close-up inspection of the breached inlet or outlet for internal blockage and remove any readily accessible blockage inside the inlet or outlet.
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 13 - Examination of VCC Assembly Air Inlets and Outlets (2 Pages)

AMP Element	AMP Activity
Operating Experience	Partial blockage of VCC air inlet duct screens from snowfall and debris (e.g., leaves or mud) has periodically been identified. Screen damage (e.g., bent screens or missing/degraded attachment hardware) has also been identified, but less frequently. All degraded conditions identified have been corrected in accordance with existing site maintenance procedures. The existing AMP activity has provided adequate aging management during the initial storage period.

Table 14 - Examination of VCC Assembly Exterior Concrete (2 Pages)

AMP Element	AMP Activity
Scope	Inspection of the readily accessible exterior concrete surfaces of all in-service VCC assemblies (TS 1.3.2).
Preventative Actions	Maintain surface condition of concrete in order to prevent degradation of the concrete interior (e.g., reinforcing steel.)
Parameters Monitored or Inspected	Damage/degradation of concrete exterior surface including: (1) Cracking, loss of bond, and loss of material (spalling or scaling) due to freeze-thaw, aggregate reactions, or corrosion of embedded steel, (2) Increased porosity and/or discoloration due to CaOH leaching or aggressive chemical attack.
Detection of Aging Effects	Aging effects on the exterior concrete surfaces will be detected before the affected SSC lose the ability to perform their intended functions.
-Method or Technique:	Visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.56). Inspector qualifications in accordance with ASME Code, Section XI, Subsection IWL (Ref. 3.2.17) or ACI 349.3R (Ref. 3.2.18) are both acceptable.
-Frequency:	Yearly.
-Sample Size:	All readily accessible external concrete surfaces of all in-service casks.
-Data Collection:	Video/photographs of examination, crack maps with sizes and depths. Records of corrective actions.
-Timing of inspections:	Routine.
Monitoring and Trending	Crack maps shall be monitored and trended to identify progressive growth of defects that may indicate degradation due to ASR-induced expansion or corrosion of rebar. Crack maps should be compared with those from previous inspections to identify accelerated degradation of the structure during the period of extended storage. A baseline crack map should be developed at the beginning of the extended storage period either from previous inspection results or from the initial inspection during the extended storage period.
Acceptance Criteria	No defects on concrete exterior surface that that are greater than ½-inch in diameter (or width) and ¼-inch deep. No evidence of degradation mechanisms that may result in loss of concrete strength (e.g., ASR-induced expansion, leaching, or corrosion of rebar.)

Table 14 - Examination of VCC Assembly Exterior Concrete (2 Pages)

AMP Element	AMP Activity
Corrective Actions	Defects on the concrete exterior surface exceeding acceptance criteria shall be evaluated to determine their cause and repaired by re-grouting in accordance with the GL's procedures. Concrete that shows evidence of degradation mechanisms that may result in loss of concrete strength (e.g., ASR-induced expansion, leaching, or corrosion of rebar) shall be evaluated for continued storage.
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	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.

Table 15 - Examination of VCC Assembly Ventilation Ducts and Annulus (2 Pages)

AMP Element	AMP Activity
Scope	The interior (i.e., inlet ducts, VCC annulus, and outlet ducts) of the first VSC cask placed into service at each site (TS 1.3.3).
Preventative Actions	Identify and remove any unanticipated blockage in the VCC inlet ducts, outlet ducts, and annulus to prevent system temperatures from exceeding the applicable temperature limits.
Parameters Monitored or Inspected	Blockage of the internal ventilation flow path and degradation of the coated carbon steel surfaces that line the ventilation flow path (i.e., air inlet and outlet assemblies, VCC liner shell, and MSB shell).
Detection of Aging Effects	Identification of unanticipated blockage and degradation of the surfaces on the VCC interior.
-Method or Technique:	Remote visual examination.
-Frequency:	5-year.
-Sample Size:	First cask placed in-service at each site.
-Data Collection:	Documentation of examination, including blockage identified and condition of VCC interior surfaces. Records of corrective actions.
-Timing of inspections:	After the first cask is loaded at the site.
Monitoring and Trending	Blockage, coating degradation, and corrosion of the internal ventilation flow path shall be compared with results from previous inspections to identify potential accelerated degradation of the structure during the extended storage period. A baseline should be developed at the beginning of the extended storage period either from previous inspection results or from the initial inspection during the extended storage period.
Acceptance Criteria	No significant blockage (i.e., >10% of segment cross-section area) of any air flow paths. No corrosion on the VCC inlet ducts, outlet ducts, and liner that prevents the VCC from performing its intended functions.
Corrective Actions	Blockage that exceeds the acceptance criteria shall be removed. Any blockage that can be removed by reasonable means should be removed. VCC assemblies with significant corrosion on the plates that line the inlet and outlet vents and/or the VCC liner shall be evaluated for continued use and the extent of condition must be evaluated.
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 15 - Examination of VCC Assembly Ventilation Ducts and Annulus (2 Pages)

AMP Element	AMP Activity
Operating Experience	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.

Table 16 - Examination of VSC Top End Steel Components (2 Pages)

AMP Element	AMP Activity
Scope	Measurement of the neutron dose rate at the centerline on the top surface of the VCC cask lid. Inspection of the readily accessible surfaces (internal and external) of the VCC cask lid, VCC liner flange, VCC shield ring plates, VCC lid gasket, VCC lid bolts, MSB structural lid, MSB valve covers, and MSB closure weld.
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	Neutron dose rate at the centerline on the top surface of the VCC cask lid. Degradation of the VCC cask lid, liner flange, shield ring plates, lid gasket, and lid bolts, and the MSB structural lid, valve covers, and closure weld.
Detection of Aging Effects	Identification of increased neutron dose rates at the centerline on the top surface of the VCC cask lid could indicate unanticipated aging effects in the MSB shield lid neutron shield RX-277 material. 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:	Dose rate measurements obtained using calibrated equipment by site radiation protection personnel. Direct or remote visual examination of readily accessible surfaces. Visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.56). Qualifications for personnel performing the general visual examinations of the coated steel surfaces of the VCC and MSB assemblies in accordance with the requirements of IWE-2330 are acceptable.
-Frequency:	10-year (± 1 year).
-Sample Size:	One cask at each site.
-Data Collection:	Documentation of examination, including condition of VCC top interior surfaces. Records of corrective actions.
-Timing of inspections:	Starting within 1 year (before or after) of the 20th anniversary of the first cask loaded at the site.
Monitoring and Trending	Compare the neutron dose rate measurement at the top centerline of the VCC cask lid with the measurements taken at the time of loading and those taken during the extended storage period. Coating degradation and corrosion shall be compared with those from previous inspections to identify accelerated degradation of the structure during the period of extended storage. A baseline should be developed from the initial inspection during the extended storage period.

Table 16 - Examination of VSC Top End Steel Components (2 Pages)

AMP Element	AMP Activity
Acceptance Criteria	No increasing trend in neutron dose rate at the top centerline of the VCC cask lid. No significant coating degradation on the VCC cask lid and liner flange, or the MSB structural lid, valve covers, and closure weld that exposes the underlying carbon steel surface, and no corrosion that results in significant loss of material and prevents the VCC and MSB assemblies from performing their intended functions. Corrosion that results only in discoloration (e.g., oxidation or "rust blooms") of these surfaces, is not considered to be significant since it will not result in the loss of intended functions. Coating degradation and corrosion of the VCC shield rings is permitted as it will not significantly diminish its shielding capacity.
Corrective Actions	Evaluate increases in dose rates measurements at the top centerline of the VCC cask lid in accordance with the site's Corrective Action Program, determine extent of condition, and evaluate affected casks for continued storage. Repair unacceptable coating degradation on the VCC cask lid and liner flange, and MSB structural lid, valve covers, and closure weld in accordance with the GL's procedures and evaluate the extent of condition, which may require the similar inspection of additional casks. Replace any VCC lid bolts that are corroded. Replace the VCC lid gasket.
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 VCC top interior 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.

Table 17 - Examination of MTC Assembly (2 Pages)

AMP Element	AMP Activity
Scope	Examination of all readily accessible interior and exterior surfaces of the MTC assembly and functional test of the MTC shield doors.
Preventative Actions	Identification and repair of 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. Maintenance of the lubrication on the sliding surfaces of the MTC shield door assembly assures that the shield doors will function.
Parameters Monitored or Inspected	Degradation of the coating and corrosion of the underlying carbon steel on all readily accessible surfaces. Degradation of the lubrication on the sliding surfaces of the MTC shield door assembly.
Detection of Aging Effects	Identification of unanticipated degradation of coatings and lubricants and corrosion of the MTC assembly subcomponents.
-Method or Technique:	Visual examination.
-Frequency:	Annually.[6]
-Sample Size:	Each MTC assembly.
-Data Collection:	Photographs of examination.
-Timing of inspections:	Not more than 1-year prior to use.
Monitoring and Trending	Areas of degraded coating and corrosion that the GL determines do not require repair before MTC use must be recorded and monitored during subsequent examinations to identify potential accelerated degradation of the structure during the extended storage period.
Acceptance Criteria	No coating degradation that exposes the underlying carbon steel surface and no corrosion of the underlying carbon steel surfaces that results in significant loss of material and prevents the MTC assembly from performing its intended structural and shielding functions. MTC shield door must be capable of being opened and closed with the MTC hydraulic assemblies.
Corrective Actions	Repair degraded coating, as required, to prevent corrosion of the MTC assembly and protect the spent fuel pool chemistry during fuel loading/unloading operations. If corrosion has resulted in significant loss of material, evaluate the MTC assembly for continued use. Coat sliding surfaces of MTC shield doors with lubrication.
Confirmation Process	Ensure that corrective actions are completed and effective in accordance with the GL's Corrective Action Program.

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[6] If the MTC assembly has not been used for a period exceeding one year, annual examination is not required, but the examination must be performed prior to use of the MTC assembly.

Table 17 - Examination of MTC Assembly (2 Pages)

AMP Element	AMP Activity
Administrative Controls	Formal review and approval of Corrective Actions in accordance with the GL's Corrective Action Program.
Operating Experience	N/A.

Table 18 - Lead Cask Inspection (2 Pages)

AMP Element	AMP Activity
Scope	Inspection of the bottom surface of VCC, internal ventilation flow path (i.e., inlet ducts, VCC annulus, and outlet ducts), and VCC top interior (i.e., VCC cask lid, liner flange and shield plates, and the MSB structural lid and closure weld) of a lead cask.
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	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., air inlet and outlet assemblies, VCC liner shell, and MSB shell); and degradation of the VCC cask lid, VCC shield plates, MSB structural lid and MSB closure weld.
Detection of Aging Effects	Identification of unanticipated degradation on the VCC internal ventilation flow path surfaces, bottom surface, and top interior surfaces; Identification of unanticipated degradation on the side and top surfaces of the MSB assembly.
-Method or Technique:	Direct visual examination of readily accessible surfaces and remote visual examination of the VCC ventilation flow path and VCC bottom surface. Visual examination performed and evaluated by personnel qualified in accordance with industry guidelines for implementing the requirements of the Maintenance Rule (10 CFR 50.56). Qualifications for personnel performing the general 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.
-Sample Size:	One or more casks at one or more sites.
-Data Collection:	Video/photographs of examination.
-Timing of inspections:	Initial lead cask inspection prior to CoC renewal.
Monitoring and Trending	Coating degradation and corrosion shall be compared with those from previous inspections to identify accelerated degradation of the structure during the period of extended storage. A baseline should be developed from the initial inspection during the extended storage period.
Acceptance Criteria	No significant coating degradation on the VCC liner shell, liner bottom, cask lid, and liner flange, or the MSB structural lid and closure weld that exposes the underlying carbon steel surface and no corrosion that results in significant loss of material and prevents the VCC and MSB assemblies from performing their intended functions. No significant blockage (i.e., >10% of segment cross-section area) of any air flow paths.

Table 18 - Lead Cask Inspection (2 Pages)

AMP Element	AMP Activity
Corrective Actions	Repair unacceptable coating degradation on the VCC cask lid, MSB structural lid, or MSB closure weld in accordance with the GL's procedures. Remove unacceptable blockage from VCC ventilation path.
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 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 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.

Appendix A

VSC-24 Storage System FSAR Changes

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Appendix A: VSC-24 Storage System FSAR Changes

The proposed changes to the VSC-24 Storage System FSAR to support the VSC-24 Storage System CoC renewal are summarized in Table A-1.

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Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
1.1	Change 2nd paragraph, 1st sentence on pg. 1-2 to read: "The VSC-24 System has been designed and analyzed for a lifetime of ~~50~~ **60** years."	Extended storage period.
1.2.1.1	Change 2nd paragraph, 5th sentence on pg. 1-4 to read: "The **MSB** shell **and bottom plate** thickness**es** ~~was~~ **are** designed to withstand ~~more than 50 years~~ **60 years** of corrosion in an uncoated condition in a coastal, marine environment.".	MSB corrosion TLAA updated. (Section 3.3.3.3)
Table 1.2-4	Change service life to read: "~~>50 years~~ **60 years**"	Extended storage period.
3.3	Add the following sentences at the end of the section: "**Gamma and neutron radiation exposure of the VSC-24 storage system materials over the 60-year storage period are below the levels at which the material properties are adversely affected.**".	Address radiation effects for extended storage period.
3.4.4.1.5	Change "(a) Full Range Pressure Cycles" to read: "The normal operating pressure for the MSB is 14.7 psia (0 psig). The full range pressure cycles are due to: vacuum drying, two pressure tests, postulated failure of all fuel rods and ~~significant ambient temperature changes (conservatively assumed to occur 10 times per year during 50 years of the cask lifetime)~~**unloading (backfill).** Therefore, the total number of fluctuations of this type is (a) = 1 + 2 + 1 + **1** ~~10 * 50~~ = ~~504~~ **5**." Change "(b) Expected Number of Pressure Cycles" to read: "~~The expected number of pressure cycles of this type is 0 since fluctuations in weather conditions need not be considered here.~~ **MSB service pressure fluctuations in which the range of pressure variation is expected to exceed 20% of the design pressure will result from seasonal variations in ambient temperature. The normal full range of seasonal variation in ambient temperature is expected to occur once annually. However, it is conservatively assumed in this evaluation that ten (10) of these service pressure cycles occur each year. Therefore, the expected number of pressure cycles for the MSB assembly in which the range of pressure variation exceeds 20% of the design pressure is determined to be 600 cycles over a 60-year storage period.**".	MSB fatigue TLAA updated. (Section 3.3.3.2)

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
	Change 1st sentence of the last paragraph to read: "The discussion presented in the preceding paragraphs shows that (a) + (b) + (c) + (d) = ~~504~~ **605** and less than 1000.".	
9.3	Add heading "**Section 9.3 Aging Management**".	New SAR section.
9.3.1	Add heading "**Section 9.3.1 Aging Management Review**". Add text: "**The Aging Management Review (AMR) of the VSC-24 Ventilated Storage Cask System provides an assessment of aging effects that could adversely affect the ability of in-scope SSC to perform their intended functions during the extended storage period. Aging effects, and the mechanisms that cause them, are evaluated for the combinations of materials and environments identified for the subcomponent of the in-scope SSC based upon a comprehensive review of known literature, industry operating experience, and maintenance and inspection records. Aging effects that could adversely affect the ability of the in-scope SSC to perform their safety function(s) require additional Aging Management Activity (AMA) to address potential degradation that may occur during the extended storage period. Aging effects that require AMA, either by a Time-Limited Aging Analysis (TLAA) or an Aging Management Program (AMP) are summarized in Table 9.3-1 through Table 9.3-4. The TLAAs and AMPs that are credited with managing aging effects during the extended storage period are discussed in Sections 9.3.2 and 9.3.3, respectively.**". Add AMR summary tables: (See Tables 9.3-1 through 9.3-4).	New section describing AMR.
9.3.2	Add heading "**Section 9.3.2 Time-Limited Aging Analysis**". Add text: "**A comprehensive review of the TLAAs for the in-scope SSC of the VSC-24 Storage System was performed to identify the analyses that could be credited with managing aging effects over the extended storage period. The TLAAs identified involved the in-scope SSC, considered the effects of aging, involved explicit time-limited assumptions, provided conclusions regarding the capability of the SSC to perform its**	New section discusses TLAAs that are credited with managing aging effects during the extended storage

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
	intended function through the operating term, and were contained or incorporated in the licensing basis. The TLAAs identified include: (1) MSB helium leakage evaluation, (2) MSB fatigue evaluation, (3) MSB corrosion evaluation, (4) Radiation effects analysis, and (5) Fuel cladding creep evaluation. Each of TLAAs identified was further evaluated and dispositioned for the extended period of operation to demonstrate that the TLAA adequately manages the aging effects on intended safety functions for the extended period of operation, as discussed in the following sections.".	period.
9.3.2.1	Add heading "**Section 9.3.2.1 MSB Helium Leakage Evaluation**". Add text: "**The MSB helium leakage evaluation has been projected to the end of the 60-year service period. The evaluation postulates different sized leak paths through the MSB confinement boundary that produce a flow rate of $1.0x10^{-4}$ standard cubic centimeter (std. cc) per second (i.e., the maximum permissible MSB helium leak rate per TS 1.2.2) under the limiting helium leak test conditions. The helium leakage rates for normal, off-normal, and accident storage conditions are determined for postulated leak paths using the maximum upstream pressure and temperature. The maximum helium leakage rate is then used to determine the total volume of helium gas leaked over the 60-year extended storage period, conservatively assuming a constant leakage rate. The results show that the maximum amount of helium gas leaked from the MSB cavity during the 60-year extended storage period is approximately 2.7%, which will have a smaller effect on the MSB thermal performance than the decay of the SNF heat-generation rate.**".	New section to discuss TLAA.
9.3.2.2	Add heading "**Section 9.3.2.2 MSB Fatigue Evaluation**". Add text: "**The MSB fatigue analysis presented in Section 3.4.4.1.5 has been projected to the end of the 60-year service period. The total number of expected cycles remains below 1,000, thus satisfying Condition A of NC-3219.2 of the ASME Code.**".	New section to discuss TLAA.
9.3.2.3	Add heading "**Section 9.3.2.3 MSB Corrosion Evaluation**". Add text: "**As discussed in Section 1.2.1.1, the MSB shell and bottom plate thicknesses are**	New section to discuss TLAA.

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change[(1)]	Basis
	designed to withstand 60 years of corrosion in an uncoated condition in a coastal, marine environment. The maximum corrosion loss on the external surfaces of the MSB shell and bottom plate under these conditions is conservatively estimated to be 0.18-inch over a 60-year period based on a uniform rate of 0.003-inch/year. The maximum stresses in the corroded MSB shell and bottom plate are determined for the controlling load combinations using a combination of hand-calculations and finite element analysis and shown to satisfy the corresponding allowable stress design criteria. The controlling load combination for the MSB shell is vertical drop plus internal pressure. The MSB vertical drop analysis described in Section 11.2.2.2 is repeated for the corroded material condition. The maximum membrane (P_m) stress and membrane plus bending ($P_L + P_b$) stress intensities in the corroded MSB shell for the vertical drop plus internal pressure loading are 47.0 ksi and 47.3 ksi, respectively, compared to the corresponding ASME Code allowable stress intensity limits of 49.0 ksi and 63.0 ksi, respectively. The controlling load combinations for the MSB bottom plate are horizontal drop plus internal pressure for primary membrane (P_m) stress intensity and dead load plus off-normal pressure plus off-normal handling for membrane plus bending ($P_L + P_b$) stress intensity. The maximum primary membrane (P_m) stress intensity in the corroded MSB bottom plate for the combined horizontal drop plus internal pressure loading is determined by linearly scaling the stresses by the ratio of the plate thickness (i.e., by 0.75”/0.57”.) The resulting maximum primary membrane (P_m) stress intensity in the corroded MSB bottom plate is 43.6 ksi, compared to the ASME Code allowable stress intensity limit of 49.0 ksi. The maximum membrane plus bending ($P_L + P_b$) stress intensity in the corroded MSB bottom plate for the combined dead load plus off-normal pressure plus off-normal handling loading is determined by repeating the analysis described in Section 3.4.4.1.2. The resulting maximum membrane plus bending ($P_L + P_b$) stress intensity in the corroded MSB bottom plate is 35.5 ksi, compared to the ASME Code allowable stress intensity limit of 40.5 ksi.”.	

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
9.3.2.4	Add heading "Section 9.3.2.4 Radiation Effects Analysis". Add text: "The cumulative effect of neutron and gamma radiation on the structural and shielding properties of the VSC-24 storage system materials is evaluated for an extended storage period of 60-years. The cumulative neutron and gamma radiation levels in all components of the VSC-24 storage system over 60-years of storage are much lower than the radiation levels at which the structural and shielding properties of the carbon steel, concrete, and neutron shielding materials are adversely affected. The cumulative neutron and gamma radiation exposures for the inner steel components of the VSC-24 storage system (i.e., the MSB assembly and VCC steel liner) over 60-years are estimated to be approximately 1.3x10^{14} n/cm^2 and 1x10^{10} rads, respectively. The damaging effects of neutron radiation on steel are seen at a fast neutron (i.e., > 1.0 MeV) fluence level above 1x10^{17} n/cm^2, or approximately three orders of magnitude greater than the total neutron exposure for the steel components of the VSC-24 storage system. Gamma radiation has no measureable impact on the mechanical properties of steel. The cumulative neutron and gamma radiation doses on the VCC concrete over the 60-year extended storage period are estimated to be 1.3x10^{14} n/cm^2 and 1x10^{9} rads, respectively, considering the dose attenuation provided by the 2.75-inch combined thickness of carbon steel MSB shell and VCC liner shell. The neutron and gamma radiation doses at which concrete properties are adversely affected are 1x10^{17} n/cm^2 and 1x10^{10} rads, respectively. Thus, the VCC concrete will not be adversely affected by neutron and gamma radiation doses over the 60-year extended storage period. The cumulative neutron and gamma radiation doses over the 60-year extended storage period on the RX-277 neutron shielding material in the MSB shield lid, considering the dose attenuation provided by the MSB shield lid support plate and bottom plate, are estimated to be 1.3x10^{14} n/cm^2 and 7x10^{7} rads, respectively. The RX-277 neutron shielding material can withstand neutron and gamma radiation levels of 5x10^{19} n/cm^2 and 1x10^{10}	New section to discuss TLAA.

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
	rads, respectively. Therefore, the cumulative neutron and gamma radiation doses will not adversely affect the properties of RX-277 during the extended storage period.".	
9.3.2.5	Add heading "**Section 9.3.2.5 Fuel Cladding Creep Evaluation**". Add text: "**The maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system are based on the cladding creep methodology described in PNL-6364 (Reference 4.1), as discussed in Appendix C. The criterion applied limits the total strain in the fuel cladding due to creep to 1% over a 40-year storage period. The creep methodology accounts for the decrease in cladding temperature and hoop stress that are expected to occur during the storage period.** **After the initial 40-year storage period, the peak cladding temperature for design basis fuel will reduce to approximately 150°C and the corresponding cladding hoop stress will be approximately 67 megapascals (MPa). Based on PNL-6364, the cladding strain rate under these conditions is estimated to be approximately 10^{-17} s^{-1}. Conservatively assuming the cladding strain rate remains constant for the extended storage period, the additional accumulated strain for the additional 20-year period is $6.3x10^{-9}$ in/in; an insignificant fraction of the allowable total strain (1%). Therefore, it is concluded that the maximum allowable cladding temperatures for PWR fuel assemblies stored in the VSC-24 storage system remain applicable for the 60-year extended storage period.**".	New section to discuss TLAA.
9.3.3	Add heading: "**Section 9.3.3 Aging Management Program**". Add text: "**Aging effects that could result in loss of in-scope SSC's intended function(s) are managed during the extended storage period. The aging effects that require management are summarized in Table 9.3-1 through Table 9.3-4. Many aging effects are adequately managed for the extended storage period using TLAA, as discussed in Section 9.3.2. An AMP is used to manage those aging effects that are not managed by TLAA. The AMP that manage each of the identified aging effects for all in-scope SSC include of the following:**	New section summarizing AMP credited with managing aging effects during the extended storage period.

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change[1]	Basis
	(1) Examination of VCC Assembly Air Inlets and Outlets, (2) Examination of the VCC Assembly Exterior Concrete, (3) Examination of the VCC Assembly Ventilation Ducts and Annulus, (4) Examination of VSC Top End Steel Components, and (5) Examination of the MTC Assembly. In addition, the lead cask inspection provides additional assurance that the VCC and MSB assemblies do not experience any unanticipated degradation during the extended storage period. The AMP and lead cask inspection are described in Tables 9.3-5 through 9.3-10.". Add table heading: "**Table 9.3-5 - Examination of VCC Assembly Air Inlets and Outlets**" and table content (same as Table 12). Add table heading: "**Table 9.3-6 - Examination of the VCC Assembly Exterior Concrete**" and table content (same as Table 13). Add table heading: "**Table 9.3-7 - Examination of the VCC Assembly Ventilation Ducts and Annulus**" and table content (same as Table 14). Add table heading: "**Table 9.3-8 - Examination of VSC Top End Steel Components**" and table content (same as Table 15). Add table heading: "**Table 9.3-9 - Examination of the MTC Assembly**" and table content (same as Table 16) Add table heading: "**Table 9.3-10 - Lead Cask Inspection**" and table content (same as Table 17).	

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
9.3.4	Add heading "**Section 9.3.4 Retrievability**". Add text: "**The VSC-24 storage system is designed to allow ready retrieval of the SNF assemblies for further processing and disposal, in accordance with 10 CFR 72.122(l). As discussed in ISG-2 [3.19], ready retrieval of the SNF assemblies from the MSB assembly requires: (1) the ability to transfer the sealed MSB assembly to a spent fuel pool (or other facility), and (2) the ability to unload the SNF assemblies from the MSB assemblies for repackaging to allow removal from the reactor site, transportation, and ultimate disposition.** **The results of the AMR show that there are no credible aging effects in the SNF assemblies that require management during the extended storage period. Only low burnup (≤ 45 GWd/MTU), intact, zircaloy-clad PWR SNF assemblies are stored in the VSC-24 storage system. Degradation of the cladding of low burnup fuel will not occur during extended storage because the inert atmosphere inside the MSB assembly is maintained. Corrosion of the MSB assembly structural lid and closure weld are managed by AMP during the extended storage period to ensure that no aging effect result in the loss of their intended functions (primarily confinement and structural support.) This provides reasonable assurance that the MSB assembly will be able to be transferred to a spent fuel pool and the SNF assemblies will be capable of being removed from the MSB assembly by normal means.**".	Add new section addressing the requirements for fuel retrievability during the extended storage period.
12.2	Change 1st sentence of the last paragraph to read: "Each of these design features contributes significantly to the ability of the VSC to meet the requirements of 10CFR72 for ~~at least fifty~~ **a storage period of 60** years."	Extended storage period.
12.4 (B.1.2.2)	Change 1st sentence of B.1.2.2 to read: "If the MSB leaked at the largest undetectable leak rate (10^{-4} scc/sec), then only ~~1 percent~~ **2.7%** of the helium would escape over a ~~20-year span~~ **60-year extended storage period**."	Incorporate the results of the MSB helium leakage evaluation (Section 3.3.3.1).

Table A-1 - Summary of VSC-24 Storage System FSAR Changes

FSAR Section	Description of Change(1)	Basis
Appendix C, Section C.1	Add the following sentence to the end of the 2nd paragraph: "**Additional strain (or creep) that occurs after 40 years of dry storage is negligible due to the reduced clad temperatures and hoop stress.**"	Revised to incorporate the results of the fuel cladding creep TLAA evaluation (Section 3.3.3.5).
Appendix C, Section C.3	Revise the 2nd sentence to read: "Hence, a temperature limit of 712°F after 5 years cooling is adequate to ensure a less than 0.5% per rod probability of stress induced clad failure over a storage period of ~~40~~ **60** years."	

Notes:

(1) Proposed deletions are shown in strikethrough text (~~deletion~~) and proposed insertions are shown in bold underlined text (**insertion**).

Table 9.3-1 - MSB Assembly AMR Results (2 Pages)

Subcomponent	Intended Function$^{(1)}$	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Shell	HT, RS, PR, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
				Crack Growth	Fatigue	TLAA
			Sheltered	Loss of Fracture Toughness	Radiation	TLAA
				Crack Growth	Fatigue	TLAA
				Loss of Material	Corrosion	TLAA
Bottom Plate	HT, RS, PR, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
				Crack Growth	Fatigue	TLAA
			Sheltered	Loss of Fracture Toughness	Radiation	TLAA
				Crack Growth	Fatigue	TLAA
				Loss of Material	Corrosion	TLAA
Shield Lid Support Ring	SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Lifting Lug	SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Structural Lid	HT, RS, PR, SS	Coated CS	Inert Gas	Crack Growth	Fatigue	TLAA
				Loss of Fracture Toughness	Radiation	TLAA
			Sheltered	Loss of Material	Corrosion	AMP
				Crack Growth	Fatigue	TLAA
				Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Top Plate	RS, PR, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Bottom Plate	RS, PR, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Side Ring	PR, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA

Table 9.3-1 - MSB Assembly AMR Results (2 Pages)

Subcomponent	Intended Function[1]	Material	Environ-ment	Aging Effect	Aging Mechanism	Aging Management Activities
Shield Lid Neutron Shield	RS	RX-277	Embedded	Loss of Shielding Effectiveness	Radiation	TLAA & AMP
Structural Lid Valve Covers	PR, RS	Coated CS	Inert Gas	Crack Growth	Fatigue	TLAA
				Loss of Fracture Toughness	Radiation	TLAA
			Sheltered	Loss of Material	General Corrosion	AMP
				Crack Growth	Fatigue	TLAA
				Loss of Fracture Toughness	Radiation	TLAA
Shield Lid Support Plate	PR, RS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Storage Sleeve	CC, HT, RS, SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA
Basket Edge Structure	SS	Coated CS	Inert Gas	Loss of Fracture Toughness	Radiation	TLAA

Notes:

[1] Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

Table 9.3-2 - VCC Assembly AMR Results (2 Pages)

Subcomponent	Intended Function(1)	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Concrete Shell	HT, RS, SS	Concrete	Exposed	Loss of Strength	ASR	AMP
					CaOH Leaching	
					Radiation	TLAA
				Scaling, Cracking, & Spalling	Freeze/Thaw	AMP
					ASR	AMP
					Corrosion (Rebar)	AMP
Rebar	SS	CS	Embedded	Loss of Material	Corrosion (Rebar)	AMP
				Loss of Fracture Toughness	Radiation	TLAA
Cask Liner Shell	HT, RS, SS	Coated CS(2)	Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Cask Liner Bottom	HT, RS, SS	Coated CS(2)	Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Liner Flange	SS	Coated CS(2)	Exposed	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Cask Lid	RS, SS	Coated CS	Exposed	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA

Table 9.3-2 - VCC Assembly AMR Results (2 Pages)

Subcomponent	Intended Function[1]	Material	Environ-ment	Aging Effect	Aging Mechanism	Aging Management Activities
Lid Bolts, Nuts, Lockwashers	SS	Coated CS	Exposed	Loss of Material	Corrosion	AMP
Shielding Ring Plates	RS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Air Inlet Assembly	HT	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
Air Outlet Weldment	HT	Coated CS[2]	Sheltered	Loss of Material	Corrosion	AMP
Air Inlet Screen/Hardware	HT	Galvanized Steel	Exposed	Loss of Material	Corrosion	AMP
Air Outlet Screen/Hardware	HT	Varies	Exposed	Loss of Material	Corrosion	AMP
Bottom Plate Assembly	HT	Coated CS[2]	Exposed	Loss of Material	Corrosion	AMP
VSC Lifting Lugs (Optional)	SS	Coated CS[2]	Exposed	Loss of Material	Corrosion	AMP
			Embedded	Loss of Fracture Toughness	Radiation	TLAA

Notes:

[1] Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

[2] Coatings are only applied to the air-facing surfaces of these steel components. The embedded surfaces are not coated.

Table 9.3-3 - MTC Assembly AMR Results

Subcomponent	Intended Function[1]	Material	Environ-ment	Aging Effect	Aging Mechanism	Aging Management Activities
Outer Shell	SS, RS, HT	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Inner Shell	SS, RS, HT	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Top Ring	SS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Bottom Ring	SS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
				Loss of Fracture Toughness	Radiation	TLAA
			Embedded	Loss of Fracture Toughness	Radiation	TLAA
Neutron Absorber Shield	RS, HT	RX-277	Embedded	Loss of Shielding Effectiveness	Radiation	TLAA
Trunnion	SS	CS	Sheltered	Loss of Material	General Corrosion	AMP
Trunnion Cylinder / End Covers	---	Coated CS	Sheltered	Loss of Material	General Corrosion	AMP
MTC Lid	SS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Lid Bolts	SS	CS	Sheltered	Loss of Material	Corrosion	AMP
Shim/Flange	RS	CS	Sheltered	Loss of Material	Corrosion	AMP
Rail Shield	SS, RS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Rail Lower Plate	SS	Coated CS	Sheltered	Loss of Material	Corrosion	AMP
Shield Door	SS, RS, HT	Coated CS	Sheltered	Loss of Material	Corrosion	AMP

Notes:

[1] Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

Table 9.3-4 - SNF Assembly AMR Results

Subcomponent	Intended Function[1]	Material	Environment	Aging Effect	Aging Mechanism	Aging Management Activities
Fuel Cladding	CC, RS, PR, SS	Zircaloy	Inert Gas	Change in Dimension	Cladding Creep	TLAA

Notes:

[1] Criticality Control (CC), Heat Transfer (HT), Radiation Shielding (RS), Confinement (PR), and Structural Support (SS).

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Appendix B

VSC-24 Storage System Technical Specification Changes

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Appendix B: VSC-24 Storage System Technical Specification Changes

No changes to the VSC-24 Storage System Technical Specifications are proposed to support the VSC-24 Storage System CoC renewal.

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